

# Detailed Member Calculations

**Units: N&mm**

**Regulation: ASCE 41-17**

## Calculation No. 1

column C1, Floor 1

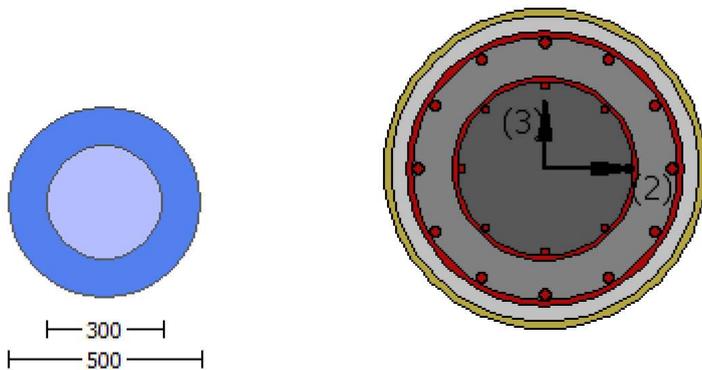
Limit State: Immediate Occupancy (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Shear capacity 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 Secondary Member: Concrete Strength,  $f_c = f_{c\_lower\_bound} = 25.00$

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

Concrete Elasticity,  $E_c = 26999.444$   
Steel Elasticity,  $E_s = 200000.00$   
Existing Column  
New material of Secondary Member: Concrete Strength,  $f_c = f_{c\_lower\_bound} = 25.00$   
New material of Secondary Member: Steel Strength,  $f_s = f_{s\_lower\_bound} = 500.00$   
Concrete Elasticity,  $E_c = 26999.444$   
Steel Elasticity,  $E_s = 200000.00$   
#####  
Note: Especially for the calculation of  $\gamma$  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,  $f_c = f_{cm} = 33.00$   
New material: Steel Strength,  $f_s = f_{sm} = 555.56$   
Existing Column  
New material: Concrete Strength,  $f_c = f_{cm} = 33.00$   
New material: Steel Strength,  $f_s = f_{sm} = 555.56$   
#####  
External Diameter,  $D = 500.00$   
Internal Diameter,  $D = 300.00$   
Cover Thickness,  $c = 25.00$   
Element Length,  $L = 3000.00$   
Secondary Member  
Ribbed Bars  
Ductile Steel  
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)  
Longitudinal Bars With Ends Lapped Starting at the End Sections  
Inadequate Lap Length with  $l_o/l_{ou,min} = l_b/l_d = 0.30$   
FRP Wrapping Data  
Type: Carbon  
Cured laminate properties (design values)  
Thickness,  $t = 1.016$   
Tensile Strength,  $f_{fu} = 1055.00$   
Tensile Modulus,  $E_f = 64828.00$   
Elongation,  $e_{fu} = 0.01$   
Number of directions,  $NoDir = 1$   
Fiber orientations,  $bi: 0.00^\circ$   
Number of layers,  $NL = 1$   
Radius of rounding corners,  $R = 40.00$

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Stepwise Properties  
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EDGE -A-  
Bending Moment,  $M_a = -2.2657E+007$   
Shear Force,  $V_a = -7550.492$   
EDGE -B-  
Bending Moment,  $M_b = 0.08820332$   
Shear Force,  $V_b = 7550.492$   
BOTH EDGES  
Axial Force,  $F = -7386.193$   
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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New component: From table 7-7, ASCE 41\_17: Final Shear Capacity  $V_R = 1.0 * V_n = 515957.072$   
 $V_n ((10.3), ASCE 41-17) = knl * V_{ColO} = 515957.072$   
 $V_{Col} = 515957.072$   
 $knl = 1.00$

displacement\_ductility\_demand = 0.02784913

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:  $f_c' = (f_c'_{\text{jacket}} \cdot \text{Area}_{\text{jacket}} + f_c'_{\text{core}} \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 25.00$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M/Vd = 4.00$

$\mu_u = 2.2657E+007$

$V_u = 7550.492$

$d = 0.8 \cdot D = 400.00$

$N_u = 7386.193$

$A_g = 196349.541$

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:

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

$f_y = 500.00$

$s = 100.00$

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

$s/d = 0.25$

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

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

$f_y = 500.00$

$s = 250.00$

$V_{s2}$  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  $V_f(\theta, \alpha)$ , 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:  $\theta = b_1 + 90^\circ = 90.00$

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

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

$d_{fv} = d$  (figure 11.2, ACI 440) = 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:  $V_s + V_f \leq 417394.406$

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

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

- Calculation of  $\phi / \gamma$  for END A -

for rotation axis 3 and integ. section (a)

From analysis, chord rotation  $\theta = 0.00025215$

$\gamma = (M_y \cdot L_s / 3) / E_{\text{eff}} = 0.0090541$  ((4.29), Biskinis Phd))

$M_y = 2.2494E+008$

$L_s = M/V$  (with  $L_s > 0.1 \cdot L$  and  $L_s < 2 \cdot L$ ) = 3000.736

From table 10.5, ASCE 41\_17:  $E_{\text{eff}} = \text{factor} \cdot E_c \cdot I_g = 2.4850E+013$

factor = 0.30

$A_g = 196349.541$

Mean concrete strength:  $f_c' = (f_c'_{\text{jacket}} \cdot \text{Area}_{\text{jacket}} + f_c'_{\text{core}} \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 33.00$

$N = 7386.193$

$E_c \cdot I_g = E_c \cdot I_{g_{\text{jacket}}} + E_c \cdot I_{g_{\text{core}}} = 8.2833E+013$

Calculation of Yielding Moment  $M_y$

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

$$M_y = \text{Min}(M_{y\_ten}, M_{y\_com}) = 2.2494E+008$$

$$y = 6.4602099E-006$$

$$M_{y\_ten} (8c) = 2.2494E+008$$

$$y_{ten} (7c) = 62.07295$$

$$\text{error of function (7c)} = 0.00023516$$

$$M_{y\_com} (8d) = 8.0674E+008$$

$$y_{com} (7d) = 63.84405$$

$$\text{error of function (7d)} = -0.00846595$$

$$\text{with } ((10.1), \text{ASCE 41-17}) \text{ } e_y = \text{Min}(e_y, 1.25 * e_y * (l_b/l_d)^{2/3}) = 0.0027778$$

$$e_{co} = 0.002$$

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

$$d_1 = 44.00$$

$$R = 250.00$$

$$v = 0.00103619$$

$$N = 7386.193$$

$$A_c = 196349.541$$

$$((10.1), \text{ASCE 41-17}) = \text{Min}(, 1.25 * * (l_b/l_d)^{2/3}) = 0.23799351$$

$$\text{with } f_c^* \text{ ((12.3), ACI 440)} = 36.3038$$

$$f_c = 33.00$$

$$f_l = 1.05384$$

$$k = 1$$

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

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

$$f_u = 0.01$$

$$E_f = 64828.00$$

Calculation of ratio  $l_b/l_d$

Inadequate Lap Length with  $l_b/l_d = 0.30$

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

At local axis: 2

Integration Section: (a)

## Calculation No. 2

column C1, Floor 1

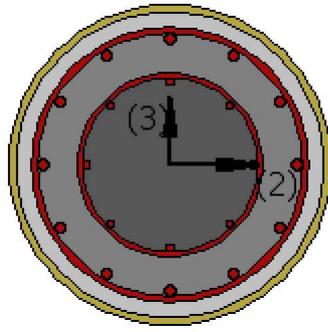
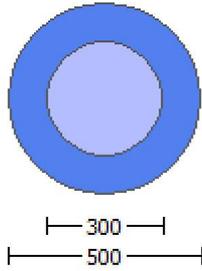
Limit State: Immediate Occupancy (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity ( $\theta_u$ )

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 Secondary Member: Concrete Strength,  $f_c = f_{cm} = 33.00$   
 New material of Secondary Member: Steel Strength,  $f_s = f_{sm} = 555.56$   
 Concrete Elasticity,  $E_c = 26999.444$   
 Steel Elasticity,  $E_s = 200000.00$

Existing Column

New material of Secondary Member: Concrete Strength,  $f_c = f_{cm} = 33.00$   
 New material of Secondary Member: Steel Strength,  $f_s = f_{sm} = 555.56$   
 Concrete Elasticity,  $E_c = 26999.444$   
 Steel Elasticity,  $E_s = 200000.00$

#####

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

Jacket

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

Existing Column

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

#####

External Diameter,  $D = 500.00$

Internal Diameter,  $D = 300.00$

Cover Thickness,  $c = 25.00$

Mean Confinement Factor overall section = 1.46748

Element Length,  $L = 3000.00$

Secondary Member

Ribbed Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

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

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness,  $t = 1.016$

Tensile Strength,  $f_{fu} = 1055.00$

Tensile Modulus,  $E_f = 64828.00$

Elongation,  $ef_u = 0.01$

Number of directions,  $NoDir = 1$

Fiber orientations,  $bi = 0.00^\circ$

Number of layers,  $NL = 1$

Radius of rounding corners,  $R = 40.00$

Stepwise Properties

At local axis: 3

EDGE -A-

Shear Force,  $V_a = 1.1471900E-030$

EDGE -B-

Shear Force,  $V_b = -1.1471900E-030$

BOTH EDGES

Axial Force,  $F = -7389.214$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension:  $A_{st} = 0.00$

-Compression:  $A_{sc} = 3053.628$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

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

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

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

Calculation of Shear Capacity ratio,  $V_e/V_r = 0.23451953$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 165526.599$   
with

$M_{pr1} = \text{Max}(M_{u1+}, M_{u1-}) = 2.4829E+008$

$M_{u1+} = 2.4829E+008$ , is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination

$M_{u1-} = 2.4829E+008$ , is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination

$M_{pr2} = \text{Max}(M_{u2+}, M_{u2-}) = 2.4829E+008$

$M_{u2+} = 2.4829E+008$ , is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the the static loading combination

$M_{u2-} = 2.4829E+008$ , is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the the static loading combination

Calculation of  $M_{u1+}$

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

$M_u = 2.4829E+008$

$\phi = 0.82030475$

$\phi' = 0.72936354$

error of function (3.68), Biskinis Phd = 58391.315

From 5A.2, TBDY:  $f_{cc} = f_c \cdot c = 48.42699$

conf. factor  $c = 1.46748$

$f_c = 33.00$

From 10.3.5, ASCE 41-17, Final value of  $f_y$ :  $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3}) = 389.0139$

$l_b/l_d = 0.30$

$d_1 = 44.00$

$R = 250.00$

$v = 0.00103167$

$N = 7389.214$

$A_c = 196349.541$

$\phi \cdot \text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3}) = 0.16585331$

Calculation of ratio  $l_b/l_d$

Inadequate Lap Length with  $l_b/l_d = 0.30$

Calculation of  $M_{u1-}$

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

Mu = 2.4829E+008

-----  
= 0.82030475

' = 0.72936354

error of function (3.68), Biskinis Phd = 58391.315

From 5A.2, TBDY:  $f_{cc} = f_c \cdot c = 48.42699$

conf. factor  $c = 1.46748$

$f_c = 33.00$

From 10.3.5, ASCE 41-17, Final value of fy:  $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 389.0139$

$l_b/d = 0.30$

$d_1 = 44.00$

$R = 250.00$

$v = 0.00103167$

$N = 7389.214$

$Ac = 196349.541$

=  $\cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.16585331$   
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Calculation of ratio  $l_b/d$

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Inadequate Lap Length with  $l_b/d = 0.30$   
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Calculation of Mu2+

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

Mu = 2.4829E+008

-----  
= 0.82030475

' = 0.72936354

error of function (3.68), Biskinis Phd = 58391.315

From 5A.2, TBDY:  $f_{cc} = f_c \cdot c = 48.42699$

conf. factor  $c = 1.46748$

$f_c = 33.00$

From 10.3.5, ASCE 41-17, Final value of fy:  $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 389.0139$

$l_b/d = 0.30$

$d_1 = 44.00$

$R = 250.00$

$v = 0.00103167$

$N = 7389.214$

$Ac = 196349.541$

=  $\cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.16585331$   
-----

Calculation of ratio  $l_b/d$

-----  
Inadequate Lap Length with  $l_b/d = 0.30$   
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-----  
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Calculation of Mu2-

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

Mu = 2.4829E+008

-----  
= 0.82030475

' = 0.72936354

error of function (3.68), Biskinis Phd = 58391.315

From 5A.2, TBDY:  $f_{cc} = f_c \cdot c = 48.42699$

conf. factor  $c = 1.46748$

$f_c = 33.00$

From 10.3.5, ASCE 41-17, Final value of  $f_y$ :  $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 389.0139$

$l_b/d = 0.30$

$d_1 = 44.00$

$R = 250.00$

$v = 0.00103167$

$N = 7389.214$

$A_c = 196349.541$

$= \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.16585331$

Calculation of ratio  $l_b/d$

Inadequate Lap Length with  $l_b/d = 0.30$

Calculation of Shear Strength  $V_r = \text{Min}(V_{r1}, V_{r2}) = 705811.584$

Calculation of Shear Strength at edge 1,  $V_{r1} = 705811.584$

$V_{r1} = V_{\text{Col}} ((10.3), \text{ASCE 41-17}) = k_{nl} \cdot V_{\text{Col}0}$

$V_{\text{Col}0} = 705811.584$

$k_{nl} = 1$  (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:  $f_c' = (f_c'_{\text{jacket}} \cdot \text{Area}_{\text{jacket}} + f_c'_{\text{core}} \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 33.00$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$\mu_u = 1.6210513E-011$

$\nu_u = 1.1471900E-030$

$d = 0.8 \cdot D = 400.00$

$N_u = 7389.214$

$A_g = 196349.541$

From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 274157.871$

$V_{s1} = 274157.871$  is calculated for jacket, with:

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

$f_y = 555.56$

$s = 100.00$

$V_{s1}$  is multiplied by  $\text{Col}1 = 1.00$

$s/d = 0.25$

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

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

$f_y = 555.56$

$s = 250.00$

$V_{s2}$  is multiplied by  $\text{Col}2 = 0.00$

$s/d = 1.04167$

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

$f = 0.95$ , 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  $(\cot \theta + \csc \theta) \sin \alpha$  which is more a generalised expression, where  $\theta$  is the angle of the crack direction (see KANEPE).

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

orientation 1:  $\theta = 45^\circ = 90.00$

$V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, \alpha)|)$ , 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

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

$E_f = 64828.00$

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

with  $f_u = 0.01$

From (11-11), ACI 440:  $V_s + V_f \leq 479549.663$

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

Calculation of Shear Strength at edge 2,  $V_{r2} = 705811.584$

$$V_{r2} = V_{CoI} \text{ ((10.3), ASCE 41-17)} = k_{nl}*V_{CoI0}$$

$$V_{CoI0} = 705811.584$$

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

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

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

Mean concrete strength:  $f_c' = (f_c'_{jacket}*Area_{jacket} + f_c'_{core}*Area_{core})/Area_{section} = 33.00$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$$M/Vd = 2.00$$

$$\mu_u = 1.6210513E-011$$

$$V_u = 1.1471900E-030$$

$$d = 0.8*D = 400.00$$

$$N_u = 7389.214$$

$$A_g = 196349.541$$

$$\text{From (11.5.4.8), ACI 318-14: } V_s = V_{s1} + V_{s2} = 274157.871$$

$V_{s1} = 274157.871$  is calculated for jacket, with:

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

$$f_y = 555.56$$

$$s = 100.00$$

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

$$s/d = 0.25$$

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

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

$$f_y = 555.56$$

$$s = 250.00$$

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

$$s/d = 1.04167$$

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

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

$w_f/s_f = 1$  (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:  $\theta = 90^\circ = 90.00$

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

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

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

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

$$E_f = 64828.00$$

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

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

$$\text{From (11-11), ACI 440: } V_s + V_f \leq 479549.663$$

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

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

At local axis: 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 Secondary Member: Concrete Strength,  $f_c = f_{cm} = 33.00$

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

Concrete Elasticity,  $E_c = 26999.444$

Steel Elasticity,  $E_s = 200000.00$

Existing Column

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

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

Concrete Elasticity,  $E_c = 26999.444$

Steel Elasticity,  $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

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

Jacket

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

Existing Column

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

#####

External Diameter,  $D = 500.00$

Internal Diameter,  $D = 300.00$

Cover Thickness,  $c = 25.00$

Mean Confinement Factor overall section = 1.46748

Element Length,  $L = 3000.00$

Secondary Member

Ribbed Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

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

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness,  $t = 1.016$

Tensile Strength,  $f_{fu} = 1055.00$

Tensile Modulus,  $E_f = 64828.00$

Elongation,  $e_{fu} = 0.01$

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

Fiber orientations,  $b_i: 0.00^\circ$

Number of layers,  $N_L = 1$

Radius of rounding corners,  $R = 40.00$

-----  
Stepwise Properties

-----  
At local axis: 2

EDGE -A-

Shear Force,  $V_a = -7.0242809E-047$

EDGE -B-

Shear Force,  $V_b = 7.0242809E-047$

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,  $V_e/V_r = 0.23451953$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 165526.599$

with

$$Mpr1 = \text{Max}(Mu1+, Mu1-) = 2.4829E+008$$

Mu1+ = 2.4829E+008, is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination

Mu1- = 2.4829E+008, is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination

$$Mpr2 = \text{Max}(Mu2+, Mu2-) = 2.4829E+008$$

Mu2+ = 2.4829E+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- = 2.4829E+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 = 2.4829E+008  
-----

$$= 0.82030475$$

$$' = 0.72936354$$

error of function (3.68), Biskinis Phd = 58391.315

From 5A.2, TBDY:  $f_{cc} = f_c \cdot c = 48.42699$

$$\text{conf. factor } c = 1.46748$$

$$f_c = 33.00$$

From 10.3.5, ASCE 41-17, Final value of  $f_y$ :  $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 389.0139$

$$l_b/d = 0.30$$

$$d1 = 44.00$$

$$R = 250.00$$

$$v = 0.00103167$$

$$N = 7389.214$$

$$Ac = 196349.541$$

$$= \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.16585331$$

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

Inadequate Lap Length with  $l_b/d = 0.30$   
-----  
-----  
-----

-----  
Calculation of Mu1-  
-----

-----  
Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), Mu  
Mu = 2.4829E+008  
-----

$$= 0.82030475$$

$$' = 0.72936354$$

error of function (3.68), Biskinis Phd = 58391.315

From 5A.2, TBDY:  $f_{cc} = f_c \cdot c = 48.42699$

$$\text{conf. factor } c = 1.46748$$

$$f_c = 33.00$$

From 10.3.5, ASCE 41-17, Final value of  $f_y$ :  $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 389.0139$

$$l_b/d = 0.30$$

$$d1 = 44.00$$

$$R = 250.00$$

$$v = 0.00103167$$

$$N = 7389.214$$

$$Ac = 196349.541$$

$$= \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.16585331$$

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

Inadequate Lap Length with  $l_b/d = 0.30$   
-----

-----  
-----  
-----  
Calculation of Mu2+  
-----

-----  
Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), Mu  
Mu = 2.4829E+008  
-----

-----  
= 0.82030475  
' = 0.72936354  
error of function (3.68), Biskinis Phd = 58391.315  
From 5A.2, TBDY: fcc = fc\* c = 48.42699  
conf. factor c = 1.46748  
fc = 33.00  
From 10.3.5, ASCE 41-17, Final value of fy: fy\*Min(1,1.25\*(lb/d)^ 2/3) = 389.0139  
lb/d = 0.30  
d1 = 44.00  
R = 250.00  
v = 0.00103167  
N = 7389.214  
Ac = 196349.541  
= \*Min(1,1.25\*(lb/d)^ 2/3) = 0.16585331  
-----

-----  
Calculation of ratio lb/d  
-----

Inadequate Lap Length with lb/d = 0.30  
-----  
-----  
-----

-----  
Calculation of Mu2-  
-----

-----  
Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), Mu  
Mu = 2.4829E+008  
-----

-----  
= 0.82030475  
' = 0.72936354  
error of function (3.68), Biskinis Phd = 58391.315  
From 5A.2, TBDY: fcc = fc\* c = 48.42699  
conf. factor c = 1.46748  
fc = 33.00  
From 10.3.5, ASCE 41-17, Final value of fy: fy\*Min(1,1.25\*(lb/d)^ 2/3) = 389.0139  
lb/d = 0.30  
d1 = 44.00  
R = 250.00  
v = 0.00103167  
N = 7389.214  
Ac = 196349.541  
= \*Min(1,1.25\*(lb/d)^ 2/3) = 0.16585331  
-----

-----  
Calculation of ratio lb/d  
-----

Inadequate Lap Length with lb/d = 0.30  
-----  
-----  
-----

-----  
Calculation of Shear Strength Vr = Min(Vr1,Vr2) = 705811.584  
-----

-----  
Calculation of Shear Strength at edge 1, Vr1 = 705811.584  
Vr1 = VCol ((10.3), ASCE 41-17) = knl\*VColO  
VColO = 705811.584  
-----

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

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

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

Mean concrete strength:  $f_c' = (f_c'_{jacket} \cdot Area_{jacket} + f_c'_{core} \cdot Area_{core}) / Area_{section} = 33.00$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$\mu_u = 1.7556432E-011$

$\nu_u = 7.0242809E-047$

$d = 0.8 \cdot D = 400.00$

$N_u = 7389.214$

$A_g = 196349.541$

From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 274157.871$

$V_{s1} = 274157.871$  is calculated for jacket, with:

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

$f_y = 555.56$

$s = 100.00$

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

$s/d = 0.25$

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

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

$f_y = 555.56$

$s = 250.00$

$V_{s2}$  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)  $\sin \theta + \cos \theta$  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  $V_f(\theta, \alpha)$ , 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:  $\theta = b_1 + 90^\circ = 90.00$

$V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, \theta)|)$ , 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:  $V_s + V_f \leq 479549.663$

$b_w \cdot d = A_{stirrup} \cdot d / 4 = 125663.706$

Calculation of Shear Strength at edge 2,  $V_{r2} = 705811.584$

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

$V_{Col0} = 705811.584$

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

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

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

Mean concrete strength:  $f_c' = (f_c'_{jacket} \cdot Area_{jacket} + f_c'_{core} \cdot Area_{core}) / Area_{section} = 33.00$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$\mu_u = 1.7556432E-011$

$\nu_u = 7.0242809E-047$

$d = 0.8 \cdot D = 400.00$

$N_u = 7389.214$

$A_g = 196349.541$

From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 274157.871$

$V_{s1} = 274157.871$  is calculated for jacket, with:

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

$f_y = 555.56$

$s = 100.00$   
 $V_{s1}$  is multiplied by  $Col1 = 1.00$   
 $s/d = 0.25$   
 $V_{s2} = 0.00$  is calculated for core, with:  
 $A_v = \sqrt{2} * A_{stirrup} = 78956.835$   
 $f_y = 555.56$   
 $s = 250.00$   
 $V_{s2}$  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)  $\sin \theta + \cos \theta$  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  $V_f(\theta, \alpha)$ , 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:  $\theta = b1 + 90^\circ = 90.00$   
 $V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, \theta)|)$ , with:  
 total thickness per orientation,  $t_{f1} = NL * t / NoDir = 1.016$   
 $d_{fv} = d$  (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:  $V_s + V_f \leq 479549.663$   
 $b_w * d = \sqrt{V_s + V_f} * d / 4 = 125663.706$

-----  
 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 Secondary Member: Concrete Strength,  $f_c = f_{cm} = 33.00$   
 New material of Secondary Member: Steel Strength,  $f_s = f_{sm} = 555.56$   
 Concrete Elasticity,  $E_c = 26999.444$   
 Steel Elasticity,  $E_s = 200000.00$   
 Existing Column  
 New material of Secondary Member: Concrete Strength,  $f_c = f_{cm} = 33.00$   
 New material of Secondary Member: Steel Strength,  $f_s = f_{sm} = 555.56$   
 Concrete Elasticity,  $E_c = 26999.444$   
 Steel Elasticity,  $E_s = 200000.00$   
 External Diameter,  $D = 500.00$   
 Internal Diameter,  $D = 300.00$   
 Cover Thickness,  $c = 25.00$   
 Element Length,  $L = 3000.00$   
 Secondary Member  
 Ribbed Bars  
 Ductile Steel  
 Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)  
 Longitudinal Bars With Ends Lapped Starting at the End Sections  
 Inadequate Lap Length with  $l_b/l_d = 0.30$   
 FRP Wrapping Data  
 Type: Carbon

Cured laminate properties (design values)

Thickness,  $t = 1.016$

Tensile Strength,  $f_{fu} = 1055.00$

Tensile Modulus,  $E_f = 64828.00$

Elongation,  $e_{fu} = 0.01$

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

Fiber orientations,  $b_i = 0.00^\circ$

Number of layers,  $N_L = 1$

Radius of rounding corners,  $R = 40.00$

-----  
Stepwise Properties

Bending Moment,  $M = 1.4085270E-009$

Shear Force,  $V_2 = -7550.492$

Shear Force,  $V_3 = -4.7296730E-013$

Axial Force,  $F = -7386.193$

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,  $D_{bL} = 18.00$

-----  
New component: From table 7-7, ASCE 41\_17: Final chord rotation Capacity  $u_{,R} = 1.0^*$   $u = 0.00452594$

$u = y + p = 0.00452594$

-----  
- Calculation of  $y$  -

$y = (M_y * L_s / 3) / E_{eff} = 0.00452594$  ((4.29), Biskinis Phd)

$M_y = 2.2494E+008$

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

From table 10.5, ASCE 41\_17:  $E_{eff} = factor * E_c * I_g = 2.4850E+013$

factor = 0.30

$A_g = 196349.541$

Mean concrete strength:  $f_c' = (f_c'_{jacket} * Area_{jacket} + f_c'_{core} * Area_{core}) / Area_{section} = 33.00$

$N = 7386.193$

$E_c * I_g = E_c * I_{g,jacket} + E_c * I_{g,core} = 8.2833E+013$

-----  
Calculation of Yielding Moment  $M_y$

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

$M_y = \text{Min}(M_{y,ten}, M_{y,com}) = 2.2494E+008$

$y = 6.4602099E-006$

$M_{y,ten}$  (8c) = 2.2494E+008

$_{ten}$  (7c) = 62.07295

error of function (7c) = 0.00023516

$M_{y,com}$  (8d) = 8.0674E+008

$_{com}$  (7d) = 63.84405

error of function (7d) = -0.00846595

with ((10.1), ASCE 41-17)  $e_y = \text{Min}(e_y, 1.25 * e_y * (I_b / I_d)^{2/3}) = 0.0027778$

$e_{co} = 0.002$

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

$d_1 = 44.00$

$R = 250.00$

$v = 0.00103619$

$N = 7386.193$

$A_c = 196349.541$

$((10.1), ASCE 41-17) = \text{Min}( , 1.25 * (lb/ld)^{2/3} ) = 0.23799351$   
 with  $f_c$  ((12.3), ACI 440) = 36.3038  
 $f_c = 33.00$   
 $f_l = 1.05384$   
 $k = 1$   
 Effective FRP thickness,  $t_f = NL * t * \text{Cos}(b1) = 1.016$   
 $e_{fe}$  ((12.5) and (12.7)) = 0.004  
 $f_u = 0.01$   
 $E_f = 64828.00$

Calculation of ratio  $lb/ld$

Inadequate Lap Length with  $lb/ld = 0.30$

- Calculation of  $p$  -

From table 10-9:  $p = 0.00$

with:

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

shear control ratio  $V_y E / V_{col} O E = 0.23451953$

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

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

$t = s_1 + s_2 + 2 * t_f / bw * (f_{fe} / f_s) = 0.00702809$

jacket:  $s_1 = A_{v1} * (Dc1 / 2) / (s_1 * A_g) = 0.0027646$

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

$Dc1 = D_{\text{ext}} - 2 * \text{cover} - \text{External Hoop Diameter} = 440.00$ , is the total Length of all stirrups parallel to loading

(shear) direction

$s_1 = 100.00$

core:  $s_2 = A_{v2} * (Dc2 / 2) / (s_2 * A_g) = 0.00046968$

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

$Dc2 = D_{\text{int}} - \text{Internal Hoop Diameter} = 292.00$ , is the total Length of all stirrups parallel to loading (shear)

direction

$s_2 = 250.00$

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

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

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

For the normalisation  $f_s$  of jacket is used.

$N_{UD} = 7386.193$

$A_g = 196349.541$

$f_{cE} = (f_{c_{\text{jacket}}} * \text{Area}_{\text{jacket}} + f_{c_{\text{core}}} * \text{Area}_{\text{core}}) / \text{section\_area} = 33.00$

$f_{yIE} = (f_{y_{\text{ext\_Long\_Reinf}}} * \text{Area}_{\text{ext\_Long\_Reinf}} + f_{y_{\text{int\_Long\_Reinf}}} * \text{Area}_{\text{int\_Long\_Reinf}}) / \text{Area}_{\text{Tot\_Long\_Rein}} = 2.1219958E-314$

$f_{yTE} = (f_{y_{\text{ext\_Trans\_Reinf}}} * \text{Area}_{\text{ext\_Trans\_Reinf}} + f_{y_{\text{int\_Trans\_Reinf}}} * \text{Area}_{\text{int\_Trans\_Reinf}}) / \text{Area}_{\text{Tot\_Trans\_Rein}} = 555.56$

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

$f_{cE} = 33.00$

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

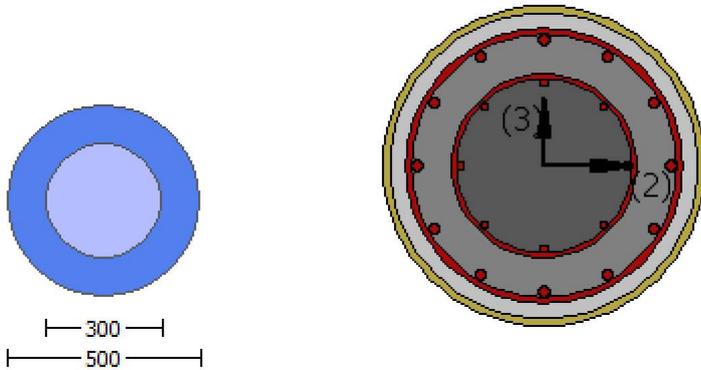
Limit State: Immediate Occupancy (data interpolation between analysis steps 1 and 2)

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 Secondary Member: Concrete Strength,  $f_c = f_{c\_lower\_bound} = 25.00$

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

Concrete Elasticity,  $E_c = 26999.444$

Steel Elasticity,  $E_s = 200000.00$

Existing Column

New material of Secondary Member: Concrete Strength,  $f_c = f_{c\_lower\_bound} = 25.00$

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

Concrete Elasticity,  $E_c = 26999.444$

Steel Elasticity,  $E_s = 200000.00$

#####

Note: Especially for the calculation of  $\gamma$  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,  $f_c = f_{cm} = 33.00$

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

Existing Column

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

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

#####

External Diameter,  $D = 500.00$

Internal Diameter,  $D = 300.00$

Cover Thickness,  $c = 25.00$

Element Length,  $L = 3000.00$

Secondary Member

Ribbed Bars

Ductile Steel

Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)  
Longitudinal Bars With Ends Lapped Starting at the End Sections  
Inadequate Lap Length with  $l_o/l_{ou,min} = l_b/l_d = 0.30$   
FRP Wrapping Data  
Type: Carbon  
Cured laminate properties (design values)  
Thickness,  $t = 1.016$   
Tensile Strength,  $f_{fu} = 1055.00$   
Tensile Modulus,  $E_f = 64828.00$   
Elongation,  $e_{fu} = 0.01$   
Number of directions,  $N_{oDir} = 1$   
Fiber orientations,  $b_i: 0.00^\circ$   
Number of layers,  $N_L = 1$   
Radius of rounding corners,  $R = 40.00$

-----  
Stepwise Properties  
-----

EDGE -A-  
Bending Moment,  $M_a = 1.4085270E-009$   
Shear Force,  $V_a = -4.7296730E-013$   
EDGE -B-  
Bending Moment,  $M_b = 1.0742266E-011$   
Shear Force,  $V_b = 4.7296730E-013$   
BOTH EDGES  
Axial Force,  $F = -7386.193$   
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,  $Db_{L,ten} = 18.00$

-----  
-----  
New component: From table 7-7, ASCE 41\_17: Final Shear Capacity  $V_R = 1.0 * V_n = 614519.737$   
 $V_n ((10.3), ASCE 41-17) = knl * V_{CoI0} = 614519.737$   
 $V_{CoI} = 614519.737$   
 $knl = 1.00$   
 $displacement\_ductility\_demand = 0.00$

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

-----  
= 1 (normal-weight concrete)  
Mean concrete strength:  $f'_c = (f'_{c,jacket} * Area_{jacket} + f'_{c,core} * Area_{core}) / Area_{section} = 25.00$ , but  $f_c^{0.5} \leq 8.3$   
MPa (22.5.3.1, ACI 318-14)  
 $M / Vd = 2.00$   
 $M_u = 1.4085270E-009$   
 $V_u = 4.7296730E-013$   
 $d = 0.8 * D = 400.00$   
 $N_u = 7386.193$   
 $A_g = 196349.541$   
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:  
 $A_v = \sqrt{2} * A_{stirrup} = 123370.055$   
 $f_y = 500.00$   
 $s = 100.00$   
 $V_{s1}$  is multiplied by  $Col1 = 1.00$   
 $s/d = 0.25$   
 $V_{s2} = 0.00$  is calculated for core, with:  
 $A_v = \sqrt{2} * A_{stirrup} = 78956.835$   
 $f_y = 500.00$   
 $s = 250.00$

$V_{s2}$  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  $\theta$  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,  $tf1 = NL * t / NoDir = 1.016$   
 $dfv = d$  (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:  $V_s + V_f \leq 417394.406$   
 $bw * d = \rho * d * d / 4 = 125663.706$

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  $\theta = 1.6665634E-020$   
 $y = (M_y * L_s / 3) / E_{eff} = 0.00452594$  ((4.29), Biskinis Phd)  
 $M_y = 2.2494E+008$   
 $L_s = M/V$  (with  $L_s > 0.1 * L$  and  $L_s < 2 * L$ ) = 1500.00  
 From table 10.5, ASCE 41\_17:  $E_{eff} = \text{factor} * E_c * I_g = 2.4850E+013$   
 $\text{factor} = 0.30$   
 $A_g = 196349.541$   
 Mean concrete strength:  $f'_c = (f'_c_{jacket} * Area_{jacket} + f'_c_{core} * Area_{core}) / Area_{section} = 33.00$   
 $N = 7386.193$   
 $E_c * I_g = E_{c,jacket} * I_{g,jacket} + E_{c,core} * I_{g,core} = 8.2833E+013$

Calculation of Yielding Moment  $M_y$

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

$M_y = \text{Min}(M_{y\_ten}, M_{y\_com}) = 2.2494E+008$   
 $y = 6.4602099E-006$   
 $M_{y\_ten}$  (8c) = 2.2494E+008  
 $\delta_{ten}$  (7c) = 62.07295  
 error of function (7c) = 0.00023516  
 $M_{y\_com}$  (8d) = 8.0674E+008  
 $\delta_{com}$  (7d) = 63.84405  
 error of function (7d) = -0.00846595  
 with ((10.1), ASCE 41-17)  $e_y = \text{Min}(e_y, 1.25 * e_y * (I_b / I_d)^{2/3}) = 0.0027778$   
 $e_{co} = 0.002$   
 $a_{pl} = 0.45$  ((9c) in Biskinis and Fardis for FRP Wrap)  
 $d1 = 44.00$   
 $R = 250.00$   
 $v = 0.00103619$   
 $N = 7386.193$   
 $A_c = 196349.541$   
 ((10.1), ASCE 41-17)  $e_y = \text{Min}(e_y, 1.25 * e_y * (I_b / I_d)^{2/3}) = 0.23799351$   
 with  $f'_c$  ((12.3), ACI 440) = 36.3038  
 $f'_c = 33.00$   
 $f_l = 1.05384$   
 $k = 1$   
 Effective FRP thickness,  $tf = NL * t * \text{Cos}(b1) = 1.016$   
 $e_{fe}$  ((12.5) and (12.7)) = 0.004

$f_u = 0.01$   
 $E_f = 64828.00$

Calculation of ratio  $l_b/l_d$

Inadequate Lap Length with  $l_b/l_d = 0.30$

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

At local axis: 3

Integration Section: (a)

## Calculation No. 4

column C1, Floor 1

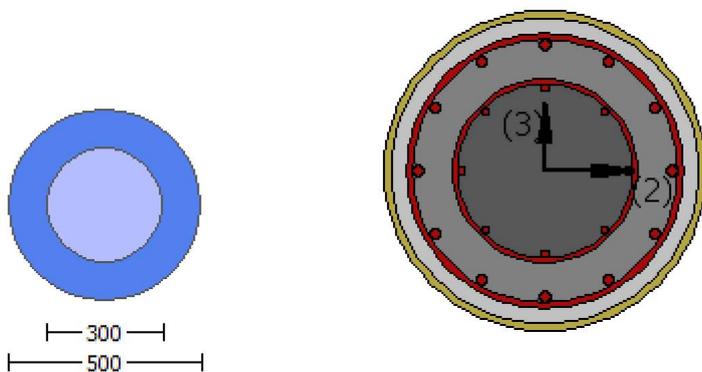
Limit State: Immediate Occupancy (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity (  $\theta$  )

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

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

Concrete Elasticity,  $E_c = 26999.444$

Steel Elasticity,  $E_s = 200000.00$

Existing Column

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

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

Concrete Elasticity,  $E_c = 26999.444$

Steel Elasticity,  $E_s = 200000.00$

#####

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

Jacket

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

Existing Column

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

#####

External Diameter,  $D = 500.00$

Internal Diameter,  $D = 300.00$

Cover Thickness,  $c = 25.00$

Mean Confinement Factor overall section = 1.46748

Element Length,  $L = 3000.00$

Secondary Member

Ribbed Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

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

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness,  $t = 1.016$

Tensile Strength,  $f_{fu} = 1055.00$

Tensile Modulus,  $E_f = 64828.00$

Elongation,  $e_{fu} = 0.01$

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

Fiber orientations,  $b_i: 0.00^\circ$

Number of layers,  $N_L = 1$

Radius of rounding corners,  $R = 40.00$

-----  
Stepwise Properties

At local axis: 3

EDGE -A-

Shear Force,  $V_a = 1.1471900E-030$

EDGE -B-

Shear Force,  $V_b = -1.1471900E-030$

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,  $V_e/V_r = 0.23451953$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 165526.599$

with

$M_{pr1} = \text{Max}(M_{u1+}, M_{u1-}) = 2.4829E+008$

$M_{u1+} = 2.4829E+008$ , is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination

$M_{u1-} = 2.4829E+008$ , is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination

$M_{pr2} = \text{Max}(M_{u2+}, M_{u2-}) = 2.4829E+008$

Mu2+ = 2.4829E+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- = 2.4829E+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 = 2.4829E+008

-----  
= 0.82030475

' = 0.72936354

error of function (3.68), Biskinis Phd = 58391.315

From 5A.2, TBDY: fcc = fc\* c = 48.42699

conf. factor c = 1.46748

fc = 33.00

From 10.3.5, ASCE 41-17, Final value of fy: fy\*Min(1,1.25\*(lb/d)^ 2/3) = 389.0139

lb/d = 0.30

d1 = 44.00

R = 250.00

v = 0.00103167

N = 7389.214

Ac = 196349.541

= \*Min(1,1.25\*(lb/d)^ 2/3) = 0.16585331  
-----

Calculation of ratio lb/d  
-----

Inadequate Lap Length with lb/d = 0.30  
-----  
-----

Calculation of Mu1-  
-----

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

Mu = 2.4829E+008

-----  
= 0.82030475

' = 0.72936354

error of function (3.68), Biskinis Phd = 58391.315

From 5A.2, TBDY: fcc = fc\* c = 48.42699

conf. factor c = 1.46748

fc = 33.00

From 10.3.5, ASCE 41-17, Final value of fy: fy\*Min(1,1.25\*(lb/d)^ 2/3) = 389.0139

lb/d = 0.30

d1 = 44.00

R = 250.00

v = 0.00103167

N = 7389.214

Ac = 196349.541

= \*Min(1,1.25\*(lb/d)^ 2/3) = 0.16585331  
-----

Calculation of ratio lb/d  
-----

Inadequate Lap Length with lb/d = 0.30  
-----  
-----

Calculation of Mu2+  
-----

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), Mu  
Mu = 2.4829E+008

$$= 0.82030475$$

$$' = 0.72936354$$

error of function (3.68), Biskinis Phd = 58391.315

From 5A.2, TBDY:  $f_{cc} = f_c \cdot c = 48.42699$

$$\text{conf. factor } c = 1.46748$$

$$f_c = 33.00$$

From 10.3.5, ASCE 41-17, Final value of  $f_y$ :  $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 389.0139$

$$l_b/d = 0.30$$

$$d_1 = 44.00$$

$$R = 250.00$$

$$v = 0.00103167$$

$$N = 7389.214$$

$$A_c = 196349.541$$

$$= \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.16585331$$

Calculation of ratio  $l_b/d$

Inadequate Lap Length with  $l_b/d = 0.30$

Calculation of Mu2-

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), Mu  
Mu = 2.4829E+008

$$= 0.82030475$$

$$' = 0.72936354$$

error of function (3.68), Biskinis Phd = 58391.315

From 5A.2, TBDY:  $f_{cc} = f_c \cdot c = 48.42699$

$$\text{conf. factor } c = 1.46748$$

$$f_c = 33.00$$

From 10.3.5, ASCE 41-17, Final value of  $f_y$ :  $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 389.0139$

$$l_b/d = 0.30$$

$$d_1 = 44.00$$

$$R = 250.00$$

$$v = 0.00103167$$

$$N = 7389.214$$

$$A_c = 196349.541$$

$$= \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.16585331$$

Calculation of ratio  $l_b/d$

Inadequate Lap Length with  $l_b/d = 0.30$

Calculation of Shear Strength  $V_r = \text{Min}(V_{r1}, V_{r2}) = 705811.584$

Calculation of Shear Strength at edge 1,  $V_{r1} = 705811.584$

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

$$V_{Col0} = 705811.584$$

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

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:  $f_c' = (f_c'_{\text{jacket}} \cdot \text{Area}_{\text{jacket}} + f_c'_{\text{core}} \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 33.00$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$\mu_u = 1.6210513E-011$

$\nu_u = 1.1471900E-030$

$d = 0.8 \cdot D = 400.00$

$N_u = 7389.214$

$A_g = 196349.541$

From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 274157.871$

$V_{s1} = 274157.871$  is calculated for jacket, with:

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

$f_y = 555.56$

$s = 100.00$

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

$s/d = 0.25$

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

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

$f_y = 555.56$

$s = 250.00$

$V_{s2}$  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:  $\theta = b_1 + 90^\circ = 90.00$

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

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

$d_{fv} = d$  (figure 11.2, ACI 440) = 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:  $V_s + V_f \leq 479549.663$

$b_w \cdot d = \sqrt{2} \cdot d^2 / 4 = 125663.706$

Calculation of Shear Strength at edge 2,  $V_{r2} = 705811.584$

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

$V_{\text{Col}0} = 705811.584$

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

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

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

Mean concrete strength:  $f_c' = (f_c'_{\text{jacket}} \cdot \text{Area}_{\text{jacket}} + f_c'_{\text{core}} \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 33.00$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$\mu_u = 1.6210513E-011$

$\nu_u = 1.1471900E-030$

$d = 0.8 \cdot D = 400.00$

$N_u = 7389.214$

$A_g = 196349.541$

From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 274157.871$

$V_{s1} = 274157.871$  is calculated for jacket, with:

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

$f_y = 555.56$

$s = 100.00$

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

$s/d = 0.25$

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

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

$f_y = 555.56$

$s = 250.00$   
 $V_s$  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  $\theta$  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,  $tf1 = NL * t / NoDir = 1.016$   
 $dfv = d$  (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:  $V_s + V_f \leq 479549.663$   
 $bw * d = \rho * d * d / 4 = 125663.706$

-----  
 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 Secondary Member: Concrete Strength,  $f_c = f_{cm} = 33.00$   
 New material of Secondary Member: Steel Strength,  $f_s = f_{sm} = 555.56$   
 Concrete Elasticity,  $E_c = 26999.444$   
 Steel Elasticity,  $E_s = 200000.00$   
 Existing Column  
 New material of Secondary Member: Concrete Strength,  $f_c = f_{cm} = 33.00$   
 New material of Secondary Member: Steel Strength,  $f_s = f_{sm} = 555.56$   
 Concrete Elasticity,  $E_c = 26999.444$   
 Steel Elasticity,  $E_s = 200000.00$   
 #####  
 Note: Especially for the calculation of moment strengths,  
 the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14  
 Jacket  
 New material: Steel Strength,  $f_s = 1.25 * f_{sm} = 694.45$   
 Existing Column  
 New material: Steel Strength,  $f_s = 1.25 * f_{sm} = 694.45$   
 #####  
 External Diameter,  $D = 500.00$   
 Internal Diameter,  $D = 300.00$   
 Cover Thickness,  $c = 25.00$   
 Mean Confinement Factor overall section = 1.46748  
 Element Length,  $L = 3000.00$   
 Secondary Member  
 Ribbed Bars  
 Ductile Steel  
 Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)  
 Longitudinal Bars With Ends Lapped Starting at the End Sections  
 Inadequate Lap Length with  $l_o / l_{ou, min} = 0.30$

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness,  $t = 1.016$

Tensile Strength,  $f_{fu} = 1055.00$

Tensile Modulus,  $E_f = 64828.00$

Elongation,  $\epsilon_{fu} = 0.01$

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

Fiber orientations,  $b_i = 0.00^\circ$

Number of layers,  $N_L = 1$

Radius of rounding corners,  $R = 40.00$

Stepwise Properties

At local axis: 2

EDGE -A-

Shear Force,  $V_a = -7.0242809E-047$

EDGE -B-

Shear Force,  $V_b = 7.0242809E-047$

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,  $V_e/V_r = 0.23451953$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 165526.599$

with

$M_{pr1} = \text{Max}(M_{u1+}, M_{u1-}) = 2.4829E+008$

$M_{u1+} = 2.4829E+008$ , is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination

$M_{u1-} = 2.4829E+008$ , is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination

$M_{pr2} = \text{Max}(M_{u2+}, M_{u2-}) = 2.4829E+008$

$M_{u2+} = 2.4829E+008$ , is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the static loading combination

$M_{u2-} = 2.4829E+008$ , is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the static loading combination

Calculation of  $M_{u1+}$

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

$M_u = 2.4829E+008$

$\beta_1 = 0.82030475$

$\beta_2 = 0.72936354$

error of function (3.68), Biskinis Phd = 58391.315

From 5A.2, TBDY:  $f_{cc} = f_c \cdot c = 48.42699$

conf. factor  $c = 1.46748$

$f_c = 33.00$

From 10.3.5, ASCE 41-17, Final value of  $f_y$ :  $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3}) = 389.0139$

$l_b/l_d = 0.30$

$d_1 = 44.00$

$R = 250.00$

$v = 0.00103167$

$$N = 7389.214$$
$$Ac = 196349.541$$
$$= *Min(1,1.25*(lb/d)^{2/3}) = 0.16585331$$

Calculation of ratio lb/d

Inadequate Lap Length with lb/d = 0.30

Calculation of Mu1-

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), Mu  
Mu = 2.4829E+008

$$= 0.82030475$$
$$' = 0.72936354$$

error of function (3.68), Biskinis Phd = 58391.315

From 5A.2, TBDY: fcc = fc\* c = 48.42699

conf. factor c = 1.46748

fc = 33.00

From 10.3.5, ASCE 41-17, Final value of fy: fy\*Min(1,1.25\*(lb/d)^{2/3}) = 389.0139

lb/d = 0.30

d1 = 44.00

R = 250.00

v = 0.00103167

N = 7389.214

Ac = 196349.541

$$= *Min(1,1.25*(lb/d)^{2/3}) = 0.16585331$$

Calculation of ratio lb/d

Inadequate Lap Length with lb/d = 0.30

Calculation of Mu2+

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), Mu  
Mu = 2.4829E+008

$$= 0.82030475$$
$$' = 0.72936354$$

error of function (3.68), Biskinis Phd = 58391.315

From 5A.2, TBDY: fcc = fc\* c = 48.42699

conf. factor c = 1.46748

fc = 33.00

From 10.3.5, ASCE 41-17, Final value of fy: fy\*Min(1,1.25\*(lb/d)^{2/3}) = 389.0139

lb/d = 0.30

d1 = 44.00

R = 250.00

v = 0.00103167

N = 7389.214

Ac = 196349.541

$$= *Min(1,1.25*(lb/d)^{2/3}) = 0.16585331$$

Calculation of ratio lb/d

Inadequate Lap Length with lb/d = 0.30

Calculation of Mu2-

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), Mu  
Mu = 2.4829E+008

$$= 0.82030475$$

$$' = 0.72936354$$

error of function (3.68), Biskinis Phd = 58391.315

From 5A.2, TBDY:  $f_{cc} = f_c' \cdot c = 48.42699$

conf. factor  $c = 1.46748$

$f_c = 33.00$

From 10.3.5, ASCE 41-17, Final value of fy:  $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 389.0139$

$l_b/d = 0.30$

$d_1 = 44.00$

$R = 250.00$

$v = 0.00103167$

$N = 7389.214$

$A_c = 196349.541$

$= \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.16585331$

Calculation of ratio  $l_b/d$

Inadequate Lap Length with  $l_b/d = 0.30$

Calculation of Shear Strength  $V_r = \text{Min}(V_{r1}, V_{r2}) = 705811.584$

Calculation of Shear Strength at edge 1,  $V_{r1} = 705811.584$

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

$V_{Col0} = 705811.584$

$k_{nl} = 1$  (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:  $f_c' = (f_c'_{jacket} \cdot \text{Area}_{jacket} + f_c'_{core} \cdot \text{Area}_{core}) / \text{Area}_{section} = 33.00$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$M_u = 1.7556432E-011$

$V_u = 7.0242809E-047$

$d = 0.8 \cdot D = 400.00$

$N_u = 7389.214$

$A_g = 196349.541$

From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 274157.871$

$V_{s1} = 274157.871$  is calculated for jacket, with:

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

$f_y = 555.56$

$s = 100.00$

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

$s/d = 0.25$

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

$A_v = \sqrt{2} \cdot A_{stirup} = 78956.835$

$f_y = 555.56$

$s = 250.00$

$V_{s2}$  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)  $\sin \theta + \cos \theta$  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  $V_f(\theta, \alpha)$ , 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:  $\theta = b1 + 90^\circ = 90.00$   
 $V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, \alpha)|)$ , 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), 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:  $V_s + V_f \leq 479549.663$   
 $b_w \cdot d = \frac{A_s \cdot d}{4} = 125663.706$

Calculation of Shear Strength at edge 2,  $V_{r2} = 705811.584$   
 $V_{r2} = V_{Col}$  ((10.3), ASCE 41-17) =  $k_{nl} \cdot V_{Col0}$   
 $V_{Col0} = 705811.584$   
 $k_{nl} = 1$  (zero step-static loading)

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

$\rho = 1$  (normal-weight concrete)  
Mean concrete strength:  $f_c' = (f_c'_{jacket} \cdot \text{Area}_{jacket} + f_c'_{core} \cdot \text{Area}_{core}) / \text{Area}_{section} = 33.00$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)  
 $M/Vd = 2.00$   
 $\mu_u = 1.7556432E-011$   
 $\nu_u = 7.0242809E-047$   
 $d = 0.8 \cdot D = 400.00$   
 $N_u = 7389.214$   
 $A_g = 196349.541$   
From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 274157.871$   
 $V_{s1} = 274157.871$  is calculated for jacket, with:  
 $A_v = \frac{A_s}{2} = 123370.055$   
 $f_y = 555.56$   
 $s = 100.00$   
 $V_{s1}$  is multiplied by  $\text{Col1} = 1.00$   
 $s/d = 0.25$   
 $V_{s2} = 0.00$  is calculated for core, with:  
 $A_v = \frac{A_s}{2} = 78956.835$   
 $f_y = 555.56$   
 $s = 250.00$   
 $V_{s2}$  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  $V_f(\theta, \alpha)$ , 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:  $\theta = b1 + 90^\circ = 90.00$   
 $V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, \alpha)|)$ , 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), 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:  $V_s + V_f \leq 479549.663$   
 $b_w \cdot d = \frac{A_s \cdot d}{4} = 125663.706$

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

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

Concrete Elasticity,  $E_c = 26999.444$

Steel Elasticity,  $E_s = 200000.00$

Existing Column

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

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

Concrete Elasticity,  $E_c = 26999.444$

Steel Elasticity,  $E_s = 200000.00$

External Diameter,  $D = 500.00$

Internal Diameter,  $D = 300.00$

Cover Thickness,  $c = 25.00$

Element Length,  $L = 3000.00$

Secondary Member

Ribbed Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

Inadequate Lap Length with  $l_b/l_d = 0.30$

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness,  $t = 1.016$

Tensile Strength,  $f_{fu} = 1055.00$

Tensile Modulus,  $E_f = 64828.00$

Elongation,  $e_{fu} = 0.01$

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

Fiber orientations,  $b_i = 0.00^\circ$

Number of layers,  $N_L = 1$

Radius of rounding corners,  $R = 40.00$

#### Stepwise Properties

Bending Moment,  $M = -2.2657E+007$

Shear Force,  $V_2 = -7550.492$

Shear Force,  $V_3 = -4.7296730E-013$

Axial Force,  $F = -7386.193$

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,  $DbL = 18.00$

New component: From table 7-7, ASCE 41\_17: Final chord rotation Capacity  $\mu_{u,R} = 1.0^*$   $\mu = 0.0090541$

$$u = y + p = 0.0090541$$

- Calculation of  $y$  -

$$y = (M_y * L_s / 3) / E_{\text{eff}} = 0.0090541 \text{ ((4.29), Biskinis Phd)}$$

$$M_y = 2.2494E+008$$

$$L_s = M/V \text{ (with } L_s > 0.1 * L \text{ and } L_s < 2 * L) = 3000.736$$

$$\text{From table 10.5, ASCE 41-17: } E_{\text{eff}} = \text{factor} * E_c * I_g = 2.4850E+013$$

$$\text{factor} = 0.30$$

$$A_g = 196349.541$$

$$\text{Mean concrete strength: } f_c' = (f_c'_{\text{jacket}} * A_{\text{jacket}} + f_c'_{\text{core}} * A_{\text{core}}) / A_{\text{section}} = 33.00$$

$$N = 7386.193$$

$$E_c * I_g = E_{c_{\text{jacket}}} * I_{g_{\text{jacket}}} + E_{c_{\text{core}}} * I_{g_{\text{core}}} = 8.2833E+013$$

Calculation of Yielding Moment  $M_y$

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

$$M_y = \text{Min}(M_{y_{\text{ten}}}, M_{y_{\text{com}}}) = 2.2494E+008$$

$$y = 6.4602099E-006$$

$$M_{y_{\text{ten}}} \text{ (8c)} = 2.2494E+008$$

$$y_{\text{ten}} \text{ (7c)} = 62.07295$$

$$\text{error of function (7c)} = 0.00023516$$

$$M_{y_{\text{com}}} \text{ (8d)} = 8.0674E+008$$

$$y_{\text{com}} \text{ (7d)} = 63.84405$$

$$\text{error of function (7d)} = -0.00846595$$

$$\text{with ((10.1), ASCE 41-17) } e_y = \text{Min}(e_y, 1.25 * e_y * (l_b / l_d)^{2/3}) = 0.0027778$$

$$e_{c0} = 0.002$$

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

$$d_1 = 44.00$$

$$R = 250.00$$

$$v = 0.00103619$$

$$N = 7386.193$$

$$A_c = 196349.541$$

$$\text{((10.1), ASCE 41-17) } = \text{Min}( , 1.25 * * (l_b / l_d)^{2/3}) = 0.23799351$$

$$\text{with } f_c' \text{ ((12.3), ACI 440)} = 36.3038$$

$$f_c = 33.00$$

$$f_l = 1.05384$$

$$k = 1$$

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

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

$$f_u = 0.01$$

$$E_f = 64828.00$$

Calculation of ratio  $l_b / l_d$

Inadequate Lap Length with  $l_b / l_d = 0.30$

- Calculation of  $p$  -

From table 10-9:  $p = 0.00$

with:

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

$$\text{shear control ratio } V_y E / V_c O E = 0.23451953$$

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

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

$$t = s_1 + s_2 + 2 * t_f / b_w * (f_{fe} / f_s) = 0.00702809$$

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

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

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

$$s1 = 100.00$$

$$\text{core: } s2 = Av2 * (\pi * Dc2 / 2) / (s2 * Ag) = 0.00046968$$

Av2 = 50.26548, is the area of stirrup

Dc2 = Dint - Internal Hoop Diameter = 292.00, is the total Length of all stirrups parallel to loading (shear)

direction

$$s2 = 250.00$$

The term  $2 * tf / bw * (ffe / fs)$  is implemented to account for FRP contribution

where  $f = 2 * tf / bw$  is FRP ratio (EC8 - 3, A.4.4.3(6)) and  $ffe / fs$  normalises  $f$  to steel strength

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

For the normalisation  $fs$  of jacket is used.

$$NUD = 7386.193$$

$$Ag = 196349.541$$

$$fcE = (fc\_jacket * Area\_jacket + fc\_core * Area\_core) / section\_area = 33.00$$

$$fyIE = (fy\_ext\_Long\_Reinf * Area\_ext\_Long\_Reinf + fy\_int\_Long\_Reinf * Area\_int\_Long\_Reinf) / Area\_Tot\_Long\_Rein = 2.1219958E-314$$

$$fytE = (fy\_ext\_Trans\_Reinf * Area\_ext\_Trans\_Reinf + fy\_int\_Trans\_Reinf * Area\_int\_Trans\_Reinf) / Area\_Tot\_Trans\_Rein = 555.56$$

$$pl = Area\_Tot\_Long\_Rein / (Ag) = 0.015552$$

$$fcE = 33.00$$

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

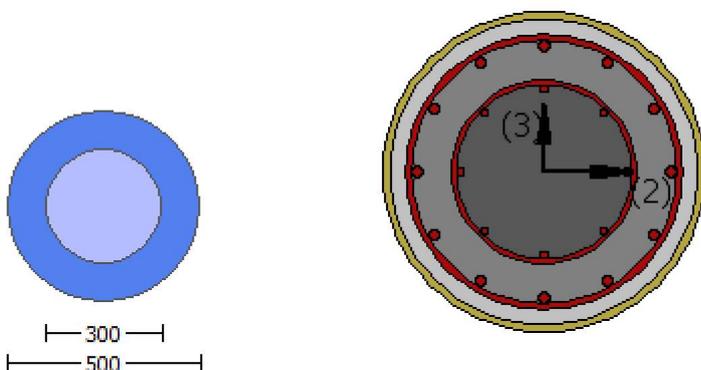
Limit State: Immediate Occupancy (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Shear capacity VRd

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 Secondary Member: Concrete Strength,  $f_c = f_{c\_lower\_bound} = 25.00$

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

Concrete Elasticity,  $E_c = 26999.444$

Steel Elasticity,  $E_s = 200000.00$

Existing Column

New material of Secondary Member: Concrete Strength,  $f_c = f_{c\_lower\_bound} = 25.00$

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

Concrete Elasticity,  $E_c = 26999.444$

Steel Elasticity,  $E_s = 200000.00$

#####

Note: Especially for the calculation of  $\gamma$  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,  $f_c = f_{cm} = 33.00$

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

Existing Column

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

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

#####

External Diameter,  $D = 500.00$

Internal Diameter,  $D = 300.00$

Cover Thickness,  $c = 25.00$

Element Length,  $L = 3000.00$

Secondary Member

Ribbed Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

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

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness,  $t = 1.016$

Tensile Strength,  $f_{fu} = 1055.00$

Tensile Modulus,  $E_f = 64828.00$

Elongation,  $e_{fu} = 0.01$

Number of directions,  $NoDir = 1$

Fiber orientations,  $b_i = 0.00^\circ$

Number of layers,  $NL = 1$

Radius of rounding corners,  $R = 40.00$

Stepwise Properties

EDGE -A-

Bending Moment,  $M_a = -2.2657E+007$

Shear Force,  $V_a = -7550.492$

EDGE -B-

Bending Moment,  $M_b = 0.08820332$

Shear Force,  $V_b = 7550.492$

BOTH EDGES

Axial Force,  $F = -7386.193$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension:  $As_t = 0.00$

-Compression:  $As_c = 3053.628$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

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

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

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

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

New component: From table 7-7, ASCE 41\_17: Final Shear Capacity  $V_R = 1.0 \cdot V_n = 614519.737$

$V_n$  ((10.3), ASCE 41-17) =  $k_n \cdot V_{CoI0} = 614519.737$

$V_{CoI} = 614519.737$

$k_n = 1.00$

$displacement\_ductility\_demand = 0.15107258$

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:  $f_c' = (f_c'_{jacket} \cdot Area_{jacket} + f_c'_{core} \cdot Area_{core}) / Area_{section} = 25.00$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$\mu_u = 0.08820332$

$V_u = 7550.492$

$d = 0.8 \cdot D = 400.00$

$N_u = 7386.193$

$A_g = 196349.541$

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:

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

$f_y = 500.00$

$s = 100.00$

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

$s/d = 0.25$

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

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

$f_y = 500.00$

$s = 250.00$

$V_{s2}$  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  $(\cot + \cot) \sin \alpha$  which is more a generalised expression, where  $\alpha$  is the angle of the crack direction (see KANEPE).

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

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

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

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

$d_{fv} = d$  (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:  $V_s + V_f \leq 417394.406$

$b_w \cdot d = \sqrt{4} \cdot d = 125663.706$

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

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

for rotation axis 3 and integ. section (b)

From analysis, chord rotation  $\theta = 0.00013675$

$y = (M_y \cdot L_s / 3) / E_{eff} = 0.00090519$  ((4.29), Biskinis Phd)

$M_y = 2.2494E+008$

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

From table 10.5, ASCE 41\_17:  $E_{eff} = factor * E_c * I_g = 2.4850E+013$

factor = 0.30

$A_g = 196349.541$

Mean concrete strength:  $f_c' = (f_c'_{jacket} * Area_{jacket} + f_c'_{core} * Area_{core}) / Area_{section} = 33.00$

$N = 7386.193$

$E_c * I_g = E_c_{jacket} * I_{g_{jacket}} + E_c_{core} * I_{g_{core}} = 8.2833E+013$

Calculation of Yielding Moment  $M_y$

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

$M_y = \text{Min}(M_{y_{ten}}, M_{y_{com}}) = 2.2494E+008$

$y = 6.4602099E-006$

$M_{y_{ten}} (8c) = 2.2494E+008$

$\rho_{y_{ten}} (7c) = 62.07295$

error of function (7c) = 0.00023516

$M_{y_{com}} (8d) = 8.0674E+008$

$\rho_{y_{com}} (7d) = 63.84405$

error of function (7d) = -0.00846595

with ((10.1), ASCE 41-17)  $\rho_y = \text{Min}(\rho_y, 1.25 * \rho_y * (l_b / l_d)^{2/3}) = 0.0027778$

$\rho_{co} = 0.002$

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

$d_1 = 44.00$

$R = 250.00$

$v = 0.00103619$

$N = 7386.193$

$A_c = 196349.541$

((10.1), ASCE 41-17)  $\rho_y = \text{Min}(\rho_y, 1.25 * \rho_y * (l_b / l_d)^{2/3}) = 0.23799351$

with  $f_c' ((12.3), ACI 440) = 36.3038$

$f_c = 33.00$

$f_l = 1.05384$

$k = 1$

Effective FRP thickness,  $t_f = NL * t * \text{Cos}(b_1) = 1.016$

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

$f_u = 0.01$

$E_f = 64828.00$

Calculation of ratio  $l_b / l_d$

Inadequate Lap Length with  $l_b / l_d = 0.30$

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

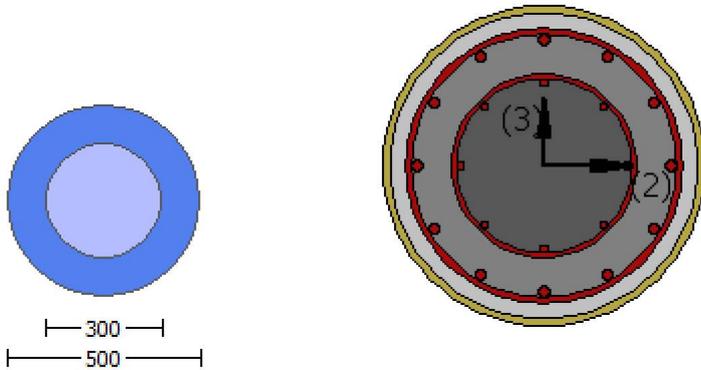
Limit State: Immediate Occupancy (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity ( $\theta_u$ )

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

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

Concrete Elasticity,  $E_c = 26999.444$

Steel Elasticity,  $E_s = 200000.00$

Existing Column

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

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

Concrete Elasticity,  $E_c = 26999.444$

Steel Elasticity,  $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

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

Jacket

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

Existing Column

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

#####

External Diameter,  $D = 500.00$

Internal Diameter,  $D = 300.00$

Cover Thickness,  $c = 25.00$

Mean Confinement Factor overall section = 1.46748

Element Length,  $L = 3000.00$

Secondary Member

Ribbed Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

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

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness,  $t = 1.016$

Tensile Strength,  $f_{fu} = 1055.00$

Tensile Modulus,  $E_f = 64828.00$

Elongation,  $\epsilon_{fu} = 0.01$

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

Fiber orientations,  $b_i = 0.00^\circ$

Number of layers,  $N_L = 1$

Radius of rounding corners,  $R = 40.00$

Stepwise Properties

At local axis: 3

EDGE -A-

Shear Force,  $V_a = 1.1471900E-030$

EDGE -B-

Shear Force,  $V_b = -1.1471900E-030$

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,  $V_e/V_r = 0.23451953$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 165526.599$

with

$M_{pr1} = \text{Max}(Mu_{1+}, Mu_{1-}) = 2.4829E+008$

$Mu_{1+} = 2.4829E+008$ , is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination

$Mu_{1-} = 2.4829E+008$ , is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination

$M_{pr2} = \text{Max}(Mu_{2+}, Mu_{2-}) = 2.4829E+008$

$Mu_{2+} = 2.4829E+008$ , is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the static loading combination

$Mu_{2-} = 2.4829E+008$ , 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),  $Mu$

$Mu = 2.4829E+008$

$\phi = 0.82030475$

$\phi' = 0.72936354$

error of function (3.68), Biskinis Phd = 58391.315

From 5A.2, TBDY:  $f_{cc} = f_c \cdot c = 48.42699$

conf. factor  $c = 1.46748$

$f_c = 33.00$

From 10.3.5, ASCE 41-17, Final value of  $f_y$ :  $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3}) = 389.0139$

$l_b/l_d = 0.30$

$d_1 = 44.00$

$R = 250.00$

$v = 0.00103167$

$$N = 7389.214$$
$$Ac = 196349.541$$
$$= *Min(1,1.25*(lb/d)^{2/3}) = 0.16585331$$

Calculation of ratio lb/d

Inadequate Lap Length with lb/d = 0.30

Calculation of Mu1-

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), Mu  
Mu = 2.4829E+008

$$= 0.82030475$$
$$' = 0.72936354$$

error of function (3.68), Biskinis Phd = 58391.315

From 5A.2, TBDY: fcc = fc\* c = 48.42699

conf. factor c = 1.46748

fc = 33.00

From 10.3.5, ASCE 41-17, Final value of fy: fy\*Min(1,1.25\*(lb/d)^{2/3}) = 389.0139

lb/d = 0.30

d1 = 44.00

R = 250.00

v = 0.00103167

N = 7389.214

Ac = 196349.541

$$= *Min(1,1.25*(lb/d)^{2/3}) = 0.16585331$$

Calculation of ratio lb/d

Inadequate Lap Length with lb/d = 0.30

Calculation of Mu2+

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), Mu  
Mu = 2.4829E+008

$$= 0.82030475$$
$$' = 0.72936354$$

error of function (3.68), Biskinis Phd = 58391.315

From 5A.2, TBDY: fcc = fc\* c = 48.42699

conf. factor c = 1.46748

fc = 33.00

From 10.3.5, ASCE 41-17, Final value of fy: fy\*Min(1,1.25\*(lb/d)^{2/3}) = 389.0139

lb/d = 0.30

d1 = 44.00

R = 250.00

v = 0.00103167

N = 7389.214

Ac = 196349.541

$$= *Min(1,1.25*(lb/d)^{2/3}) = 0.16585331$$

Calculation of ratio lb/d

Inadequate Lap Length with lb/d = 0.30

Calculation of Mu2-

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), Mu  
Mu = 2.4829E+008

$$= 0.82030475$$

$$' = 0.72936354$$

error of function (3.68), Biskinis Phd = 58391.315

From 5A.2, TBDY:  $f_{cc} = f_c' \cdot c = 48.42699$

conf. factor  $c = 1.46748$

$f_c = 33.00$

From 10.3.5, ASCE 41-17, Final value of fy:  $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 389.0139$

$l_b/d = 0.30$

$d_1 = 44.00$

$R = 250.00$

$v = 0.00103167$

$N = 7389.214$

$A_c = 196349.541$

$= \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.16585331$

Calculation of ratio  $l_b/d$

Inadequate Lap Length with  $l_b/d = 0.30$

Calculation of Shear Strength  $V_r = \text{Min}(V_{r1}, V_{r2}) = 705811.584$

Calculation of Shear Strength at edge 1,  $V_{r1} = 705811.584$

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

$V_{Col0} = 705811.584$

$k_{nl} = 1$  (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:  $f_c' = (f_c'_{jacket} \cdot \text{Area}_{jacket} + f_c'_{core} \cdot \text{Area}_{core}) / \text{Area}_{section} = 33.00$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$\mu_u = 1.6210513E-011$

$\nu_u = 1.1471900E-030$

$d = 0.8 \cdot D = 400.00$

$N_u = 7389.214$

$A_g = 196349.541$

From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 274157.871$

$V_{s1} = 274157.871$  is calculated for jacket, with:

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

$f_y = 555.56$

$s = 100.00$

$V_{s1}$  is multiplied by  $\phi_{col1} = 1.00$

$s/d = 0.25$

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

$A_v = \sqrt{2} \cdot A_{stirup} = 78956.835$

$f_y = 555.56$

$s = 250.00$

$V_{s2}$  is multiplied by  $\phi_{col2} = 0.00$

$s/d = 1.04167$

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

$f = 0.95$ , for fully-wrapped sections

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

In (11.3)  $\sin \theta + \cos \theta$  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  $V_f(\theta, \alpha)$ , 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:  $\theta = b1 + 90^\circ = 90.00$   
 $V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, \theta)|)$ , 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), 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:  $V_s + V_f \leq 479549.663$   
 $b_w \cdot d = \frac{A_s \cdot d}{4} = 125663.706$

Calculation of Shear Strength at edge 2,  $V_{r2} = 705811.584$   
 $V_{r2} = V_{Col}$  ((10.3), ASCE 41-17) =  $k_{nl} \cdot V_{Col0}$   
 $V_{Col0} = 705811.584$   
 $k_{nl} = 1$  (zero step-static loading)

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

$\rho = 1$  (normal-weight concrete)  
Mean concrete strength:  $f'_c = (f'_c \cdot \text{Area}_{\text{jacket}} + f'_c \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 33.00$ , but  $f'_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)  
 $M / Vd = 2.00$   
 $\mu_u = 1.6210513E-011$   
 $\nu_u = 1.1471900E-030$   
 $d = 0.8 \cdot D = 400.00$   
 $N_u = 7389.214$   
 $A_g = 196349.541$   
From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 274157.871$   
 $V_{s1} = 274157.871$  is calculated for jacket, with:  
 $A_v = \frac{A_s}{2} = 123370.055$   
 $f_y = 555.56$   
 $s = 100.00$   
 $V_{s1}$  is multiplied by  $\rho_{col1} = 1.00$   
 $s/d = 0.25$   
 $V_{s2} = 0.00$  is calculated for core, with:  
 $A_v = \frac{A_s}{2} = 78956.835$   
 $f_y = 555.56$   
 $s = 250.00$   
 $V_{s2}$  is multiplied by  $\rho_{col2} = 0.00$   
 $s/d = 1.04167$   
 $V_f$  ((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  $V_f(\theta, \alpha)$ , 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:  $\theta = b1 + 90^\circ = 90.00$   
 $V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, \theta)|)$ , 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), 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:  $V_s + V_f \leq 479549.663$   
 $b_w \cdot d = \frac{A_s \cdot d}{4} = 125663.706$

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 Secondary Member: Concrete Strength,  $f_c = f_{cm} = 33.00$   
New material of Secondary Member: Steel Strength,  $f_s = f_{sm} = 555.56$   
Concrete Elasticity,  $E_c = 26999.444$   
Steel Elasticity,  $E_s = 200000.00$   
Existing Column  
New material of Secondary Member: Concrete Strength,  $f_c = f_{cm} = 33.00$   
New material of Secondary Member: Steel Strength,  $f_s = f_{sm} = 555.56$   
Concrete Elasticity,  $E_c = 26999.444$   
Steel Elasticity,  $E_s = 200000.00$

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

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

External Diameter,  $D = 500.00$   
Internal Diameter,  $D = 300.00$   
Cover Thickness,  $c = 25.00$   
Mean Confinement Factor overall section = 1.46748  
Element Length,  $L = 3000.00$   
Secondary Member  
Ribbed Bars  
Ductile Steel  
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)  
Longitudinal Bars With Ends Lapped Starting at the End Sections  
Inadequate Lap Length with  $l_o/l_{ou, \min} = 0.30$   
FRP Wrapping Data  
Type: Carbon  
Cured laminate properties (design values)  
Thickness,  $t = 1.016$   
Tensile Strength,  $f_{fu} = 1055.00$   
Tensile Modulus,  $E_f = 64828.00$   
Elongation,  $e_{fu} = 0.01$   
Number of directions,  $N_{oDir} = 1$   
Fiber orientations,  $b_i: 0.00^\circ$   
Number of layers,  $N_L = 1$   
Radius of rounding corners,  $R = 40.00$

Stepwise Properties

At local axis: 2  
EDGE -A-  
Shear Force,  $V_a = -7.0242809E-047$   
EDGE -B-  
Shear Force,  $V_b = 7.0242809E-047$   
BOTH EDGES  
Axial Force,  $F = -7389.214$   
Longitudinal Reinforcement Area Distribution (in 2 divisions)  
-Tension:  $A_{st} = 0.00$

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

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-----  
Calculation of Shear Capacity ratio,  $V_e/V_r = 0.23451953$   
Member Controlled by Flexure ( $V_e/V_r < 1$ )  
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 165526.599$   
with

$M_{pr1} = \text{Max}(M_{u1+}, M_{u1-}) = 2.4829E+008$   
 $M_{u1+} = 2.4829E+008$ , is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination  
 $M_{u1-} = 2.4829E+008$ , is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination  
 $M_{pr2} = \text{Max}(M_{u2+}, M_{u2-}) = 2.4829E+008$   
 $M_{u2+} = 2.4829E+008$ , is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the the static loading combination  
 $M_{u2-} = 2.4829E+008$ , is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the the static loading combination

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

-----  
Calculation of ultimate Moment Strength ((3.67), Biskinis Phd),  $M_u$   
 $M_u = 2.4829E+008$

-----  
= 0.82030475  
' = 0.72936354  
error of function (3.68), Biskinis Phd = 58391.315  
From 5A.2, TBDY:  $f_{cc} = f_c^* c = 48.42699$   
conf. factor  $c = 1.46748$   
 $f_c = 33.00$   
From 10.3.5, ASCE 41-17, Final value of  $f_y: f_y * \text{Min}(1, 1.25 * (l_b/d)^{2/3}) = 389.0139$   
 $l_b/d = 0.30$   
 $d_1 = 44.00$   
 $R = 250.00$   
 $v = 0.00103167$   
 $N = 7389.214$   
 $A_c = 196349.541$   
=  $*\text{Min}(1, 1.25 * (l_b/d)^{2/3}) = 0.16585331$

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

Inadequate Lap Length with  $l_b/d = 0.30$   
-----  
-----

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

-----  
Calculation of ultimate Moment Strength ((3.67), Biskinis Phd),  $M_u$   
 $M_u = 2.4829E+008$

-----  
= 0.82030475  
' = 0.72936354  
error of function (3.68), Biskinis Phd = 58391.315  
From 5A.2, TBDY:  $f_{cc} = f_c^* c = 48.42699$   
conf. factor  $c = 1.46748$   
 $f_c = 33.00$

From 10.3.5, ASCE 41-17, Final value of  $f_y$ :  $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 389.0139$

$$l_b/d = 0.30$$

$$d_1 = 44.00$$

$$R = 250.00$$

$$v = 0.00103167$$

$$N = 7389.214$$

$$A_c = 196349.541$$

$$= \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.16585331$$

Calculation of ratio  $l_b/d$

Inadequate Lap Length with  $l_b/d = 0.30$

Calculation of  $\mu_{2+}$

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

$$\mu = 2.4829E+008$$

$$= 0.82030475$$

$$' = 0.72936354$$

error of function (3.68), Biskinis Phd = 58391.315

From 5A.2, TBDY:  $f_{cc} = f_c \cdot c = 48.42699$

$$\text{conf. factor } c = 1.46748$$

$$f_c = 33.00$$

From 10.3.5, ASCE 41-17, Final value of  $f_y$ :  $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 389.0139$

$$l_b/d = 0.30$$

$$d_1 = 44.00$$

$$R = 250.00$$

$$v = 0.00103167$$

$$N = 7389.214$$

$$A_c = 196349.541$$

$$= \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.16585331$$

Calculation of ratio  $l_b/d$

Inadequate Lap Length with  $l_b/d = 0.30$

Calculation of  $\mu_{2-}$

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

$$\mu = 2.4829E+008$$

$$= 0.82030475$$

$$' = 0.72936354$$

error of function (3.68), Biskinis Phd = 58391.315

From 5A.2, TBDY:  $f_{cc} = f_c \cdot c = 48.42699$

$$\text{conf. factor } c = 1.46748$$

$$f_c = 33.00$$

From 10.3.5, ASCE 41-17, Final value of  $f_y$ :  $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 389.0139$

$$l_b/d = 0.30$$

$$d_1 = 44.00$$

$$R = 250.00$$

$$v = 0.00103167$$

$$N = 7389.214$$

$$A_c = 196349.541$$

$$= \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.16585331$$

Calculation of ratio  $l_b/l_d$

Inadequate Lap Length with  $l_b/l_d = 0.30$

Calculation of Shear Strength  $V_r = \text{Min}(V_{r1}, V_{r2}) = 705811.584$

Calculation of Shear Strength at edge 1,  $V_{r1} = 705811.584$

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

$V_{Col0} = 705811.584$

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

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

$= 1$  (normal-weight concrete)

Mean concrete strength:  $f_c' = (f_c'_{jacket} \text{Area}_{jacket} + f_c'_{core} \text{Area}_{core}) / \text{Area}_{section} = 33.00$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$\mu_u = 1.7556432E-011$

$\nu_u = 7.0242809E-047$

$d = 0.8D = 400.00$

$N_u = 7389.214$

$A_g = 196349.541$

From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 274157.871$

$V_{s1} = 274157.871$  is calculated for jacket, with:

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

$f_y = 555.56$

$s = 100.00$

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

$s/d = 0.25$

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

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

$f_y = 555.56$

$s = 250.00$

$V_{s2}$  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  $(\cot \theta + \csc \theta) \sin \alpha$  which is more a generalised expression,

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

This later relation, considered as a function  $V_f(\theta, \alpha)$ , 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:  $\theta = b_1 + 90^\circ = 90.00$

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

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

$d_{fv} = d$  (figure 11.2, ACI 440) = 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:  $V_s + V_f \leq 479549.663$

$b_w d = \sqrt{2} d^2 / 4 = 125663.706$

Calculation of Shear Strength at edge 2,  $V_{r2} = 705811.584$

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

$V_{Col0} = 705811.584$

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

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

= 1 (normal-weight concrete)

Mean concrete strength:  $f'_c = (f'_{c\_jacket} \cdot Area\_jacket + f'_{c\_core} \cdot Area\_core) / Area\_section = 33.00$ , but  $f'_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$\mu_u = 1.7556432E-011$

$V_u = 7.0242809E-047$

$d = 0.8 \cdot D = 400.00$

$N_u = 7389.214$

$A_g = 196349.541$

From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 274157.871$

$V_{s1} = 274157.871$  is calculated for jacket, with:

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

$f_y = 555.56$

$s = 100.00$

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

$s/d = 0.25$

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

$A_v = \sqrt{2} \cdot A_{stirup} = 78956.835$

$f_y = 555.56$

$s = 250.00$

$V_{s2}$  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)  $\sin \theta + \cos \theta$  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  $V_f(\theta, \alpha)$ , 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:  $\theta = \theta_1 + 90^\circ = 90.00$

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

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

$d_{fv} = d$  (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:  $V_s + V_f \leq 479549.663$

$b_w \cdot d = \sqrt{V_s \cdot V_f} / 4 = 125663.706$

-----  
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 Secondary Member: Concrete Strength,  $f_c = f_{cm} = 33.00$

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

Concrete Elasticity,  $E_c = 26999.444$

Steel Elasticity,  $E_s = 200000.00$

Existing Column

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

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

Concrete Elasticity,  $E_c = 26999.444$

Steel Elasticity,  $E_s = 200000.00$   
 External Diameter,  $D = 500.00$   
 Internal Diameter,  $D = 300.00$   
 Cover Thickness,  $c = 25.00$   
 Element Length,  $L = 3000.00$   
 Secondary Member  
 Ribbed Bars  
 Ductile Steel  
 Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)  
 Longitudinal Bars With Ends Lapped Starting at the End Sections  
 Inadequate Lap Length with  $l_b/l_d = 0.30$   
 FRP Wrapping Data  
 Type: Carbon  
 Cured laminate properties (design values)  
 Thickness,  $t = 1.016$   
 Tensile Strength,  $f_{fu} = 1055.00$   
 Tensile Modulus,  $E_f = 64828.00$   
 Elongation,  $e_{fu} = 0.01$   
 Number of directions,  $N_{oDir} = 1$   
 Fiber orientations,  $b_i = 0.00^\circ$   
 Number of layers,  $N_L = 1$   
 Radius of rounding corners,  $R = 40.00$

#### Stepwise Properties

Bending Moment,  $M = 1.0742266E-011$   
 Shear Force,  $V_2 = 7550.492$   
 Shear Force,  $V_3 = 4.7296730E-013$   
 Axial Force,  $F = -7386.193$   
 Longitudinal Reinforcement Area Distribution (in 2 divisions)  
   -Tension:  $A_{st} = 0.00$   
   -Compression:  $A_{sc} = 3053.628$   
 Longitudinal Reinforcement Area Distribution (in 3 divisions)  
   -Tension:  $A_{st,ten} = 1017.876$   
   -Compression:  $A_{sc,com} = 1017.876$   
   -Middle:  $A_{st,mid} = 1017.876$   
 Mean Diameter of Tension Reinforcement,  $D_bL = 18.00$

New component: From table 7-7, ASCE 41\_17: Final chord rotation Capacity  $u_{,R} = 1.0^*$   $u = 0.00452594$   
 $u = y + p = 0.00452594$

- Calculation of  $y$  -

$y = (M_y * L_s / 3) / E_{eff} = 0.00452594$  ((4.29), Biskinis Phd)  
 $M_y = 2.2494E+008$   
 $L_s = M/V$  (with  $L_s > 0.1 * L$  and  $L_s < 2 * L$ ) = 1500.00  
 From table 10.5, ASCE 41\_17:  $E_{eff} = factor * E_c * I_g = 2.4850E+013$   
 $factor = 0.30$   
 $A_g = 196349.541$   
 Mean concrete strength:  $f'_c = (f'_{c,jacket} * Area_{jacket} + f'_{c,core} * Area_{core}) / Area_{section} = 33.00$   
 $N = 7386.193$   
 $E_c * I_g = E_{c,jacket} * I_{g,jacket} + E_{c,core} * I_{g,core} = 8.2833E+013$

Calculation of Yielding Moment  $M_y$

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

$M_y = \text{Min}(M_{y,ten}, M_{y,com}) = 2.2494E+008$   
 $y = 6.4602099E-006$   
 $M_{y,ten} (8c) = 2.2494E+008$

$\rho_{ten}(7c) = 62.07295$   
error of function (7c) = 0.00023516  
My\_com (8d) = 8.0674E+008  
 $\rho_{com}(7d) = 63.84405$   
error of function (7d) = -0.00846595  
with ((10.1), ASCE 41-17)  $e_y = \text{Min}(e_y, 1.25 * e_y * (l_b/l_d)^{2/3}) = 0.0027778$   
 $e_{co} = 0.002$   
apl = 0.45 ((9c) in Biskinis and Fardis for FRP Wrap)  
d1 = 44.00  
R = 250.00  
v = 0.00103619  
N = 7386.193  
Ac = 196349.541  
((10.1), ASCE 41-17)  $\rho = \text{Min}(\rho, 1.25 * \rho * (l_b/l_d)^{2/3}) = 0.23799351$   
with  $f_c^*$  ((12.3), ACI 440) = 36.3038  
 $f_c = 33.00$   
 $f_l = 1.05384$   
k = 1  
Effective FRP thickness,  $t_f = N L * t * \text{Cos}(b_1) = 1.016$   
 $e_{fe}$  ((12.5) and (12.7)) = 0.004  
 $f_u = 0.01$   
 $E_f = 64828.00$

-----  
Calculation of ratio  $l_b/l_d$

-----  
Inadequate Lap Length with  $l_b/l_d = 0.30$

-----  
- Calculation of  $\rho_p$  -

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

with:

- Columns controlled by inadequate development or splicing along the clear height because  $l_b/l_d < 1$   
shear control ratio  $V_y E / V_{CoI} O E = 0.23451953$   
 $d = d_{external} = 0.00$   
 $s = s_{external} = 0.00$   
 $t = s_1 + s_2 + 2 * t_f / b_w * (f_{fe} / f_s) = 0.00702809$   
jacket:  $s_1 = A_{v1} * (D_{c1} / 2) / (s_1 * A_g) = 0.0027646$   
 $A_{v1} = 78.53982$ , is the area of stirrup  
 $D_{c1} = D_{ext} - 2 * \text{cover} - \text{External Hoop Diameter} = 440.00$ , is the total Length of all stirrups parallel to loading (shear) direction  
 $s_1 = 100.00$   
core:  $s_2 = A_{v2} * (D_{c2} / 2) / (s_2 * A_g) = 0.00046968$   
 $A_{v2} = 50.26548$ , 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  $2 * t_f / b_w * (f_{fe} / f_s)$  is implemented to account for FRP contribution  
where  $f = 2 * t_f / b_w$  is FRP ratio (EC8 - 3, A.4.4.3(6)) and  $f_{fe} / f_s$  normalises  $f$  to steel strength  
All these variables have already been given in Shear control ratio calculation.  
For the normalisation  $f_s$  of jacket is used.

NUD = 7386.193  
Ag = 196349.541  
 $f_{cE} = (f_{c\_jacket} * \text{Area}_{jacket} + f_{c\_core} * \text{Area}_{core}) / \text{section\_area} = 33.00$   
 $f_{yLE} = (f_{y\_ext\_Long\_Reinf} * \text{Area}_{ext\_Long\_Reinf} + f_{y\_int\_Long\_Reinf} * \text{Area}_{int\_Long\_Reinf}) / \text{Area}_{Tot\_Long\_Rein} = 2.1219958E-314$   
 $f_{yTE} = (f_{y\_ext\_Trans\_Reinf} * \text{Area}_{ext\_Trans\_Reinf} + f_{y\_int\_Trans\_Reinf} * \text{Area}_{int\_Trans\_Reinf}) / \text{Area}_{Tot\_Trans\_Rein} = 555.56$   
 $\rho_l = \text{Area}_{Tot\_Long\_Rein} / (A_g) = 0.015552$   
 $f_{cE} = 33.00$

-----  
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

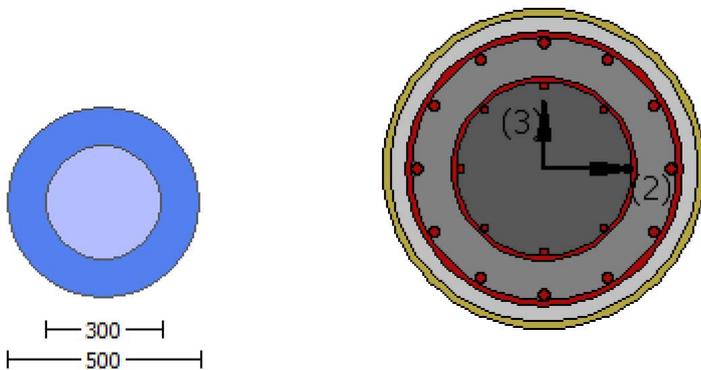
Limit State: Immediate Occupancy (data interpolation between analysis steps 1 and 2)

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 Secondary Member: Concrete Strength,  $f_c = f_{c\_lower\_bound} = 25.00$

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

Concrete Elasticity,  $E_c = 26999.444$

Steel Elasticity,  $E_s = 200000.00$

Existing Column

New material of Secondary Member: Concrete Strength,  $f_c = f_{c\_lower\_bound} = 25.00$

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

Concrete Elasticity,  $E_c = 26999.444$

Steel Elasticity,  $E_s = 200000.00$

#####

Note: Especially for the calculation of  $\gamma$  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,  $f_c = f_{cm} = 33.00$

New material: Steel Strength,  $f_s = f_{sm} = 555.56$   
 Existing Column  
 New material: Concrete Strength,  $f_c = f_{cm} = 33.00$   
 New material: Steel Strength,  $f_s = f_{sm} = 555.56$   
 #####  
 External Diameter,  $D = 500.00$   
 Internal Diameter,  $D = 300.00$   
 Cover Thickness,  $c = 25.00$   
 Element Length,  $L = 3000.00$   
 Secondary Member  
 Ribbed Bars  
 Ductile Steel  
 Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)  
 Longitudinal Bars With Ends Lapped Starting at the End Sections  
 Inadequate Lap Length with  $l_o/l_{ou,min} = l_b/l_d = 0.30$   
 FRP Wrapping Data  
 Type: Carbon  
 Cured laminate properties (design values)  
 Thickness,  $t = 1.016$   
 Tensile Strength,  $f_{fu} = 1055.00$   
 Tensile Modulus,  $E_f = 64828.00$   
 Elongation,  $e_{fu} = 0.01$   
 Number of directions,  $N_{oDir} = 1$   
 Fiber orientations,  $b_i: 0.00^\circ$   
 Number of layers,  $N_L = 1$   
 Radius of rounding corners,  $R = 40.00$

-----  
 Stepwise Properties  
 -----

EDGE -A-  
 Bending Moment,  $M_a = 1.4085270E-009$   
 Shear Force,  $V_a = -4.7296730E-013$   
 EDGE -B-  
 Bending Moment,  $M_b = 1.0742266E-011$   
 Shear Force,  $V_b = 4.7296730E-013$   
 BOTH EDGES  
 Axial Force,  $F = -7386.193$   
 Longitudinal Reinforcement Area Distribution (in 2 divisions)  
   -Tension:  $A_{st} = 0.00$   
   -Compression:  $A_{sc} = 3053.628$   
 Longitudinal Reinforcement Area Distribution (in 3 divisions)  
   -Tension:  $A_{st,ten} = 1017.876$   
   -Compression:  $A_{sc,com} = 1017.876$   
   -Middle:  $A_{sc,mid} = 1017.876$   
 Mean Diameter of Tension Reinforcement,  $D_{bL,ten} = 18.00$

-----  
 -----  
 New component: From table 7-7, ASCE 41\_17: Final Shear Capacity  $V_R = 1.0 \cdot V_n = 614519.737$   
 $V_n ((10.3), ASCE 41-17) = k_n l \cdot V_{CoI0} = 614519.737$   
 $V_{CoI} = 614519.737$   
 $k_n l = 1.00$   
 displacement\_ductility\_demand = 0.00

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

-----  
 = 1 (normal-weight concrete)  
 Mean concrete strength:  $f_c' = (f_c'_{jacket} \cdot Area_{jacket} + f_c'_{core} \cdot Area_{core}) / Area_{section} = 25.00$ , but  $f_c'^{0.5} \leq 8.3$   
 MPa (22.5.3.1, ACI 318-14)  
 $M/Vd = 2.00$   
 $\mu_u = 1.0742266E-011$   
 $V_u = 4.7296730E-013$   
 $d = 0.8 \cdot D = 400.00$   
 $N_u = 7386.193$

$A_g = 196349.541$   
 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:  
 $A_v = \sqrt{2} \cdot A_{stirrup} = 123370.055$   
 $f_y = 500.00$   
 $s = 100.00$   
 $V_{s1}$  is multiplied by  $Col1 = 1.00$   
 $s/d = 0.25$   
 $V_{s2} = 0.00$  is calculated for core, with:  
 $A_v = \sqrt{2} \cdot A_{stirrup} = 78956.835$   
 $f_y = 500.00$   
 $s = 250.00$   
 $V_{s2}$  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:  $\theta = 45^\circ$  and  $a = 90^\circ$   
 $V_f = \text{Min}(|V_f(45, 90)|, |V_f(-45, 90)|)$ , 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), 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:  $V_s + V_f \leq 417394.406$   
 $b_w \cdot d = A_g \cdot d / 4 = 125663.706$

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  $\theta = 8.1909685E-021$   
 $y = (M_y \cdot L_s / 3) / E_{eff} = 0.00452594$  ((4.29), Biskinis Phd)  
 $M_y = 2.2494E+008$   
 $L_s = M/V$  (with  $L_s > 0.1 \cdot L$  and  $L_s < 2 \cdot L$ ) = 1500.00  
 From table 10.5, ASCE 41\_17:  $E_{eff} = \text{factor} \cdot E_c \cdot I_g = 2.4850E+013$   
 factor = 0.30  
 $A_g = 196349.541$   
 Mean concrete strength:  $f_c' = (f_c'_{jacket} \cdot \text{Area}_{jacket} + f_c'_{core} \cdot \text{Area}_{core}) / \text{Area}_{section} = 33.00$   
 $N = 7386.193$   
 $E_c \cdot I_g = E_{c,jacket} \cdot I_{g,jacket} + E_{c,core} \cdot I_{g,core} = 8.2833E+013$

Calculation of Yielding Moment  $M_y$

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

$M_y = \text{Min}(M_{y,ten}, M_{y,com}) = 2.2494E+008$   
 $y = 6.4602099E-006$   
 $M_{y,ten}$  (8c) = 2.2494E+008  
 $\delta_{ten}$  (7c) = 62.07295  
 error of function (7c) = 0.00023516  
 $M_{y,com}$  (8d) = 8.0674E+008  
 $\delta_{com}$  (7d) = 63.84405  
 error of function (7d) = -0.00846595  
 with ((10.1), ASCE 41-17)  $e_y = \text{Min}(e_y, 1.25 \cdot e_y \cdot (I_b / I_d)^{2/3}) = 0.0027778$   
 $e_{co} = 0.002$   
 $\text{apl} = 0.45$  ((9c) in Biskinis and Fardis for FRP Wrap)

$d1 = 44.00$   
 $R = 250.00$   
 $v = 0.00103619$   
 $N = 7386.193$   
 $Ac = 196349.541$   
 $((10.1), ASCE 41-17) = \text{Min}( , 1.25 * (lb/d)^{2/3} ) = 0.23799351$   
 with  $fc^* ((12.3), ACI 440) = 36.3038$   
 $fc = 33.00$   
 $fl = 1.05384$   
 $k = 1$   
 Effective FRP thickness,  $tf = NL*t*\text{Cos}(b1) = 1.016$   
 $efe ((12.5) \text{ and } (12.7)) = 0.004$   
 $fu = 0.01$   
 $Ef = 64828.00$

Calculation of ratio  $lb/d$

Inadequate Lap Length with  $lb/d = 0.30$

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

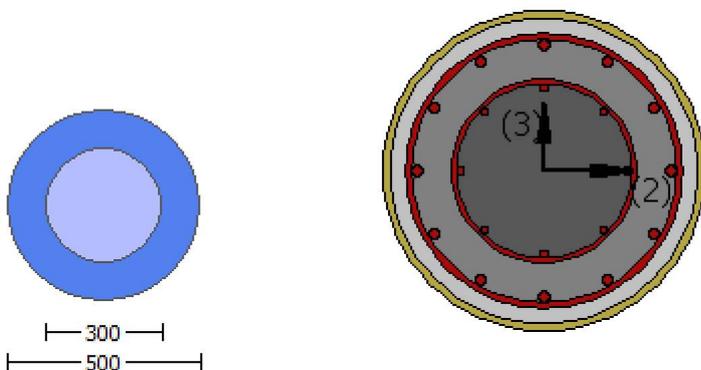
Limit State: Immediate Occupancy (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity ( $\theta_u$ )

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

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

Concrete Elasticity,  $E_c = 26999.444$

Steel Elasticity,  $E_s = 200000.00$

Existing Column

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

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

Concrete Elasticity,  $E_c = 26999.444$

Steel Elasticity,  $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

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

Jacket

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

Existing Column

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

#####

External Diameter,  $D = 500.00$

Internal Diameter,  $D = 300.00$

Cover Thickness,  $c = 25.00$

Mean Confinement Factor overall section = 1.46748

Element Length,  $L = 3000.00$

Secondary Member

Ribbed Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

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

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness,  $t = 1.016$

Tensile Strength,  $f_{fu} = 1055.00$

Tensile Modulus,  $E_f = 64828.00$

Elongation,  $e_{fu} = 0.01$

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

Fiber orientations,  $b_i = 0.00^\circ$

Number of layers,  $N_L = 1$

Radius of rounding corners,  $R = 40.00$

Stepwise Properties

At local axis: 3

EDGE -A-

Shear Force,  $V_a = 1.1471900E-030$

EDGE -B-

Shear Force,  $V_b = -1.1471900E-030$

BOTH EDGES

Axial Force,  $F = -7389.214$

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:  $A_{sl, \text{ten}} = 1017.876$

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

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

Calculation of Shear Capacity ratio ,  $V_e/V_r = 0.23451953$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 165526.599$

with

$M_{pr1} = \text{Max}(M_{u1+} , M_{u1-}) = 2.4829E+008$

$M_{u1+} = 2.4829E+008$ , is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination

$M_{u1-} = 2.4829E+008$ , is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination

$M_{pr2} = \text{Max}(M_{u2+} , M_{u2-}) = 2.4829E+008$

$M_{u2+} = 2.4829E+008$ , is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the the static loading combination

$M_{u2-} = 2.4829E+008$ , is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the the static loading combination

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

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

$M_u = 2.4829E+008$

-----  
= 0.82030475

' = 0.72936354

error of function (3.68), Biskinis Phd = 58391.315

From 5A.2, TBDY:  $f_{cc} = f_c^* \quad c = 48.42699$

conf. factor  $c = 1.46748$

$f_c = 33.00$

From 10.3.5, ASCE 41-17, Final value of  $f_y$ :  $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 389.0139$

$l_b/d = 0.30$

$d_1 = 44.00$

$R = 250.00$

$v = 0.00103167$

$N = 7389.214$

$A_c = 196349.541$

=  $\cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.16585331$   
-----

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

Inadequate Lap Length with  $l_b/d = 0.30$   
-----  
-----  
-----

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

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

$M_u = 2.4829E+008$

-----  
= 0.82030475

' = 0.72936354

error of function (3.68), Biskinis Phd = 58391.315

From 5A.2, TBDY:  $f_{cc} = f_c^* \quad c = 48.42699$

conf. factor  $c = 1.46748$

$f_c = 33.00$

From 10.3.5, ASCE 41-17, Final value of  $f_y$ :  $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 389.0139$

$l_b/d = 0.30$

$d_1 = 44.00$

$R = 250.00$

$v = 0.00103167$

$N = 7389.214$

$A_c = 196349.541$

$$= \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.16585331$$

Calculation of ratio  $l_b/d$

Inadequate Lap Length with  $l_b/d = 0.30$

Calculation of  $\mu_{2+}$

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd),  $\mu$   
 $\mu = 2.4829E+008$

$$= 0.82030475$$

$$\lambda = 0.72936354$$

error of function (3.68), Biskinis Phd = 58391.315

From 5A.2, TBDY:  $f_{cc} = f_c \cdot c = 48.42699$

conf. factor  $c = 1.46748$

$f_c = 33.00$

From 10.3.5, ASCE 41-17, Final value of  $f_y$ :  $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 389.0139$

$l_b/d = 0.30$

$d_1 = 44.00$

$R = 250.00$

$v = 0.00103167$

$N = 7389.214$

$A_c = 196349.541$

$$= \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.16585331$$

Calculation of ratio  $l_b/d$

Inadequate Lap Length with  $l_b/d = 0.30$

Calculation of  $\mu_{2-}$

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd),  $\mu$   
 $\mu = 2.4829E+008$

$$= 0.82030475$$

$$\lambda = 0.72936354$$

error of function (3.68), Biskinis Phd = 58391.315

From 5A.2, TBDY:  $f_{cc} = f_c \cdot c = 48.42699$

conf. factor  $c = 1.46748$

$f_c = 33.00$

From 10.3.5, ASCE 41-17, Final value of  $f_y$ :  $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 389.0139$

$l_b/d = 0.30$

$d_1 = 44.00$

$R = 250.00$

$v = 0.00103167$

$N = 7389.214$

$A_c = 196349.541$

$$= \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.16585331$$

Calculation of ratio  $l_b/d$

Inadequate Lap Length with  $l_b/d = 0.30$

Calculation of Shear Strength  $V_r = \text{Min}(V_{r1}, V_{r2}) = 705811.584$

Calculation of Shear Strength at edge 1,  $V_{r1} = 705811.584$

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

$V_{CoI0} = 705811.584$

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

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

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

Mean concrete strength:  $f_c' = (f_c'_{\text{jacket}} * \text{Area}_{\text{jacket}} + f_c'_{\text{core}} * \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 33.00$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M / Vd = 2.00$

$\mu_u = 1.6210513E-011$

$\nu_u = 1.1471900E-030$

$d = 0.8 * D = 400.00$

$N_u = 7389.214$

$A_g = 196349.541$

From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 274157.871$

$V_{s1} = 274157.871$  is calculated for jacket, with:

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

$f_y = 555.56$

$s = 100.00$

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

$s/d = 0.25$

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

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

$f_y = 555.56$

$s = 250.00$

$V_{s2}$  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  $V_f(\theta, a)$ , is implemented for every different fiber orientation  $a_i$ , as well as for 2 crack directions,  $\theta = 45^\circ$  and  $\theta = -45^\circ$  to take into consideration the cyclic seismic loading.

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

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

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

$d_{fv} = d$  (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:  $V_s + V_f \leq 479549.663$

$b_w * d = \sqrt{2} * d / 4 = 125663.706$

Calculation of Shear Strength at edge 2,  $V_{r2} = 705811.584$

$V_{r2} = V_{CoI} ((10.3), \text{ASCE } 41-17) = k_{nl} * V_{CoI0}$

$V_{CoI0} = 705811.584$

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

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

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

Mean concrete strength:  $f_c' = (f_c'_{\text{jacket}} * \text{Area}_{\text{jacket}} + f_c'_{\text{core}} * \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 33.00$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M / Vd = 2.00$

$\mu_u = 1.6210513E-011$

$\nu_u = 1.1471900E-030$

$d = 0.8 * D = 400.00$

Nu = 7389.214  
 Ag = 196349.541  
 From (11.5.4.8), ACI 318-14: Vs = Vs1 + Vs2 = 274157.871  
 Vs1 = 274157.871 is calculated for jacket, with:  
   Av = /2\*A\_stirrup = 123370.055  
   fy = 555.56  
   s = 100.00  
 Vs1 is multiplied by Col1 = 1.00  
   s/d = 0.25  
 Vs2 = 0.00 is calculated for core, with:  
   Av = /2\*A\_stirrup = 78956.835  
   fy = 555.56  
   s = 250.00  
 Vs2 is multiplied by Col2 = 0.00  
   s/d = 1.04167  
 Vf ((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 + cota)sina which is more a generalised expression,  
 where is the angle of the crack direction (see KANEPE).  
 This later relation, considered as a function Vf( , ), is implemented for every different fiber orientation ai,  
 as well as for 2 crack directions, =45° and =-45° to take into consideration the cyclic seismic loading.  
 orientation 1: 1 = b1 + 90° = 90.00  
 Vf = Min(|Vf(45, 1)|, |Vf(-45,a1)|), with:  
 total thickness per orientation, tf1 = NL\*t/NoDir = 1.016  
 dfv = d (figure 11.2, ACI 440) = 470.00  
 ffe ((11-5), ACI 440) = 259.312  
   Ef = 64828.00  
   fe = 0.004, from (11.6a), ACI 440  
   with fu = 0.01  
 From (11-11), ACI 440: Vs + Vf <= 479549.663  
   bw\*d = \*d\*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, = 1.00  
 Mean strength values are used for both shear and moment calculations.  
 Consequently:  
 Jacket  
 New material of Secondary Member: Concrete Strength, fc = fcm = 33.00  
 New material of Secondary Member: Steel Strength, fs = fsm = 555.56  
 Concrete Elasticity, Ec = 26999.444  
 Steel Elasticity, Es = 200000.00  
 Existing Column  
 New material of Secondary Member: Concrete Strength, fc = fcm = 33.00  
 New material of Secondary Member: Steel Strength, fs = fsm = 555.56  
 Concrete Elasticity, Ec = 26999.444  
 Steel Elasticity, Es = 200000.00  
 #####  
 Note: Especially for the calculation of moment strengths,  
 the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14  
 Jacket  
 New material: Steel Strength, fs = 1.25\*fsm = 694.45  
 Existing Column  
 New material: Steel Strength, fs = 1.25\*fsm = 694.45

#####

External Diameter, D = 500.00  
Internal Diameter, D = 300.00  
Cover Thickness, c = 25.00  
Mean Confinement Factor overall section = 1.46748  
Element Length, L = 3000.00  
Secondary Member  
Ribbed Bars  
Ductile Steel  
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)  
Longitudinal Bars With Ends Lapped Starting at the End Sections  
Inadequate Lap Length with  $l_o/l_{o,min}$  = 0.30  
FRP Wrapping Data  
Type: Carbon  
Cured laminate properties (design values)  
Thickness, t = 1.016  
Tensile Strength,  $f_{fu}$  = 1055.00  
Tensile Modulus,  $E_f$  = 64828.00  
Elongation,  $e_{fu}$  = 0.01  
Number of directions, NoDir = 1  
Fiber orientations,  $b_i$ : 0.00°  
Number of layers, NL = 1  
Radius of rounding corners, R = 40.00

-----  
Stepwise Properties

-----  
At local axis: 2  
EDGE -A-  
Shear Force,  $V_a$  = -7.0242809E-047  
EDGE -B-  
Shear Force,  $V_b$  = 7.0242809E-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 ,  $V_e/V_r$  = 0.23451953  
Member Controlled by Flexure ( $V_e/V_r < 1$ )  
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 165526.599$   
with  
 $M_{pr1} = \text{Max}(\mu_{u1+} , \mu_{u1-}) = 2.4829E+008$   
 $\mu_{u1+} = 2.4829E+008$ , is the ultimate moment strength at the edge 1 of the member in the actual moment direction  
which is defined for the static loading combination  
 $\mu_{u1-} = 2.4829E+008$ , is the ultimate moment strength at the edge 1 of the member in the opposite moment  
direction which is defined for the static loading combination  
 $M_{pr2} = \text{Max}(\mu_{u2+} , \mu_{u2-}) = 2.4829E+008$   
 $\mu_{u2+} = 2.4829E+008$ , is the ultimate moment strength at the edge 2 of the member in the actual moment direction  
which is defined for the the static loading combination  
 $\mu_{u2-} = 2.4829E+008$ , is the ultimate moment strength at the edge 2 of the member in the opposite moment  
direction which is defined for the the static loading combination

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

-----  
Calculation of ultimate Moment Strength ((3.67), Biskinis Phd),  $\mu_u$   
 $\mu_u = 2.4829E+008$

= 0.82030475  
' = 0.72936354  
error of function (3.68), Biskinis Phd = 58391.315  
From 5A.2, TBDY:  $f_{cc} = f_c \cdot c = 48.42699$   
conf. factor  $c = 1.46748$   
 $f_c = 33.00$   
From 10.3.5, ASCE 41-17, Final value of  $f_y$ :  $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 389.0139$   
 $l_b/d = 0.30$   
 $d_1 = 44.00$   
 $R = 250.00$   
 $v = 0.00103167$   
 $N = 7389.214$   
 $Ac = 196349.541$   
 $= \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.16585331$

Calculation of ratio  $l_b/d$

Inadequate Lap Length with  $l_b/d = 0.30$

Calculation of  $\mu_{1-}$

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd),  $\mu$   
 $\mu = 2.4829E+008$

= 0.82030475  
' = 0.72936354  
error of function (3.68), Biskinis Phd = 58391.315  
From 5A.2, TBDY:  $f_{cc} = f_c \cdot c = 48.42699$   
conf. factor  $c = 1.46748$   
 $f_c = 33.00$   
From 10.3.5, ASCE 41-17, Final value of  $f_y$ :  $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 389.0139$   
 $l_b/d = 0.30$   
 $d_1 = 44.00$   
 $R = 250.00$   
 $v = 0.00103167$   
 $N = 7389.214$   
 $Ac = 196349.541$   
 $= \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.16585331$

Calculation of ratio  $l_b/d$

Inadequate Lap Length with  $l_b/d = 0.30$

Calculation of  $\mu_{2+}$

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd),  $\mu$   
 $\mu = 2.4829E+008$

= 0.82030475  
' = 0.72936354  
error of function (3.68), Biskinis Phd = 58391.315  
From 5A.2, TBDY:  $f_{cc} = f_c \cdot c = 48.42699$   
conf. factor  $c = 1.46748$   
 $f_c = 33.00$   
From 10.3.5, ASCE 41-17, Final value of  $f_y$ :  $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 389.0139$   
 $l_b/d = 0.30$

d1 = 44.00  
R = 250.00  
v = 0.00103167  
N = 7389.214  
Ac = 196349.541  
= \*Min(1,1.25\*(lb/d)^ 2/3) = 0.16585331

Calculation of ratio lb/d

Inadequate Lap Length with lb/d = 0.30

Calculation of Mu2-

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

Mu = 2.4829E+008

= 0.82030475

' = 0.72936354

error of function (3.68), Biskinis Phd = 58391.315

From 5A.2, TBDY: fcc = fc\* c = 48.42699

conf. factor c = 1.46748

fc = 33.00

From 10.3.5, ASCE 41-17, Final value of fy: fy\*Min(1,1.25\*(lb/d)^ 2/3) = 389.0139

lb/d = 0.30

d1 = 44.00

R = 250.00

v = 0.00103167

N = 7389.214

Ac = 196349.541

= \*Min(1,1.25\*(lb/d)^ 2/3) = 0.16585331

Calculation of ratio lb/d

Inadequate Lap Length with lb/d = 0.30

Calculation of Shear Strength Vr = Min(Vr1,Vr2) = 705811.584

Calculation of Shear Strength at edge 1, Vr1 = 705811.584

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

VCol0 = 705811.584

knl = 1 (zero step-static loading)

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

= 1 (normal-weight concrete)

Mean concrete strength: fc' = (fc'\_jacket\*Area\_jacket + fc'\_core\*Area\_core)/Area\_section = 33.00, but fc'^0.5 <= 8.3 MPa (22.5.3.1, ACI 318-14)

M/Vd = 2.00

Mu = 1.7556432E-011

Vu = 7.0242809E-047

d = 0.8\*D = 400.00

Nu = 7389.214

Ag = 196349.541

From (11.5.4.8), ACI 318-14: Vs = Vs1 + Vs2 = 274157.871

Vs1 = 274157.871 is calculated for jacket, with:

Av = /2\*A\_stirrup = 123370.055

fy = 555.56

$s = 100.00$   
 $V_{s1}$  is multiplied by  $Col1 = 1.00$   
 $s/d = 0.25$   
 $V_{s2} = 0.00$  is calculated for core, with:  
 $A_v = \sqrt{2} \cdot A_{stirrup} = 78956.835$   
 $f_y = 555.56$   
 $s = 250.00$   
 $V_{s2}$  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)  $\sin \theta + \cos \theta$  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  $V_f(\theta, \alpha)$ , 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:  $\theta = b_1 + 90^\circ = 90.00$   
 $V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, \theta)|)$ , 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:  $V_s + V_f \leq 479549.663$   
 $b_w \cdot d = \sqrt{V_s + V_f} \cdot d / 4 = 125663.706$

-----  
 Calculation of Shear Strength at edge 2,  $V_{r2} = 705811.584$   
 $V_{r2} = V_{Col}$  ((10.3), ASCE 41-17) =  $k_{nl} \cdot V_{ColO}$   
 $V_{ColO} = 705811.584$   
 $k_{nl} = 1$  (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).

-----  
 $\beta = 1$  (normal-weight concrete)  
 Mean concrete strength:  $f_c' = (f_c'_{jacket} \cdot Area_{jacket} + f_c'_{core} \cdot Area_{core}) / Area_{section} = 33.00$ , but  $f_c'^{0.5} \leq 8.3$   
 MPa (22.5.3.1, ACI 318-14)  
 $M/Vd = 2.00$   
 $M_u = 1.7556432E-011$   
 $V_u = 7.0242809E-047$   
 $d = 0.8 \cdot D = 400.00$   
 $N_u = 7389.214$   
 $A_g = 196349.541$   
 From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 274157.871$   
 $V_{s1} = 274157.871$  is calculated for jacket, with:  
 $A_v = \sqrt{2} \cdot A_{stirrup} = 123370.055$   
 $f_y = 555.56$   
 $s = 100.00$   
 $V_{s1}$  is multiplied by  $Col1 = 1.00$   
 $s/d = 0.25$   
 $V_{s2} = 0.00$  is calculated for core, with:  
 $A_v = \sqrt{2} \cdot A_{stirrup} = 78956.835$   
 $f_y = 555.56$   
 $s = 250.00$   
 $V_{s2}$  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)  $\sin \theta + \cos \theta$  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  $V_f(\theta, \alpha)$ , 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:  $\theta = b_1 + 90^\circ = 90.00$   
 $V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, \theta)|)$ , with:

total thickness per orientation,  $tf1 = NL*t/NoDir = 1.016$   
 $dfv = d$  (figure 11.2, ACI 440) = 470.00  
 $ffe$  ((11-5), ACI 440) = 259.312  
 $Ef = 64828.00$   
 $fe = 0.004$ , from (11.6a), ACI 440  
with  $fu = 0.01$   
From (11-11), ACI 440:  $Vs + Vf \leq 479549.663$   
 $bw*d = *d*d/4 = 125663.706$

-----  
-----  
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, = 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 Secondary Member: Concrete Strength,  $fc = fcm = 33.00$   
New material of Secondary Member: Steel Strength,  $fs = fsm = 555.56$   
Concrete Elasticity,  $Ec = 26999.444$   
Steel Elasticity,  $Es = 200000.00$   
Existing Column  
New material of Secondary Member: Concrete Strength,  $fc = fcm = 33.00$   
New material of Secondary Member: Steel Strength,  $fs = fsm = 555.56$   
Concrete Elasticity,  $Ec = 26999.444$   
Steel Elasticity,  $Es = 200000.00$   
External Diameter,  $D = 500.00$   
Internal Diameter,  $D = 300.00$   
Cover Thickness,  $c = 25.00$   
Element Length,  $L = 3000.00$   
Secondary Member  
Ribbed Bars  
Ductile Steel  
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)  
Longitudinal Bars With Ends Lapped Starting at the End Sections  
Inadequate Lap Length with  $lb/ld = 0.30$   
FRP Wrapping Data  
Type: Carbon  
Cured laminate properties (design values)  
Thickness,  $t = 1.016$   
Tensile Strength,  $ffu = 1055.00$   
Tensile Modulus,  $Ef = 64828.00$   
Elongation,  $efu = 0.01$   
Number of directions,  $NoDir = 1$   
Fiber orientations,  $bi: 0.00^\circ$   
Number of layers,  $NL = 1$   
Radius of rounding corners,  $R = 40.00$

-----  
Stepwise Properties

-----  
Bending Moment,  $M = 0.08820332$   
Shear Force,  $V2 = 7550.492$   
Shear Force,  $V3 = 4.7296730E-013$   
Axial Force,  $F = -7386.193$   
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,  $Db_L = 18.00$

New component: From table 7-7, ASCE 41\_17: Final chord rotation Capacity  $u_{,R} = 1.0^*$   $u = 0.00090519$   
 $u = y + p = 0.00090519$

- Calculation of  $y$  -

$y = (M_y * L_s / 3) / E_{eff} = 0.00090519$  ((4.29), Biskinis Phd)

$M_y = 2.2494E+008$

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

From table 10.5, ASCE 41\_17:  $E_{eff} = factor * E_c * I_g = 2.4850E+013$

factor = 0.30

$A_g = 196349.541$

Mean concrete strength:  $f_c' = (f_c'_{jacket} * Area_{jacket} + f_c'_{core} * Area_{core}) / Area_{section} = 33.00$

$N = 7386.193$

$E_c * I_g = E_{c,jacket} * I_{g,jacket} + E_{c,core} * I_{g,core} = 8.2833E+013$

Calculation of Yielding Moment  $M_y$

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

$M_y = \text{Min}(M_{y,ten}, M_{y,com}) = 2.2494E+008$

$y = 6.4602099E-006$

$M_{y,ten}$  (8c) = 2.2494E+008

$y_{ten}$  (7c) = 62.07295

error of function (7c) = 0.00023516

$M_{y,com}$  (8d) = 8.0674E+008

$y_{com}$  (7d) = 63.84405

error of function (7d) = -0.00846595

with ((10.1), ASCE 41-17)  $e_y = \text{Min}(e_y, 1.25 * e_y * (l_b / l_d)^{2/3}) = 0.0027778$

$e_{co} = 0.002$

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

$d_1 = 44.00$

$R = 250.00$

$v = 0.00103619$

$N = 7386.193$

$A_c = 196349.541$

((10.1), ASCE 41-17)  $e_y = \text{Min}(e_y, 1.25 * e_y * (l_b / l_d)^{2/3}) = 0.23799351$

with  $f_c^*$  ((12.3), ACI 440) = 36.3038

$f_c = 33.00$

$f_l = 1.05384$

$k = 1$

Effective FRP thickness,  $t_f = NL * t * \text{Cos}(b_1) = 1.016$

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

$f_u = 0.01$

$E_f = 64828.00$

Calculation of ratio  $l_b / l_d$

Inadequate Lap Length with  $l_b / l_d = 0.30$

- Calculation of  $p$  -

From table 10-9:  $p = 0.00$

with:

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

shear control ratio  $V_y E / V_{Co} I_{OE} = 0.23451953$

$d = d_{external} = 0.00$

$s = s_{external} = 0.00$

$t = s_1 + s_2 + 2 * t_f / b_w * (f_{fe} / f_s) = 0.00702809$

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

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

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

(shear) direction

$s_1 = 100.00$

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

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

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

direction

$s_2 = 250.00$

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

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

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

For the normalisation  $f_s$  of jacket is used.

$NUD = 7386.193$

$A_g = 196349.541$

$f_{cE} = (f_{c\_jacket} * Area\_jacket + f_{c\_core} * Area\_core) / section\_area = 33.00$

$f_{yIE} = (f_{y\_ext\_Long\_Reinf} * Area\_ext\_Long\_Reinf + f_{y\_int\_Long\_Reinf} * Area\_int\_Long\_Reinf) / Area\_Tot\_Long\_Rein = 2.1219958E-314$

$f_{yTE} = (f_{y\_ext\_Trans\_Reinf} * Area\_ext\_Trans\_Reinf + f_{y\_int\_Trans\_Reinf} * Area\_int\_Trans\_Reinf) / Area\_Tot\_Trans\_Rein = 555.56$

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

$f_{cE} = 33.00$

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

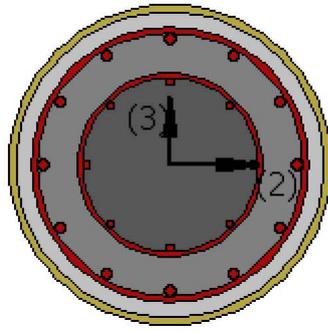
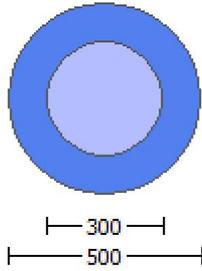
Limit State: Collapse Prevention (data interpolation between analysis steps 1 and 2)

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 Secondary Member: Concrete Strength,  $f_c = f_{c\_lower\_bound} = 25.00$

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

Concrete Elasticity,  $E_c = 26999.444$

Steel Elasticity,  $E_s = 200000.00$

Existing Column

New material of Secondary Member: Concrete Strength,  $f_c = f_{c\_lower\_bound} = 25.00$

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

Concrete Elasticity,  $E_c = 26999.444$

Steel Elasticity,  $E_s = 200000.00$

#####

Note: Especially for the calculation of  $\gamma$  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,  $f_c = f_{cm} = 33.00$

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

Existing Column

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

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

#####

External Diameter,  $D = 500.00$

Internal Diameter,  $D = 300.00$

Cover Thickness,  $c = 25.00$

Element Length,  $L = 3000.00$

Secondary Member

Ribbed Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

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

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness,  $t = 1.016$

Tensile Strength,  $f_{fu} = 1055.00$

Tensile Modulus,  $E_f = 64828.00$

Elongation,  $ef_u = 0.01$

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, Ma = -2.7391E+007

Shear Force, Va = -9128.06

EDGE -B-

Bending Moment, Mb = 0.10663216

Shear Force, Vb = 9128.06

BOTH EDGES

Axial Force, F = -7385.561

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: Aslt = 1272.345

-Compression: Aslc = 1781.283

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension: Asl,ten = 1017.876

-Compression: Asl,com = 1017.876

-Middle: Asl,mid = 1017.876

Mean Diameter of Tension Reinforcement, DbL,ten = 18.00

New component: From table 7-7, ASCE 41\_17: Final Shear Capacity VR = 1.0\*Vn = 515957.009

Vn ((10.3), ASCE 41-17) = knl\*VCol0 = 515957.009

VCol = 515957.009

knl = 1.00

displacement\_ductility\_demand = 0.03366782

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

= 1 (normal-weight concrete)

Mean concrete strength: fc' = (fc'\_jacket\*Area\_jacket + fc'\_core\*Area\_core)/Area\_section = 25.00, but fc'^0.5 <= 8.3 MPa (22.5.3.1, ACI 318-14)

M/Vd = 4.00

Mu = 2.7391E+007

Vu = 9128.06

d = 0.8\*D = 400.00

Nu = 7385.561

Ag = 196349.541

From (11.5.4.8), ACI 318-14: Vs = Vs1 + Vs2 = 246740.11

Vs1 = 246740.11 is calculated for jacket, with:

Av = /2\*A\_stirrup = 123370.055

fy = 500.00

s = 100.00

Vs1 is multiplied by Col1 = 1.00

s/d = 0.25

Vs2 = 0.00 is calculated for core, with:

Av = /2\*A\_stirrup = 78956.835

fy = 500.00

s = 250.00

Vs2 is multiplied by Col2 = 0.00

s/d = 1.04167

Vf ((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 + cota)sina which is more a generalised expression, where is the angle of the crack direction (see KANEPE).

This later relation, considered as a function Vf( , ), is implemented for every different fiber orientation ai, as well as for 2 crack directions, = 45° and = -45° to take into consideration the cyclic seismic loading.

orientation 1: 1 = b1 + 90° = 90.00

Vf = Min(|Vf(45, 1)|, |Vf(-45,a1)|), with:

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

dfv = d (figure 11.2, ACI 440) = 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:  $V_s + V_f \leq 417394.406$   
 $b_w \cdot d = \frac{d^2}{4} = 125663.706$

displacement\_ductility\_demand is calculated as  $\frac{M}{y}$

- Calculation of  $\frac{M}{y}$  for END A -  
for rotation axis 3 and integ. section (a)

From analysis, chord rotation = 0.00030483  
 $y = \frac{(M_y \cdot L_s / 3)}{E_{eff}} = 0.00905409$  ((4.29), Biskinis Phd)  
 $M_y = 2.2494E+008$   
 $L_s = M/V$  (with  $L_s > 0.1 \cdot L$  and  $L_s < 2 \cdot L$ ) = 3000.736  
From table 10.5, ASCE 41\_17:  $E_{eff} = \text{factor} \cdot E_c \cdot I_g = 2.4850E+013$   
factor = 0.30  
 $A_g = 196349.541$   
Mean concrete strength:  $f'_c = \frac{(f'_c \cdot \text{jacket} \cdot \text{Area}_{\text{jacket}} + f'_c \cdot \text{core} \cdot \text{Area}_{\text{core}})}{\text{Area}_{\text{section}}} = 33.00$   
 $N = 7385.561$   
 $E_c \cdot I_g = E_c \cdot \text{jacket} \cdot I_{g \cdot \text{jacket}} + E_c \cdot \text{core} \cdot I_{g \cdot \text{core}} = 8.2833E+013$

Calculation of Yielding Moment  $M_y$

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

$M_y = \text{Min}(M_{y \cdot \text{ten}}, M_{y \cdot \text{com}}) = 2.2494E+008$   
 $y = 6.4602088E-006$   
 $M_{y \cdot \text{ten}}$  (8c) =  $2.2494E+008$   
 $\frac{M}{y}$  (7c) = 62.07293  
error of function (7c) = 0.00023516  
 $M_{y \cdot \text{com}}$  (8d) =  $8.0674E+008$   
 $\frac{M}{y}$  (7d) = 63.84405  
error of function (7d) = -0.00846597  
with ((10.1), ASCE 41-17)  $e_y = \text{Min}(e_y, 1.25 \cdot e_y \cdot (l_b / l_d)^{2/3}) = 0.0027778$   
 $e_{co} = 0.002$   
 $a_{pl} = 0.45$  ((9c) in Biskinis and Fardis for FRP Wrap)  
 $d_1 = 44.00$   
 $R = 250.00$   
 $v = 0.0010361$   
 $N = 7385.561$   
 $A_c = 196349.541$   
((10.1), ASCE 41-17) =  $\text{Min}( , 1.25 \cdot \cdot (l_b / l_d)^{2/3}) = 0.23799351$   
with  $f'_c$  ((12.3), ACI 440) = 36.3038  
 $f_c = 33.00$   
 $f_l = 1.05384$   
 $k = 1$   
Effective FRP thickness,  $t_f = N \cdot l \cdot \text{Cos}(b_1) = 1.016$   
 $e_{fe}$  ((12.5) and (12.7)) = 0.004  
 $f_u = 0.01$   
 $E_f = 64828.00$

Calculation of ratio  $l_b / l_d$

Inadequate Lap Length with  $l_b / l_d = 0.30$

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

At local axis: 2

Integration Section: (a)

## Calculation No. 10

column C1, Floor 1

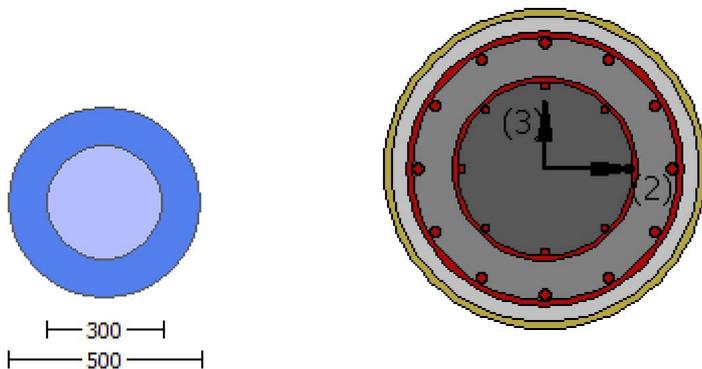
Limit State: Collapse Prevention (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity ( $\theta$ )

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

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

Concrete Elasticity,  $E_c = 26999.444$

Steel Elasticity,  $E_s = 200000.00$

Existing Column

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

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

Concrete Elasticity,  $E_c = 26999.444$

Steel Elasticity,  $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

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

Jacket

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

Existing Column

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

#####

External Diameter, D = 500.00  
Internal Diameter, D = 300.00  
Cover Thickness, c = 25.00  
Mean Confinement Factor overall section = 1.46748  
Element Length, L = 3000.00  
Secondary Member  
Ribbed Bars  
Ductile Steel  
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)  
Longitudinal Bars With Ends Lapped Starting at the End Sections  
Inadequate Lap Length with  $l_o/l_{o,min}$  = 0.30  
FRP Wrapping Data  
Type: Carbon  
Cured laminate properties (design values)  
Thickness, t = 1.016  
Tensile Strength,  $f_{fu}$  = 1055.00  
Tensile Modulus,  $E_f$  = 64828.00  
Elongation,  $ε_{fu}$  = 0.01  
Number of directions, NoDir = 1  
Fiber orientations,  $b_i$ : 0.00°  
Number of layers, NL = 1  
Radius of rounding corners, R = 40.00

-----  
Stepwise Properties  
-----

At local axis: 3  
EDGE -A-  
Shear Force,  $V_a$  = 1.1471900E-030  
EDGE -B-  
Shear Force,  $V_b$  = -1.1471900E-030  
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 ,  $V_e/V_r$  = 0.23451953  
Member Controlled by Flexure ( $V_e/V_r < 1$ )  
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 165526.599$   
with  
 $M_{pr1} = \text{Max}(M_{u1+} , M_{u1-}) = 2.4829E+008$   
 $M_{u1+} = 2.4829E+008$ , is the ultimate moment strength at the edge 1 of the member in the actual moment direction  
which is defined for the static loading combination  
 $M_{u1-} = 2.4829E+008$ , is the ultimate moment strength at the edge 1 of the member in the opposite moment  
direction which is defined for the static loading combination  
 $M_{pr2} = \text{Max}(M_{u2+} , M_{u2-}) = 2.4829E+008$   
 $M_{u2+} = 2.4829E+008$ , is the ultimate moment strength at the edge 2 of the member in the actual moment direction  
which is defined for the the static loading combination  
 $M_{u2-} = 2.4829E+008$ , is the ultimate moment strength at the edge 2 of the member in the opposite moment  
direction which is defined for the the static loading combination

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

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd),  $M_u$   
 $M_u = 2.4829E+008$   
-----

= 0.82030475  
' = 0.72936354  
error of function (3.68), Biskinis Phd = 58391.315  
From 5A.2, TBDY:  $f_{cc} = f_c \cdot c = 48.42699$   
conf. factor  $c = 1.46748$   
 $f_c = 33.00$   
From 10.3.5, ASCE 41-17, Final value of  $f_y$ :  $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3}) = 389.0139$   
 $l_b/l_d = 0.30$   
 $d_1 = 44.00$   
 $R = 250.00$   
 $v = 0.00103167$   
 $N = 7389.214$   
 $A_c = 196349.541$   
 $= \cdot \text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3}) = 0.16585331$

-----  
Calculation of ratio  $l_b/l_d$

-----  
Inadequate Lap Length with  $l_b/l_d = 0.30$   
-----  
-----

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

-----  
Calculation of ultimate Moment Strength ((3.67), Biskinis Phd),  $\mu$   
 $\mu = 2.4829E+008$

-----  
= 0.82030475  
' = 0.72936354  
error of function (3.68), Biskinis Phd = 58391.315  
From 5A.2, TBDY:  $f_{cc} = f_c \cdot c = 48.42699$   
conf. factor  $c = 1.46748$   
 $f_c = 33.00$   
From 10.3.5, ASCE 41-17, Final value of  $f_y$ :  $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3}) = 389.0139$   
 $l_b/l_d = 0.30$   
 $d_1 = 44.00$   
 $R = 250.00$   
 $v = 0.00103167$   
 $N = 7389.214$   
 $A_c = 196349.541$   
 $= \cdot \text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3}) = 0.16585331$

-----  
Calculation of ratio  $l_b/l_d$

-----  
Inadequate Lap Length with  $l_b/l_d = 0.30$   
-----  
-----

-----  
Calculation of  $\mu_{2+}$   
-----  
-----

-----  
Calculation of ultimate Moment Strength ((3.67), Biskinis Phd),  $\mu$   
 $\mu = 2.4829E+008$

-----  
= 0.82030475  
' = 0.72936354  
error of function (3.68), Biskinis Phd = 58391.315  
From 5A.2, TBDY:  $f_{cc} = f_c \cdot c = 48.42699$   
conf. factor  $c = 1.46748$   
 $f_c = 33.00$   
From 10.3.5, ASCE 41-17, Final value of  $f_y$ :  $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3}) = 389.0139$   
 $l_b/l_d = 0.30$   
 $d_1 = 44.00$

R = 250.00  
v = 0.00103167  
N = 7389.214  
Ac = 196349.541  
= \*Min(1,1.25\*(lb/d)^ 2/3) = 0.16585331

-----  
Calculation of ratio lb/d

-----  
Inadequate Lap Length with lb/d = 0.30  
-----  
-----

-----  
Calculation of Mu2-  
-----  
-----

-----  
Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), Mu  
Mu = 2.4829E+008

-----  
= 0.82030475  
' = 0.72936354  
error of function (3.68), Biskinis Phd = 58391.315  
From 5A.2, TBDY: fcc = fc\* c = 48.42699  
conf. factor c = 1.46748  
fc = 33.00  
From 10.3.5, ASCE 41-17, Final value of fy: fy\*Min(1,1.25\*(lb/d)^ 2/3) = 389.0139  
lb/d = 0.30  
d1 = 44.00  
R = 250.00  
v = 0.00103167  
N = 7389.214  
Ac = 196349.541  
= \*Min(1,1.25\*(lb/d)^ 2/3) = 0.16585331

-----  
Calculation of ratio lb/d

-----  
Inadequate Lap Length with lb/d = 0.30  
-----  
-----

-----  
Calculation of Shear Strength Vr = Min(Vr1,Vr2) = 705811.584  
-----

-----  
Calculation of Shear Strength at edge 1, Vr1 = 705811.584

Vr1 = VCol ((10.3), ASCE 41-17) = knl\*VCol0  
VCol0 = 705811.584  
knl = 1 (zero step-static loading)

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

-----  
= 1 (normal-weight concrete)  
Mean concrete strength: fc' = (fc'\_jacket\*Area\_jacket + fc'\_core\*Area\_core)/Area\_section = 33.00, but fc'^0.5 <= 8.3  
MPa (22.5.3.1, ACI 318-14)  
M/Vd = 2.00  
Mu = 1.6210513E-011  
Vu = 1.1471900E-030  
d = 0.8\*D = 400.00  
Nu = 7389.214  
Ag = 196349.541  
From (11.5.4.8), ACI 318-14: Vs = Vs1 + Vs2 = 274157.871  
Vs1 = 274157.871 is calculated for jacket, with:  
Av = /2\*A\_stirup = 123370.055  
fy = 555.56  
s = 100.00

Vs1 is multiplied by Col1 = 1.00  
s/d = 0.25

Vs2 = 0.00 is calculated for core, with:

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

$$f_y = 555.56$$

$$s = 250.00$$

Vs2 is multiplied by Col2 = 0.00

$$s/d = 1.04167$$

Vf ((11-3)-(11.4), ACI 440) = 247653.332

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

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

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

This later relation, considered as a function  $V_f(\theta, \alpha)$ , 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

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

$$E_f = 64828.00$$

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

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

From (11-11), ACI 440:  $V_s + V_f \leq 479549.663$

$$b_w \cdot d = \sqrt{4} \cdot d = 125663.706$$

-----  
Calculation of Shear Strength at edge 2,  $V_{r2} = 705811.584$

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

$$V_{\text{Col0}} = 705811.584$$

$k_{nl} = 1$  (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:  $f'_c = (f'_{c, \text{jacket}} \cdot \text{Area}_{\text{jacket}} + f'_{c, \text{core}} \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 33.00$ , but  $f'_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$$M/Vd = 2.00$$

$$M_u = 1.6210513E-011$$

$$V_u = 1.1471900E-030$$

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

$$N_u = 7389.214$$

$$A_g = 196349.541$$

From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 274157.871$

$V_{s1} = 274157.871$  is calculated for jacket, with:

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

$$f_y = 555.56$$

$$s = 100.00$$

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

$$s/d = 0.25$$

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

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

$$f_y = 555.56$$

$$s = 250.00$$

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

$$s/d = 1.04167$$

Vf ((11-3)-(11.4), ACI 440) = 247653.332

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

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

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

This later relation, considered as a function  $V_f(\theta, \alpha)$ , 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,  $t_{f1} = N_L \cdot t / N_{\text{Dir}} = 1.016$

dfv = d (figure 11.2, ACI 440) = 470.00  
ffe ((11-5), ACI 440) = 259.312  
Ef = 64828.00  
fe = 0.004, from (11.6a), ACI 440  
with fu = 0.01  
From (11-11), ACI 440: Vs + Vf <= 479549.663  
bw\*d = \*d\*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, = 1.00  
Mean strength values are used for both shear and moment calculations.  
Consequently:  
Jacket  
New material of Secondary Member: Concrete Strength, fc = fcm = 33.00  
New material of Secondary Member: Steel Strength, fs = fsm = 555.56  
Concrete Elasticity, Ec = 26999.444  
Steel Elasticity, Es = 200000.00  
Existing Column  
New material of Secondary Member: Concrete Strength, fc = fcm = 33.00  
New material of Secondary Member: Steel Strength, fs = fsm = 555.56  
Concrete Elasticity, Ec = 26999.444  
Steel Elasticity, Es = 200000.00  
#####  
Note: Especially for the calculation of moment strengths,  
the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14  
Jacket  
New material: Steel Strength, fs = 1.25\*fsm = 694.45  
Existing Column  
New material: Steel Strength, fs = 1.25\*fsm = 694.45  
#####  
External Diameter, D = 500.00  
Internal Diameter, D = 300.00  
Cover Thickness, c = 25.00  
Mean Confinement Factor overall section = 1.46748  
Element Length, L = 3000.00  
Secondary Member  
Ribbed Bars  
Ductile Steel  
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)  
Longitudinal Bars With Ends Lapped Starting at the End Sections  
Inadequate Lap Length with lo/lo,min = 0.30  
FRP Wrapping Data  
Type: Carbon  
Cured laminate properties (design values)  
Thickness, t = 1.016  
Tensile Strength, ffu = 1055.00  
Tensile Modulus, Ef = 64828.00  
Elongation, efu = 0.01  
Number of directions, NoDir = 1  
Fiber orientations, bi: 0.00°  
Number of layers, NL = 1  
Radius of rounding corners, R = 40.00  
-----

Stepwise Properties

At local axis: 2

EDGE -A-

Shear Force,  $V_a = -7.0242809E-047$

EDGE -B-

Shear Force,  $V_b = 7.0242809E-047$

BOTH EDGES

Axial Force,  $F = -7389.214$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension:  $A_{st} = 0.00$

-Compression:  $A_{sc} = 3053.628$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

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

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

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

Calculation of Shear Capacity ratio,  $V_e/V_r = 0.23451953$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 165526.599$   
with

$M_{pr1} = \text{Max}(M_{u1+}, M_{u1-}) = 2.4829E+008$

$M_{u1+} = 2.4829E+008$ , is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination

$M_{u1-} = 2.4829E+008$ , is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination

$M_{pr2} = \text{Max}(M_{u2+}, M_{u2-}) = 2.4829E+008$

$M_{u2+} = 2.4829E+008$ , is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the the static loading combination

$M_{u2-} = 2.4829E+008$ , is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the the static loading combination

Calculation of  $M_{u1+}$

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

$M_u = 2.4829E+008$

$\phi = 0.82030475$

$\phi' = 0.72936354$

error of function (3.68), Biskinis Phd = 58391.315

From 5A.2, TBDY:  $f_{cc} = f_c \cdot c = 48.42699$

conf. factor  $c = 1.46748$

$f_c = 33.00$

From 10.3.5, ASCE 41-17, Final value of  $f_y$ :  $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 389.0139$

$l_b/d = 0.30$

$d_1 = 44.00$

$R = 250.00$

$v = 0.00103167$

$N = 7389.214$

$A_c = 196349.541$

$\phi' \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.16585331$

Calculation of ratio  $l_b/d$

Inadequate Lap Length with  $l_b/d = 0.30$

Calculation of  $M_{u1-}$

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

Mu = 2.4829E+008

-----  
= 0.82030475

' = 0.72936354

error of function (3.68), Biskinis Phd = 58391.315

From 5A.2, TBDY:  $f_{cc} = f_c \cdot c = 48.42699$

conf. factor  $c = 1.46748$

$f_c = 33.00$

From 10.3.5, ASCE 41-17, Final value of fy:  $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 389.0139$

$l_b/d = 0.30$

$d_1 = 44.00$

$R = 250.00$

$v = 0.00103167$

$N = 7389.214$

$Ac = 196349.541$

=  $\cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.16585331$   
-----

Calculation of ratio  $l_b/d$

-----  
Inadequate Lap Length with  $l_b/d = 0.30$   
-----  
-----  
-----

Calculation of Mu2+

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

Mu = 2.4829E+008

-----  
= 0.82030475

' = 0.72936354

error of function (3.68), Biskinis Phd = 58391.315

From 5A.2, TBDY:  $f_{cc} = f_c \cdot c = 48.42699$

conf. factor  $c = 1.46748$

$f_c = 33.00$

From 10.3.5, ASCE 41-17, Final value of fy:  $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 389.0139$

$l_b/d = 0.30$

$d_1 = 44.00$

$R = 250.00$

$v = 0.00103167$

$N = 7389.214$

$Ac = 196349.541$

=  $\cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.16585331$   
-----

Calculation of ratio  $l_b/d$

-----  
Inadequate Lap Length with  $l_b/d = 0.30$   
-----  
-----  
-----

Calculation of Mu2-

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

Mu = 2.4829E+008

-----  
= 0.82030475

' = 0.72936354

error of function (3.68), Biskinis Phd = 58391.315

From 5A.2, TBDY:  $f_{cc} = f_c \cdot c = 48.42699$

conf. factor  $c = 1.46748$

$f_c = 33.00$

From 10.3.5, ASCE 41-17, Final value of  $f_y$ :  $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 389.0139$

$l_b/d = 0.30$

$d_1 = 44.00$

$R = 250.00$

$v = 0.00103167$

$N = 7389.214$

$A_c = 196349.541$

$= \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.16585331$

Calculation of ratio  $l_b/d$

Inadequate Lap Length with  $l_b/d = 0.30$

Calculation of Shear Strength  $V_r = \text{Min}(V_{r1}, V_{r2}) = 705811.584$

Calculation of Shear Strength at edge 1,  $V_{r1} = 705811.584$

$V_{r1} = V_{\text{Col}} ((10.3), \text{ASCE 41-17}) = k_{nl} \cdot V_{\text{Col}0}$

$V_{\text{Col}0} = 705811.584$

$k_{nl} = 1$  (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:  $f_c' = (f_c'_{\text{jacket}} \cdot \text{Area}_{\text{jacket}} + f_c'_{\text{core}} \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 33.00$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M/d = 2.00$

$M_u = 1.7556432\text{E-}011$

$V_u = 7.0242809\text{E-}047$

$d = 0.8 \cdot D = 400.00$

$N_u = 7389.214$

$A_g = 196349.541$

From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 274157.871$

$V_{s1} = 274157.871$  is calculated for jacket, with:

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

$f_y = 555.56$

$s = 100.00$

$V_{s1}$  is multiplied by  $\text{Col}1 = 1.00$

$s/d = 0.25$

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

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

$f_y = 555.56$

$s = 250.00$

$V_{s2}$  is multiplied by  $\text{Col}2 = 0.00$

$s/d = 1.04167$

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

$f = 0.95$ , 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  $(\cot \theta + \csc \theta) \sin \alpha$  which is more a generalised expression, where  $\theta$  is the angle of the crack direction (see KANEPE).

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

orientation 1:  $\theta = 45^\circ = 90.00$

$V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, \alpha)|)$ , 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

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

$E_f = 64828.00$

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

with  $f_u = 0.01$

From (11-11), ACI 440:  $V_s + V_f \leq 479549.663$

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

Calculation of Shear Strength at edge 2,  $V_{r2} = 705811.584$

$$V_{r2} = V_{CoI} \text{ ((10.3), ASCE 41-17)} = k_{nl} * V_{CoI0}$$

$$V_{CoI0} = 705811.584$$

$k_{nl} = 1$  (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).

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

Mean concrete strength:  $f_c' = (f_c'_{jacket} * Area_{jacket} + f_c'_{core} * Area_{core}) / Area_{section} = 33.00$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$$M/Vd = 2.00$$

$$\mu_u = 1.7556432E-011$$

$$V_u = 7.0242809E-047$$

$$d = 0.8 * D = 400.00$$

$$N_u = 7389.214$$

$$A_g = 196349.541$$

From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 274157.871$

$V_{s1} = 274157.871$  is calculated for jacket, with:

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

$$f_y = 555.56$$

$$s = 100.00$$

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

$$s/d = 0.25$$

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

$$A_v = /2 * A_{stirrup} = 78956.835$$

$$f_y = 555.56$$

$$s = 250.00$$

$V_{s2}$  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,  $t_{f1} = N_L * t / \text{NoDir} = 1.016$

$d_{fv} = d$  (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:  $V_s + V_f \leq 479549.663$

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

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: 2

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

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

Concrete Elasticity,  $E_c = 26999.444$

Steel Elasticity,  $E_s = 200000.00$

Existing Column

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

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

Concrete Elasticity,  $E_c = 26999.444$

Steel Elasticity,  $E_s = 200000.00$

External Diameter,  $D = 500.00$

Internal Diameter,  $D = 300.00$

Cover Thickness,  $c = 25.00$

Element Length,  $L = 3000.00$

Secondary Member

Ribbed Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

Inadequate Lap Length with  $l_b/l_d = 0.30$

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness,  $t = 1.016$

Tensile Strength,  $f_{fu} = 1055.00$

Tensile Modulus,  $E_f = 64828.00$

Elongation,  $e_{fu} = 0.01$

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

Fiber orientations,  $b_i = 0.00^\circ$

Number of layers,  $N_L = 1$

Radius of rounding corners,  $R = 40.00$

-----  
Stepwise Properties

Bending Moment,  $M = 1.6994319E-009$

Shear Force,  $V_2 = -9128.06$

Shear Force,  $V_3 = -5.7178712E-013$

Axial Force,  $F = -7385.561$

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,  $D_{bL} = 18.00$

-----  
New component: From table 7-7, ASCE 41\_17: Final chord rotation Capacity  $u_{,R} = 1.0^*$   $u = 0.04652594$

$u = y + p = 0.04652594$

-----  
- Calculation of  $y$  -

$y = (M_y * L_s / 3) / E_{eff} = 0.00452594$  ((4.29), Biskinis Phd)

$M_y = 2.2494E+008$

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

From table 10.5, ASCE 41\_17:  $E_{eff} = factor * E_c * I_g = 2.4850E+013$

factor = 0.30

$A_g = 196349.541$

Mean concrete strength:  $f_c' = (f_c'_{jacket} * Area_{jacket} + f_c'_{core} * Area_{core}) / Area_{section} = 33.00$

$N = 7385.561$

$$E_c I_g = E_{c\_jacket} I_{g\_jacket} + E_{c\_core} I_{g\_core} = 8.2833E+013$$

Calculation of Yielding Moment  $M_y$

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

$$M_y = \min(M_{y\_ten}, M_{y\_com}) = 2.2494E+008$$

$$y = 6.4602088E-006$$

$$M_{y\_ten} (8c) = 2.2494E+008$$

$$\rho_{y\_ten} (7c) = 62.07293$$

$$\text{error of function (7c)} = 0.00023516$$

$$M_{y\_com} (8d) = 8.0674E+008$$

$$\rho_{y\_com} (7d) = 63.84405$$

$$\text{error of function (7d)} = -0.00846597$$

$$\text{with } ((10.1), \text{ASCE 41-17}) \rho_y = \min(\rho_y, 1.25 \rho_y (l_b/l_d)^{2/3}) = 0.0027778$$

$$e_{co} = 0.002$$

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

$$d_1 = 44.00$$

$$R = 250.00$$

$$v = 0.0010361$$

$$N = 7385.561$$

$$A_c = 196349.541$$

$$((10.1), \text{ASCE 41-17}) \rho_y = \min(\rho_y, 1.25 \rho_y (l_b/l_d)^{2/3}) = 0.23799351$$

$$\text{with } f_c \text{ ((12.3), ACI 440)} = 36.3038$$

$$f_c = 33.00$$

$$f_l = 1.05384$$

$$k = 1$$

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

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

$$f_u = 0.01$$

$$E_f = 64828.00$$

Calculation of ratio  $l_b/l_d$

Inadequate Lap Length with  $l_b/l_d = 0.30$

- Calculation of  $\rho_p$  -

From table 10-9:  $\rho_p = 0.042$

with:

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

$$\text{shear control ratio } V_y E / V_{CoI} O E = 0.23451953$$

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

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

$$t = s_1 + s_2 + 2 t_f / b w (f_{fe} / f_s) = 0.00702809$$

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

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

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

(shear) direction

$$s_1 = 100.00$$

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

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

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

direction

$$s_2 = 250.00$$

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

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

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

For the normalisation  $f_s$  of jacket is used.

$$N U D = 7385.561$$

$$A_g = 196349.541$$

$$f_{cE} = (f_{c\_jacket} \cdot \text{Area}_{\text{jacket}} + f_{c\_core} \cdot \text{Area}_{\text{core}}) / \text{section\_area} = 33.00$$

$$f_y E = (f_{y\_ext\_Long\_Reinf} \cdot Area\_ext\_Long\_Reinf + f_{y\_int\_Long\_Reinf} \cdot Area\_int\_Long\_Reinf) / Area\_Tot\_Long\_Rein = 2.1219958E-314$$

$$f_y E = (f_{y\_ext\_Trans\_Reinf} \cdot Area\_ext\_Trans\_Reinf + f_{y\_int\_Trans\_Reinf} \cdot Area\_int\_Trans\_Reinf) / Area\_Tot\_Trans\_Rein = 555.56$$

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

$$f_c E = 33.00$$

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

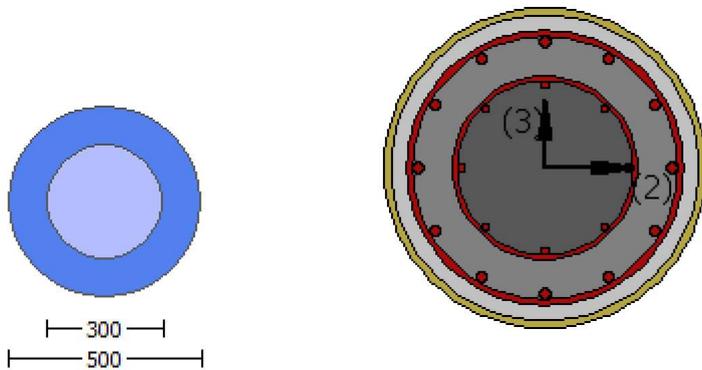
Limit State: Collapse Prevention (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Shear capacity VRd

Edge: Start

Local Axis: (3)



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

At local axis: 3

Integration Section: (a)

Section Type: rcjcs

Constant Properties

Knowledge Factor, = 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 Secondary Member: Concrete Strength,  $f_c = f_{c\_lower\_bound} = 25.00$

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

Concrete Elasticity,  $E_c = 26999.444$

Steel Elasticity,  $E_s = 200000.00$

```

Existing Column
New material of Secondary Member: Concrete Strength, fc = fc_lower_bound = 25.00
New material of Secondary Member: Steel Strength, fs = fs_lower_bound = 500.00
Concrete Elasticity, Ec = 26999.444
Steel Elasticity, Es = 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, fc = fcm = 33.00
New material: Steel Strength, fs = fsm = 555.56
Existing Column
New material: Concrete Strength, fc = fcm = 33.00
New material: Steel Strength, fs = fsm = 555.56
#####
External Diameter, D = 500.00
Internal Diameter, D = 300.00
Cover Thickness, c = 25.00
Element Length, L = 3000.00
Secondary Member
Ribbed Bars
Ductile Steel
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
Inadequate Lap Length with  $l_o/l_{ou,min} = l_b/l_d = 0.30$ 
FRP Wrapping Data
Type: Carbon
Cured laminate properties (design values)
Thickness, t = 1.016
Tensile Strength,  $f_{fu} = 1055.00$ 
Tensile Modulus,  $E_f = 64828.00$ 
Elongation,  $e_{fu} = 0.01$ 
Number of directions, NoDir = 1
Fiber orientations,  $b_i = 0.00^\circ$ 
Number of layers, NL = 1
Radius of rounding corners, R = 40.00
-----

Stepwise Properties
-----
EDGE -A-
Bending Moment,  $M_a = 1.6994319E-009$ 
Shear Force,  $V_a = -5.7178712E-013$ 
EDGE -B-
Bending Moment,  $M_b = 1.6373668E-011$ 
Shear Force,  $V_b = 5.7178712E-013$ 
BOTH EDGES
Axial Force, F = -7385.561
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,  $Db_{L,ten} = 18.00$ 
-----
-----

New component: From table 7-7, ASCE 41_17: Final Shear Capacity  $V_R = 1.0*V_n = 614519.612$ 
 $V_n ((10.3), ASCE 41-17) = knl*V_{CoIO} = 614519.612$ 
 $V_{CoI} = 614519.612$ 
 $knl = 1.00$ 
displacement_ductility_demand = 0.00
-----

```

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

= 1 (normal-weight concrete)

Mean concrete strength:  $f_c' = (f_c'_{\text{jacket}} \cdot \text{Area}_{\text{jacket}} + f_c'_{\text{core}} \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 25.00$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$\mu_u = 1.6994319E-009$

$V_u = 5.7178712E-013$

$d = 0.8 \cdot D = 400.00$

$N_u = 7385.561$

$A_g = 196349.541$

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:

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

$f_y = 500.00$

$s = 100.00$

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

$s/d = 0.25$

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

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

$f_y = 500.00$

$s = 250.00$

$V_{s2}$  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  $(\cot + \csc) \sin \alpha$  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:  $\alpha = b1 + 90^\circ = 90.00$

$V_f = \text{Min}(|V_f(45, 1)|, |V_f(-45, a1)|)$ , with:

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

$d_{fv} = d$  (figure 11.2, ACI 440) = 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:  $V_s + V_f \leq 417394.406$

$b_w \cdot d = \sqrt{2} \cdot d^2 / 4 = 125663.706$

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  $\theta = 2.0147682E-020$

$y = (M_y \cdot L_s / 3) / E_{\text{eff}} = 0.00452594$  ((4.29), Biskinis Phd)

$M_y = 2.2494E+008$

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

From table 10.5, ASCE 41\_17:  $E_{\text{eff}} = \text{factor} \cdot E_c \cdot I_g = 2.4850E+013$

factor = 0.30

$A_g = 196349.541$

Mean concrete strength:  $f_c' = (f_c'_{\text{jacket}} \cdot \text{Area}_{\text{jacket}} + f_c'_{\text{core}} \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 33.00$

$N = 7385.561$

$E_c \cdot I_g = E_{c_{\text{jacket}}} \cdot I_{g_{\text{jacket}}} + E_{c_{\text{core}}} \cdot I_{g_{\text{core}}} = 8.2833E+013$

Calculation of Yielding Moment  $M_y$

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

$M_y = \text{Min}(M_{y\_ten}, M_{y\_com}) = 2.2494E+008$   
 $y = 6.4602088E-006$   
 $M_{y\_ten} (8c) = 2.2494E+008$   
 $_{ten} (7c) = 62.07293$   
error of function (7c) = 0.00023516  
 $M_{y\_com} (8d) = 8.0674E+008$   
 $_{com} (7d) = 63.84405$   
error of function (7d) = -0.00846597  
with ((10.1), ASCE 41-17)  $e_y = \text{Min}(e_y, 1.25 * e_y * (l_b / l_d)^{2/3}) = 0.0027778$   
 $e_{co} = 0.002$   
 $a_{pl} = 0.45$  ((9c) in Biskinis and Fardis for FRP Wrap)  
 $d_1 = 44.00$   
 $R = 250.00$   
 $v = 0.0010361$   
 $N = 7385.561$   
 $A_c = 196349.541$   
((10.1), ASCE 41-17)  $= \text{Min}( , 1.25 * * (l_b / l_d)^{2/3}) = 0.23799351$   
with  $f_c^*$  ((12.3), ACI 440) = 36.3038  
 $f_c = 33.00$   
 $f_l = 1.05384$   
 $k = 1$   
Effective FRP thickness,  $t_f = N L * t * \text{Cos}(b_1) = 1.016$   
 $e_{fe}$  ((12.5) and (12.7)) = 0.004  
 $f_u = 0.01$   
 $E_f = 64828.00$

-----  
-----  
Calculation of ratio  $l_b / l_d$

-----  
Inadequate Lap Length with  $l_b / l_d = 0.30$   
-----

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

At local axis: 3

Integration Section: (a)  
-----

## Calculation No. 12

column C1, Floor 1

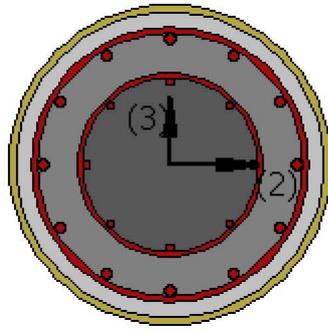
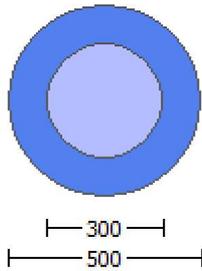
Limit State: Collapse Prevention (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity (  $\theta_u$  )

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 Secondary Member: Concrete Strength,  $f_c = f_{cm} = 33.00$   
 New material of Secondary Member: Steel Strength,  $f_s = f_{sm} = 555.56$   
 Concrete Elasticity,  $E_c = 26999.444$   
 Steel Elasticity,  $E_s = 200000.00$

Existing Column

New material of Secondary Member: Concrete Strength,  $f_c = f_{cm} = 33.00$   
 New material of Secondary Member: Steel Strength,  $f_s = f_{sm} = 555.56$   
 Concrete Elasticity,  $E_c = 26999.444$   
 Steel Elasticity,  $E_s = 200000.00$

#####

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

Jacket

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

Existing Column

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

#####

External Diameter,  $D = 500.00$

Internal Diameter,  $D = 300.00$

Cover Thickness,  $c = 25.00$

Mean Confinement Factor overall section = 1.46748

Element Length,  $L = 3000.00$

Secondary Member

Ribbed Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

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

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness,  $t = 1.016$

Tensile Strength,  $f_{fu} = 1055.00$

Tensile Modulus,  $E_f = 64828.00$

Elongation,  $ef_u = 0.01$

Number of directions,  $NoDir = 1$

Fiber orientations,  $bi = 0.00^\circ$

Number of layers,  $NL = 1$

Radius of rounding corners,  $R = 40.00$

Stepwise Properties

At local axis: 3

EDGE -A-

Shear Force,  $V_a = 1.1471900E-030$

EDGE -B-

Shear Force,  $V_b = -1.1471900E-030$

BOTH EDGES

Axial Force,  $F = -7389.214$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension:  $A_{st} = 0.00$

-Compression:  $A_{sc} = 3053.628$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

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

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

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

Calculation of Shear Capacity ratio,  $V_e/V_r = 0.23451953$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 165526.599$

with

$M_{pr1} = \text{Max}(M_{u1+}, M_{u1-}) = 2.4829E+008$

$M_{u1+} = 2.4829E+008$ , is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination

$M_{u1-} = 2.4829E+008$ , is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination

$M_{pr2} = \text{Max}(M_{u2+}, M_{u2-}) = 2.4829E+008$

$M_{u2+} = 2.4829E+008$ , is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the the static loading combination

$M_{u2-} = 2.4829E+008$ , is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the the static loading combination

Calculation of  $M_{u1+}$

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

$M_u = 2.4829E+008$

$\phi = 0.82030475$

$\phi' = 0.72936354$

error of function (3.68), Biskinis Phd = 58391.315

From 5A.2, TBDY:  $f_{cc} = f_c \cdot c = 48.42699$

conf. factor  $c = 1.46748$

$f_c = 33.00$

From 10.3.5, ASCE 41-17, Final value of  $f_y$ :  $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3}) = 389.0139$

$l_b/l_d = 0.30$

$d_1 = 44.00$

$R = 250.00$

$v = 0.00103167$

$N = 7389.214$

$A_c = 196349.541$

$\phi' = \phi \cdot \text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3}) = 0.16585331$

Calculation of ratio  $l_b/l_d$

Inadequate Lap Length with  $l_b/l_d = 0.30$

Calculation of  $M_{u1-}$

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

Mu = 2.4829E+008

-----  
= 0.82030475

' = 0.72936354

error of function (3.68), Biskinis Phd = 58391.315

From 5A.2, TBDY:  $f_{cc} = f_c \cdot c = 48.42699$

conf. factor  $c = 1.46748$

$f_c = 33.00$

From 10.3.5, ASCE 41-17, Final value of fy:  $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 389.0139$

$l_b/d = 0.30$

$d_1 = 44.00$

$R = 250.00$

$v = 0.00103167$

$N = 7389.214$

$Ac = 196349.541$

=  $\cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.16585331$   
-----

Calculation of ratio  $l_b/d$

-----  
Inadequate Lap Length with  $l_b/d = 0.30$   
-----  
-----  
-----

Calculation of Mu2+

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

Mu = 2.4829E+008

-----  
= 0.82030475

' = 0.72936354

error of function (3.68), Biskinis Phd = 58391.315

From 5A.2, TBDY:  $f_{cc} = f_c \cdot c = 48.42699$

conf. factor  $c = 1.46748$

$f_c = 33.00$

From 10.3.5, ASCE 41-17, Final value of fy:  $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 389.0139$

$l_b/d = 0.30$

$d_1 = 44.00$

$R = 250.00$

$v = 0.00103167$

$N = 7389.214$

$Ac = 196349.541$

=  $\cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.16585331$   
-----

Calculation of ratio  $l_b/d$

-----  
Inadequate Lap Length with  $l_b/d = 0.30$   
-----  
-----  
-----

Calculation of Mu2-

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

Mu = 2.4829E+008

-----  
= 0.82030475

' = 0.72936354

error of function (3.68), Biskinis Phd = 58391.315

From 5A.2, TBDY:  $f_{cc} = f_c \cdot c = 48.42699$

conf. factor  $c = 1.46748$

$f_c = 33.00$

From 10.3.5, ASCE 41-17, Final value of  $f_y$ :  $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 389.0139$

$l_b/d = 0.30$

$d_1 = 44.00$

$R = 250.00$

$v = 0.00103167$

$N = 7389.214$

$A_c = 196349.541$

$= \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.16585331$

Calculation of ratio  $l_b/d$

Inadequate Lap Length with  $l_b/d = 0.30$

Calculation of Shear Strength  $V_r = \text{Min}(V_{r1}, V_{r2}) = 705811.584$

Calculation of Shear Strength at edge 1,  $V_{r1} = 705811.584$

$V_{r1} = V_{\text{Col}} ((10.3), \text{ASCE 41-17}) = k_{nl} \cdot V_{\text{Col}0}$

$V_{\text{Col}0} = 705811.584$

$k_{nl} = 1$  (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:  $f_c' = (f_c'_{\text{jacket}} \cdot \text{Area}_{\text{jacket}} + f_c'_{\text{core}} \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 33.00$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$\mu_u = 1.6210513E-011$

$\nu_u = 1.1471900E-030$

$d = 0.8 \cdot D = 400.00$

$N_u = 7389.214$

$A_g = 196349.541$

From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 274157.871$

$V_{s1} = 274157.871$  is calculated for jacket, with:

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

$f_y = 555.56$

$s = 100.00$

$V_{s1}$  is multiplied by  $\text{Col}1 = 1.00$

$s/d = 0.25$

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

$A_v = \rho_v \cdot A_{\text{stirrup}} = 78956.835$

$f_y = 555.56$

$s = 250.00$

$V_{s2}$  is multiplied by  $\text{Col}2 = 0.00$

$s/d = 1.04167$

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

$f = 0.95$ , 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  $(\cot \theta + \csc \theta) \sin \alpha$  which is more a generalised expression, where  $\theta$  is the angle of the crack direction (see KANEPE).

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

orientation 1:  $\theta = 45^\circ + 90^\circ = 135^\circ$

$V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, \alpha)|)$ , 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

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

$E_f = 64828.00$

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

with  $f_u = 0.01$

From (11-11), ACI 440:  $V_s + V_f \leq 479549.663$

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

Calculation of Shear Strength at edge 2,  $V_{r2} = 705811.584$

$$V_{r2} = V_{CoI} \text{ ((10.3), ASCE 41-17)} = k_{nl}*V_{CoI0}$$

$$V_{CoI0} = 705811.584$$

$k_{nl} = 1$  (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:  $f_c' = (f_c'_{jacket}*Area_{jacket} + f_c'_{core}*Area_{core})/Area_{section} = 33.00$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$$M/Vd = 2.00$$

$$\mu_u = 1.6210513E-011$$

$$V_u = 1.1471900E-030$$

$$d = 0.8*D = 400.00$$

$$N_u = 7389.214$$

$$A_g = 196349.541$$

From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 274157.871$

$V_{s1} = 274157.871$  is calculated for jacket, with:

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

$$f_y = 555.56$$

$$s = 100.00$$

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

$$s/d = 0.25$$

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

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

$$f_y = 555.56$$

$$s = 250.00$$

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

$$s/d = 1.04167$$

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

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

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

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

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

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

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

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

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

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

$$E_f = 64828.00$$

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

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

From (11-11), ACI 440:  $V_s + V_f \leq 479549.663$

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

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

At local axis: 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 Secondary Member: Concrete Strength,  $f_c = f_{cm} = 33.00$

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

Concrete Elasticity,  $E_c = 26999.444$

Steel Elasticity,  $E_s = 200000.00$

Existing Column

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

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

Concrete Elasticity,  $E_c = 26999.444$

Steel Elasticity,  $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

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

Jacket

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

Existing Column

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

#####

External Diameter,  $D = 500.00$

Internal Diameter,  $D = 300.00$

Cover Thickness,  $c = 25.00$

Mean Confinement Factor overall section = 1.46748

Element Length,  $L = 3000.00$

Secondary Member

Ribbed Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

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

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness,  $t = 1.016$

Tensile Strength,  $f_{fu} = 1055.00$

Tensile Modulus,  $E_f = 64828.00$

Elongation,  $e_{fu} = 0.01$

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

Fiber orientations,  $b_i = 0.00^\circ$

Number of layers,  $N_L = 1$

Radius of rounding corners,  $R = 40.00$

-----  
Stepwise Properties

-----  
At local axis: 2

EDGE -A-

Shear Force,  $V_a = -7.0242809E-047$

EDGE -B-

Shear Force,  $V_b = 7.0242809E-047$

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,  $V_e/V_r = 0.23451953$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 165526.599$

with

$$Mpr1 = \text{Max}(Mu1+, Mu1-) = 2.4829E+008$$

Mu1+ = 2.4829E+008, is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination

Mu1- = 2.4829E+008, is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination

$$Mpr2 = \text{Max}(Mu2+, Mu2-) = 2.4829E+008$$

Mu2+ = 2.4829E+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- = 2.4829E+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 = 2.4829E+008  
-----

$$= 0.82030475$$

$$' = 0.72936354$$

error of function (3.68), Biskinis Phd = 58391.315

From 5A.2, TBDY:  $f_{cc} = f_c \cdot c = 48.42699$

conf. factor  $c = 1.46748$

$$f_c = 33.00$$

From 10.3.5, ASCE 41-17, Final value of  $f_y$ :  $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3}) = 389.0139$

$$l_b/l_d = 0.30$$

$$d1 = 44.00$$

$$R = 250.00$$

$$v = 0.00103167$$

$$N = 7389.214$$

$$Ac = 196349.541$$

$$= \cdot \text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3}) = 0.16585331$$

-----  
Calculation of ratio  $l_b/l_d$   
-----

Inadequate Lap Length with  $l_b/l_d = 0.30$   
-----  
-----  
-----

-----  
Calculation of Mu1-  
-----

-----  
Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), Mu  
Mu = 2.4829E+008  
-----

$$= 0.82030475$$

$$' = 0.72936354$$

error of function (3.68), Biskinis Phd = 58391.315

From 5A.2, TBDY:  $f_{cc} = f_c \cdot c = 48.42699$

conf. factor  $c = 1.46748$

$$f_c = 33.00$$

From 10.3.5, ASCE 41-17, Final value of  $f_y$ :  $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3}) = 389.0139$

$$l_b/l_d = 0.30$$

$$d1 = 44.00$$

$$R = 250.00$$

$$v = 0.00103167$$

$$N = 7389.214$$

$$Ac = 196349.541$$

$$= \cdot \text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3}) = 0.16585331$$

-----  
Calculation of ratio  $l_b/l_d$   
-----

Inadequate Lap Length with  $l_b/l_d = 0.30$   
-----

-----  
-----  
-----  
Calculation of Mu2+  
-----

-----  
Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), Mu  
Mu = 2.4829E+008  
-----

= 0.82030475  
' = 0.72936354  
error of function (3.68), Biskinis Phd = 58391.315  
From 5A.2, TBDY: fcc = fc\* c = 48.42699  
conf. factor c = 1.46748  
fc = 33.00  
From 10.3.5, ASCE 41-17, Final value of fy: fy\*Min(1,1.25\*(lb/d)^ 2/3) = 389.0139  
lb/d = 0.30  
d1 = 44.00  
R = 250.00  
v = 0.00103167  
N = 7389.214  
Ac = 196349.541  
= \*Min(1,1.25\*(lb/d)^ 2/3) = 0.16585331  
-----

-----  
Calculation of ratio lb/d  
-----

Inadequate Lap Length with lb/d = 0.30  
-----  
-----  
-----

-----  
Calculation of Mu2-  
-----

-----  
Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), Mu  
Mu = 2.4829E+008  
-----

= 0.82030475  
' = 0.72936354  
error of function (3.68), Biskinis Phd = 58391.315  
From 5A.2, TBDY: fcc = fc\* c = 48.42699  
conf. factor c = 1.46748  
fc = 33.00  
From 10.3.5, ASCE 41-17, Final value of fy: fy\*Min(1,1.25\*(lb/d)^ 2/3) = 389.0139  
lb/d = 0.30  
d1 = 44.00  
R = 250.00  
v = 0.00103167  
N = 7389.214  
Ac = 196349.541  
= \*Min(1,1.25\*(lb/d)^ 2/3) = 0.16585331  
-----

-----  
Calculation of ratio lb/d  
-----

Inadequate Lap Length with lb/d = 0.30  
-----  
-----  
-----

-----  
Calculation of Shear Strength Vr = Min(Vr1,Vr2) = 705811.584  
-----

Calculation of Shear Strength at edge 1, Vr1 = 705811.584  
Vr1 = VCol ((10.3), ASCE 41-17) = knl\*VColO  
VColO = 705811.584  
-----

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

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

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

Mean concrete strength:  $f_c' = (f_c'_{jacket} \cdot Area_{jacket} + f_c'_{core} \cdot Area_{core}) / Area_{section} = 33.00$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$\mu_u = 1.7556432E-011$

$\nu_u = 7.0242809E-047$

$d = 0.8 \cdot D = 400.00$

$N_u = 7389.214$

$A_g = 196349.541$

From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 274157.871$

$V_{s1} = 274157.871$  is calculated for jacket, with:

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

$f_y = 555.56$

$s = 100.00$

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

$s/d = 0.25$

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

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

$f_y = 555.56$

$s = 250.00$

$V_{s2}$  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)  $\sin \theta + \cos \theta$  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  $V_f(\theta, \alpha)$ , is implemented for every different fiber orientation  $\alpha_i$ , as well as for 2 crack directions,  $\theta = 45^\circ$  and  $\theta = -45^\circ$  to take into consideration the cyclic seismic loading.

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

$V_f = \text{Min}(|V_f(45, 1)|, |V_f(-45, a1)|)$ , with:

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

$d_{fv} = d$  (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:  $V_s + V_f \leq 479549.663$

$b_w \cdot d = A_{stirrup} \cdot d / 4 = 125663.706$

Calculation of Shear Strength at edge 2,  $V_{r2} = 705811.584$

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

$V_{Col0} = 705811.584$

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

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

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

Mean concrete strength:  $f_c' = (f_c'_{jacket} \cdot Area_{jacket} + f_c'_{core} \cdot Area_{core}) / Area_{section} = 33.00$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$\mu_u = 1.7556432E-011$

$\nu_u = 7.0242809E-047$

$d = 0.8 \cdot D = 400.00$

$N_u = 7389.214$

$A_g = 196349.541$

From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 274157.871$

$V_{s1} = 274157.871$  is calculated for jacket, with:

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

$f_y = 555.56$

$s = 100.00$   
 $V_{s1}$  is multiplied by  $Col1 = 1.00$   
 $s/d = 0.25$   
 $V_{s2} = 0.00$  is calculated for core, with:  
 $A_v = \sqrt{2} * A_{stirrup} = 78956.835$   
 $f_y = 555.56$   
 $s = 250.00$   
 $V_{s2}$  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)  $\sin \theta + \cos \theta$  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  $V_f(\theta, \alpha)$ , 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:  $\theta = b1 + 90^\circ = 90.00$   
 $V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, \theta)|)$ , with:  
 total thickness per orientation,  $tf1 = NL * t / NoDir = 1.016$   
 $df_v = d$  (figure 11.2, ACI 440) = 470.00  
 $ff_e ((11-5), ACI 440) = 259.312$   
 $E_f = 64828.00$   
 $f_e = 0.004$ , from (11.6a), ACI 440  
 with  $f_u = 0.01$   
 From (11-11), ACI 440:  $V_s + V_f \leq 479549.663$   
 $bw * d = \sqrt{V_s + V_f} * d / 4 = 125663.706$

-----  
 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,  $\phi = 1.00$   
 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 Secondary Member: Concrete Strength,  $f_c = f_{cm} = 33.00$   
 New material of Secondary Member: Steel Strength,  $f_s = f_{sm} = 555.56$   
 Concrete Elasticity,  $E_c = 26999.444$   
 Steel Elasticity,  $E_s = 200000.00$   
 Existing Column  
 New material of Secondary Member: Concrete Strength,  $f_c = f_{cm} = 33.00$   
 New material of Secondary Member: Steel Strength,  $f_s = f_{sm} = 555.56$   
 Concrete Elasticity,  $E_c = 26999.444$   
 Steel Elasticity,  $E_s = 200000.00$   
 External Diameter,  $D = 500.00$   
 Internal Diameter,  $D = 300.00$   
 Cover Thickness,  $c = 25.00$   
 Element Length,  $L = 3000.00$   
 Secondary Member  
 Ribbed Bars  
 Ductile Steel  
 Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)  
 Longitudinal Bars With Ends Lapped Starting at the End Sections  
 Inadequate Lap Length with  $l_b/l_d = 0.30$   
 FRP Wrapping Data  
 Type: Carbon

Cured laminate properties (design values)

Thickness,  $t = 1.016$

Tensile Strength,  $f_{fu} = 1055.00$

Tensile Modulus,  $E_f = 64828.00$

Elongation,  $e_{fu} = 0.01$

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

Fiber orientations,  $b_i = 0.00^\circ$

Number of layers,  $N_L = 1$

Radius of rounding corners,  $R = 40.00$

-----  
Stepwise Properties

Bending Moment,  $M = -2.7391E+007$

Shear Force,  $V_2 = -9128.06$

Shear Force,  $V_3 = -5.7178712E-013$

Axial Force,  $F = -7385.561$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension:  $A_{st} = 1272.345$

-Compression:  $A_{sc} = 1781.283$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

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

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

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

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

-----  
New component: From table 7-7, ASCE 41\_17: Final chord rotation Capacity  $u_{,R} = 1.0^*$   $u = 0.05105409$

$u = y + p = 0.05105409$

-----  
- Calculation of  $y$  -

$y = (M_y * L_s / 3) / E_{eff} = 0.00905409$  ((4.29), Biskinis Phd)

$M_y = 2.2494E+008$

$L_s = M/V$  (with  $L_s > 0.1 * L$  and  $L_s < 2 * L$ ) = 3000.736

From table 10.5, ASCE 41\_17:  $E_{eff} = factor * E_c * I_g = 2.4850E+013$

factor = 0.30

$A_g = 196349.541$

Mean concrete strength:  $f_c' = (f_c'_{jacket} * Area_{jacket} + f_c'_{core} * Area_{core}) / Area_{section} = 33.00$

$N = 7385.561$

$E_c * I_g = E_c * I_{g,jacket} + E_c * I_{g,core} = 8.2833E+013$

-----  
Calculation of Yielding Moment  $M_y$

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

$M_y = \text{Min}(M_{y,ten}, M_{y,com}) = 2.2494E+008$

$y = 6.4602088E-006$

$M_{y,ten}$  (8c) = 2.2494E+008

$_{ten}$  (7c) = 62.07293

error of function (7c) = 0.00023516

$M_{y,com}$  (8d) = 8.0674E+008

$_{com}$  (7d) = 63.84405

error of function (7d) = -0.00846597

with ((10.1), ASCE 41-17)  $e_y = \text{Min}(e_y, 1.25 * e_y * (l_b / l_d)^{2/3}) = 0.0027778$

$e_{co} = 0.002$

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

$d_1 = 44.00$

$R = 250.00$

$v = 0.0010361$

$N = 7385.561$

$A_c = 196349.541$

$((10.1), ASCE 41-17) = \text{Min}( , 1.25 * (lb/ld)^{2/3} ) = 0.23799351$   
 with  $f_c$  ((12.3), ACI 440) = 36.3038  
 $f_c = 33.00$   
 $f_l = 1.05384$   
 $k = 1$   
 Effective FRP thickness,  $t_f = NL * t * \text{Cos}(b1) = 1.016$   
 $e_{fe}$  ((12.5) and (12.7)) = 0.004  
 $f_u = 0.01$   
 $E_f = 64828.00$

Calculation of ratio  $lb/ld$

Inadequate Lap Length with  $lb/ld = 0.30$

- Calculation of  $p$  -

From table 10-9:  $p = 0.042$

with:

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

shear control ratio  $V_y E / V_{col} O E = 0.23451953$

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

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

$t = s_1 + s_2 + 2 * t_f / bw * (f_{fe} / f_s) = 0.00702809$

jacket:  $s_1 = A_{v1} * (Dc1 / 2) / (s_1 * A_g) = 0.0027646$

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

$Dc1 = D_{\text{ext}} - 2 * \text{cover} - \text{External Hoop Diameter} = 440.00$ , is the total Length of all stirrups parallel to loading

(shear) direction

$s_1 = 100.00$

core:  $s_2 = A_{v2} * (Dc2 / 2) / (s_2 * A_g) = 0.00046968$

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

$Dc2 = D_{\text{int}} - \text{Internal Hoop Diameter} = 292.00$ , is the total Length of all stirrups parallel to loading (shear)

direction

$s_2 = 250.00$

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

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

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

For the normalisation  $f_s$  of jacket is used.

$N_{UD} = 7385.561$

$A_g = 196349.541$

$f_{cE} = (f_{c_{\text{jacket}}} * \text{Area}_{\text{jacket}} + f_{c_{\text{core}}} * \text{Area}_{\text{core}}) / \text{section\_area} = 33.00$

$f_{yIE} = (f_{y_{\text{ext\_Long\_Reinf}}} * \text{Area}_{\text{ext\_Long\_Reinf}} + f_{y_{\text{int\_Long\_Reinf}}} * \text{Area}_{\text{int\_Long\_Reinf}}) / \text{Area}_{\text{Tot\_Long\_Rein}} = 2.1219958E-314$

$f_{yTE} = (f_{y_{\text{ext\_Trans\_Reinf}}} * \text{Area}_{\text{ext\_Trans\_Reinf}} + f_{y_{\text{int\_Trans\_Reinf}}} * \text{Area}_{\text{int\_Trans\_Reinf}}) / \text{Area}_{\text{Tot\_Trans\_Rein}} = 555.56$

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

$f_{cE} = 33.00$

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

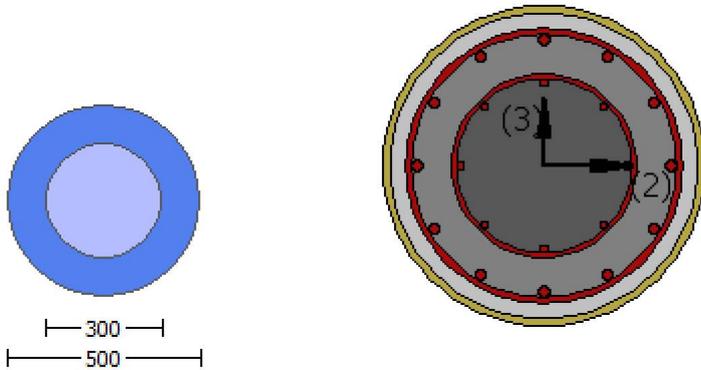
Limit State: Collapse Prevention (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Shear capacity VRd

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 Secondary Member: Concrete Strength,  $f_c = f_{c\_lower\_bound} = 25.00$

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

Concrete Elasticity,  $E_c = 26999.444$

Steel Elasticity,  $E_s = 200000.00$

Existing Column

New material of Secondary Member: Concrete Strength,  $f_c = f_{c\_lower\_bound} = 25.00$

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

Concrete Elasticity,  $E_c = 26999.444$

Steel Elasticity,  $E_s = 200000.00$

#####

Note: Especially for the calculation of  $\gamma$  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,  $f_c = f_{cm} = 33.00$

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

Existing Column

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

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

#####

External Diameter,  $D = 500.00$

Internal Diameter,  $D = 300.00$

Cover Thickness,  $c = 25.00$

Element Length,  $L = 3000.00$

Secondary Member

Ribbed Bars

Ductile Steel

Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)  
Longitudinal Bars With Ends Lapped Starting at the End Sections  
Inadequate Lap Length with  $l_o/l_{ou,min} = l_b/d = 0.30$   
FRP Wrapping Data  
Type: Carbon  
Cured laminate properties (design values)  
Thickness,  $t = 1.016$   
Tensile Strength,  $f_{fu} = 1055.00$   
Tensile Modulus,  $E_f = 64828.00$   
Elongation,  $e_{fu} = 0.01$   
Number of directions,  $NoDir = 1$   
Fiber orientations,  $bi: 0.00^\circ$   
Number of layers,  $NL = 1$   
Radius of rounding corners,  $R = 40.00$

-----  
Stepwise Properties  
-----

EDGE -A-  
Bending Moment,  $M_a = -2.7391E+007$   
Shear Force,  $V_a = -9128.06$   
EDGE -B-  
Bending Moment,  $M_b = 0.10663216$   
Shear Force,  $V_b = 9128.06$   
BOTH EDGES  
Axial Force,  $F = -7385.561$   
Longitudinal Reinforcement Area Distribution (in 2 divisions)  
-Tension:  $As_t = 0.00$   
-Compression:  $As_c = 3053.628$   
Longitudinal Reinforcement Area Distribution (in 3 divisions)  
-Tension:  $As_{t,ten} = 1017.876$   
-Compression:  $As_{c,com} = 1017.876$   
-Middle:  $As_{mid} = 1017.876$   
Mean Diameter of Tension Reinforcement,  $Db_{L,ten} = 18.00$

-----  
-----  
New component: From table 7-7, ASCE 41\_17: Final Shear Capacity  $V_R = 1.0 * V_n = 614519.612$   
 $V_n ((10.3), ASCE 41-17) = knl * V_{CoI0} = 614519.612$   
 $V_{CoI} = 614519.612$   
 $knl = 1.00$   
 $displacement\_ductility\_demand = 0.18263715$

-----  
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:  $f'_c = (f'_{c,jacket} * Area_{jacket} + f'_{c,core} * Area_{core}) / Area_{section} = 25.00$ , but  $f_c^{0.5} \leq 8.3$   
MPa (22.5.3.1, ACI 318-14)  
 $M/Vd = 2.00$   
 $M_u = 0.10663216$   
 $V_u = 9128.06$   
 $d = 0.8 * D = 400.00$   
 $N_u = 7385.561$   
 $A_g = 196349.541$   
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:  
 $A_v = /2 * A_{stirrup} = 123370.055$   
 $f_y = 500.00$   
 $s = 100.00$   
 $V_{s1}$  is multiplied by  $Col1 = 1.00$   
 $s/d = 0.25$   
 $V_{s2} = 0.00$  is calculated for core, with:  
 $A_v = /2 * A_{stirrup} = 78956.835$   
 $f_y = 500.00$   
 $s = 250.00$

Vs2 is multiplied by Col2 = 0.00

s/d = 1.04167

Vf ((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)  $\sin \theta + \cos \theta$  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 Vf(  $\theta$ ,  $\alpha$  ), is implemented for every different fiber orientation ai, as well as for 2 crack directions,  $\theta = 45^\circ$  and  $\theta = -45^\circ$  to take into consideration the cyclic seismic loading.

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

Vf = Min(|Vf(45,  $\theta$ )|, |Vf(-45,  $\theta$ )|), with:

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

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

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

Ef = 64828.00

fe = 0.004, from (11.6a), ACI 440

with fu = 0.01

From (11-11), ACI 440: Vs + Vf <= 417394.406

bw\*d =  $\rho_s d^2 / 4 = 125663.706$

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  $\theta = 0.00016532$

y = (My\* $L_s/3$ )/Eleff = 0.00090519 ((4.29), Biskinis Phd))

My = 2.2494E+008

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

From table 10.5, ASCE 41\_17: Eleff = factor\*Ec\*Ig = 2.4850E+013

factor = 0.30

Ag = 196349.541

Mean concrete strength:  $f'_c = (f'_{c\_jacket} * Area\_jacket + f'_{c\_core} * Area\_core) / Area\_section = 33.00$

N = 7385.561

$E_c * I_g = E_{c\_jacket} * I_{g\_jacket} + E_{c\_core} * I_{g\_core} = 8.2833E+013$

Calculation of Yielding Moment My

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

My = Min(My\_ten, My\_com) = 2.2494E+008

y = 6.4602088E-006

My\_ten (8c) = 2.2494E+008

$\delta / y$ \_ten (7c) = 62.07293

error of function (7c) = 0.00023516

My\_com (8d) = 8.0674E+008

$\delta / y$ \_com (7d) = 63.84405

error of function (7d) = -0.00846597

with ((10.1), ASCE 41-17)  $e_y = \text{Min}(e_y, 1.25 * e_y * (I_b / I_d)^{2/3}) = 0.0027778$

eco = 0.002

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

d1 = 44.00

R = 250.00

v = 0.0010361

N = 7385.561

Ac = 196349.541

((10.1), ASCE 41-17)  $\delta / y = \text{Min}(\delta / y, 1.25 * \delta / y * (I_b / I_d)^{2/3}) = 0.23799351$

with  $f'_c$  ((12.3), ACI 440) = 36.3038

$f'_c = 33.00$

fl = 1.05384

k = 1

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

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

$f_u = 0.01$   
 $E_f = 64828.00$

Calculation of ratio  $I_b/I_d$

Inadequate Lap Length with  $I_b/I_d = 0.30$

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

At local axis: 2

Integration Section: (b)

## Calculation No. 14

column C1, Floor 1

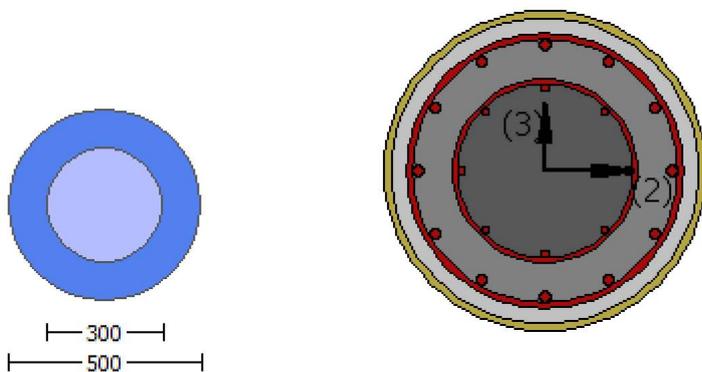
Limit State: Collapse Prevention (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity (  $\theta$  )

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

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

Concrete Elasticity,  $E_c = 26999.444$

Steel Elasticity,  $E_s = 200000.00$

Existing Column

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

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

Concrete Elasticity,  $E_c = 26999.444$

Steel Elasticity,  $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

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

Jacket

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

Existing Column

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

#####

External Diameter,  $D = 500.00$

Internal Diameter,  $D = 300.00$

Cover Thickness,  $c = 25.00$

Mean Confinement Factor overall section = 1.46748

Element Length,  $L = 3000.00$

Secondary Member

Ribbed Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

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

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness,  $t = 1.016$

Tensile Strength,  $f_{fu} = 1055.00$

Tensile Modulus,  $E_f = 64828.00$

Elongation,  $e_{fu} = 0.01$

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

Fiber orientations,  $b_i = 0.00^\circ$

Number of layers,  $N_L = 1$

Radius of rounding corners,  $R = 40.00$

-----  
Stepwise Properties

At local axis: 3

EDGE -A-

Shear Force,  $V_a = 1.1471900E-030$

EDGE -B-

Shear Force,  $V_b = -1.1471900E-030$

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,  $V_e/V_r = 0.23451953$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 165526.599$

with

$M_{pr1} = \text{Max}(M_{u1+}, M_{u1-}) = 2.4829E+008$

$M_{u1+} = 2.4829E+008$ , is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination

$M_{u1-} = 2.4829E+008$ , is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination

$M_{pr2} = \text{Max}(M_{u2+}, M_{u2-}) = 2.4829E+008$

Mu2+ = 2.4829E+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- = 2.4829E+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 = 2.4829E+008

-----  
= 0.82030475

' = 0.72936354

error of function (3.68), Biskinis Phd = 58391.315

From 5A.2, TBDY: fcc = fc\* c = 48.42699

conf. factor c = 1.46748

fc = 33.00

From 10.3.5, ASCE 41-17, Final value of fy: fy\*Min(1,1.25\*(lb/d)^ 2/3) = 389.0139

lb/d = 0.30

d1 = 44.00

R = 250.00

v = 0.00103167

N = 7389.214

Ac = 196349.541

= \*Min(1,1.25\*(lb/d)^ 2/3) = 0.16585331  
-----

Calculation of ratio lb/d  
-----

Inadequate Lap Length with lb/d = 0.30  
-----  
-----

-----  
Calculation of Mu1-  
-----

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

Mu = 2.4829E+008

-----  
= 0.82030475

' = 0.72936354

error of function (3.68), Biskinis Phd = 58391.315

From 5A.2, TBDY: fcc = fc\* c = 48.42699

conf. factor c = 1.46748

fc = 33.00

From 10.3.5, ASCE 41-17, Final value of fy: fy\*Min(1,1.25\*(lb/d)^ 2/3) = 389.0139

lb/d = 0.30

d1 = 44.00

R = 250.00

v = 0.00103167

N = 7389.214

Ac = 196349.541

= \*Min(1,1.25\*(lb/d)^ 2/3) = 0.16585331  
-----

Calculation of ratio lb/d  
-----

Inadequate Lap Length with lb/d = 0.30  
-----  
-----

-----  
Calculation of Mu2+  
-----

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), Mu  
Mu = 2.4829E+008

$$= 0.82030475$$

$$' = 0.72936354$$

error of function (3.68), Biskinis Phd = 58391.315

From 5A.2, TBDY:  $f_{cc} = f_c \cdot c = 48.42699$

$$\text{conf. factor } c = 1.46748$$

$$f_c = 33.00$$

From 10.3.5, ASCE 41-17, Final value of  $f_y$ :  $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 389.0139$

$$l_b/d = 0.30$$

$$d_1 = 44.00$$

$$R = 250.00$$

$$v = 0.00103167$$

$$N = 7389.214$$

$$A_c = 196349.541$$

$$= \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.16585331$$

Calculation of ratio  $l_b/d$

Inadequate Lap Length with  $l_b/d = 0.30$

Calculation of Mu2-

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), Mu  
Mu = 2.4829E+008

$$= 0.82030475$$

$$' = 0.72936354$$

error of function (3.68), Biskinis Phd = 58391.315

From 5A.2, TBDY:  $f_{cc} = f_c \cdot c = 48.42699$

$$\text{conf. factor } c = 1.46748$$

$$f_c = 33.00$$

From 10.3.5, ASCE 41-17, Final value of  $f_y$ :  $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 389.0139$

$$l_b/d = 0.30$$

$$d_1 = 44.00$$

$$R = 250.00$$

$$v = 0.00103167$$

$$N = 7389.214$$

$$A_c = 196349.541$$

$$= \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.16585331$$

Calculation of ratio  $l_b/d$

Inadequate Lap Length with  $l_b/d = 0.30$

Calculation of Shear Strength  $V_r = \text{Min}(V_{r1}, V_{r2}) = 705811.584$

Calculation of Shear Strength at edge 1,  $V_{r1} = 705811.584$

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

$$V_{Col0} = 705811.584$$

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

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:  $f_c' = (f_c'_{\text{jacket}} \cdot \text{Area}_{\text{jacket}} + f_c'_{\text{core}} \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 33.00$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$$M/Vd = 2.00$$

$$\mu_u = 1.6210513E-011$$

$$V_u = 1.1471900E-030$$

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

$$N_u = 7389.214$$

$$A_g = 196349.541$$

From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 274157.871$

$V_{s1} = 274157.871$  is calculated for jacket, with:

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

$$f_y = 555.56$$

$$s = 100.00$$

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

$$s/d = 0.25$$

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

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

$$f_y = 555.56$$

$$s = 250.00$$

$V_{s2}$  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:  $\theta = b1 + 90^\circ = 90.00$

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

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

$d_{fv} = d$  (figure 11.2, ACI 440) = 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:  $V_s + V_f \leq 479549.663$

$$b_w \cdot d = \sqrt{2} \cdot d^2 / 4 = 125663.706$$

Calculation of Shear Strength at edge 2,  $V_{r2} = 705811.584$

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

$$V_{\text{Col}0} = 705811.584$$

$k_{nl} = 1$  (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:  $f_c' = (f_c'_{\text{jacket}} \cdot \text{Area}_{\text{jacket}} + f_c'_{\text{core}} \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 33.00$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$$M/Vd = 2.00$$

$$\mu_u = 1.6210513E-011$$

$$V_u = 1.1471900E-030$$

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

$$N_u = 7389.214$$

$$A_g = 196349.541$$

From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 274157.871$

$V_{s1} = 274157.871$  is calculated for jacket, with:

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

$$f_y = 555.56$$

$$s = 100.00$$

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

$$s/d = 0.25$$

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

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

$$f_y = 555.56$$

$s = 250.00$   
 $V_s$  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  $\theta$  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,  $tf1 = NL * t / NoDir = 1.016$   
 $dfv = d$  (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:  $V_s + V_f \leq 479549.663$   
 $bw * d = \rho * d * d / 4 = 125663.706$

-----  
 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 Secondary Member: Concrete Strength,  $f_c = f_{cm} = 33.00$   
 New material of Secondary Member: Steel Strength,  $f_s = f_{sm} = 555.56$   
 Concrete Elasticity,  $E_c = 26999.444$   
 Steel Elasticity,  $E_s = 200000.00$   
 Existing Column  
 New material of Secondary Member: Concrete Strength,  $f_c = f_{cm} = 33.00$   
 New material of Secondary Member: Steel Strength,  $f_s = f_{sm} = 555.56$   
 Concrete Elasticity,  $E_c = 26999.444$   
 Steel Elasticity,  $E_s = 200000.00$   
 #####  
 Note: Especially for the calculation of moment strengths,  
 the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14  
 Jacket  
 New material: Steel Strength,  $f_s = 1.25 * f_{sm} = 694.45$   
 Existing Column  
 New material: Steel Strength,  $f_s = 1.25 * f_{sm} = 694.45$   
 #####  
 External Diameter,  $D = 500.00$   
 Internal Diameter,  $D = 300.00$   
 Cover Thickness,  $c = 25.00$   
 Mean Confinement Factor overall section = 1.46748  
 Element Length,  $L = 3000.00$   
 Secondary Member  
 Ribbed Bars  
 Ductile Steel  
 Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)  
 Longitudinal Bars With Ends Lapped Starting at the End Sections  
 Inadequate Lap Length with  $l_o / l_{ou, min} = 0.30$

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness,  $t = 1.016$

Tensile Strength,  $f_{fu} = 1055.00$

Tensile Modulus,  $E_f = 64828.00$

Elongation,  $\epsilon_{fu} = 0.01$

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

Fiber orientations,  $b_i = 0.00^\circ$

Number of layers,  $N_L = 1$

Radius of rounding corners,  $R = 40.00$

Stepwise Properties

At local axis: 2

EDGE -A-

Shear Force,  $V_a = -7.0242809E-047$

EDGE -B-

Shear Force,  $V_b = 7.0242809E-047$

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,  $V_e/V_r = 0.23451953$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 165526.599$

with

$M_{pr1} = \text{Max}(Mu_{1+}, Mu_{1-}) = 2.4829E+008$

$Mu_{1+} = 2.4829E+008$ , is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination

$Mu_{1-} = 2.4829E+008$ , is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination

$M_{pr2} = \text{Max}(Mu_{2+}, Mu_{2-}) = 2.4829E+008$

$Mu_{2+} = 2.4829E+008$ , is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the static loading combination

$Mu_{2-} = 2.4829E+008$ , 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),  $Mu$

$Mu = 2.4829E+008$

$\beta = 0.82030475$

$\beta' = 0.72936354$

error of function (3.68), Biskinis Phd = 58391.315

From 5A.2, TBDY:  $f_{cc} = f_c \cdot c = 48.42699$

conf. factor  $c = 1.46748$

$f_c = 33.00$

From 10.3.5, ASCE 41-17, Final value of  $f_y$ :  $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3}) = 389.0139$

$l_b/l_d = 0.30$

$d_1 = 44.00$

$R = 250.00$

$v = 0.00103167$

$$N = 7389.214$$
$$Ac = 196349.541$$
$$= *Min(1,1.25*(lb/d)^{2/3}) = 0.16585331$$

Calculation of ratio lb/d

Inadequate Lap Length with lb/d = 0.30

Calculation of Mu1-

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), Mu  
Mu = 2.4829E+008

$$= 0.82030475$$
$$' = 0.72936354$$

error of function (3.68), Biskinis Phd = 58391.315

From 5A.2, TBDY: fcc = fc\* c = 48.42699

conf. factor c = 1.46748

fc = 33.00

From 10.3.5, ASCE 41-17, Final value of fy: fy\*Min(1,1.25\*(lb/d)^{2/3}) = 389.0139

lb/d = 0.30

d1 = 44.00

R = 250.00

v = 0.00103167

N = 7389.214

Ac = 196349.541

$$= *Min(1,1.25*(lb/d)^{2/3}) = 0.16585331$$

Calculation of ratio lb/d

Inadequate Lap Length with lb/d = 0.30

Calculation of Mu2+

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), Mu  
Mu = 2.4829E+008

$$= 0.82030475$$
$$' = 0.72936354$$

error of function (3.68), Biskinis Phd = 58391.315

From 5A.2, TBDY: fcc = fc\* c = 48.42699

conf. factor c = 1.46748

fc = 33.00

From 10.3.5, ASCE 41-17, Final value of fy: fy\*Min(1,1.25\*(lb/d)^{2/3}) = 389.0139

lb/d = 0.30

d1 = 44.00

R = 250.00

v = 0.00103167

N = 7389.214

Ac = 196349.541

$$= *Min(1,1.25*(lb/d)^{2/3}) = 0.16585331$$

Calculation of ratio lb/d

Inadequate Lap Length with lb/d = 0.30

Calculation of Mu2-

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), Mu  
Mu = 2.4829E+008

$$= 0.82030475$$

$$' = 0.72936354$$

error of function (3.68), Biskinis Phd = 58391.315

From 5A.2, TBDY:  $f_{cc} = f_c' \cdot c = 48.42699$

conf. factor  $c = 1.46748$

$f_c = 33.00$

From 10.3.5, ASCE 41-17, Final value of fy:  $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 389.0139$

$l_b/d = 0.30$

$d_1 = 44.00$

$R = 250.00$

$v = 0.00103167$

$N = 7389.214$

$A_c = 196349.541$

$= \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.16585331$

Calculation of ratio  $l_b/d$

Inadequate Lap Length with  $l_b/d = 0.30$

Calculation of Shear Strength  $V_r = \text{Min}(V_{r1}, V_{r2}) = 705811.584$

Calculation of Shear Strength at edge 1,  $V_{r1} = 705811.584$

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

$V_{Col0} = 705811.584$

$k_{nl} = 1$  (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:  $f_c' = (f_c'_{jacket} \cdot \text{Area}_{jacket} + f_c'_{core} \cdot \text{Area}_{core}) / \text{Area}_{section} = 33.00$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$M_u = 1.7556432E-011$

$V_u = 7.0242809E-047$

$d = 0.8 \cdot D = 400.00$

$N_u = 7389.214$

$A_g = 196349.541$

From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 274157.871$

$V_{s1} = 274157.871$  is calculated for jacket, with:

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

$f_y = 555.56$

$s = 100.00$

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

$s/d = 0.25$

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

$A_v = \sqrt{2} \cdot A_{stirup} = 78956.835$

$f_y = 555.56$

$s = 250.00$

$V_{s2}$  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)  $\sin \theta + \cos \theta$  is replaced with  $(\cot \theta + \csc \theta) \sin \theta$  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  $a_i$ , 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,  $t_{f1} = NL \cdot t / \text{NoDir} = 1.016$   
 $d_{fv} = d$  (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:  $V_s + V_f \leq 479549.663$   
 $b_w \cdot d = \sqrt[4]{V_s \cdot d} = 125663.706$

Calculation of Shear Strength at edge 2,  $V_{r2} = 705811.584$   
 $V_{r2} = V_{Col}$  ((10.3), ASCE 41-17) =  $k_{nl} \cdot V_{Col0}$   
 $V_{Col0} = 705811.584$   
 $k_{nl} = 1$  (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).

$k_{nl} = 1$  (normal-weight concrete)  
Mean concrete strength:  $f'_c = (f'_c \cdot \text{Area}_{\text{jacket}} + f'_c \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 33.00$ , but  $f'_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)  
 $M/Vd = 2.00$   
 $\mu_u = 1.7556432E-011$   
 $V_u = 7.0242809E-047$   
 $d = 0.8 \cdot D = 400.00$   
 $N_u = 7389.214$   
 $A_g = 196349.541$   
From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 274157.871$   
 $V_{s1} = 274157.871$  is calculated for jacket, with:  
 $A_v = \sqrt{2} \cdot A_{\text{stirrup}} = 123370.055$   
 $f_y = 555.56$   
 $s = 100.00$   
 $V_{s1}$  is multiplied by  $\text{Col1} = 1.00$   
 $s/d = 0.25$   
 $V_{s2} = 0.00$  is calculated for core, with:  
 $A_v = \sqrt{2} \cdot A_{\text{stirrup}} = 78956.835$   
 $f_y = 555.56$   
 $s = 250.00$   
 $V_{s2}$  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  $(\cot \theta + \csc \theta) \sin \theta$  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  $a_i$ , 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,  $t_{f1} = NL \cdot t / \text{NoDir} = 1.016$   
 $d_{fv} = d$  (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:  $V_s + V_f \leq 479549.663$   
 $b_w \cdot d = \sqrt[4]{V_s \cdot d} = 125663.706$

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: 2

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

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

Concrete Elasticity,  $E_c = 26999.444$

Steel Elasticity,  $E_s = 200000.00$

Existing Column

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

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

Concrete Elasticity,  $E_c = 26999.444$

Steel Elasticity,  $E_s = 200000.00$

External Diameter,  $D = 500.00$

Internal Diameter,  $D = 300.00$

Cover Thickness,  $c = 25.00$

Element Length,  $L = 3000.00$

Secondary Member

Ribbed Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

Inadequate Lap Length with  $l_b/l_d = 0.30$

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness,  $t = 1.016$

Tensile Strength,  $f_{fu} = 1055.00$

Tensile Modulus,  $E_f = 64828.00$

Elongation,  $e_{fu} = 0.01$

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

Fiber orientations,  $b_i = 0.00^\circ$

Number of layers,  $N_L = 1$

Radius of rounding corners,  $R = 40.00$

#### Stepwise Properties

Bending Moment,  $M = 1.6373668E-011$

Shear Force,  $V_2 = 9128.06$

Shear Force,  $V_3 = 5.7178712E-013$

Axial Force,  $F = -7385.561$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension:  $A_{sl} = 0.00$

-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,  $DbL = 18.00$

New component: From table 7-7, ASCE 41\_17: Final chord rotation Capacity  $\mu_{u,R} = 1.0^*$   $\mu = 0.04652594$

$$u = y + p = 0.04652594$$

- Calculation of  $y$  -

$$y = (M_y \cdot L_s / 3) / E_{\text{eff}} = 0.00452594 \text{ ((4.29), Biskinis Phd)}$$

$$M_y = 2.2494 \text{E} + 008$$

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

$$\text{From table 10.5, ASCE 41-17: } E_{\text{eff}} = \text{factor} \cdot E_c \cdot I_g = 2.4850 \text{E} + 013$$

$$\text{factor} = 0.30$$

$$A_g = 196349.541$$

$$\text{Mean concrete strength: } f_c' = (f_c'_{\text{jacket}} \cdot \text{Area}_{\text{jacket}} + f_c'_{\text{core}} \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 33.00$$

$$N = 7385.561$$

$$E_c \cdot I_g = E_{c_{\text{jacket}}} \cdot I_{g_{\text{jacket}}} + E_{c_{\text{core}}} \cdot I_{g_{\text{core}}} = 8.2833 \text{E} + 013$$

Calculation of Yielding Moment  $M_y$

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

$$M_y = \text{Min}(M_{y_{\text{ten}}}, M_{y_{\text{com}}}) = 2.2494 \text{E} + 008$$

$$y = 6.4602088 \text{E} - 006$$

$$M_{y_{\text{ten}}} \text{ (8c)} = 2.2494 \text{E} + 008$$

$$y_{\text{ten}} \text{ (7c)} = 62.07293$$

$$\text{error of function (7c)} = 0.00023516$$

$$M_{y_{\text{com}}} \text{ (8d)} = 8.0674 \text{E} + 008$$

$$y_{\text{com}} \text{ (7d)} = 63.84405$$

$$\text{error of function (7d)} = -0.00846597$$

$$\text{with ((10.1), ASCE 41-17) } e_y = \text{Min}(e_y, 1.25 \cdot e_y \cdot (l_b / l_d)^{2/3}) = 0.0027778$$

$$e_{c0} = 0.002$$

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

$$d_1 = 44.00$$

$$R = 250.00$$

$$v = 0.0010361$$

$$N = 7385.561$$

$$A_c = 196349.541$$

$$\text{((10.1), ASCE 41-17) } = \text{Min}( , 1.25 \cdot \cdot (l_b / l_d)^{2/3}) = 0.23799351$$

$$\text{with } f_c' \text{ ((12.3), ACI 440) } = 36.3038$$

$$f_c = 33.00$$

$$f_l = 1.05384$$

$$k = 1$$

$$\text{Effective FRP thickness, } t_f = N \cdot l \cdot \text{Cos}(b_1) = 1.016$$

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

$$f_u = 0.01$$

$$E_f = 64828.00$$

Calculation of ratio  $l_b / l_d$

Inadequate Lap Length with  $l_b / l_d = 0.30$

- Calculation of  $p$  -

From table 10-9:  $p = 0.042$

with:

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

$$\text{shear control ratio } V_y E / V_c O E = 0.23451953$$

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

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

$$t = s_1 + s_2 + 2 \cdot t_f / b_w \cdot (f_{fe} / f_s) = 0.00702809$$

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

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

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

$$s1 = 100.00$$

$$\text{core: } s2 = Av2 * (\pi * Dc2 / 2) / (s2 * Ag) = 0.00046968$$

Av2 = 50.26548, is the area of stirrup

Dc2 = Dint - Internal Hoop Diameter = 292.00, is the total Length of all stirrups parallel to loading (shear)

direction

$$s2 = 250.00$$

The term  $2 * tf / bw * (ffe / fs)$  is implemented to account for FRP contribution

where  $f = 2 * tf / bw$  is FRP ratio (EC8 - 3, A.4.4.3(6)) and  $ffe / fs$  normalises  $f$  to steel strength

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

For the normalisation  $fs$  of jacket is used.

$$NUD = 7385.561$$

$$Ag = 196349.541$$

$$fcE = (fc\_jacket * Area\_jacket + fc\_core * Area\_core) / section\_area = 33.00$$

$$fyIE = (fy\_ext\_Long\_Reinf * Area\_ext\_Long\_Reinf + fy\_int\_Long\_Reinf * Area\_int\_Long\_Reinf) / Area\_Tot\_Long\_Rein = 2.1219958E-314$$

$$fytE = (fy\_ext\_Trans\_Reinf * Area\_ext\_Trans\_Reinf + fy\_int\_Trans\_Reinf * Area\_int\_Trans\_Reinf) / Area\_Tot\_Trans\_Rein = 555.56$$

$$pl = Area\_Tot\_Long\_Rein / (Ag) = 0.015552$$

$$fcE = 33.00$$

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

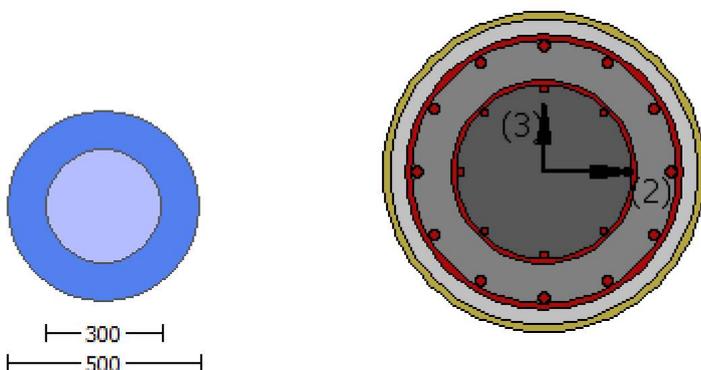
Limit State: Collapse Prevention (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Shear capacity VRd

Edge: End

Local Axis: (3)



Start Of Calculation of Shear Capacity for element: column 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 Secondary Member: Concrete Strength,  $f_c = f_{c\_lower\_bound} = 25.00$

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

Concrete Elasticity,  $E_c = 26999.444$

Steel Elasticity,  $E_s = 200000.00$

Existing Column

New material of Secondary Member: Concrete Strength,  $f_c = f_{c\_lower\_bound} = 25.00$

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

Concrete Elasticity,  $E_c = 26999.444$

Steel Elasticity,  $E_s = 200000.00$

#####

Note: Especially for the calculation of  $\gamma$  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,  $f_c = f_{cm} = 33.00$

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

Existing Column

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

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

#####

External Diameter,  $D = 500.00$

Internal Diameter,  $D = 300.00$

Cover Thickness,  $c = 25.00$

Element Length,  $L = 3000.00$

Secondary Member

Ribbed Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

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

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness,  $t = 1.016$

Tensile Strength,  $f_{fu} = 1055.00$

Tensile Modulus,  $E_f = 64828.00$

Elongation,  $e_{fu} = 0.01$

Number of directions,  $NoDir = 1$

Fiber orientations,  $b_i = 0.00^\circ$

Number of layers,  $NL = 1$

Radius of rounding corners,  $R = 40.00$

Stepwise Properties

EDGE -A-

Bending Moment,  $M_a = 1.6994319E-009$

Shear Force,  $V_a = -5.7178712E-013$

EDGE -B-

Bending Moment,  $M_b = 1.6373668E-011$

Shear Force,  $V_b = 5.7178712E-013$

BOTH EDGES

Axial Force,  $F = -7385.561$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension:  $As_t = 0.00$

-Compression:  $As_c = 3053.628$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

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

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

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

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

New component: From table 7-7, ASCE 41\_17: Final Shear Capacity  $V_R = 1.0 \cdot V_n = 614519.612$

$V_n$  ((10.3), ASCE 41-17) =  $k_{nl} \cdot V_{CoI0} = 614519.612$

$V_{CoI} = 614519.612$

$k_{nl} = 1.00$

$displacement\_ductility\_demand = 0.00$

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:  $f_c' = (f_c'_{jacket} \cdot Area_{jacket} + f_c'_{core} \cdot Area_{core}) / Area_{section} = 25.00$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$\mu_u = 1.6373668E-011$

$V_u = 5.7178712E-013$

$d = 0.8 \cdot D = 400.00$

$N_u = 7385.561$

$A_g = 196349.541$

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:

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

$f_y = 500.00$

$s = 100.00$

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

$s/d = 0.25$

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

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

$f_y = 500.00$

$s = 250.00$

$V_{s2}$  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  $(\cot + \cot) \sin \alpha$  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:  $\alpha = 45^\circ = 90.00$

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

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

$d_{fv} = d$  (figure 11.2, ACI 440) = 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:  $V_s + V_f \leq 417394.406$

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

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

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

for rotation axis 2 and integ. section (b)

From analysis, chord rotation  $\theta = 9.9023554E-021$

$y = (M_y \cdot L_s / 3) / E_{eff} = 0.00452594$  ((4.29), Biskinis Phd)

$M_y = 2.2494E+008$

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

From table 10.5, ASCE 41\_17:  $E_{eff} = factor * E_c * I_g = 2.4850E+013$

factor = 0.30

$A_g = 196349.541$

Mean concrete strength:  $f_c' = (f_c'_{jacket} * Area_{jacket} + f_c'_{core} * Area_{core}) / Area_{section} = 33.00$

$N = 7385.561$

$E_c * I_g = E_c_{jacket} * I_{g,jacket} + E_c_{core} * I_{g,core} = 8.2833E+013$

Calculation of Yielding Moment  $M_y$

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

$M_y = \text{Min}(M_{y,ten}, M_{y,com}) = 2.2494E+008$

$\rho_y = 6.4602088E-006$

$M_{y,ten} (8c) = 2.2494E+008$

$\rho_{y,ten} (7c) = 62.07293$

error of function (7c) = 0.00023516

$M_{y,com} (8d) = 8.0674E+008$

$\rho_{y,com} (7d) = 63.84405$

error of function (7d) = -0.00846597

with ((10.1), ASCE 41-17)  $\rho_y = \text{Min}(\rho_y, 1.25 * \rho_y * (l_b / l_d)^{2/3}) = 0.0027778$

$\rho_{y,co} = 0.002$

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

$d_1 = 44.00$

$R = 250.00$

$v = 0.0010361$

$N = 7385.561$

$A_c = 196349.541$

with ((10.1), ASCE 41-17)  $\rho_y = \text{Min}(\rho_y, 1.25 * \rho_y * (l_b / l_d)^{2/3}) = 0.23799351$

with  $f_c' ((12.3), ACI 440) = 36.3038$

$f_c = 33.00$

$f_l = 1.05384$

$k = 1$

Effective FRP thickness,  $t_f = NL * t * \text{Cos}(b_1) = 1.016$

$\rho_{y,ef} ((12.5) \text{ and } (12.7)) = 0.004$

$f_u = 0.01$

$E_f = 64828.00$

Calculation of ratio  $l_b / l_d$

Inadequate Lap Length with  $l_b / l_d = 0.30$

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

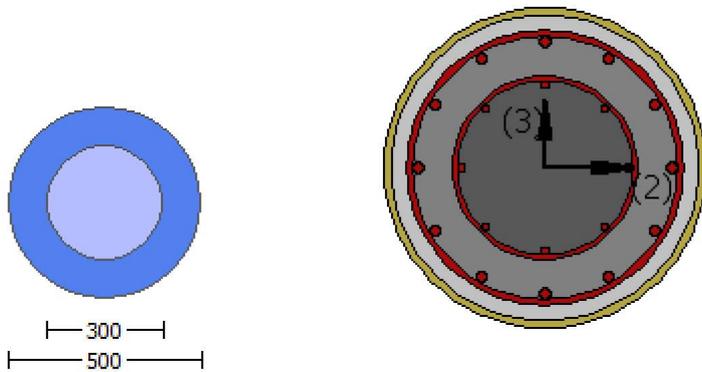
Limit State: Collapse Prevention (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity ( $\theta_r$ )

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

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

Concrete Elasticity,  $E_c = 26999.444$

Steel Elasticity,  $E_s = 200000.00$

Existing Column

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

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

Concrete Elasticity,  $E_c = 26999.444$

Steel Elasticity,  $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

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

Jacket

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

Existing Column

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

#####

External Diameter,  $D = 500.00$

Internal Diameter,  $D = 300.00$

Cover Thickness,  $c = 25.00$

Mean Confinement Factor overall section = 1.46748

Element Length,  $L = 3000.00$

Secondary Member

Ribbed Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

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

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness,  $t = 1.016$

Tensile Strength,  $f_{fu} = 1055.00$

Tensile Modulus,  $E_f = 64828.00$

Elongation,  $\epsilon_{fu} = 0.01$

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

Fiber orientations,  $b_i = 0.00^\circ$

Number of layers,  $N_L = 1$

Radius of rounding corners,  $R = 40.00$

Stepwise Properties

At local axis: 3

EDGE -A-

Shear Force,  $V_a = 1.1471900E-030$

EDGE -B-

Shear Force,  $V_b = -1.1471900E-030$

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,  $V_e/V_r = 0.23451953$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 165526.599$

with

$M_{pr1} = \text{Max}(M_{u1+}, M_{u1-}) = 2.4829E+008$

$M_{u1+} = 2.4829E+008$ , is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination

$M_{u1-} = 2.4829E+008$ , is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination

$M_{pr2} = \text{Max}(M_{u2+}, M_{u2-}) = 2.4829E+008$

$M_{u2+} = 2.4829E+008$ , is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the static loading combination

$M_{u2-} = 2.4829E+008$ , is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the static loading combination

Calculation of  $M_{u1+}$

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

$M_u = 2.4829E+008$

$\beta_1 = 0.82030475$

$\beta_2 = 0.72936354$

error of function (3.68), Biskinis Phd = 58391.315

From 5A.2, TBDY:  $f_{cc} = f_c \cdot c = 48.42699$

conf. factor  $c = 1.46748$

$f_c = 33.00$

From 10.3.5, ASCE 41-17, Final value of  $f_y$ :  $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3}) = 389.0139$

$l_b/l_d = 0.30$

$d_1 = 44.00$

$R = 250.00$

$v = 0.00103167$

$$N = 7389.214$$
$$Ac = 196349.541$$
$$= *Min(1,1.25*(lb/d)^{2/3}) = 0.16585331$$

Calculation of ratio lb/d

Inadequate Lap Length with lb/d = 0.30

Calculation of Mu1-

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), Mu  
Mu = 2.4829E+008

$$= 0.82030475$$
$$' = 0.72936354$$

error of function (3.68), Biskinis Phd = 58391.315

From 5A.2, TBDY: fcc = fc\* c = 48.42699

conf. factor c = 1.46748

fc = 33.00

From 10.3.5, ASCE 41-17, Final value of fy: fy\*Min(1,1.25\*(lb/d)^{2/3}) = 389.0139

lb/d = 0.30

d1 = 44.00

R = 250.00

v = 0.00103167

N = 7389.214

Ac = 196349.541

$$= *Min(1,1.25*(lb/d)^{2/3}) = 0.16585331$$

Calculation of ratio lb/d

Inadequate Lap Length with lb/d = 0.30

Calculation of Mu2+

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), Mu  
Mu = 2.4829E+008

$$= 0.82030475$$
$$' = 0.72936354$$

error of function (3.68), Biskinis Phd = 58391.315

From 5A.2, TBDY: fcc = fc\* c = 48.42699

conf. factor c = 1.46748

fc = 33.00

From 10.3.5, ASCE 41-17, Final value of fy: fy\*Min(1,1.25\*(lb/d)^{2/3}) = 389.0139

lb/d = 0.30

d1 = 44.00

R = 250.00

v = 0.00103167

N = 7389.214

Ac = 196349.541

$$= *Min(1,1.25*(lb/d)^{2/3}) = 0.16585331$$

Calculation of ratio lb/d

Inadequate Lap Length with lb/d = 0.30

Calculation of Mu2-

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), Mu  
Mu = 2.4829E+008

$$= 0.82030475$$

$$' = 0.72936354$$

error of function (3.68), Biskinis Phd = 58391.315

From 5A.2, TBDY:  $f_{cc} = f_c' \cdot c = 48.42699$

conf. factor  $c = 1.46748$

$$f_c = 33.00$$

From 10.3.5, ASCE 41-17, Final value of fy:  $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 389.0139$

$$l_b/d = 0.30$$

$$d_1 = 44.00$$

$$R = 250.00$$

$$v = 0.00103167$$

$$N = 7389.214$$

$$A_c = 196349.541$$

$$= \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.16585331$$

Calculation of ratio lb/d

Inadequate Lap Length with  $l_b/d = 0.30$

Calculation of Shear Strength  $V_r = \text{Min}(V_{r1}, V_{r2}) = 705811.584$

Calculation of Shear Strength at edge 1,  $V_{r1} = 705811.584$

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

$$V_{Col0} = 705811.584$$

$k_{nl} = 1$  (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:  $f_c' = (f_c'_{jacket} \cdot \text{Area}_{jacket} + f_c'_{core} \cdot \text{Area}_{core}) / \text{Area}_{section} = 33.00$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$$M/Vd = 2.00$$

$$\text{Mu} = 1.6210513\text{E}-011$$

$$\text{Vu} = 1.1471900\text{E}-030$$

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

$$N_u = 7389.214$$

$$A_g = 196349.541$$

From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 274157.871$

$V_{s1} = 274157.871$  is calculated for jacket, with:

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

$$f_y = 555.56$$

$$s = 100.00$$

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

$$s/d = 0.25$$

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

$$A_v = \sqrt{2} \cdot A_{stirup} = 78956.835$$

$$f_y = 555.56$$

$$s = 250.00$$

$V_{s2}$  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)  $\sin \theta + \cos \theta$  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  $V_f(\theta, \alpha)$ , 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:  $\theta = b1 + 90^\circ = 90.00$   
 $V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, \alpha)|)$ , with:  
total thickness per orientation,  $t_{f1} = NL * t / \text{NoDir} = 1.016$   
 $d_{fv} = d$  (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:  $V_s + V_f \leq 479549.663$   
 $b_w * d = \sqrt[4]{V_s * d} = 125663.706$

Calculation of Shear Strength at edge 2,  $V_{r2} = 705811.584$   
 $V_{r2} = V_{Col}$  ((10.3), ASCE 41-17) =  $k_{nl} * V_{Col0}$   
 $V_{Col0} = 705811.584$   
 $k_{nl} = 1$  (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).

$k_{nl} = 1$  (normal-weight concrete)  
Mean concrete strength:  $f'_c = (f'_c \text{ jacket} * \text{Area}_{\text{jacket}} + f'_c \text{ core} * \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 33.00$ , but  $f'_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)  
 $M / Vd = 2.00$   
 $\mu_u = 1.6210513E-011$   
 $\nu_u = 1.1471900E-030$   
 $d = 0.8 * D = 400.00$   
 $N_u = 7389.214$   
 $A_g = 196349.541$   
From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 274157.871$   
 $V_{s1} = 274157.871$  is calculated for jacket, with:  
 $A_v = \sqrt[2]{V_s * A_{\text{stirrup}}} = 123370.055$   
 $f_y = 555.56$   
 $s = 100.00$   
 $V_{s1}$  is multiplied by  $Col1 = 1.00$   
 $s/d = 0.25$   
 $V_{s2} = 0.00$  is calculated for core, with:  
 $A_v = \sqrt[2]{V_s * A_{\text{stirrup}}} = 78956.835$   
 $f_y = 555.56$   
 $s = 250.00$   
 $V_{s2}$  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)  $\sin \theta + \cos \theta$  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  $V_f(\theta, \alpha)$ , 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:  $\theta = b1 + 90^\circ = 90.00$   
 $V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, \alpha)|)$ , with:  
total thickness per orientation,  $t_{f1} = NL * t / \text{NoDir} = 1.016$   
 $d_{fv} = d$  (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:  $V_s + V_f \leq 479549.663$   
 $b_w * d = \sqrt[4]{V_s * d} = 125663.706$

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,  $\gamma = 1.00$   
Mean strength values are used for both shear and moment calculations.  
Consequently:  
Jacket  
New material of Secondary Member: Concrete Strength,  $f_c = f_{cm} = 33.00$   
New material of Secondary Member: Steel Strength,  $f_s = f_{sm} = 555.56$   
Concrete Elasticity,  $E_c = 26999.444$   
Steel Elasticity,  $E_s = 200000.00$   
Existing Column  
New material of Secondary Member: Concrete Strength,  $f_c = f_{cm} = 33.00$   
New material of Secondary Member: Steel Strength,  $f_s = f_{sm} = 555.56$   
Concrete Elasticity,  $E_c = 26999.444$   
Steel Elasticity,  $E_s = 200000.00$

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

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

#####  
External Diameter,  $D = 500.00$   
Internal Diameter,  $D = 300.00$   
Cover Thickness,  $c = 25.00$   
Mean Confinement Factor overall section = 1.46748  
Element Length,  $L = 3000.00$   
Secondary Member  
Ribbed Bars  
Ductile Steel  
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)  
Longitudinal Bars With Ends Lapped Starting at the End Sections  
Inadequate Lap Length with  $l_o/l_{ou, \min} = 0.30$   
FRP Wrapping Data  
Type: Carbon  
Cured laminate properties (design values)  
Thickness,  $t = 1.016$   
Tensile Strength,  $f_{fu} = 1055.00$   
Tensile Modulus,  $E_f = 64828.00$   
Elongation,  $e_{fu} = 0.01$   
Number of directions,  $N_{oDir} = 1$   
Fiber orientations,  $b_i: 0.00^\circ$   
Number of layers,  $N_L = 1$   
Radius of rounding corners,  $R = 40.00$

Stepwise Properties

At local axis: 2  
EDGE -A-  
Shear Force,  $V_a = -7.0242809E-047$   
EDGE -B-  
Shear Force,  $V_b = 7.0242809E-047$   
BOTH EDGES  
Axial Force,  $F = -7389.214$   
Longitudinal Reinforcement Area Distribution (in 2 divisions)  
-Tension:  $A_{st} = 0.00$

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

-----  
-----  
Calculation of Shear Capacity ratio,  $V_e/V_r = 0.23451953$   
Member Controlled by Flexure ( $V_e/V_r < 1$ )  
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 165526.599$   
with

$M_{pr1} = \text{Max}(M_{u1+}, M_{u1-}) = 2.4829E+008$   
 $M_{u1+} = 2.4829E+008$ , is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination  
 $M_{u1-} = 2.4829E+008$ , is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination  
 $M_{pr2} = \text{Max}(M_{u2+}, M_{u2-}) = 2.4829E+008$   
 $M_{u2+} = 2.4829E+008$ , is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the the static loading combination  
 $M_{u2-} = 2.4829E+008$ , is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the the static loading combination

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

-----  
Calculation of ultimate Moment Strength ((3.67), Biskinis Phd),  $M_u$   
 $M_u = 2.4829E+008$

-----  
= 0.82030475  
' = 0.72936354  
error of function (3.68), Biskinis Phd = 58391.315  
From 5A.2, TBDY:  $f_{cc} = f_c^* c = 48.42699$   
conf. factor  $c = 1.46748$   
 $f_c = 33.00$   
From 10.3.5, ASCE 41-17, Final value of  $f_y: f_y * \text{Min}(1, 1.25 * (l_b/d)^{2/3}) = 389.0139$   
 $l_b/d = 0.30$   
 $d_1 = 44.00$   
 $R = 250.00$   
 $v = 0.00103167$   
 $N = 7389.214$   
 $A_c = 196349.541$   
= \* $\text{Min}(1, 1.25 * (l_b/d)^{2/3}) = 0.16585331$

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

Inadequate Lap Length with  $l_b/d = 0.30$   
-----  
-----

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

-----  
Calculation of ultimate Moment Strength ((3.67), Biskinis Phd),  $M_u$   
 $M_u = 2.4829E+008$

-----  
= 0.82030475  
' = 0.72936354  
error of function (3.68), Biskinis Phd = 58391.315  
From 5A.2, TBDY:  $f_{cc} = f_c^* c = 48.42699$   
conf. factor  $c = 1.46748$   
 $f_c = 33.00$

From 10.3.5, ASCE 41-17, Final value of  $f_y$ :  $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 389.0139$

$$l_b/d = 0.30$$

$$d_1 = 44.00$$

$$R = 250.00$$

$$v = 0.00103167$$

$$N = 7389.214$$

$$A_c = 196349.541$$

$$= \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.16585331$$

Calculation of ratio  $l_b/d$

Inadequate Lap Length with  $l_b/d = 0.30$

Calculation of  $\mu_{2+}$

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

$$\mu = 2.4829E+008$$

$$= 0.82030475$$

$$' = 0.72936354$$

error of function (3.68), Biskinis Phd = 58391.315

From 5A.2, TBDY:  $f_{cc} = f_c \cdot c = 48.42699$

$$\text{conf. factor } c = 1.46748$$

$$f_c = 33.00$$

From 10.3.5, ASCE 41-17, Final value of  $f_y$ :  $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 389.0139$

$$l_b/d = 0.30$$

$$d_1 = 44.00$$

$$R = 250.00$$

$$v = 0.00103167$$

$$N = 7389.214$$

$$A_c = 196349.541$$

$$= \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.16585331$$

Calculation of ratio  $l_b/d$

Inadequate Lap Length with  $l_b/d = 0.30$

Calculation of  $\mu_{2-}$

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

$$\mu = 2.4829E+008$$

$$= 0.82030475$$

$$' = 0.72936354$$

error of function (3.68), Biskinis Phd = 58391.315

From 5A.2, TBDY:  $f_{cc} = f_c \cdot c = 48.42699$

$$\text{conf. factor } c = 1.46748$$

$$f_c = 33.00$$

From 10.3.5, ASCE 41-17, Final value of  $f_y$ :  $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 389.0139$

$$l_b/d = 0.30$$

$$d_1 = 44.00$$

$$R = 250.00$$

$$v = 0.00103167$$

$$N = 7389.214$$

$$A_c = 196349.541$$

$$= \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.16585331$$

Calculation of ratio  $l_b/l_d$

Inadequate Lap Length with  $l_b/l_d = 0.30$

Calculation of Shear Strength  $V_r = \text{Min}(V_{r1}, V_{r2}) = 705811.584$

Calculation of Shear Strength at edge 1,  $V_{r1} = 705811.584$

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

$V_{Col0} = 705811.584$

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

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

$= 1$  (normal-weight concrete)

Mean concrete strength:  $f_c' = (f_c'_{jacket} \text{Area}_{jacket} + f_c'_{core} \text{Area}_{core}) / \text{Area}_{section} = 33.00$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$\mu_u = 1.7556432E-011$

$\nu_u = 7.0242809E-047$

$d = 0.8 \cdot D = 400.00$

$N_u = 7389.214$

$A_g = 196349.541$

From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 274157.871$

$V_{s1} = 274157.871$  is calculated for jacket, with:

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

$f_y = 555.56$

$s = 100.00$

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

$s/d = 0.25$

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

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

$f_y = 555.56$

$s = 250.00$

$V_{s2}$  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  $V_f(\theta, \alpha)$ , 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:  $\theta = b_1 + 90^\circ = 90.00$

$V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, \theta)|)$ , 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:  $V_s + V_f \leq 479549.663$

$b_w \cdot d = \sqrt{2} \cdot d \cdot d / 4 = 125663.706$

Calculation of Shear Strength at edge 2,  $V_{r2} = 705811.584$

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

$V_{Col0} = 705811.584$

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

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

= 1 (normal-weight concrete)

Mean concrete strength:  $f_c' = (f_c'_{\text{jacket}} \cdot \text{Area}_{\text{jacket}} + f_c'_{\text{core}} \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 33.00$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$\mu_u = 1.7556432E-011$

$V_u = 7.0242809E-047$

$d = 0.8 \cdot D = 400.00$

$N_u = 7389.214$

$A_g = 196349.541$

From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 274157.871$

$V_{s1} = 274157.871$  is calculated for jacket, with:

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

$f_y = 555.56$

$s = 100.00$

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

$s/d = 0.25$

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

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

$f_y = 555.56$

$s = 250.00$

$V_{s2}$  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  $V_f(\theta, \alpha)$ , 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:  $\theta = \theta_1 + 90^\circ = 90.00$

$V_f = \text{Min}(|V_f(45, \theta_1)|, |V_f(-45, \theta_1)|)$ , 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:  $V_s + V_f \leq 479549.663$

$b_w \cdot d = \sqrt{2} \cdot d^2 / 4 = 125663.706$

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

At local axis: 2

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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

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

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

Concrete Elasticity,  $E_c = 26999.444$

Steel Elasticity,  $E_s = 200000.00$

Existing Column

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

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

Concrete Elasticity,  $E_c = 26999.444$

Steel Elasticity,  $E_s = 200000.00$   
External Diameter,  $D = 500.00$   
Internal Diameter,  $D = 300.00$   
Cover Thickness,  $c = 25.00$   
Element Length,  $L = 3000.00$   
Secondary Member  
Ribbed Bars  
Ductile Steel  
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)  
Longitudinal Bars With Ends Lapped Starting at the End Sections  
Inadequate Lap Length with  $l_b/l_d = 0.30$   
FRP Wrapping Data  
Type: Carbon  
Cured laminate properties (design values)  
Thickness,  $t = 1.016$   
Tensile Strength,  $f_{fu} = 1055.00$   
Tensile Modulus,  $E_f = 64828.00$   
Elongation,  $e_{fu} = 0.01$   
Number of directions,  $N_{oDir} = 1$   
Fiber orientations,  $b_i = 0.00^\circ$   
Number of layers,  $N_L = 1$   
Radius of rounding corners,  $R = 40.00$

#### Stepwise Properties

Bending Moment,  $M = 0.10663216$   
Shear Force,  $V_2 = 9128.06$   
Shear Force,  $V_3 = 5.7178712E-013$   
Axial Force,  $F = -7385.561$   
Longitudinal Reinforcement Area Distribution (in 2 divisions)  
-Tension:  $A_{st} = 0.00$   
-Compression:  $A_{sc} = 3053.628$   
Longitudinal Reinforcement Area Distribution (in 3 divisions)  
-Tension:  $A_{st,ten} = 1017.876$   
-Compression:  $A_{sc,com} = 1017.876$   
-Middle:  $A_{st,mid} = 1017.876$   
Mean Diameter of Tension Reinforcement,  $D_{bL} = 18.00$

New component: From table 7-7, ASCE 41\_17: Final chord rotation Capacity  $u_{,R} = 1.0^*$   $u = 0.04290519$   
 $u = y + p = 0.04290519$

- Calculation of  $y$  -

$y = (M_y * L_s / 3) / E_{eff} = 0.00090519$  ((4.29), Biskinis Phd)  
 $M_y = 2.2494E+008$   
 $L_s = M/V$  (with  $L_s > 0.1 * L$  and  $L_s < 2 * L$ ) =  $300.00$   
From table 10.5, ASCE 41\_17:  $E_{eff} = factor * E_c * I_g = 2.4850E+013$   
factor =  $0.30$   
 $A_g = 196349.541$   
Mean concrete strength:  $f_c' = (f_c'_{jacket} * Area_{jacket} + f_c'_{core} * Area_{core}) / Area_{section} = 33.00$   
 $N = 7385.561$   
 $E_c * I_g = E_c * I_{g,jacket} + E_c * I_{g,core} = 8.2833E+013$

Calculation of Yielding Moment  $M_y$

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

$M_y = \text{Min}(M_{y,ten}, M_{y,com}) = 2.2494E+008$   
 $y = 6.4602088E-006$   
 $M_{y,ten} (8c) = 2.2494E+008$

$\rho_{ten}(7c) = 62.07293$   
 error of function (7c) = 0.00023516  
 $M_{y\_com}(8d) = 8.0674E+008$   
 $\rho_{com}(7d) = 63.84405$   
 error of function (7d) = -0.00846597  
 with ((10.1), ASCE 41-17)  $e_y = \text{Min}(e_y, 1.25 * e_y * (l_b/l_d)^{2/3}) = 0.0027778$   
 $e_{co} = 0.002$   
 $a_{pl} = 0.45$  ((9c) in Biskinis and Fardis for FRP Wrap)  
 $d_1 = 44.00$   
 $R = 250.00$   
 $v = 0.0010361$   
 $N = 7385.561$   
 $A_c = 196349.541$   
 ((10.1), ASCE 41-17)  $= \text{Min}( , 1.25 * (l_b/l_d)^{2/3}) = 0.23799351$   
 with  $f_c^*$  ((12.3), ACI 440) = 36.3038  
 $f_c = 33.00$   
 $f_l = 1.05384$   
 $k = 1$   
 Effective FRP thickness,  $t_f = N L * t * \text{Cos}(b_1) = 1.016$   
 $e_{fe}$  ((12.5) and (12.7)) = 0.004  
 $f_u = 0.01$   
 $E_f = 64828.00$

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 Calculation of ratio  $l_b/l_d$

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 Inadequate Lap Length with  $l_b/l_d = 0.30$

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 - Calculation of  $\rho_p$  -

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 From table 10-9:  $\rho_p = 0.042$

with:

- Columns controlled by inadequate development or splicing along the clear height because  $l_b/l_d < 1$   
 shear control ratio  $V_y E / V_{CoI} E = 0.23451953$   
 $d = d_{external} = 0.00$   
 $s = s_{external} = 0.00$   
 $t = s_1 + s_2 + 2 * t_f / b_w * (f_{fe} / f_s) = 0.00702809$   
 jacket:  $s_1 = A_{v1} * (D_{c1} / 2) / (s_1 * A_g) = 0.0027646$   
 $A_{v1} = 78.53982$ , is the area of stirrup  
 $D_{c1} = D_{ext} - 2 * \text{cover} - \text{External Hoop Diameter} = 440.00$ , is the total Length of all stirrups parallel to loading (shear) direction  
 $s_1 = 100.00$   
 core:  $s_2 = A_{v2} * (D_{c2} / 2) / (s_2 * A_g) = 0.00046968$   
 $A_{v2} = 50.26548$ , 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  $2 * t_f / b_w * (f_{fe} / f_s)$  is implemented to account for FRP contribution  
 where  $f = 2 * t_f / b_w$  is FRP ratio (EC8 - 3, A.4.4.3(6)) and  $f_{fe} / f_s$  normalises  $f$  to steel strength  
 All these variables have already been given in Shear control ratio calculation.  
 For the normalisation  $f_s$  of jacket is used.

$N_{UD} = 7385.561$   
 $A_g = 196349.541$   
 $f_{cE} = (f_{c\_jacket} * \text{Area}_{jacket} + f_{c\_core} * \text{Area}_{core}) / \text{section\_area} = 33.00$   
 $f_{yE} = (f_{y\_ext\_Long\_Reinf} * \text{Area}_{ext\_Long\_Reinf} + f_{y\_int\_Long\_Reinf} * \text{Area}_{int\_Long\_Reinf}) / \text{Area}_{Tot\_Long\_Rein} = 2.1219958E-314$   
 $f_{yE} = (f_{y\_ext\_Trans\_Reinf} * \text{Area}_{ext\_Trans\_Reinf} + f_{y\_int\_Trans\_Reinf} * \text{Area}_{int\_Trans\_Reinf}) / \text{Area}_{Tot\_Trans\_Rein} = 555.56$   
 $\rho_l = \text{Area}_{Tot\_Long\_Rein} / (A_g) = 0.015552$   
 $f_{cE} = 33.00$

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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)

