

Detailed Member Calculations

Units: N&mm

Regulation: ASCE 41-17

Calculation No. 1

column C1, Floor 1

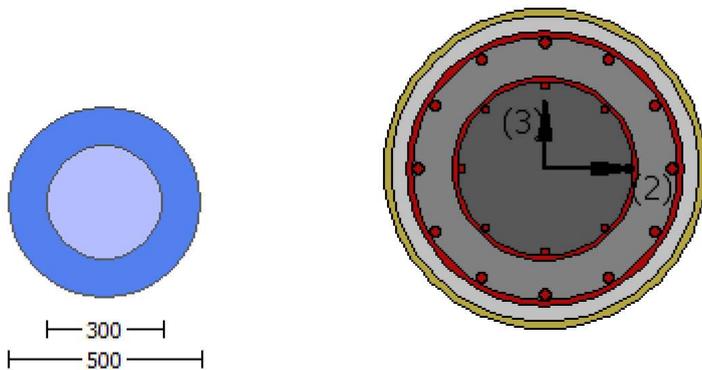
Limit State: Operational Level (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Shear capacity V_{Rd}

Edge: Start

Local Axis: (2)



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

At local axis: 2

Integration Section: (a)

Section Type: rcjcs

Constant Properties

Knowledge Factor, $\gamma = 1.00$

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

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

Consequently:

Jacket

New material of Primary Member: Concrete Strength, $f_c = f_{c_lower_bound} = 20.00$

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

Concrete Elasticity, $E_c = 25742.96$
Steel Elasticity, $E_s = 200000.00$
Existing Column
Existing material of Primary Member: Concrete Strength, $f_c = f_{c_lower_bound} = 16.00$
Existing material of Primary Member: Steel Strength, $f_s = f_{s_lower_bound} = 420.00$
Concrete Elasticity, $E_c = 23025.204$
Steel Elasticity, $E_s = 200000.00$

Note: Especially for the calculation of γ for displacement ductility demand,
the expected (mean value) strengths are used (7.5.1.3, ASCE 41-17) because bending is considered as
Deformation-Controlled Action (Table C7-1, ASCE 41-17).
Jacket
New material: Concrete Strength, $f_c = f_{cm} = 30.00$
New material: Steel Strength, $f_s = f_{sm} = 625.00$
Existing Column
Existing material: Concrete Strength, $f_c = f_{cm} = 24.00$
Existing material: Steel Strength, $f_s = f_{sm} = 525.00$

External Diameter, $D = 500.00$
Internal Diameter, $D = 300.00$
Cover Thickness, $c = 25.00$
Element Length, $L = 3000.00$
Primary Member
Smooth Bars
Ductile Steel
With Detailing for Earthquake Resistance (including stirrups closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
Adequate Lap Length ($l_o/l_{ou,min} = l_b/l_d \geq 1$)
FRP Wrapping Data
Type: Carbon
Cured laminate properties (design values)
Thickness, $t = 1.016$
Tensile Strength, $f_{fu} = 1055.00$
Tensile Modulus, $E_f = 64828.00$
Elongation, $e_{fu} = 0.01$
Number of directions, $NoDir = 1$
Fiber orientations, $bi: 0.00^\circ$
Number of layers, $NL = 1$
Radius of rounding corners, $R = 40.00$

Stepwise Properties

EDGE -A-
Bending Moment, $M_a = -1.7492E+007$
Shear Force, $V_a = -5829.318$
EDGE -B-
Bending Moment, $M_b = 0.12862757$
Shear Force, $V_b = 5829.318$
BOTH EDGES
Axial Force, $F = -7386.882$
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: $As_t = 1272.345$
-Compression: $As_c = 1781.283$
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension: $As_{t,ten} = 1017.876$
-Compression: $As_{c,com} = 1017.876$
-Middle: $As_{mid} = 1017.876$
Mean Diameter of Tension Reinforcement, $Db_{L,ten} = 18.00$

Existing component: From table 7-7, ASCE 41_17: Final Shear Capacity $V_R = *V_n = 444663.668$
 $V_n ((10.3), ASCE 41-17) = knl * V_{ColO} = 444663.668$
 $V_{Col} = 444663.668$
 $knl = 1.00$

displacement_ductility_demand = 0.01087845

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

= 1 (normal-weight concrete)

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

$M/Vd = 4.00$

$\mu_u = 1.7492E+007$

$V_u = 5829.318$

$d = 0.8 \cdot D = 400.00$

$N_u = 7386.882$

$A_g = 196349.541$

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

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

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

$f_y = 500.00$

$s = 100.00$

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

$s/d = 0.25$

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

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

$f_y = 420.00$

$s = 250.00$

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

$s/d = 1.04167$

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

$f = 0.95$, for fully-wrapped sections

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

In (11.3) $\sin^2 + \cos^2$ is replaced with $(\cot^2 + \csc^2) \sin^2 \alpha$ which is more a generalised expression,

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

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

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

$V_f = \text{Min}(|V_f(45, 1)|, |V_f(-45, a1)|)$, with:

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

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

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

$E_f = 64828.00$

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

with $f_u = 0.01$

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

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

displacement_ductility_demand is calculated as δ / y

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

From analysis, chord rotation $\theta = 0.00020609$

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

$M_y = 4.4260E+008$

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

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

factor = 0.30

$A_g = 196349.541$

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

$N = 7386.882$

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

Calculation of Yielding Moment M_y

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

$M_y = \text{Min}(M_{y_ten}, M_{y_com}) = 4.4260E+008$
 $\mu_y \text{ ((10a) or (10b))} = 1.3430728E-005$
 $M_{y_ten} \text{ (8a)} = 4.4260E+008$
 $\mu_{y_ten} \text{ (7a)} = 65.19069$
error of function (7a) = 0.00234594
 $M_{y_com} \text{ (8b)} = 7.6083E+008$
 $\mu_{y_com} \text{ (7b)} = 64.49916$
error of function (7b) = -0.00733981
with $e_y = 0.003125$
 $e_{co} = 0.002$
 $a_{pl} = 0.45$ ((9c) in Biskinis and Fardis for FRP Wrap)
 $d_1 = 44.00$
 $R = 250.00$
 $v = 0.00112963$
 $N = 7386.882$
 $A_c = 196349.541$
 $\mu = 0.29185858$
with $f_c^* \text{ ((12.3), ACI 440)} = 33.3038$
 $f_c = 30.00$
 $f_l = 1.05384$
 $k = 1$
Effective FRP thickness, $t_f = NL*t*\text{Cos}(b_1) = 1.016$
 $e_{fe} \text{ ((12.5) and (12.7))} = 0.004$
 $E_f = 64828.00$

Calculation of ratio l_b/d

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

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

At local axis: 2

Integration Section: (a)

Calculation No. 2

column C1, Floor 1

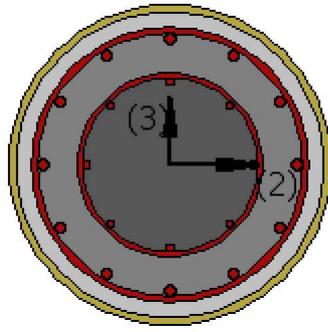
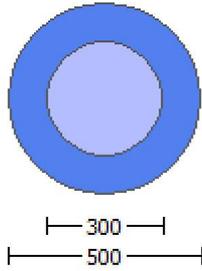
Limit State: Operational Level (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity (μ)

Edge: Start

Local Axis: (2)



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

At Shear local axis: 3
 (Bending local axis: 2)
 Section Type: rcjcs

Constant Properties

Knowledge Factor, $\gamma = 1.00$
 Mean strength values are used for both shear and moment calculations.
 Consequently:

Jacket

New material of Primary Member: Concrete Strength, $f_c = f_{cm} = 30.00$
 New material of Primary Member: Steel Strength, $f_s = f_{sm} = 625.00$
 Concrete Elasticity, $E_c = 25742.96$
 Steel Elasticity, $E_s = 200000.00$

Existing Column

Existing material of Primary Member: Concrete Strength, $f_c = f_{cm} = 24.00$
 Existing material of Primary Member: Steel Strength, $f_s = f_{sm} = 525.00$
 Concrete Elasticity, $E_c = 23025.204$
 Steel Elasticity, $E_s = 200000.00$

#####

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

Jacket

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

Existing Column

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

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External Diameter, $D = 500.00$

Internal Diameter, $D = 300.00$

Cover Thickness, $c = 25.00$

Mean Confinement Factor overall section = 1.50688

Element Length, $L = 3000.00$

Primary Member

Smooth Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

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

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $e_{fu} = 0.01$

Number of directions, $NoDir = 1$

Fiber orientations, $b_i = 0.00^\circ$

Number of layers, $NL = 1$

Radius of rounding corners, $R = 40.00$

Stepwise Properties

At local axis: 3

EDGE -A-

Shear Force, $V_a = 4.1010657E-031$

EDGE -B-

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

BOTH EDGES

Axial Force, $F = -7389.214$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: $A_{st} = 0.00$

-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, $V_e/V_r = 0.45961884$

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

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

with

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

$M_{u1+} = 4.4703E+008$, is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination

$M_{u1-} = 4.4703E+008$, is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination

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

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

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

Calculation of M_{u1+}

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

$M_u = 4.4703E+008$

$\phi = 0.97738438$

$\phi' = 0.86668818$

error of function (3.68), Biskinis Phd = 40566.604

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

conf. factor $c = 1.50688$

$f_c = 30.00$

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

$l_b/d = 1.00$

$d_1 = 44.00$

$R = 250.00$

$v = 0.00112412$

$N = 7389.214$

$A_c = 196349.541$

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

Calculation of ratio l_b/d

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

Calculation of M_{u1-}

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

Mu = 4.4703E+008

= 0.97738438

' = 0.86668818

error of function (3.68), Biskinis Phd = 40566.604

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

conf. factor $c = 1.50688$

$f_c = 30.00$

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

$l_b/d = 1.00$

$d_1 = 44.00$

$R = 250.00$

$v = 0.00112412$

$N = 7389.214$

$Ac = 196349.541$

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

Calculation of ratio l_b/d

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

Calculation of Mu2+

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

Mu = 4.4703E+008

= 0.97738438

' = 0.86668818

error of function (3.68), Biskinis Phd = 40566.604

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

conf. factor $c = 1.50688$

$f_c = 30.00$

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

$l_b/d = 1.00$

$d_1 = 44.00$

$R = 250.00$

$v = 0.00112412$

$N = 7389.214$

$Ac = 196349.541$

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

Calculation of ratio l_b/d

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

Calculation of Mu2-

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

Mu = 4.4703E+008

= 0.97738438

' = 0.86668818

error of function (3.68), Biskinis Phd = 40566.604

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

conf. factor $c = 1.50688$

$f_c = 30.00$

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

$l_b/d = 1.00$

$d_1 = 44.00$

$R = 250.00$

$v = 0.00112412$

$N = 7389.214$

$A_c = 196349.541$

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

Calculation of ratio l_b/d

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

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

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

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

$V_{Col0} = 648405.308$

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

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

$= 1$ (normal-weight concrete)

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

$M/d = 2.00$

$\mu_u = 2.1425332E-011$

$\nu_u = 4.1010657E-031$

$d = 0.8 \cdot D = 400.00$

$N_u = 7389.214$

$A_g = 196349.541$

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

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

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

$f_y = 625.00$

$s = 100.00$

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

$s/d = 0.25$

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

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

$f_y = 525.00$

$s = 250.00$

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

$s/d = 1.04167$

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

$f = 0.95$, for fully-wrapped sections

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

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

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

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

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

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

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

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

$E_f = 64828.00$

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

with $f_u = 0.01$

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

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

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

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

$$V_{CoI0} = 648405.308$$

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

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

$= 1$ (normal-weight concrete)

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

$$M/Vd = 2.00$$

$$\mu_u = 2.1425332E-011$$

$$\nu_u = 4.1010657E-031$$

$$d = 0.8 * D = 400.00$$

$$N_u = 7389.214$$

$$A_g = 196349.541$$

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

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

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

$$f_y = 625.00$$

$$s = 100.00$$

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

$$s/d = 0.25$$

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

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

$$f_y = 525.00$$

$$s = 250.00$$

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

$$s/d = 1.04167$$

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

$$f = 0.95$$
, for fully-wrapped sections

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

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

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

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

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

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

$d_{fv} = d$ (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

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

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

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

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

At local axis: 3

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

At Shear local axis: 2

(Bending local axis: 3)

Section Type: rcjcs

Constant Properties

Knowledge Factor, $= 1.00$

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

Consequently:

Jacket

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

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

Concrete Elasticity, $E_c = 25742.96$

Steel Elasticity, $E_s = 200000.00$

Existing Column

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

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

Concrete Elasticity, $E_c = 23025.204$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

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

Jacket

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

Existing Column

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

#####

External Diameter, $D = 500.00$

Internal Diameter, $D = 300.00$

Cover Thickness, $c = 25.00$

Mean Confinement Factor overall section = 1.50688

Element Length, $L = 3000.00$

Primary Member

Smooth Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

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

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $e_{fu} = 0.01$

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, $V_a = -2.5110955E-047$

EDGE -B-

Shear Force, $V_b = 2.5110955E-047$

BOTH EDGES

Axial Force, $F = -7389.214$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: $A_{slt} = 0.00$

-Compression: $A_{slc} = 3053.628$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

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

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

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

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

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

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

with

$$Mpr1 = \text{Max}(Mu1+ , Mu1-) = 4.4703E+008$$

Mu1+ = 4.4703E+008, is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination

Mu1- = 4.4703E+008, is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination

$$Mpr2 = \text{Max}(Mu2+ , Mu2-) = 4.4703E+008$$

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

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

Calculation of Mu1+

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

$$= 0.97738438$$

$$' = 0.86668818$$

error of function (3.68), Biskinis Phd = 40566.604

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

conf. factor $c = 1.50688$

$$f_c = 30.00$$

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

$$l_b/l_d = 1.00$$

$$d1 = 44.00$$

$$R = 250.00$$

$$v = 0.00112412$$

$$N = 7389.214$$

$$Ac = 196349.541$$

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

Calculation of ratio l_b/l_d

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

Calculation of Mu1-

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

$$= 0.97738438$$

$$' = 0.86668818$$

error of function (3.68), Biskinis Phd = 40566.604

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

conf. factor $c = 1.50688$

$$f_c = 30.00$$

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

$$l_b/l_d = 1.00$$

$$d1 = 44.00$$

$$R = 250.00$$

$$v = 0.00112412$$

$$N = 7389.214$$

$$Ac = 196349.541$$

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

Calculation of ratio l_b/l_d

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

Calculation of Mu2+

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

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

Calculation of ratio lb/d

Adequate Lap Length: lb/d >= 1

Calculation of Mu2-

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

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

Calculation of ratio lb/d

Adequate Lap Length: lb/d >= 1

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

Calculation of Shear Strength at edge 1, Vr1 = 648405.308
Vr1 = VCol ((10.3), ASCE 41-17) = knl*VColO
VColO = 648405.308

$k_{nl} = 1$ (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: $f_c' = (f_c'_{jacket} \cdot Area_{jacket} + f_c'_{core} \cdot Area_{core}) / Area_{section} = 27.84$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$\mu_u = 2.0093280E-011$

$\nu_u = 2.5110955E-047$

$d = 0.8 \cdot D = 400.00$

$N_u = 7389.214$

$A_g = 196349.541$

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

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

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

$f_y = 625.00$

$s = 100.00$

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

$s/d = 0.25$

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

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

$f_y = 525.00$

$s = 250.00$

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

$s/d = 1.04167$

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

$f = 0.95$, for fully-wrapped sections

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

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

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

orientation 1: $\theta = 45^\circ + 90^\circ = 135^\circ$

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

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

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

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

$E_f = 64828.00$

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

with $f_u = 0.01$

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

$b_w \cdot d = 125663.706$

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

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

$V_{Col0} = 648405.308$

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

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

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

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

$M/Vd = 2.00$

$\mu_u = 2.0093280E-011$

$\nu_u = 2.5110955E-047$

$d = 0.8 \cdot D = 400.00$

$N_u = 7389.214$

$A_g = 196349.541$

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

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

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

$f_y = 625.00$

$s = 100.00$
 V_{s1} is multiplied by $Col1 = 1.00$
 $s/d = 0.25$
 $V_{s2} = 0.00$ is calculated for core, with:
 $A_v = \sqrt{2} \cdot A_{stirrup} = 78956.835$
 $f_y = 525.00$
 $s = 250.00$
 V_{s2} is multiplied by $Col2 = 0.00$
 $s/d = 1.04167$
 $V_f ((11-3)-(11.4), ACI 440) = 247653.332$
 $f = 0.95$, for fully-wrapped sections
 $w_f/s_f = 1$ (FRP strips adjacent to one another).
 In (11.3) $\sin \theta + \cos \theta$ is replaced with $(\cot \theta + \csc \theta) \sin \alpha$ which is more a generalised expression,
 where θ is the angle of the crack direction (see KANEPE).
 This later relation, considered as a function $V_f(\theta, \alpha)$, is implemented for every different fiber orientation α_i ,
 as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.
 orientation 1: $\theta = \theta_1 = 90^\circ = 90.00$
 $V_f = \text{Min}(|V_f(45, \theta_1)|, |V_f(-45, \theta_1)|)$, with:
 total thickness per orientation, $t_{f1} = N_L \cdot t / N_{oDir} = 1.016$
 $d_{fv} = d$ (figure 11.2, ACI 440) = 470.00
 $f_{fe} ((11-5), ACI 440) = 259.312$
 $E_f = 64828.00$
 $f_e = 0.004$, from (11.6a), ACI 440
 with $f_u = 0.01$
 From (11-11), ACI 440: $V_s + V_f \leq 440464.828$
 $b_w \cdot d = \sqrt{V_s + V_f} \cdot d / 4 = 125663.706$

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

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

Constant Properties

 Knowledge Factor, $\phi = 1.00$
 Chord Rotation is generally considered as Deformation-Controlled Action according to Table C7-1, ASCE 41-17.
 Mean strengths are used for Deformation-Controlled Actions according to 7.5.1.3, ASCE 41-17
 Consequently:
 Jacket
 New material of Primary Member: Concrete Strength, $f_c = f_{cm} = 30.00$
 New material of Primary Member: Steel Strength, $f_s = f_{sm} = 625.00$
 Concrete Elasticity, $E_c = 25742.96$
 Steel Elasticity, $E_s = 200000.00$
 Existing Column
 Existing material of Primary Member: Concrete Strength, $f_c = f_{cm} = 24.00$
 Existing material of Primary Member: Steel Strength, $f_s = f_{sm} = 525.00$
 Concrete Elasticity, $E_c = 23025.204$
 Steel Elasticity, $E_s = 200000.00$
 External Diameter, $D = 500.00$
 Internal Diameter, $D = 300.00$
 Cover Thickness, $c = 25.00$
 Element Length, $L = 3000.00$
 Primary Member
 Smooth Bars
 Ductile Steel
 With Detailing for Earthquake Resistance (including stirrups closed at 135°)
 Longitudinal Bars With Ends Lapped Starting at the End Sections
 Adequate Lap Length ($l_b/d \geq 1$)
 FRP Wrapping Data
 Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $e_{fu} = 0.01$

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

Fiber orientations, $b_i = 0.00^\circ$

Number of layers, $N_L = 1$

Radius of rounding corners, $R = 40.00$

Stepwise Properties

Bending Moment, $M = 7.9133033E-010$

Shear Force, $V_2 = -5829.318$

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

Axial Force, $F = -7386.882$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: $A_{st} = 1272.345$

-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, $D_bL = 18.00$

Existing component: From table 7-7, ASCE 41_17: Final chord rotation Capacity $u_{,R} = * u = 0.01446974$

$u = y + p = 0.01446974$

- Calculation of y -

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

$M_y = 4.4260E+008$

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

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

factor = 0.30

$A_g = 196349.541$

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

$N = 7386.882$

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

Calculation of Yielding Moment M_y

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

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

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

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

y_{ten} (7a) = 65.19069

error of function (7a) = 0.00234594

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

y_{com} (7b) = 64.49916

error of function (7b) = -0.00733981

with $e_y = 0.003125$

$e_{co} = 0.002$

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

$d_1 = 44.00$

$R = 250.00$

$v = 0.00112963$

$N = 7386.882$

$A_c = 196349.541$

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

 Calculation of ratio l_b/l_d

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

 - Calculation of p -

 From table 10-9: $p = 0.005$

with:

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

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

$d = d_{external} = 0.00$

$s = s_{external} = 0.00$

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

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

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

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

(shear) direction

$s_1 = 100.00$

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

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

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

direction

$s_2 = 250.00$

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

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

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

For the normalisation f_s of jacket is used.

$N_{UD} = 7386.882$

$A_g = 196349.541$

$f_{cE} = (f_{c,jacket} \cdot Area_{jacket} + f_{c,core} \cdot Area_{core}) / section_area = 27.84$

$f_{yIE} = (f_{y,ext_Long_Reinf} \cdot Area_{ext_Long_Reinf} + f_{y,int_Long_Reinf} \cdot Area_{int_Long_Reinf}) / Area_{Tot_Long_Rein} = 2.1219958E-314$

$f_{yTE} = (f_{y,ext_Trans_Reinf} \cdot Area_{ext_Trans_Reinf} + f_{y,int_Trans_Reinf} \cdot Area_{int_Trans_Reinf}) / Area_{Tot_Trans_Rein} = 610.4781$

$p_l = Area_{Tot_Long_Rein} / (A_g) = 0.015552$

$f_{cE} = 27.84$

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

At local axis: 2

Integration Section: (a)

Calculation No. 3

column C1, Floor 1

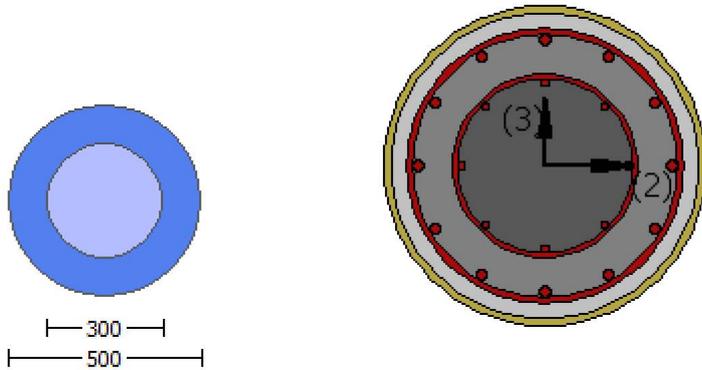
Limit State: Operational Level (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Shear capacity VRd

Edge: Start

Local Axis: (3)



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

At local axis: 3

Integration Section: (a)

Section Type: rcjcs

Constant Properties

Knowledge Factor, $\gamma = 1.00$

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

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

Consequently:

Jacket

New material of Primary Member: Concrete Strength, $f_c = f_{c_lower_bound} = 20.00$

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

Concrete Elasticity, $E_c = 25742.96$

Steel Elasticity, $E_s = 200000.00$

Existing Column

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

Existing material of Primary Member: Steel Strength, $f_s = f_{s_lower_bound} = 420.00$

Concrete Elasticity, $E_c = 23025.204$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of γ for displacement ductility demand, the expected (mean value) strengths are used (7.5.1.3, ASCE 41-17) because bending is considered as Deformation-Controlled Action (Table C7-1, ASCE 41-17).

Jacket

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

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

Existing Column

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

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

#####

External Diameter, $D = 500.00$

Internal Diameter, $D = 300.00$

Cover Thickness, $c = 25.00$

Element Length, $L = 3000.00$

Primary Member

Smooth Bars

Ductile Steel

With Detailing for Earthquake Resistance (including stirrups closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
Adequate Lap Length ($l_o/l_{ou,min} = l_b/l_d \geq 1$)
FRP Wrapping Data
Type: Carbon
Cured laminate properties (design values)
Thickness, $t = 1.016$
Tensile Strength, $f_{fu} = 1055.00$
Tensile Modulus, $E_f = 64828.00$
Elongation, $e_{fu} = 0.01$
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, $M_a = 7.9133033E-010$
Shear Force, $V_a = -2.1004643E-013$
EDGE -B-
Bending Moment, $M_b = -1.6094518E-010$
Shear Force, $V_b = 2.1004643E-013$
BOTH EDGES
Axial Force, $F = -7386.882$
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: $As_t = 1272.345$
-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, $Db_{L,ten} = 18.00$

Existing component: From table 7-7, ASCE 41_17: Final Shear Capacity $V_R = \phi V_n = 529689.31$
 $V_n ((10.3), ASCE 41-17) = knl * V_{CoI} = 529689.31$
 $V_{CoI} = 529689.31$
 $knl = 1.00$
 $displacement_ductility_demand = 0.00$

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

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

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

This later relation, considered as a function Vf(θ , α), 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, θ)|, |Vf(-45, θ)|), 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 <= 359638.026

bw*d = $\frac{Vs + Vf}{4} = 125663.706$

displacement_ductility_demand is calculated as $\frac{V_s}{V_y}$

- Calculation of $\frac{V_s}{V_y}$ for END A -

for rotation axis 2 and integ. section (a)

From analysis, chord rotation $\theta = 1.1135440E-020$

y = (My* $L_s/3$)/Eleff = 0.00946974 ((4.29), Biskinis Phd)

My = 4.4260E+008

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

From table 10.5, ASCE 41_17: Eleff = factor*Ec*Ig = 2.3369E+013

factor = 0.30

Ag = 196349.541

Mean concrete strength: fc' = (fc'_jacket*Area_jacket + fc'_core*Area_core)/Area_section = 27.84

N = 7386.882

Ec*Ig = Ec_jacket*Ig_jacket + Ec_core*Ig_core = 7.7898E+013

Calculation of Yielding Moment My

Calculation of $\frac{V_s}{V_y}$ and My according to (7) - (8) in Biskinis and Fardis

My = Min(My_ten, My_com) = 4.4260E+008

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

My_ten (8a) = 4.4260E+008

_ten (7a) = 65.19069

error of function (7a) = 0.00234594

My_com (8b) = 7.6083E+008

_com (7b) = 64.49916

error of function (7b) = -0.00733981

with ey = 0.003125

eco = 0.002

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

d1 = 44.00

R = 250.00

v = 0.00112963

N = 7386.882

Ac = 196349.541

= 0.29185858

with fc' ((12.3), ACI 440) = 33.3038

fc = 30.00

fl = 1.05384

k = 1

Effective FRP thickness, tf = NL*t*Cos(b1) = 1.016

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

Ef = 64828.00

Calculation of ratio l_b/l_d

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

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

At local axis: 3

Integration Section: (a)

Calculation No. 4

column C1, Floor 1

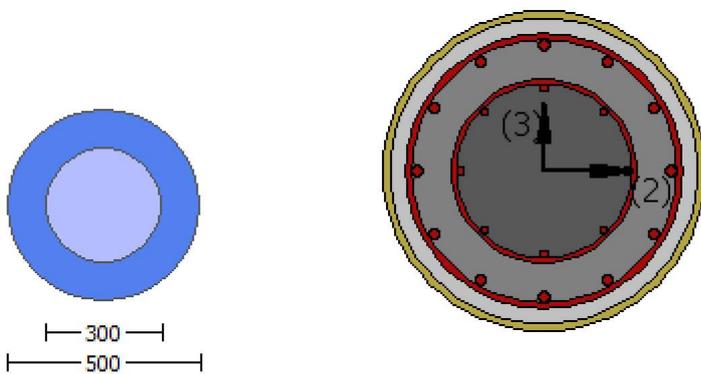
Limit State: Operational Level (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity (θ)

Edge: Start

Local Axis: (3)



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

At Shear local axis: 3

(Bending local axis: 2)

Section Type: rcjcs

Constant Properties

Knowledge Factor, $\gamma = 1.00$

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

Consequently:

Jacket

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

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

Concrete Elasticity, $E_c = 25742.96$

Steel Elasticity, $E_s = 200000.00$

Existing Column

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

Existing material of Primary Member: Steel Strength, $f_s = f_{sm} = 525.00$
Concrete Elasticity, $E_c = 23025.204$
Steel Elasticity, $E_s = 200000.00$

Note: Especially for the calculation of moment strengths,
the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14
Jacket
New material: Steel Strength, $f_s = 1.25 \cdot f_{sm} = 781.25$
Existing Column
Existing material: Steel Strength, $f_s = 1.25 \cdot f_{sm} = 656.25$

External Diameter, $D = 500.00$
Internal Diameter, $D = 300.00$
Cover Thickness, $c = 25.00$
Mean Confinement Factor overall section = 1.50688
Element Length, $L = 3000.00$
Primary Member
Smooth Bars
Ductile Steel
With Detailing for Earthquake Resistance (including stirrups closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
Adequate Lap Length ($l_o/l_{ou, min} > 1$)
FRP Wrapping Data
Type: Carbon
Cured laminate properties (design values)
Thickness, $t = 1.016$
Tensile Strength, $f_{fu} = 1055.00$
Tensile Modulus, $E_f = 64828.00$
Elongation, $e_{fu} = 0.01$
Number of directions, $N_{oDir} = 1$
Fiber orientations, $b_i: 0.00^\circ$
Number of layers, $N_L = 1$
Radius of rounding corners, $R = 40.00$

Stepwise Properties

At local axis: 3
EDGE -A-
Shear Force, $V_a = 4.1010657E-031$
EDGE -B-
Shear Force, $V_b = -4.1010657E-031$
BOTH EDGES
Axial Force, $F = -7389.214$
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: $A_{sl} = 0.00$
-Compression: $A_{slc} = 3053.628$
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension: $A_{sl, ten} = 1017.876$
-Compression: $A_{sl, com} = 1017.876$
-Middle: $A_{sl, mid} = 1017.876$

Calculation of Shear Capacity ratio, $V_e/V_r = 0.45961884$
Member Controlled by Flexure ($V_e/V_r < 1$)
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 298019.298$
with
 $M_{pr1} = \text{Max}(M_{u1+}, M_{u1-}) = 4.4703E+008$
 $M_{u1+} = 4.4703E+008$, is the ultimate moment strength at the edge 1 of the member in the actual moment direction
which is defined for the static loading combination
 $M_{u1-} = 4.4703E+008$, is the ultimate moment strength at the edge 1 of the member in the opposite moment
direction which is defined for the static loading combination
 $M_{pr2} = \text{Max}(M_{u2+}, M_{u2-}) = 4.4703E+008$
 $M_{u2+} = 4.4703E+008$, is the ultimate moment strength at the edge 2 of the member in the actual moment direction
which is defined for the the static loading combination

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

Calculation of Mu1+

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

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

Calculation of ratio lb/d

Adequate Lap Length: lb/d >= 1

Calculation of Mu1-

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

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

Calculation of ratio lb/d

Adequate Lap Length: lb/d >= 1

Calculation of Mu2+

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

$$\mu = 4.4703E+008$$

$$= 0.97738438$$

$$\lambda = 0.86668818$$

error of function (3.68), Biskinis Phd = 40566.604

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

conf. factor $c = 1.50688$

$f_c = 30.00$

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

$l_b/d = 1.00$

$d_1 = 44.00$

$R = 250.00$

$v = 0.00112412$

$N = 7389.214$

$A_c = 196349.541$

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

Calculation of ratio l_b/d

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

Calculation of μ_2

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

$$\mu = 4.4703E+008$$

$$= 0.97738438$$

$$\lambda = 0.86668818$$

error of function (3.68), Biskinis Phd = 40566.604

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

conf. factor $c = 1.50688$

$f_c = 30.00$

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

$l_b/d = 1.00$

$d_1 = 44.00$

$R = 250.00$

$v = 0.00112412$

$N = 7389.214$

$A_c = 196349.541$

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

Calculation of ratio l_b/d

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

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

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

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

$V_{Co10} = 648405.308$

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

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

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

$f = 1$ (normal-weight concrete)

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

$M/Vd = 2.00$
 $\mu_u = 2.1425332E-011$
 $V_u = 4.1010657E-031$
 $d = 0.8 \cdot D = 400.00$
 $N_u = 7389.214$
 $A_g = 196349.541$
 From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 308425.138$
 $V_{s1} = 308425.138$ is calculated for jacket, with:
 $A_v = \sqrt{2} \cdot A_{stirrup} = 123370.055$
 $f_y = 625.00$
 $s = 100.00$
 V_{s1} is multiplied by $Col1 = 1.00$
 $s/d = 0.25$
 $V_{s2} = 0.00$ is calculated for core, with:
 $A_v = \sqrt{2} \cdot A_{stirrup} = 78956.835$
 $f_y = 525.00$
 $s = 250.00$
 V_{s2} is multiplied by $Col2 = 0.00$
 $s/d = 1.04167$
 V_f ((11-3)-(11.4), ACI 440) = 247653.332
 $f = 0.95$, for fully-wrapped sections
 $w_f/s_f = 1$ (FRP strips adjacent to one another).
 In (11.3) $\sin \theta + \cos \theta$ is replaced with $(\cot \theta + \csc \theta) \sin \alpha$ which is more a generalised expression,
 where θ is the angle of the crack direction (see KANEPE).
 This later relation, considered as a function $V_f(\theta, \alpha)$, is implemented for every different fiber orientation α_i ,
 as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.
 orientation 1: $\theta = 45^\circ$
 $V_f = \text{Min}(|V_f(45, \alpha_1)|, |V_f(-45, \alpha_1)|)$, 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: $V_s + V_f \leq 440464.828$
 $b_w \cdot d = \sqrt{4} \cdot V_s = 125663.706$

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

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

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

$$s/d = 1.04167$$

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

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

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

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

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

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

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

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

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

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

$$E_f = 64828.00$$

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

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

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

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

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

$$\text{Knowledge Factor, } \phi = 1.00$$

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

Consequently:

Jacket

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

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

$$\text{Concrete Elasticity, } E_c = 25742.96$$

$$\text{Steel Elasticity, } E_s = 200000.00$$

Existing Column

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

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

$$\text{Concrete Elasticity, } E_c = 23025.204$$

$$\text{Steel Elasticity, } E_s = 200000.00$$

#####

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

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

Existing Column

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

#####

$$\text{External Diameter, } D = 500.00$$

$$\text{Internal Diameter, } D = 300.00$$

$$\text{Cover Thickness, } c = 25.00$$

$$\text{Mean Confinement Factor overall section} = 1.50688$$

$$\text{Element Length, } L = 3000.00$$

Primary Member

Smooth Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

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

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $e_{fu} = 0.01$

Number of directions, $NoDir = 1$

Fiber orientations, $b_i = 0.00^\circ$

Number of layers, $NL = 1$

Radius of rounding corners, $R = 40.00$

Stepwise Properties

At local axis: 2

EDGE -A-

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

EDGE -B-

Shear Force, $V_b = 2.5110955E-047$

BOTH EDGES

Axial Force, $F = -7389.214$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: $As_t = 0.00$

-Compression: $As_c = 3053.628$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

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

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

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

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

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

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

with

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

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

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

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

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

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

Calculation of Mu_{1+}

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

$Mu = 4.4703E+008$

 $\lambda = 0.97738438$

$\lambda' = 0.86668818$

error of function (3.68), Biskinis Phd = 40566.604

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

conf. factor $c = 1.50688$

$f_c = 30.00$

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

$l_b/d = 1.00$

$d_1 = 44.00$

$R = 250.00$

$v = 0.00112412$

$N = 7389.214$

$Ac = 196349.541$

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

Calculation of ratio l_b/d

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

Calculation of μ_{1-}

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), μ
 $\mu = 4.4703E+008$

$$= 0.97738438$$

$$\lambda = 0.86668818$$

error of function (3.68), Biskinis Phd = 40566.604

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

conf. factor $c = 1.50688$

$f_c = 30.00$

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

$$l_b/d = 1.00$$

$$d_1 = 44.00$$

$$R = 250.00$$

$$v = 0.00112412$$

$$N = 7389.214$$

$$A_c = 196349.541$$

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

Calculation of ratio l_b/d

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

Calculation of μ_{2+}

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), μ
 $\mu = 4.4703E+008$

$$= 0.97738438$$

$$\lambda = 0.86668818$$

error of function (3.68), Biskinis Phd = 40566.604

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

conf. factor $c = 1.50688$

$f_c = 30.00$

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

$$l_b/d = 1.00$$

$$d_1 = 44.00$$

$$R = 250.00$$

$$v = 0.00112412$$

$$N = 7389.214$$

$$A_c = 196349.541$$

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

Calculation of ratio l_b/d

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

Calculation of Mu2-

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

$$= 0.97738438$$

$$' = 0.86668818$$

error of function (3.68), Biskinis Phd = 40566.604

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

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

$$f_c = 30.00$$

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

$$l_b/d = 1.00$$

$$d1 = 44.00$$

$$R = 250.00$$

$$v = 0.00112412$$

$$N = 7389.214$$

$$A_c = 196349.541$$

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

Calculation of ratio lb/d

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

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

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

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

$$V_{Col0} = 648405.308$$

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

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

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

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

$$M/d = 2.00$$

$$Mu = 2.0093280E-011$$

$$Vu = 2.5110955E-047$$

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

$$Nu = 7389.214$$

$$Ag = 196349.541$$

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

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

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

$$f_y = 625.00$$

$$s = 100.00$$

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

$$s/d = 0.25$$

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

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

$$f_y = 525.00$$

$$s = 250.00$$

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

$$s/d = 1.04167$$

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

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

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

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

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

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

$V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, \theta)|)$, 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: $V_s + V_f \leq 440464.828$

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

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

$V_{r2} = V_{Co1}$ ((10.3), ASCE 41-17) = $k_{nl} \cdot V_{Co10}$

$V_{Co10} = 648405.308$

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

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

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

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

$M / Vd = 2.00$

$\mu_u = 2.0093280E-011$

$\nu_u = 2.5110955E-047$

$d = 0.8 \cdot D = 400.00$

$N_u = 7389.214$

$A_g = 196349.541$

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

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

$A_v = \frac{A_s}{2} = 123370.055$

$f_y = 625.00$

$s = 100.00$

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

$s/d = 0.25$

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

$A_v = \frac{A_s}{2} = 78956.835$

$f_y = 525.00$

$s = 250.00$

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

$s/d = 1.04167$

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

$f = 0.95$, for fully-wrapped sections

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

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

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

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

$V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, \theta)|)$, 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: $V_s + V_f \leq 440464.828$

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

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

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

Concrete Elasticity, $E_c = 25742.96$

Steel Elasticity, $E_s = 200000.00$

Existing Column

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

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

Concrete Elasticity, $E_c = 23025.204$

Steel Elasticity, $E_s = 200000.00$

External Diameter, $D = 500.00$

Internal Diameter, $D = 300.00$

Cover Thickness, $c = 25.00$

Element Length, $L = 3000.00$

Primary Member

Smooth Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

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

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $e_{fu} = 0.01$

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

Fiber orientations, $b_i = 0.00^\circ$

Number of layers, $N_L = 1$

Radius of rounding corners, $R = 40.00$

Stepwise Properties

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

Shear Force, $V_2 = -5829.318$

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

Axial Force, $F = -7386.882$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: $As_t = 1272.345$

-Compression: $As_c = 1781.283$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

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

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

-Middle: $As_{mid} = 1017.876$

Mean Diameter of Tension Reinforcement, $Db_L = 18.00$

Existing component: From table 7-7, ASCE 41_17: Final chord rotation Capacity $u_{,R} = * u = 0.0239444$

$u = y + p = 0.0239444$

- Calculation of ρ_y -

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

$$M_y = 4.4260E+008$$

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

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

$$\text{factor} = 0.30$$

$$A_g = 196349.541$$

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

$$N = 7386.882$$

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

Calculation of Yielding Moment M_y

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

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

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

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

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

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

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

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

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

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

$$e_{co} = 0.002$$

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

$$d_1 = 44.00$$

$$R = 250.00$$

$$v = 0.00112963$$

$$N = 7386.882$$

$$A_c = 196349.541$$

$$= 0.29185858$$

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

$$f_c = 30.00$$

$$f_l = 1.05384$$

$$k = 1$$

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

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

$$E_f = 64828.00$$

Calculation of ratio l_b/d

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

- Calculation of ρ_p -

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

with:

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

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

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

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

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

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

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

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

(shear) direction

$$s_1 = 100.00$$

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

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

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

direction

$$s_2 = 250.00$$

The term $2 \cdot t_f / b_w \cdot (f_{fe} / f_s)$ is implemented to account for FRP contribution where $f = 2 \cdot t_f / b_w$ is FRP ratio (EC8 - 3, A.4.4.3(6)) and f_{fe} / f_s normalises f to steel strength. All these variables have already been given in Shear control ratio calculation.

For the normalisation f_s of jacket is used.

$$N_{UD} = 7386.882$$

$$A_g = 196349.541$$

$$f_{cE} = (f_{c_jacket} \cdot Area_jacket + f_{c_core} \cdot Area_core) / section_area = 27.84$$

$$f_{yIE} = (f_{y_ext_Long_Reinf} \cdot Area_ext_Long_Reinf + f_{y_int_Long_Reinf} \cdot Area_int_Long_Reinf) / Area_Tot_Long_Rein = 2.1219958E-314$$

$$f_{yTE} = (f_{y_ext_Trans_Reinf} \cdot Area_ext_Trans_Reinf + f_{y_int_Trans_Reinf} \cdot Area_int_Trans_Reinf) / Area_Tot_Trans_Rein = 610.4781$$

$$\rho_l = Area_Tot_Long_Rein / (A_g) = 0.015552$$

$$f_{cE} = 27.84$$

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

At local axis: 3

Integration Section: (a)

Calculation No. 5

column C1, Floor 1

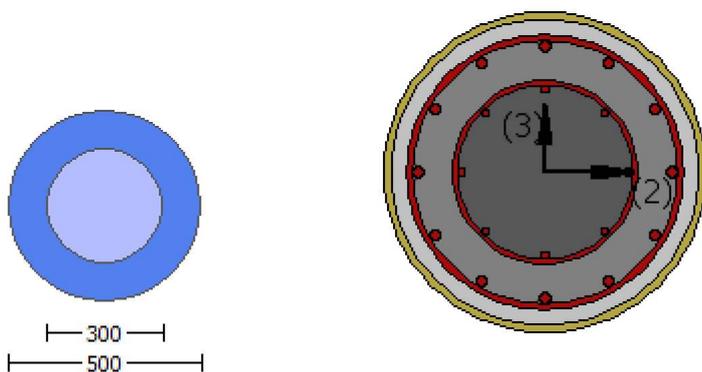
Limit State: Operational Level (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Shear capacity V_{Rd}

Edge: End

Local Axis: (2)



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

At local axis: 2

Integration Section: (b)

Section Type: rcjcs

Constant Properties

```

Knowledge Factor,  $\gamma = 1.00$ 
Member Shear Force is generally considered as Force-Controlled Action according to Table C7-1, ASCE 41-17.
Lower-bound strengths are used for Force-Controlled Actions according to 7.5.1.3, ASCE 41-17
Consequently:
Jacket
New material of Primary Member: Concrete Strength,  $f_c = f_{c\_lower\_bound} = 20.00$ 
New material of Primary Member: Steel Strength,  $f_s = f_{s\_lower\_bound} = 500.00$ 
Concrete Elasticity,  $E_c = 25742.96$ 
Steel Elasticity,  $E_s = 200000.00$ 
Existing Column
Existing material of Primary Member: Concrete Strength,  $f_c = f_{c\_lower\_bound} = 16.00$ 
Existing material of Primary Member: Steel Strength,  $f_s = f_{s\_lower\_bound} = 420.00$ 
Concrete Elasticity,  $E_c = 23025.204$ 
Steel Elasticity,  $E_s = 200000.00$ 
#####
Note: Especially for the calculation of  $\gamma$  for displacement ductility demand,
the expected (mean value) strengths are used (7.5.1.3, ASCE 41-17) because bending is considered as
Deformation-Controlled Action (Table C7-1, ASCE 41-17).
Jacket
New material: Concrete Strength,  $f_c = f_{cm} = 30.00$ 
New material: Steel Strength,  $f_s = f_{sm} = 625.00$ 
Existing Column
Existing material: Concrete Strength,  $f_c = f_{cm} = 24.00$ 
Existing material: Steel Strength,  $f_s = f_{sm} = 525.00$ 
#####
External Diameter,  $D = 500.00$ 
Internal Diameter,  $D = 300.00$ 
Cover Thickness,  $c = 25.00$ 
Element Length,  $L = 3000.00$ 
Primary Member
Smooth Bars
Ductile Steel
With Detailing for Earthquake Resistance (including stirrups closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
Adequate Lap Length ( $l_o/l_{ou,min} = l_b/l_d \geq 1$ )
FRP Wrapping Data
Type: Carbon
Cured laminate properties (design values)
Thickness,  $t = 1.016$ 
Tensile Strength,  $f_{fu} = 1055.00$ 
Tensile Modulus,  $E_f = 64828.00$ 
Elongation,  $e_{fu} = 0.01$ 
Number of directions,  $NoDir = 1$ 
Fiber orientations,  $b_i: 0.00^\circ$ 
Number of layers,  $NL = 1$ 
Radius of rounding corners,  $R = 40.00$ 
-----

Stepwise Properties
-----
EDGE -A-
Bending Moment,  $M_a = -1.7492E+007$ 
Shear Force,  $V_a = -5829.318$ 
EDGE -B-
Bending Moment,  $M_b = 0.12862757$ 
Shear Force,  $V_b = 5829.318$ 
BOTH EDGES
Axial Force,  $F = -7386.882$ 
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension:  $As_t = 0.00$ 
-Compression:  $As_c = 3053.628$ 
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension:  $As_{l,ten} = 1017.876$ 
-Compression:  $As_{l,com} = 1017.876$ 
-Middle:  $As_{l,mid} = 1017.876$ 
Mean Diameter of Tension Reinforcement,  $Db_{L,ten} = 18.00$ 
-----

```

Existing component: From table 7-7, ASCE 41_17: Final Shear Capacity $V_R = V_n = 529689.31$
 V_n ((10.3), ASCE 41-17) = $k_n \cdot V_{CoI} = 529689.31$
 $V_{CoI} = 529689.31$
 $k_n = 1.00$
 $displacement_ductility_demand = 0.05927674$

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

= 1 (normal-weight concrete)
 Mean concrete strength: $f_c' = (f_c'_{jacket} \cdot Area_{jacket} + f_c'_{core} \cdot Area_{core}) / Area_{section} = 18.56$, but $f_c'^{0.5} \leq 8.3$
 MPa (22.5.3.1, ACI 318-14)
 $M/Vd = 2.00$
 $\mu_u = 0.12862757$
 $V_u = 5829.318$
 $d = 0.8 \cdot D = 400.00$
 $N_u = 7386.882$
 $A_g = 196349.541$
 From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 246740.11$
 $V_{s1} = 246740.11$ is calculated for jacket, with:
 $A_v = \sqrt{2} \cdot A_{stirrup} = 123370.055$
 $f_y = 500.00$
 $s = 100.00$
 V_{s1} is multiplied by $Col1 = 1.00$
 $s/d = 0.25$
 $V_{s2} = 0.00$ is calculated for core, with:
 $A_v = \sqrt{2} \cdot A_{stirrup} = 78956.835$
 $f_y = 420.00$
 $s = 250.00$
 V_{s2} is multiplied by $Col2 = 0.00$
 $s/d = 1.04167$
 V_f ((11-3)-(11.4), ACI 440) = 247653.332
 $f = 0.95$, for fully-wrapped sections
 $w_f/s_f = 1$ (FRP strips adjacent to one another).
 In (11.3) $\sin + \cos$ is replaced with $(\cot + \cot_a) \sin a$ which is more a generalised expression,
 where a is the angle of the crack direction (see KANEPE).
 This later relation, considered as a function $V_f(\theta, a)$, 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: $\theta = 45^\circ + 90^\circ = 135^\circ$
 $V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, a)|)$, 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: $V_s + V_f \leq 359638.026$
 $b_w \cdot d = V_n \cdot d / 4 = 125663.706$

$displacement_ductility_demand$ is calculated as θ / y

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

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

$$N = 7386.882$$
$$E_c \cdot I_g = E_{c_jacket} \cdot I_{g_jacket} + E_{c_core} \cdot I_{g_core} = 7.7898E+013$$

Calculation of Yielding Moment M_y

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

$$M_y = \min(M_{y_ten}, M_{y_com}) = 4.4260E+008$$
$$y \text{ ((10a) or (10b))} = 1.3430728E-005$$
$$M_{y_ten} \text{ (8a)} = 4.4260E+008$$
$$y_{ten} \text{ (7a)} = 65.19069$$
$$\text{error of function (7a)} = 0.00234594$$
$$M_{y_com} \text{ (8b)} = 7.6083E+008$$
$$y_{com} \text{ (7b)} = 64.49916$$
$$\text{error of function (7b)} = -0.00733981$$
$$\text{with } e_y = 0.003125$$
$$e_{co} = 0.002$$
$$a_{pl} = 0.45 \text{ ((9c) in Biskinis and Fardis for FRP Wrap)}$$
$$d_1 = 44.00$$
$$R = 250.00$$
$$v = 0.00112963$$
$$N = 7386.882$$
$$A_c = 196349.541$$
$$= 0.29185858$$
$$\text{with } f_c^* \text{ ((12.3), ACI 440)} = 33.3038$$
$$f_c = 30.00$$
$$f_l = 1.05384$$
$$k = 1$$
$$\text{Effective FRP thickness, } t_f = NL \cdot t \cdot \cos(\beta_1) = 1.016$$
$$e_{fe} \text{ ((12.5) and (12.7))} = 0.004$$
$$E_f = 64828.00$$

Calculation of ratio l_b/d

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

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

At local axis: 2

Integration Section: (b)

Calculation No. 6

column C1, Floor 1

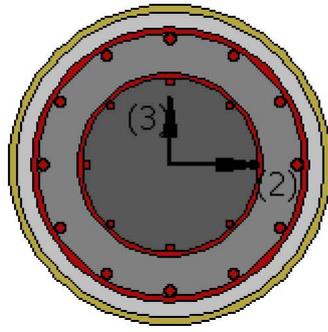
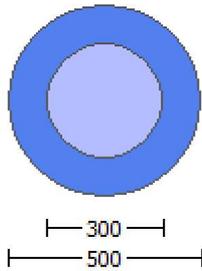
Limit State: Operational Level (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity (θ_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 Primary Member: Concrete Strength, $f_c = f_{cm} = 30.00$
 New material of Primary Member: Steel Strength, $f_s = f_{sm} = 625.00$
 Concrete Elasticity, $E_c = 25742.96$
 Steel Elasticity, $E_s = 200000.00$

Existing Column

Existing material of Primary Member: Concrete Strength, $f_c = f_{cm} = 24.00$
 Existing material of Primary Member: Steel Strength, $f_s = f_{sm} = 525.00$
 Concrete Elasticity, $E_c = 23025.204$
 Steel Elasticity, $E_s = 200000.00$

#####

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

Jacket

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

Existing Column

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

#####

External Diameter, $D = 500.00$

Internal Diameter, $D = 300.00$

Cover Thickness, $c = 25.00$

Mean Confinement Factor overall section = 1.50688

Element Length, $L = 3000.00$

Primary Member

Smooth Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

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

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $e_{fu} = 0.01$

Number of directions, $NoDir = 1$

Fiber orientations, $b_i = 0.00^\circ$

Number of layers, $NL = 1$

Radius of rounding corners, $R = 40.00$

Stepwise Properties

At local axis: 3

EDGE -A-

Shear Force, $V_a = 4.1010657E-031$

EDGE -B-

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

BOTH EDGES

Axial Force, $F = -7389.214$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: $A_{st} = 0.00$

-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, $V_e/V_r = 0.45961884$

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

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

with

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

$M_{u1+} = 4.4703E+008$, is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination

$M_{u1-} = 4.4703E+008$, is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination

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

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

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

Calculation of M_{u1+}

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

$M_u = 4.4703E+008$

$\phi = 0.97738438$

$\phi' = 0.86668818$

error of function (3.68), Biskinis Phd = 40566.604

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

conf. factor $c = 1.50688$

$f_c = 30.00$

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

$l_b/d = 1.00$

$d_1 = 44.00$

$R = 250.00$

$v = 0.00112412$

$N = 7389.214$

$A_c = 196349.541$

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

Calculation of ratio l_b/d

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

Calculation of M_{u1-}

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

Mu = 4.4703E+008

= 0.97738438

' = 0.86668818

error of function (3.68), Biskinis Phd = 40566.604

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

conf. factor $c = 1.50688$

$f_c = 30.00$

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

$l_b/d = 1.00$

$d_1 = 44.00$

$R = 250.00$

$v = 0.00112412$

$N = 7389.214$

$Ac = 196349.541$

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

Calculation of ratio l_b/d

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

Calculation of Mu2+

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

Mu = 4.4703E+008

= 0.97738438

' = 0.86668818

error of function (3.68), Biskinis Phd = 40566.604

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

conf. factor $c = 1.50688$

$f_c = 30.00$

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

$l_b/d = 1.00$

$d_1 = 44.00$

$R = 250.00$

$v = 0.00112412$

$N = 7389.214$

$Ac = 196349.541$

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

Calculation of ratio l_b/d

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

Calculation of Mu2-

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

Mu = 4.4703E+008

= 0.97738438

' = 0.86668818

error of function (3.68), Biskinis Phd = 40566.604

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

conf. factor $c = 1.50688$

$f_c = 30.00$

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

$l_b/d = 1.00$

$d_1 = 44.00$

$R = 250.00$

$v = 0.00112412$

$N = 7389.214$

$A_c = 196349.541$

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

Calculation of ratio l_b/d

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

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

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

$V_{r1} = V_{\text{Col}} ((10.3), \text{ASCE 41-17}) = k_{n1} \cdot V_{\text{Col}0}$

$V_{\text{Col}0} = 648405.308$

$k_{n1} = 1$ (zero step-static loading)

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

$= 1$ (normal-weight concrete)

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

$M/d = 2.00$

$\mu_u = 2.1425332E-011$

$\nu_u = 4.1010657E-031$

$d = 0.8 \cdot D = 400.00$

$N_u = 7389.214$

$A_g = 196349.541$

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

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

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

$f_y = 625.00$

$s = 100.00$

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

$s/d = 0.25$

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

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

$f_y = 525.00$

$s = 250.00$

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

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

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

$V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, \alpha)|)$, 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: $V_s + V_f \leq 440464.828$

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

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

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

$$V_{CoI0} = 648405.308$$

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

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

$= 1$ (normal-weight concrete)

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

$$M/Vd = 2.00$$

$$\mu_u = 2.1425332E-011$$

$$\nu_u = 4.1010657E-031$$

$$d = 0.8 * D = 400.00$$

$$N_u = 7389.214$$

$$A_g = 196349.541$$

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

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

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

$$f_y = 625.00$$

$$s = 100.00$$

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

$$s/d = 0.25$$

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

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

$$f_y = 525.00$$

$$s = 250.00$$

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

$$s/d = 1.04167$$

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

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

$w_f/s_f = 1$ (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, $t_{f1} = N_L * t / N_{oDir} = 1.016$

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

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

$$E_f = 64828.00$$

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

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

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

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

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

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

Concrete Elasticity, $E_c = 25742.96$

Steel Elasticity, $E_s = 200000.00$

Existing Column

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

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

Concrete Elasticity, $E_c = 23025.204$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

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

Jacket

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

Existing Column

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

#####

External Diameter, $D = 500.00$

Internal Diameter, $D = 300.00$

Cover Thickness, $c = 25.00$

Mean Confinement Factor overall section = 1.50688

Element Length, $L = 3000.00$

Primary Member

Smooth Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

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

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $e_{fu} = 0.01$

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, $V_a = -2.5110955E-047$

EDGE -B-

Shear Force, $V_b = 2.5110955E-047$

BOTH EDGES

Axial Force, $F = -7389.214$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: $A_{slt} = 0.00$

-Compression: $A_{slc} = 3053.628$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

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

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

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

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

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

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

with

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

$M_{u1+} = 4.4703E+008$, is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination

$M_{u1-} = 4.4703E+008$, is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination

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

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

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

Calculation of M_{u1+}

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

$$= 0.97738438$$

$$' = 0.86668818$$

error of function (3.68), Biskinis Phd = 40566.604

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

conf. factor $c = 1.50688$

$$f_c = 30.00$$

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

$$l_b/l_d = 1.00$$

$$d_1 = 44.00$$

$$R = 250.00$$

$$v = 0.00112412$$

$$N = 7389.214$$

$$A_c = 196349.541$$

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

Calculation of ratio l_b/l_d

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

Calculation of M_{u1-}

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

$$= 0.97738438$$

$$' = 0.86668818$$

error of function (3.68), Biskinis Phd = 40566.604

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

conf. factor $c = 1.50688$

$$f_c = 30.00$$

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

$$l_b/l_d = 1.00$$

$$d_1 = 44.00$$

$$R = 250.00$$

$$v = 0.00112412$$

$$N = 7389.214$$

$$A_c = 196349.541$$

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

Calculation of ratio l_b/l_d

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

Calculation of Mu2+

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

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

Calculation of ratio lb/d

Adequate Lap Length: lb/d >= 1

Calculation of Mu2-

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

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

Calculation of ratio lb/d

Adequate Lap Length: lb/d >= 1

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

Calculation of Shear Strength at edge 1, Vr1 = 648405.308
Vr1 = VCol ((10.3), ASCE 41-17) = knl*VColO
VColO = 648405.308

$k_{nl} = 1$ (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: $f'_c = (f'_{c_jacket} \cdot Area_jacket + f'_{c_core} \cdot Area_core) / Area_section = 27.84$, but $f_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$\mu_u = 2.0093280E-011$

$\nu_u = 2.5110955E-047$

$d = 0.8 \cdot D = 400.00$

$N_u = 7389.214$

$A_g = 196349.541$

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

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

$A_v = \frac{1}{2} \cdot A_stirrup = 123370.055$

$f_y = 625.00$

$s = 100.00$

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

$s/d = 0.25$

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

$A_v = \frac{1}{2} \cdot A_stirrup = 78956.835$

$f_y = 525.00$

$s = 250.00$

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

$s/d = 1.04167$

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

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

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

$V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, \theta)|)$, 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: $V_s + V_f \leq 440464.828$

$b_w \cdot d = \frac{1}{4} \cdot d^2 = 125663.706$

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

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

$V_{Col0} = 648405.308$

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

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

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

Mean concrete strength: $f'_c = (f'_{c_jacket} \cdot Area_jacket + f'_{c_core} \cdot Area_core) / Area_section = 27.84$, but $f_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$\mu_u = 2.0093280E-011$

$\nu_u = 2.5110955E-047$

$d = 0.8 \cdot D = 400.00$

$N_u = 7389.214$

$A_g = 196349.541$

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

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

$A_v = \frac{1}{2} \cdot A_stirrup = 123370.055$

$f_y = 625.00$

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

 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: (b)
 Section Type: rcjcs

Constant Properties

 Knowledge Factor, $\phi = 1.00$
 Chord Rotation is generally considered as Deformation-Controlled Action according to Table C7-1, ASCE 41-17.
 Mean strengths are used for Deformation-Controlled Actions according to 7.5.1.3, ASCE 41-17
 Consequently:
 Jacket
 New material of Primary Member: Concrete Strength, $f_c = f_{cm} = 30.00$
 New material of Primary Member: Steel Strength, $f_s = f_{sm} = 625.00$
 Concrete Elasticity, $E_c = 25742.96$
 Steel Elasticity, $E_s = 200000.00$
 Existing Column
 Existing material of Primary Member: Concrete Strength, $f_c = f_{cm} = 24.00$
 Existing material of Primary Member: Steel Strength, $f_s = f_{sm} = 525.00$
 Concrete Elasticity, $E_c = 23025.204$
 Steel Elasticity, $E_s = 200000.00$
 External Diameter, $D = 500.00$
 Internal Diameter, $D = 300.00$
 Cover Thickness, $c = 25.00$
 Element Length, $L = 3000.00$
 Primary Member
 Smooth Bars
 Ductile Steel
 With Detailing for Earthquake Resistance (including stirrups closed at 135°)
 Longitudinal Bars With Ends Lapped Starting at the End Sections
 Adequate Lap Length ($l_b/d \geq 1$)
 FRP Wrapping Data
 Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $e_{fu} = 0.01$

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

Fiber orientations, $b_i = 0.00^\circ$

Number of layers, $N_L = 1$

Radius of rounding corners, $R = 40.00$

Stepwise Properties

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

Shear Force, $V_2 = 5829.318$

Shear Force, $V_3 = 2.1004643E-013$

Axial Force, $F = -7386.882$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: $A_{st} = 0.00$

-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: $A_{s,mid} = 1017.876$

Mean Diameter of Tension Reinforcement, $D_bL = 18.00$

Existing component: From table 7-7, ASCE 41_17: Final chord rotation Capacity $u_{,R} = * u = 0.01446974$

$u = y + p = 0.01446974$

- Calculation of y -

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

$M_y = 4.4260E+008$

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

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

factor = 0.30

$A_g = 196349.541$

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

$N = 7386.882$

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

Calculation of Yielding Moment M_y

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

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

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

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

y_{ten} (7a) = 65.19069

error of function (7a) = 0.00234594

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

y_{com} (7b) = 64.49916

error of function (7b) = -0.00733981

with $e_y = 0.003125$

$e_{co} = 0.002$

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

$d_1 = 44.00$

$R = 250.00$

$v = 0.00112963$

$N = 7386.882$

$A_c = 196349.541$

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

 Calculation of ratio l_b/l_d

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

 - Calculation of p -

 From table 10-9: $p = 0.005$

with:

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

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

$d = d_{external} = 0.00$

$s = s_{external} = 0.00$

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

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

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

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

(shear) direction

$s_1 = 100.00$

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

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

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

direction

$s_2 = 250.00$

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

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

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

For the normalisation f_s of jacket is used.

$N_{UD} = 7386.882$

$A_g = 196349.541$

$f_{cE} = (f_{c,jacket} \cdot Area_{jacket} + f_{c,core} \cdot Area_{core}) / section_area = 27.84$

$f_{yIE} = (f_{y,ext_Long_Reinf} \cdot Area_{ext_Long_Reinf} + f_{y,int_Long_Reinf} \cdot Area_{int_Long_Reinf}) / Area_{Tot_Long_Rein} = 2.1219958E-314$

$f_{yTE} = (f_{y,ext_Trans_Reinf} \cdot Area_{ext_Trans_Reinf} + f_{y,int_Trans_Reinf} \cdot Area_{int_Trans_Reinf}) / Area_{Tot_Trans_Rein} = 610.4781$

$p_l = Area_{Tot_Long_Rein} / (A_g) = 0.015552$

$f_{cE} = 27.84$

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

At local axis: 2

Integration Section: (b)

Calculation No. 7

column C1, Floor 1

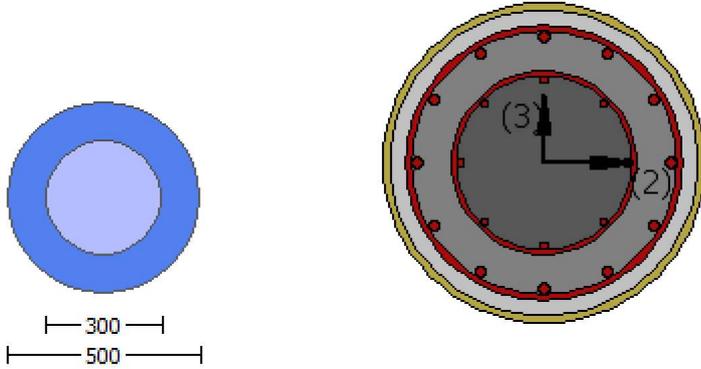
Limit State: Operational Level (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Shear capacity VRd

Edge: End

Local Axis: (3)



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

At local axis: 3

Integration Section: (b)

Section Type: rcjcs

Constant Properties

Knowledge Factor, $\gamma = 1.00$

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

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

Consequently:

Jacket

New material of Primary Member: Concrete Strength, $f_c = f_{c_lower_bound} = 20.00$

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

Concrete Elasticity, $E_c = 25742.96$

Steel Elasticity, $E_s = 200000.00$

Existing Column

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

Existing material of Primary Member: Steel Strength, $f_s = f_{s_lower_bound} = 420.00$

Concrete Elasticity, $E_c = 23025.204$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of γ for displacement ductility demand, the expected (mean value) strengths are used (7.5.1.3, ASCE 41-17) because bending is considered as Deformation-Controlled Action (Table C7-1, ASCE 41-17).

Jacket

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

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

Existing Column

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

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

#####

External Diameter, $D = 500.00$

Internal Diameter, $D = 300.00$

Cover Thickness, $c = 25.00$

Element Length, $L = 3000.00$

Primary Member

Smooth Bars

Ductile Steel

With Detailing for Earthquake Resistance (including stirrups closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
Adequate Lap Length ($l_o/l_{ou,min} = l_b/l_d \geq 1$)
FRP Wrapping Data
Type: Carbon
Cured laminate properties (design values)
Thickness, $t = 1.016$
Tensile Strength, $f_{fu} = 1055.00$
Tensile Modulus, $E_f = 64828.00$
Elongation, $e_{fu} = 0.01$
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, $M_a = 7.9133033E-010$
Shear Force, $V_a = -2.1004643E-013$
EDGE -B-
Bending Moment, $M_b = -1.6094518E-010$
Shear Force, $V_b = 2.1004643E-013$
BOTH EDGES
Axial Force, $F = -7386.882$
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: $As_t = 0.00$
-Compression: $As_c = 3053.628$
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension: $As_{t,ten} = 1017.876$
-Compression: $As_{c,com} = 1017.876$
-Middle: $As_{c,mid} = 1017.876$
Mean Diameter of Tension Reinforcement, $Db_{L,ten} = 18.00$

Existing component: From table 7-7, ASCE 41_17: Final Shear Capacity $V_R = \phi V_n = 529689.31$
 $V_n ((10.3), ASCE 41-17) = knl * V_{CoI} = 529689.31$
 $V_{CoI} = 529689.31$
 $knl = 1.00$
 $displacement_ductility_demand = 0.00$

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

 $\phi = 1$ (normal-weight concrete)
Mean concrete strength: $f'_c = (f'_{c,jacket} * Area_{jacket} + f'_{c,core} * Area_{core}) / Area_{section} = 18.56$, but $f'_c^{0.5} \leq 8.3$
MPa (22.5.3.1, ACI 318-14)
 $M / Vd = 2.00$
 $M_u = 1.6094518E-010$
 $V_u = 2.1004643E-013$
 $d = 0.8 * D = 400.00$
 $N_u = 7386.882$
 $A_g = 196349.541$
From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 246740.11$
 $V_{s1} = 246740.11$ is calculated for jacket, with:
 $A_v = \phi / 2 * A_{stirrup} = 123370.055$
 $f_y = 500.00$
 $s = 100.00$
 V_{s1} is multiplied by $Col1 = 1.00$
 $s/d = 0.25$
 $V_{s2} = 0.00$ is calculated for core, with:
 $A_v = \phi / 2 * A_{stirrup} = 78956.835$
 $f_y = 420.00$
 $s = 250.00$

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

This later relation, considered as a function Vf(θ , α), 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, θ)|, |Vf(-45, θ)|), 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 <= 359638.026

bw*d = $\frac{Vs + Vf}{4} = 125663.706$

displacement_ductility_demand is calculated as $\frac{V_s}{V_y}$

- Calculation of $\frac{V_s}{V_y}$ for END B -

for rotation axis 2 and integ. section (b)

From analysis, chord rotation $\theta = 6.6331167E-021$

y = (My*Ls/3)/Eleff = 0.00946974 ((4.29), Biskinis Phd)

My = 4.4260E+008

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

From table 10.5, ASCE 41_17: Eleff = factor*Ec*Ig = 2.3369E+013

factor = 0.30

Ag = 196349.541

Mean concrete strength: fc' = (fc'_jacket*Area_jacket + fc'_core*Area_core)/Area_section = 27.84

N = 7386.882

Ec*Ig = Ec_jacket*Ig_jacket + Ec_core*Ig_core = 7.7898E+013

Calculation of Yielding Moment My

Calculation of $\frac{V_s}{V_y}$ and My according to (7) - (8) in Biskinis and Fardis

My = Min(My_ten, My_com) = 4.4260E+008

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

My_ten (8a) = 4.4260E+008

_ten (7a) = 65.19069

error of function (7a) = 0.00234594

My_com (8b) = 7.6083E+008

_com (7b) = 64.49916

error of function (7b) = -0.00733981

with ey = 0.003125

eco = 0.002

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

d1 = 44.00

R = 250.00

v = 0.00112963

N = 7386.882

Ac = 196349.541

= 0.29185858

with fc' ((12.3), ACI 440) = 33.3038

fc = 30.00

fl = 1.05384

k = 1

Effective FRP thickness, tf = NL*t*Cos(b1) = 1.016

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

Ef = 64828.00

Calculation of ratio l_b/d

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

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

At local axis: 3

Integration Section: (b)

Calculation No. 8

column C1, Floor 1

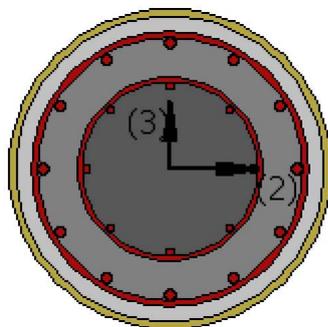
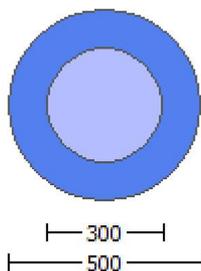
Limit State: Operational Level (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity (θ)

Edge: End

Local Axis: (3)



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

At Shear local axis: 3

(Bending local axis: 2)

Section Type: rcjcs

Constant Properties

Knowledge Factor, $\gamma = 1.00$

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

Consequently:

Jacket

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

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

Concrete Elasticity, $E_c = 25742.96$

Steel Elasticity, $E_s = 200000.00$

Existing Column

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

Existing material of Primary Member: Steel Strength, $f_s = f_{sm} = 525.00$
Concrete Elasticity, $E_c = 23025.204$
Steel Elasticity, $E_s = 200000.00$

Note: Especially for the calculation of moment strengths,
the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14
Jacket
New material: Steel Strength, $f_s = 1.25 \cdot f_{sm} = 781.25$
Existing Column
Existing material: Steel Strength, $f_s = 1.25 \cdot f_{sm} = 656.25$

External Diameter, $D = 500.00$
Internal Diameter, $D = 300.00$
Cover Thickness, $c = 25.00$
Mean Confinement Factor overall section = 1.50688
Element Length, $L = 3000.00$
Primary Member
Smooth Bars
Ductile Steel
With Detailing for Earthquake Resistance (including stirrups closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
Adequate Lap Length ($l_o/l_{ou, \min} > 1$)
FRP Wrapping Data
Type: Carbon
Cured laminate properties (design values)
Thickness, $t = 1.016$
Tensile Strength, $f_{fu} = 1055.00$
Tensile Modulus, $E_f = 64828.00$
Elongation, $e_{fu} = 0.01$
Number of directions, $N_{oDir} = 1$
Fiber orientations, $b_i: 0.00^\circ$
Number of layers, $N_L = 1$
Radius of rounding corners, $R = 40.00$

Stepwise Properties

At local axis: 3
EDGE -A-
Shear Force, $V_a = 4.1010657E-031$
EDGE -B-
Shear Force, $V_b = -4.1010657E-031$
BOTH EDGES
Axial Force, $F = -7389.214$
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: $A_{st} = 0.00$
-Compression: $A_{sc} = 3053.628$
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension: $A_{st, \text{ten}} = 1017.876$
-Compression: $A_{st, \text{com}} = 1017.876$
-Middle: $A_{st, \text{mid}} = 1017.876$

Calculation of Shear Capacity ratio, $V_e/V_r = 0.45961884$
Member Controlled by Flexure ($V_e/V_r < 1$)
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 298019.298$
with
 $M_{pr1} = \text{Max}(M_{u1+}, M_{u1-}) = 4.4703E+008$
 $M_{u1+} = 4.4703E+008$, is the ultimate moment strength at the edge 1 of the member in the actual moment direction
which is defined for the static loading combination
 $M_{u1-} = 4.4703E+008$, is the ultimate moment strength at the edge 1 of the member in the opposite moment
direction which is defined for the static loading combination
 $M_{pr2} = \text{Max}(M_{u2+}, M_{u2-}) = 4.4703E+008$
 $M_{u2+} = 4.4703E+008$, is the ultimate moment strength at the edge 2 of the member in the actual moment direction
which is defined for the the static loading combination

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

Calculation of Mu1+

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

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

Calculation of ratio lb/d

Adequate Lap Length: lb/d >= 1

Calculation of Mu1-

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

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

Calculation of ratio lb/d

Adequate Lap Length: lb/d >= 1

Calculation of Mu2+

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

$$\mu = 4.4703E+008$$

$$= 0.97738438$$

$$\lambda = 0.86668818$$

error of function (3.68), Biskinis Phd = 40566.604

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

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

$$f_c = 30.00$$

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

$$l_b/d = 1.00$$

$$d_1 = 44.00$$

$$R = 250.00$$

$$v = 0.00112412$$

$$N = 7389.214$$

$$A_c = 196349.541$$

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

Calculation of ratio l_b/d

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

Calculation of μ_2

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

$$\mu = 4.4703E+008$$

$$= 0.97738438$$

$$\lambda = 0.86668818$$

error of function (3.68), Biskinis Phd = 40566.604

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

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

$$f_c = 30.00$$

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

$$l_b/d = 1.00$$

$$d_1 = 44.00$$

$$R = 250.00$$

$$v = 0.00112412$$

$$N = 7389.214$$

$$A_c = 196349.541$$

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

Calculation of ratio l_b/d

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

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

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

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

$$V_{Co10} = 648405.308$$

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

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

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

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

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

$M/Vd = 2.00$
 $\mu_u = 2.1425332E-011$
 $V_u = 4.1010657E-031$
 $d = 0.8 \cdot D = 400.00$
 $N_u = 7389.214$
 $A_g = 196349.541$
 From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 308425.138$
 $V_{s1} = 308425.138$ is calculated for jacket, with:
 $A_v = \sqrt{2} \cdot A_{stirrup} = 123370.055$
 $f_y = 625.00$
 $s = 100.00$
 V_{s1} is multiplied by $Col1 = 1.00$
 $s/d = 0.25$
 $V_{s2} = 0.00$ is calculated for core, with:
 $A_v = \sqrt{2} \cdot A_{stirrup} = 78956.835$
 $f_y = 525.00$
 $s = 250.00$
 V_{s2} is multiplied by $Col2 = 0.00$
 $s/d = 1.04167$
 V_f ((11-3)-(11.4), ACI 440) = 247653.332
 $f = 0.95$, for fully-wrapped sections
 $w_f/s_f = 1$ (FRP strips adjacent to one another).
 In (11.3) $\sin \theta + \cos \theta$ is replaced with $(\cot \theta + \csc \theta) \sin \alpha$ which is more a generalised expression,
 where θ is the angle of the crack direction (see KANEPE).
 This later relation, considered as a function $V_f(\theta, \alpha)$, is implemented for every different fiber orientation α_i ,
 as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.
 orientation 1: $\theta = 45^\circ$
 $V_f = \text{Min}(|V_f(45, \alpha_1)|, |V_f(-45, \alpha_1)|)$, 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: $V_s + V_f \leq 440464.828$
 $b_w \cdot d = \sqrt{4} \cdot V_s = 125663.706$

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

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

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

$$s/d = 1.04167$$

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

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

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

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 $V_f(\theta, a_i)$, 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.

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

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

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

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

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

$$E_f = 64828.00$$

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

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

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

$$b_w * d = \rho * d^2 / 4 = 125663.706$$

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

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

Constant Properties

$$\text{Knowledge Factor, } \phi = 1.00$$

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

Consequently:

Jacket

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

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

$$\text{Concrete Elasticity, } E_c = 25742.96$$

$$\text{Steel Elasticity, } E_s = 200000.00$$

Existing Column

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

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

$$\text{Concrete Elasticity, } E_c = 23025.204$$

$$\text{Steel Elasticity, } E_s = 200000.00$$

#####

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

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

Existing Column

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

#####

$$\text{External Diameter, } D = 500.00$$

$$\text{Internal Diameter, } D = 300.00$$

$$\text{Cover Thickness, } c = 25.00$$

$$\text{Mean Confinement Factor overall section} = 1.50688$$

$$\text{Element Length, } L = 3000.00$$

Primary Member

Smooth Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

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

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $e_{fu} = 0.01$

Number of directions, $NoDir = 1$

Fiber orientations, $b_i = 0.00^\circ$

Number of layers, $NL = 1$

Radius of rounding corners, $R = 40.00$

Stepwise Properties

At local axis: 2

EDGE -A-

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

EDGE -B-

Shear Force, $V_b = 2.5110955E-047$

BOTH EDGES

Axial Force, $F = -7389.214$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: $As_t = 0.00$

-Compression: $As_c = 3053.628$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

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

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

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

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

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

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

with

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

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

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

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

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

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

Calculation of Mu_{1+}

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

$M_u = 4.4703E+008$

$\phi = 0.97738438$

$\lambda = 0.86668818$

error of function (3.68), Biskinis Phd = 40566.604

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

conf. factor $c = 1.50688$

$f_c = 30.00$

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

$l_b/d = 1.00$

$d_1 = 44.00$

$R = 250.00$

$v = 0.00112412$

$N = 7389.214$

$A_c = 196349.541$

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

Calculation of ratio l_b/d

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

Calculation of μ_{1-}

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), μ
 $\mu = 4.4703E+008$

$$= 0.97738438$$

$$\lambda = 0.86668818$$

error of function (3.68), Biskinis Phd = 40566.604

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

conf. factor $c = 1.50688$

$f_c = 30.00$

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

$$l_b/d = 1.00$$

$$d_1 = 44.00$$

$$R = 250.00$$

$$v = 0.00112412$$

$$N = 7389.214$$

$$A_c = 196349.541$$

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

Calculation of ratio l_b/d

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

Calculation of μ_{2+}

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), μ
 $\mu = 4.4703E+008$

$$= 0.97738438$$

$$\lambda = 0.86668818$$

error of function (3.68), Biskinis Phd = 40566.604

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

conf. factor $c = 1.50688$

$f_c = 30.00$

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

$$l_b/d = 1.00$$

$$d_1 = 44.00$$

$$R = 250.00$$

$$v = 0.00112412$$

$$N = 7389.214$$

$$A_c = 196349.541$$

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

Calculation of ratio l_b/d

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

Calculation of Mu2-

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

Mu = 4.4703E+008

= 0.97738438

' = 0.86668818

error of function (3.68), Biskinis Phd = 40566.604

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

conf. factor $c = 1.50688$

$f_c = 30.00$

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

$l_b/d = 1.00$

$d_1 = 44.00$

$R = 250.00$

$v = 0.00112412$

$N = 7389.214$

$A_c = 196349.541$

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

Calculation of ratio l_b/d

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

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

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

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

$V_{Col0} = 648405.308$

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

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

= 1 (normal-weight concrete)

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

$M/d = 2.00$

$M_u = 2.0093280E-011$

$V_u = 2.5110955E-047$

$d = 0.8 \cdot D = 400.00$

$N_u = 7389.214$

$A_g = 196349.541$

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

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

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

$f_y = 625.00$

$s = 100.00$

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

$s/d = 0.25$

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

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

$f_y = 525.00$

$s = 250.00$

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

$s/d = 1.04167$

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

$f = 0.95$, for fully-wrapped sections

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

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

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

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

$V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, \theta)|)$, 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: $V_s + V_f \leq 440464.828$

$b_w \cdot d = \frac{1}{4} \cdot d^2 = 125663.706$

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

$V_{r2} = V_{Co1}$ ((10.3), ASCE 41-17) = $k_{nl} \cdot V_{Co10}$

$V_{Co10} = 648405.308$

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

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

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

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

$M / Vd = 2.00$

$\mu_u = 2.0093280E-011$

$\nu_u = 2.5110955E-047$

$d = 0.8 \cdot D = 400.00$

$N_u = 7389.214$

$A_g = 196349.541$

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

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

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

$f_y = 625.00$

$s = 100.00$

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

$s/d = 0.25$

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

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

$f_y = 525.00$

$s = 250.00$

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

$s/d = 1.04167$

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

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

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

$V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, \theta)|)$, 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: $V_s + V_f \leq 440464.828$

$b_w \cdot d = \frac{1}{4} \cdot d^2 = 125663.706$

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

At local axis: 2

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

At local axis: 3

Integration Section: (b)

Section Type: rcjcs

Constant Properties

Knowledge Factor, $\gamma = 1.00$

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

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

Consequently:

Jacket

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

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

Concrete Elasticity, $E_c = 25742.96$

Steel Elasticity, $E_s = 200000.00$

Existing Column

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

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

Concrete Elasticity, $E_c = 23025.204$

Steel Elasticity, $E_s = 200000.00$

External Diameter, $D = 500.00$

Internal Diameter, $D = 300.00$

Cover Thickness, $c = 25.00$

Element Length, $L = 3000.00$

Primary Member

Smooth Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

Adequate Lap Length ($l_b/d >= 1$)

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $ε_{fu} = 0.01$

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

Fiber orientations, $b_i = 0.00^\circ$

Number of layers, $N_L = 1$

Radius of rounding corners, $R = 40.00$

Stepwise Properties

Bending Moment, $M = 0.12862757$

Shear Force, $V_2 = 5829.318$

Shear Force, $V_3 = 2.1004643E-013$

Axial Force, $F = -7386.882$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

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

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

Longitudinal Reinforcement Area Distribution (in 3 divisions)

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

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

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

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

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

$u = y + p = 0.00689395$

- Calculation of ρ_y -

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

$$M_y = 4.4260E+008$$

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

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

$$\text{factor} = 0.30$$

$$A_g = 196349.541$$

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

$$N = 7386.882$$

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

Calculation of Yielding Moment M_y

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

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

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

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

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

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

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

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

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

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

$$e_{co} = 0.002$$

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

$$d_1 = 44.00$$

$$R = 250.00$$

$$v = 0.00112963$$

$$N = 7386.882$$

$$A_c = 196349.541$$

$$= 0.29185858$$

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

$$f_c = 30.00$$

$$f_l = 1.05384$$

$$k = 1$$

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

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

$$E_f = 64828.00$$

Calculation of ratio l_b/d

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

- Calculation of ρ_p -

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

with:

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

$$\text{shear control ratio } V_y E / V_{CoI} E = 0.45961884$$

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

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

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

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

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

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

(shear) direction

$$s_1 = 100.00$$

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

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

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

direction

$$s_2 = 250.00$$

The term $2 \cdot t_f / b_w \cdot (f_{fe} / f_s)$ is implemented to account for FRP contribution where $f = 2 \cdot t_f / b_w$ is FRP ratio (EC8 - 3, A.4.4.3(6)) and f_{fe} / f_s normalises f to steel strength. All these variables have already been given in Shear control ratio calculation.

For the normalisation f_s of jacket is used.

$$N_{UD} = 7386.882$$

$$A_g = 196349.541$$

$$f_{cE} = (f_{c_jacket} \cdot Area_jacket + f_{c_core} \cdot Area_core) / section_area = 27.84$$

$$f_{yIE} = (f_{y_ext_Long_Reinf} \cdot Area_ext_Long_Reinf + f_{y_int_Long_Reinf} \cdot Area_int_Long_Reinf) / Area_Tot_Long_Rein = 2.1219958E-314$$

$$f_{yTE} = (f_{y_ext_Trans_Reinf} \cdot Area_ext_Trans_Reinf + f_{y_int_Trans_Reinf} \cdot Area_int_Trans_Reinf) / Area_Tot_Trans_Rein = 610.4781$$

$$\rho_l = Area_Tot_Long_Rein / (A_g) = 0.015552$$

$$f_{cE} = 27.84$$

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

At local axis: 3

Integration Section: (b)

Calculation No. 9

column C1, Floor 1

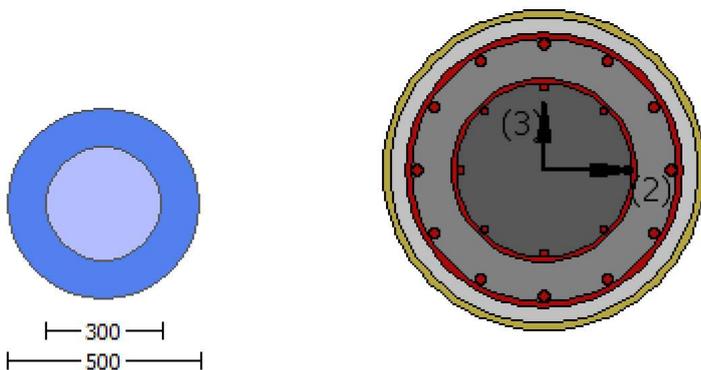
Limit State: Life Safety (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Shear capacity V_{Rd}

Edge: Start

Local Axis: (2)



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

At local axis: 2

Integration Section: (a)

Section Type: rcjcs

Constant Properties

```

Knowledge Factor,  $\gamma = 1.00$ 
Member Shear Force is generally considered as Force-Controlled Action according to Table C7-1, ASCE 41-17.
Lower-bound strengths are used for Force-Controlled Actions according to 7.5.1.3, ASCE 41-17
Consequently:
Jacket
New material of Primary Member: Concrete Strength,  $f_c = f_{c\_lower\_bound} = 20.00$ 
New material of Primary Member: Steel Strength,  $f_s = f_{s\_lower\_bound} = 500.00$ 
Concrete Elasticity,  $E_c = 25742.96$ 
Steel Elasticity,  $E_s = 200000.00$ 
Existing Column
Existing material of Primary Member: Concrete Strength,  $f_c = f_{c\_lower\_bound} = 16.00$ 
Existing material of Primary Member: Steel Strength,  $f_s = f_{s\_lower\_bound} = 420.00$ 
Concrete Elasticity,  $E_c = 23025.204$ 
Steel Elasticity,  $E_s = 200000.00$ 
#####
Note: Especially for the calculation of  $\gamma$  for displacement ductility demand,
the expected (mean value) strengths are used (7.5.1.3, ASCE 41-17) because bending is considered as
Deformation-Controlled Action (Table C7-1, ASCE 41-17).
Jacket
New material: Concrete Strength,  $f_c = f_{cm} = 30.00$ 
New material: Steel Strength,  $f_s = f_{sm} = 625.00$ 
Existing Column
Existing material: Concrete Strength,  $f_c = f_{cm} = 24.00$ 
Existing material: Steel Strength,  $f_s = f_{sm} = 525.00$ 
#####
External Diameter,  $D = 500.00$ 
Internal Diameter,  $D = 300.00$ 
Cover Thickness,  $c = 25.00$ 
Element Length,  $L = 3000.00$ 
Primary Member
Smooth Bars
Ductile Steel
With Detailing for Earthquake Resistance (including stirrups closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
Adequate Lap Length ( $l_o/l_{ou,min} = l_b/l_d \geq 1$ )
FRP Wrapping Data
Type: Carbon
Cured laminate properties (design values)
Thickness,  $t = 1.016$ 
Tensile Strength,  $f_{fu} = 1055.00$ 
Tensile Modulus,  $E_f = 64828.00$ 
Elongation,  $e_{fu} = 0.01$ 
Number of directions,  $NoDir = 1$ 
Fiber orientations,  $b_i: 0.00^\circ$ 
Number of layers,  $NL = 1$ 
Radius of rounding corners,  $R = 40.00$ 
-----

Stepwise Properties
-----
EDGE -A-
Bending Moment,  $M_a = -1.4007E+007$ 
Shear Force,  $V_a = -4667.709$ 
EDGE -B-
Bending Moment,  $M_b = 0.10299595$ 
Shear Force,  $V_b = 4667.709$ 
BOTH EDGES
Axial Force,  $F = -7387.347$ 
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension:  $As_t = 0.00$ 
-Compression:  $As_c = 3053.628$ 
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension:  $As_{l,ten} = 1017.876$ 
-Compression:  $As_{l,com} = 1017.876$ 
-Middle:  $As_{l,mid} = 1017.876$ 
Mean Diameter of Tension Reinforcement,  $Db_{L,ten} = 18.00$ 
-----

```

Existing component: From table 7-7, ASCE 41_17: Final Shear Capacity $V_R = V_n = 444663.714$
 V_n ((10.3), ASCE 41-17) = $k_n V_{CoI} = 444663.714$
 $V_{CoI} = 444663.714$
 $k_n = 1.00$
 $displacement_ductility_demand = 0.0087107$

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

= 1 (normal-weight concrete)
 Mean concrete strength: $f_c' = (f_c'_{jacket} Area_{jacket} + f_c'_{core} Area_{core}) / Area_{section} = 18.56$, but $f_c'^{0.5} \leq 8.3$
 MPa (22.5.3.1, ACI 318-14)
 $M/Vd = 4.00$
 $M_u = 1.4007E+007$
 $V_u = 4667.709$
 $d = 0.8 \cdot D = 400.00$
 $N_u = 7387.347$
 $A_g = 196349.541$
 From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 246740.11$
 $V_{s1} = 246740.11$ is calculated for jacket, with:
 $A_v = \sqrt{2} A_{stirrup} = 123370.055$
 $f_y = 500.00$
 $s = 100.00$
 V_{s1} is multiplied by $Col1 = 1.00$
 $s/d = 0.25$
 $V_{s2} = 0.00$ is calculated for core, with:
 $A_v = \sqrt{2} A_{stirrup} = 78956.835$
 $f_y = 420.00$
 $s = 250.00$
 V_{s2} is multiplied by $Col2 = 0.00$
 $s/d = 1.04167$
 V_f ((11-3)-(11.4), ACI 440) = 247653.332
 $f = 0.95$, for fully-wrapped sections
 $w_f/s_f = 1$ (FRP strips adjacent to one another).
 In (11.3) $\sin + \cos$ is replaced with $(\cot + \cot a) \sin a$ which is more a generalised expression,
 where θ 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: $\theta = 45^\circ + 90^\circ = 135^\circ$
 $V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, a)|)$, with:
 total thickness per orientation, $t_{f1} = N_L \cdot t / N_{Dir} = 1.016$
 $d_{fv} = d$ (figure 11.2, ACI 440) = 470.00
 f_{fe} ((11-5), ACI 440) = 259.312
 $E_f = 64828.00$
 $f_e = 0.004$, from (11.6a), ACI 440
 with $f_u = 0.01$
 From (11-11), ACI 440: $V_s + V_f \leq 359638.026$
 $b_w \cdot d = V_u \cdot d / 4 = 125663.706$

$displacement_ductility_demand$ is calculated as θ / y

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

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

$$N = 7387.347$$
$$E_c \cdot I_g = E_{c_jacket} \cdot I_{g_jacket} + E_{c_core} \cdot I_{g_core} = 7.7898E+013$$

Calculation of Yielding Moment M_y

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

$$M_y = \min(M_{y_ten}, M_{y_com}) = 4.4260E+008$$
$$y \text{ ((10a) or (10b))} = 1.3430729E-005$$
$$M_{y_ten} \text{ (8a)} = 4.4260E+008$$
$$y_{ten} \text{ (7a)} = 65.19069$$
$$\text{error of function (7a)} = 0.00234593$$
$$M_{y_com} \text{ (8b)} = 7.6083E+008$$
$$y_{com} \text{ (7b)} = 64.49917$$
$$\text{error of function (7b)} = -0.0073398$$
$$\text{with } e_y = 0.003125$$
$$e_{co} = 0.002$$
$$a_{pl} = 0.45 \text{ ((9c) in Biskinis and Fardis for FRP Wrap)}$$
$$d_1 = 44.00$$
$$R = 250.00$$
$$v = 0.0011297$$
$$N = 7387.347$$
$$A_c = 196349.541$$
$$= 0.29185858$$
$$\text{with } f_c^* \text{ ((12.3), ACI 440)} = 33.3038$$
$$f_c = 30.00$$
$$f_l = 1.05384$$
$$k = 1$$
$$\text{Effective FRP thickness, } t_f = NL \cdot t \cdot \cos(b_1) = 1.016$$
$$e_{fe} \text{ ((12.5) and (12.7))} = 0.004$$
$$E_f = 64828.00$$

Calculation of ratio l_b/d

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

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

At local axis: 2

Integration Section: (a)

Calculation No. 10

column C1, Floor 1

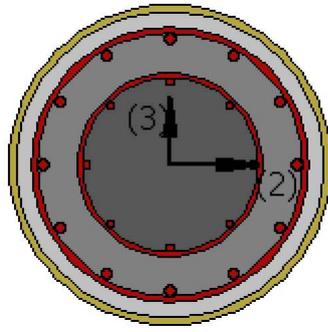
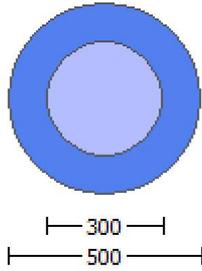
Limit State: Life Safety (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity (θ_u)

Edge: Start

Local Axis: (2)



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

At Shear local axis: 3
 (Bending local axis: 2)
 Section Type: rcjcs

Constant Properties

Knowledge Factor, $\gamma = 1.00$
 Mean strength values are used for both shear and moment calculations.
 Consequently:

Jacket

New material of Primary Member: Concrete Strength, $f_c = f_{cm} = 30.00$
 New material of Primary Member: Steel Strength, $f_s = f_{sm} = 625.00$
 Concrete Elasticity, $E_c = 25742.96$
 Steel Elasticity, $E_s = 200000.00$

Existing Column

Existing material of Primary Member: Concrete Strength, $f_c = f_{cm} = 24.00$
 Existing material of Primary Member: Steel Strength, $f_s = f_{sm} = 525.00$
 Concrete Elasticity, $E_c = 23025.204$
 Steel Elasticity, $E_s = 200000.00$

#####

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

Jacket

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

Existing Column

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

#####

External Diameter, $D = 500.00$

Internal Diameter, $D = 300.00$

Cover Thickness, $c = 25.00$

Mean Confinement Factor overall section = 1.50688

Element Length, $L = 3000.00$

Primary Member

Smooth Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

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

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $ef_u = 0.01$

Number of directions, $NoDir = 1$

Fiber orientations, $bi = 0.00^\circ$

Number of layers, $NL = 1$

Radius of rounding corners, $R = 40.00$

Stepwise Properties

At local axis: 3

EDGE -A-

Shear Force, $V_a = 4.1010657E-031$

EDGE -B-

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

BOTH EDGES

Axial Force, $F = -7389.214$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: $A_{st} = 0.00$

-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, $V_e/V_r = 0.45961884$

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

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

with

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

$M_{u1+} = 4.4703E+008$, is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination

$M_{u1-} = 4.4703E+008$, is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination

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

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

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

Calculation of M_{u1+}

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

$M_u = 4.4703E+008$

$\phi = 0.97738438$

$\phi' = 0.86668818$

error of function (3.68), Biskinis Phd = 40566.604

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

conf. factor $c = 1.50688$

$f_c = 30.00$

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

$l_b/d = 1.00$

$d_1 = 44.00$

$R = 250.00$

$v = 0.00112412$

$N = 7389.214$

$A_c = 196349.541$

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

Calculation of ratio l_b/d

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

Calculation of M_{u1-}

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

Mu = 4.4703E+008

= 0.97738438

' = 0.86668818

error of function (3.68), Biskinis Phd = 40566.604

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

conf. factor $c = 1.50688$

$f_c = 30.00$

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

$l_b/d = 1.00$

$d_1 = 44.00$

$R = 250.00$

$v = 0.00112412$

$N = 7389.214$

$Ac = 196349.541$

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

Calculation of ratio l_b/d

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

Calculation of Mu2+

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

Mu = 4.4703E+008

= 0.97738438

' = 0.86668818

error of function (3.68), Biskinis Phd = 40566.604

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

conf. factor $c = 1.50688$

$f_c = 30.00$

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

$l_b/d = 1.00$

$d_1 = 44.00$

$R = 250.00$

$v = 0.00112412$

$N = 7389.214$

$Ac = 196349.541$

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

Calculation of ratio l_b/d

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

Calculation of Mu2-

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

Mu = 4.4703E+008

= 0.97738438

' = 0.86668818

error of function (3.68), Biskinis Phd = 40566.604

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

conf. factor $c = 1.50688$

$f_c = 30.00$

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

$l_b/d = 1.00$

$d_1 = 44.00$

$R = 250.00$

$v = 0.00112412$

$N = 7389.214$

$A_c = 196349.541$

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

Calculation of ratio l_b/d

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

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

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

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

$V_{Col0} = 648405.308$

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

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

$= 1$ (normal-weight concrete)

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

$M/d = 2.00$

$\mu_u = 2.1425332E-011$

$\nu_u = 4.1010657E-031$

$d = 0.8 \cdot D = 400.00$

$N_u = 7389.214$

$A_g = 196349.541$

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

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

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

$f_y = 625.00$

$s = 100.00$

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

$s/d = 0.25$

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

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

$f_y = 525.00$

$s = 250.00$

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

$s/d = 1.04167$

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

$f = 0.95$, for fully-wrapped sections

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

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

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

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

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

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

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

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

$E_f = 64828.00$

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

with $f_u = 0.01$

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

$$b_w*d = *d*d/4 = 125663.706$$

Calculation of Shear Strength at edge 2, $V_{r2} = 648405.308$

$$V_{r2} = V_{CoI} \text{ ((10.3), ASCE 41-17)} = k_{nl} * V_{CoI0}$$

$$V_{CoI0} = 648405.308$$

$k_{nl} = 1$ (zero step-static loading)

NOTE: In expression (10-3) ' $V_s = A_v * f_y * d / s$ ' is replaced by ' $V_s + f * V_f$ ' where V_f is the contribution of FRPs (11.3), ACI 440).

$= 1$ (normal-weight concrete)

Mean concrete strength: $f_c' = (f_c'_{jacket} * Area_{jacket} + f_c'_{core} * Area_{core}) / Area_{section} = 27.84$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$$M/Vd = 2.00$$

$$\mu_u = 2.1425332E-011$$

$$\nu_u = 4.1010657E-031$$

$$d = 0.8 * D = 400.00$$

$$N_u = 7389.214$$

$$A_g = 196349.541$$

From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 308425.138$

$V_{s1} = 308425.138$ is calculated for jacket, with:

$$A_v = /2 * A_{stirrup} = 123370.055$$

$$f_y = 625.00$$

$$s = 100.00$$

V_{s1} is multiplied by $Col1 = 1.00$

$$s/d = 0.25$$

$V_{s2} = 0.00$ is calculated for core, with:

$$A_v = /2 * A_{stirrup} = 78956.835$$

$$f_y = 525.00$$

$$s = 250.00$$

V_{s2} is multiplied by $Col2 = 0.00$

$$s/d = 1.04167$$

V_f ((11-3)-(11.4), ACI 440) = 247653.332

$$f = 0.95$$
, for fully-wrapped sections

$w_f/s_f = 1$ (FRP strips adjacent to one another).

In (11.3) $\sin + \cos$ is replaced with $(\cot + \cot_a) \sin a$ which is more a generalised expression, where a is the angle of the crack direction (see KANEPE).

This later relation, considered as a function $V_f(\theta, a)$, is implemented for every different fiber orientation a_i , as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.

orientation 1: $\theta = b1 + 90^\circ = 90.00$

$V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, a1)|)$, with:

total thickness per orientation, $t_{f1} = N_L * t / N_{oDir} = 1.016$

$d_{fv} = d$ (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

$$\text{with } f_u = 0.01$$

From (11-11), ACI 440: $V_s + V_f \leq 440464.828$

$$b_w*d = *d*d/4 = 125663.706$$

End Of Calculation of Shear Capacity ratio for element: column JCC1 of floor 1

At local axis: 3

Start Of Calculation of Shear Capacity ratio for element: column JCC1 of floor 1

At Shear local axis: 2

(Bending local axis: 3)

Section Type: rcjcs

Constant Properties

Knowledge Factor, $= 1.00$

Mean strength values are used for both shear and moment calculations.

Consequently:

Jacket

New material of Primary Member: Concrete Strength, $f_c = f_{cm} = 30.00$

New material of Primary Member: Steel Strength, $f_s = f_{sm} = 625.00$

Concrete Elasticity, $E_c = 25742.96$

Steel Elasticity, $E_s = 200000.00$

Existing Column

Existing material of Primary Member: Concrete Strength, $f_c = f_{cm} = 24.00$

Existing material of Primary Member: Steel Strength, $f_s = f_{sm} = 525.00$

Concrete Elasticity, $E_c = 23025.204$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14

Jacket

New material: Steel Strength, $f_s = 1.25 \cdot f_{sm} = 781.25$

Existing Column

Existing material: Steel Strength, $f_s = 1.25 \cdot f_{sm} = 656.25$

#####

External Diameter, $D = 500.00$

Internal Diameter, $D = 300.00$

Cover Thickness, $c = 25.00$

Mean Confinement Factor overall section = 1.50688

Element Length, $L = 3000.00$

Primary Member

Smooth Bars

Ductile Steel

With Detailing for Earthquake Resistance (including stirrups closed at 135°)

Longitudinal Bars With Ends Lapped Starting at the End Sections

Adequate Lap Length ($l_o/l_{ou}, \min >= 1$)

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $e_{fu} = 0.01$

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, $V_a = -2.5110955E-047$

EDGE -B-

Shear Force, $V_b = 2.5110955E-047$

BOTH EDGES

Axial Force, $F = -7389.214$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: $A_{slt} = 0.00$

-Compression: $A_{slc} = 3053.628$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension: $A_{sl,ten} = 1017.876$

-Compression: $A_{sl,com} = 1017.876$

-Middle: $A_{sl,mid} = 1017.876$

Calculation of Shear Capacity ratio, $V_e/V_r = 0.45961884$

Member Controlled by Flexure ($V_e/V_r < 1$)

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 298019.298$

with

$$Mpr1 = \text{Max}(Mu1+ , Mu1-) = 4.4703E+008$$

Mu1+ = 4.4703E+008, is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination

Mu1- = 4.4703E+008, is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination

$$Mpr2 = \text{Max}(Mu2+ , Mu2-) = 4.4703E+008$$

Mu2+ = 4.4703E+008, is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the the static loading combination

Mu2- = 4.4703E+008, is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the the static loading combination

Calculation of Mu1+

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), Mu
Mu = 4.4703E+008

$$= 0.97738438$$

$$' = 0.86668818$$

error of function (3.68), Biskinis Phd = 40566.604

From 5A.2, TBDY: $f_{cc} = f_c \cdot c = 45.20626$

conf. factor $c = 1.50688$

$$f_c = 30.00$$

From 10.3.5, ASCE 41-17, Final value of f_y : $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3}) = 781.25$

$$l_b/l_d = 1.00$$

$$d1 = 44.00$$

$$R = 250.00$$

$$v = 0.00112412$$

$$N = 7389.214$$

$$Ac = 196349.541$$

$$= \cdot \text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3}) = 0.36292832$$

Calculation of ratio l_b/l_d

Adequate Lap Length: $l_b/l_d \geq 1$

Calculation of Mu1-

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), Mu
Mu = 4.4703E+008

$$= 0.97738438$$

$$' = 0.86668818$$

error of function (3.68), Biskinis Phd = 40566.604

From 5A.2, TBDY: $f_{cc} = f_c \cdot c = 45.20626$

conf. factor $c = 1.50688$

$$f_c = 30.00$$

From 10.3.5, ASCE 41-17, Final value of f_y : $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3}) = 781.25$

$$l_b/l_d = 1.00$$

$$d1 = 44.00$$

$$R = 250.00$$

$$v = 0.00112412$$

$$N = 7389.214$$

$$Ac = 196349.541$$

$$= \cdot \text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3}) = 0.36292832$$

Calculation of ratio l_b/l_d

Adequate Lap Length: $l_b/l_d \geq 1$

Calculation of Mu2+

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), Mu
Mu = 4.4703E+008

= 0.97738438
' = 0.86668818
error of function (3.68), Biskinis Phd = 40566.604
From 5A.2, TBDY: fcc = fc* c = 45.20626
conf. factor c = 1.50688
fc = 30.00
From 10.3.5, ASCE 41-17, Final value of fy: fy*Min(1,1.25*(lb/d)^ 2/3) = 781.25
lb/d = 1.00
d1 = 44.00
R = 250.00
v = 0.00112412
N = 7389.214
Ac = 196349.541
= *Min(1,1.25*(lb/d)^ 2/3) = 0.36292832

Calculation of ratio lb/d

Adequate Lap Length: lb/d >= 1

Calculation of Mu2-

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), Mu
Mu = 4.4703E+008

= 0.97738438
' = 0.86668818
error of function (3.68), Biskinis Phd = 40566.604
From 5A.2, TBDY: fcc = fc* c = 45.20626
conf. factor c = 1.50688
fc = 30.00
From 10.3.5, ASCE 41-17, Final value of fy: fy*Min(1,1.25*(lb/d)^ 2/3) = 781.25
lb/d = 1.00
d1 = 44.00
R = 250.00
v = 0.00112412
N = 7389.214
Ac = 196349.541
= *Min(1,1.25*(lb/d)^ 2/3) = 0.36292832

Calculation of ratio lb/d

Adequate Lap Length: lb/d >= 1

Calculation of Shear Strength Vr = Min(Vr1,Vr2) = 648405.308

Calculation of Shear Strength at edge 1, Vr1 = 648405.308
Vr1 = VCol ((10.3), ASCE 41-17) = knl*VColO
VColO = 648405.308

$k_{nl} = 1$ (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: $f_c' = (f_c'_{jacket} \cdot Area_{jacket} + f_c'_{core} \cdot Area_{core}) / Area_{section} = 27.84$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$\mu_u = 2.0093280E-011$

$\nu_u = 2.5110955E-047$

$d = 0.8 \cdot D = 400.00$

$N_u = 7389.214$

$A_g = 196349.541$

From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 308425.138$

$V_{s1} = 308425.138$ is calculated for jacket, with:

$A_v = A_{stirrup} / 2 = 123370.055$

$f_y = 625.00$

$s = 100.00$

V_{s1} is multiplied by $Col1 = 1.00$

$s/d = 0.25$

$V_{s2} = 0.00$ is calculated for core, with:

$A_v = A_{stirrup} / 2 = 78956.835$

$f_y = 525.00$

$s = 250.00$

V_{s2} is multiplied by $Col2 = 0.00$

$s/d = 1.04167$

V_f ((11-3)-(11.4), ACI 440) = 247653.332

$f = 0.95$, for fully-wrapped sections

$w_f/s_f = 1$ (FRP strips adjacent to one another).

In (11.3) $\sin^2 + \cos^2$ is replaced with $(\cot^2 + \csc^2) \sin^2 \alpha$ which is more a generalised expression, where α is the angle of the crack direction (see KANEPE).

This later relation, considered as a function $V_f(\alpha)$, is implemented for every different fiber orientation α_i , as well as for 2 crack directions, $\alpha = 45^\circ$ and $\alpha = -45^\circ$ to take into consideration the cyclic seismic loading.

orientation 1: $\alpha = b_1 + 90^\circ = 90.00$

$V_f = \text{Min}(|V_f(45, 1)|, |V_f(-45, a1)|)$, 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: $V_s + V_f \leq 440464.828$

$b_w \cdot d = A_{stirrup} \cdot d / 4 = 125663.706$

Calculation of Shear Strength at edge 2, $V_{r2} = 648405.308$

$V_{r2} = V_{Col}((10.3), ASCE 41-17) = k_{nl} \cdot V_{Col0}$

$V_{Col0} = 648405.308$

$k_{nl} = 1$ (zero step-static loading)

NOTE: In expression (10-3) ' $V_s = A_v \cdot f_y \cdot d / s$ ' is replaced by ' $V_s + f \cdot V_f$ ' where V_f is the contribution of FRPs (11.3), ACI 440).

$\lambda = 1$ (normal-weight concrete)

Mean concrete strength: $f_c' = (f_c'_{jacket} \cdot Area_{jacket} + f_c'_{core} \cdot Area_{core}) / Area_{section} = 27.84$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$\mu_u = 2.0093280E-011$

$\nu_u = 2.5110955E-047$

$d = 0.8 \cdot D = 400.00$

$N_u = 7389.214$

$A_g = 196349.541$

From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 308425.138$

$V_{s1} = 308425.138$ is calculated for jacket, with:

$A_v = A_{stirrup} / 2 = 123370.055$

$f_y = 625.00$

$s = 100.00$
 Vs1 is multiplied by Col1 = 1.00
 $s/d = 0.25$
 Vs2 = 0.00 is calculated for core, with:
 $A_v = \sqrt{2} * A_{stirrup} = 78956.835$
 $f_y = 525.00$
 $s = 250.00$
 Vs2 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 θ is the angle of the crack direction (see KANEPE).
 This later relation, considered as a function $V_f(\theta, \alpha)$, is implemented for every different fiber orientation α_i ,
 as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.
 orientation 1: $\theta = \theta_1 = 90^\circ = 90.00$
 $V_f = \text{Min}(|V_f(45, \theta_1)|, |V_f(-45, \theta_1)|)$, with:
 total thickness per orientation, $t_{f1} = N_L * t / N_{oDir} = 1.016$
 $d_{fv} = d$ (figure 11.2, ACI 440) = 470.00
 $f_{fe}((11-5), ACI 440) = 259.312$
 $E_f = 64828.00$
 $f_e = 0.004$, from (11.6a), ACI 440
 with $f_u = 0.01$
 From (11-11), ACI 440: $V_s + V_f \leq 440464.828$
 $b_w * d = \sqrt{V_s * d} / 4 = 125663.706$

 End Of Calculation of Shear Capacity ratio for element: column JCC1 of floor 1
 At local axis: 2

 Start Of Calculation of Chord Rotation Capacity for element: column JCC1 of floor 1
 At local axis: 2
 Integration Section: (a)
 Section Type: rcjcs

Constant Properties

 Knowledge Factor, $\phi = 1.00$
 Chord Rotation is generally considered as Deformation-Controlled Action according to Table C7-1, ASCE 41-17.
 Mean strengths are used for Deformation-Controlled Actions according to 7.5.1.3, ASCE 41-17
 Consequently:
 Jacket
 New material of Primary Member: Concrete Strength, $f_c = f_{cm} = 30.00$
 New material of Primary Member: Steel Strength, $f_s = f_{sm} = 625.00$
 Concrete Elasticity, $E_c = 25742.96$
 Steel Elasticity, $E_s = 200000.00$
 Existing Column
 Existing material of Primary Member: Concrete Strength, $f_c = f_{cm} = 24.00$
 Existing material of Primary Member: Steel Strength, $f_s = f_{sm} = 525.00$
 Concrete Elasticity, $E_c = 23025.204$
 Steel Elasticity, $E_s = 200000.00$
 External Diameter, $D = 500.00$
 Internal Diameter, $D = 300.00$
 Cover Thickness, $c = 25.00$
 Element Length, $L = 3000.00$
 Primary Member
 Smooth Bars
 Ductile Steel
 With Detailing for Earthquake Resistance (including stirrups closed at 135°)
 Longitudinal Bars With Ends Lapped Starting at the End Sections
 Adequate Lap Length ($l_b/d \geq 1$)
 FRP Wrapping Data
 Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $e_{fu} = 0.01$

Number of directions, $N_{oDir} = 1$

Fiber orientations, $b_i = 0.00^\circ$

Number of layers, $N_L = 1$

Radius of rounding corners, $R = 40.00$

Stepwise Properties

Bending Moment, $M = 6.3791133E-010$

Shear Force, $V_2 = -4667.709$

Shear Force, $V_3 = -1.6819047E-013$

Axial Force, $F = -7387.347$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: $A_{sl,t} = 0.00$

-Compression: $A_{sl,c} = 3053.628$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension: $A_{sl,ten} = 1017.876$

-Compression: $A_{sl,com} = 1017.876$

-Middle: $A_{sl,mid} = 1017.876$

Mean Diameter of Tension Reinforcement, $D_{bL} = 18.00$

Existing component: From table 7-7, ASCE 41_17: Final chord rotation Capacity $u_{,R} = u = 0.05990359$

$u = y + p = 0.05990359$

- Calculation of y -

$y = (M_y * L_s / 3) / E_{eff} = 0.00946974$ ((4.29), Biskinis Phd)

$M_y = 4.4260E+008$

$L_s = M/V$ (with $L_s > 0.1 * L$ and $L_s < 2 * L$) = 1500.00

From table 10.5, ASCE 41_17: $E_{eff} = factor * E_c * I_g = 2.3369E+013$

factor = 0.30

$A_g = 196349.541$

Mean concrete strength: $f_c' = (f_c'_{jacket} * Area_{jacket} + f_c'_{core} * Area_{core}) / Area_{section} = 27.84$

$N = 7387.347$

$E_c * I_g = E_c * I_{g,jacket} + E_c * I_{g,core} = 7.7898E+013$

Calculation of Yielding Moment M_y

Calculation of y and M_y according to (7) - (8) in Biskinis and Fardis

$M_y = \text{Min}(M_{y,ten}, M_{y,com}) = 4.4260E+008$

y ((10a) or (10b)) = 1.3430729E-005

$M_{y,ten}$ (8a) = 4.4260E+008

y_{ten} (7a) = 65.19069

error of function (7a) = 0.00234593

$M_{y,com}$ (8b) = 7.6083E+008

y_{com} (7b) = 64.49917

error of function (7b) = -0.0073398

with $e_y = 0.003125$

$e_{co} = 0.002$

$a_{pl} = 0.45$ ((9c) in Biskinis and Fardis for FRP Wrap)

$d_1 = 44.00$

$R = 250.00$

$v = 0.0011297$

$N = 7387.347$

$A_c = 196349.541$

$= 0.29185858$
 with f_c^* ((12.3), ACI 440) = 33.3038
 $f_c = 30.00$
 $f_l = 1.05384$
 $k = 1$
 Effective FRP thickness, $t_f = NL \cdot t \cdot \cos(b_1) = 1.016$
 e_{fe} ((12.5) and (12.7)) = 0.004
 $E_f = 64828.00$

 Calculation of ratio l_b/l_d

 Adequate Lap Length: $l_b/l_d \geq 1$

 - Calculation of p -

 From table 10-9: $p = 0.05043385$

with:

- Columns not controlled by inadequate development or splicing along the clear height because $l_b/l_d \geq 1$

shear control ratio $V_y E / V_{col} O E = 0.45961884$

$d = d_{external} = 0.00$

$s = s_{external} = 0.00$

$t = s_1 + s_2 + 2 \cdot t_f / b_w \cdot (f_{fe} / f_s) = 0.00660658$

jacket: $s_1 = A_{v1} \cdot (D_{c1} / 2) / (s_1 \cdot A_g) = 0.0027646$

$A_{v1} = 78.53982$, is the area of stirrup

$D_{c1} = D_{ext} - 2 \cdot cover$ - External Hoop Diameter = 440.00, is the total Length of all stirrups parallel to loading

(shear) direction

$s_1 = 100.00$

core: $s_2 = A_{v2} \cdot (D_{c2} / 2) / (s_2 \cdot A_g) = 0.00046968$

$A_{v2} = 50.26548$, is the area of stirrup

$D_{c2} = D_{int}$ - Internal Hoop Diameter = 292.00, is the total Length of all stirrups parallel to loading (shear)

direction

$s_2 = 250.00$

The term $2 \cdot t_f / b_w \cdot (f_{fe} / f_s)$ is implemented to account for FRP contribution

where $f = 2 \cdot t_f / b_w$ is FRP ratio (EC8 - 3, A.4.4.3(6)) and f_{fe} / f_s normalises f to steel strength

All these variables have already been given in Shear control ratio calculation.

For the normalisation f_s of jacket is used.

$N_{UD} = 7387.347$

$A_g = 196349.541$

$f_{cE} = (f_{c,jacket} \cdot Area_{jacket} + f_{c,core} \cdot Area_{core}) / section_area = 27.84$

$f_{yIE} = (f_{y,ext_Long_Reinf} \cdot Area_{ext_Long_Reinf} + f_{y,int_Long_Reinf} \cdot Area_{int_Long_Reinf}) / Area_{Tot_Long_Rein} = 2.1219958E-314$

$f_{yTE} = (f_{y,ext_Trans_Reinf} \cdot Area_{ext_Trans_Reinf} + f_{y,int_Trans_Reinf} \cdot Area_{int_Trans_Reinf}) / Area_{Tot_Trans_Rein} = 610.4781$

$p_l = Area_{Tot_Long_Rein} / (A_g) = 0.015552$

$f_{cE} = 27.84$

 End Of Calculation of Chord Rotation Capacity for element: column JCC1 of floor 1

At local axis: 2

Integration Section: (a)

Calculation No. 11

column C1, Floor 1

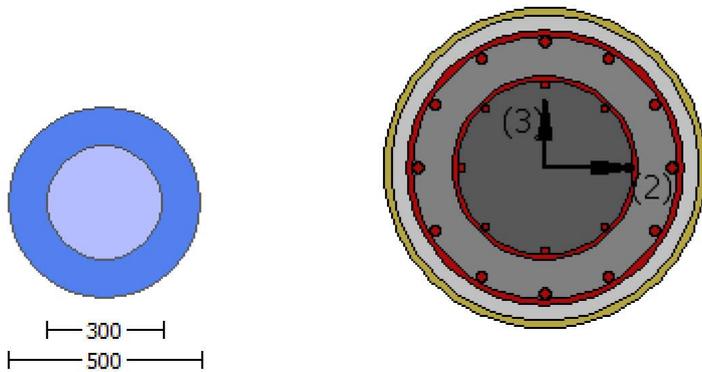
Limit State: Life Safety (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Shear capacity VRd

Edge: Start

Local Axis: (3)



Start Of Calculation of Shear Capacity for element: column JCC1 of floor 1

At local axis: 3

Integration Section: (a)

Section Type: rcjcs

Constant Properties

Knowledge Factor, $\gamma = 1.00$

Member Shear Force is generally considered as Force-Controlled Action according to Table C7-1, ASCE 41-17.

Lower-bound strengths are used for Force-Controlled Actions according to 7.5.1.3, ASCE 41-17

Consequently:

Jacket

New material of Primary Member: Concrete Strength, $f_c = f_{c_lower_bound} = 20.00$

New material of Primary Member: Steel Strength, $f_s = f_{s_lower_bound} = 500.00$

Concrete Elasticity, $E_c = 25742.96$

Steel Elasticity, $E_s = 200000.00$

Existing Column

Existing material of Primary Member: Concrete Strength, $f_c = f_{c_lower_bound} = 16.00$

Existing material of Primary Member: Steel Strength, $f_s = f_{s_lower_bound} = 420.00$

Concrete Elasticity, $E_c = 23025.204$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of γ for displacement ductility demand, the expected (mean value) strengths are used (7.5.1.3, ASCE 41-17) because bending is considered as Deformation-Controlled Action (Table C7-1, ASCE 41-17).

Jacket

New material: Concrete Strength, $f_c = f_{cm} = 30.00$

New material: Steel Strength, $f_s = f_{sm} = 625.00$

Existing Column

Existing material: Concrete Strength, $f_c = f_{cm} = 24.00$

Existing material: Steel Strength, $f_s = f_{sm} = 525.00$

#####

External Diameter, $D = 500.00$

Internal Diameter, $D = 300.00$

Cover Thickness, $c = 25.00$

Element Length, $L = 3000.00$

Primary Member

Smooth Bars

Ductile Steel

With Detailing for Earthquake Resistance (including stirrups closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
Adequate Lap Length ($l_o/l_{o,u,min} = l_b/l_d \geq 1$)
FRP Wrapping Data
Type: Carbon
Cured laminate properties (design values)
Thickness, $t = 1.016$
Tensile Strength, $f_{fu} = 1055.00$
Tensile Modulus, $E_f = 64828.00$
Elongation, $e_{fu} = 0.01$
Number of directions, $NoDir = 1$
Fiber orientations, $b_i: 0.00^\circ$
Number of layers, $NL = 1$
Radius of rounding corners, $R = 40.00$

Stepwise Properties

EDGE -A-
Bending Moment, $M_a = 6.3791133E-010$
Shear Force, $V_a = -1.6819047E-013$
EDGE -B-
Bending Moment, $M_b = -1.3314306E-010$
Shear Force, $V_b = 1.6819047E-013$
BOTH EDGES
Axial Force, $F = -7387.347$
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: $As_t = 0.00$
-Compression: $As_c = 3053.628$
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension: $As_{t,ten} = 1017.876$
-Compression: $As_{c,com} = 1017.876$
-Middle: $As_{c,mid} = 1017.876$
Mean Diameter of Tension Reinforcement, $Db_{L,ten} = 18.00$

Existing component: From table 7-7, ASCE 41-17: Final Shear Capacity $V_R = \phi V_n = 529689.402$
 $V_n ((10.3), ASCE 41-17) = knl * V_{CoI} = 529689.402$
 $V_{CoI} = 529689.402$
 $knl = 1.00$
 $displacement_ductility_demand = 0.00$

NOTE: In expression (10-3) ' $V_s = A_v * f_y * d / s$ ' is replaced by ' $V_{s+} = \phi * V_f$ '
where V_f is the contribution of FRPs (11.3), ACI 440).

 $\phi = 1$ (normal-weight concrete)
Mean concrete strength: $f'_c = (f'_{c,jacket} * Area_{jacket} + f'_{c,core} * Area_{core}) / Area_{section} = 18.56$, but $f'_c^{0.5} \leq 8.3$
MPa (22.5.3.1, ACI 318-14)
 $M / Vd = 2.00$
 $M_u = 6.3791133E-010$
 $V_u = 1.6819047E-013$
 $d = 0.8 * D = 400.00$
 $N_u = 7387.347$
 $A_g = 196349.541$
From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 246740.11$
 $V_{s1} = 246740.11$ is calculated for jacket, with:
 $A_v = \phi / 2 * A_{stirrup} = 123370.055$
 $f_y = 500.00$
 $s = 100.00$
 V_{s1} is multiplied by $Col1 = 1.00$
 $s/d = 0.25$
 $V_{s2} = 0.00$ is calculated for core, with:
 $A_v = \phi / 2 * A_{stirrup} = 78956.835$
 $f_y = 420.00$
 $s = 250.00$

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 θ is the angle of the crack direction (see KANEPE).

This later relation, considered as a function Vf(θ , α), 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, θ)|, |Vf(-45, θ)|), 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 <= 359638.026

bw*d = $\frac{Vs + Vf}{4} = 125663.706$

displacement_ductility_demand is calculated as $\frac{V_s}{V_y}$

- Calculation of $\frac{V_s}{V_y}$ for END A -
for rotation axis 2 and integ. section (a)

From analysis, chord rotation $\theta = 8.9164805E-021$

y = (My*Ls/3)/Eleff = 0.00946974 ((4.29), Biskinis Phd)

My = 4.4260E+008

Ls = M/V (with Ls > 0.1*L and Ls < 2*L) = 1500.00

From table 10.5, ASCE 41_17: Eleff = factor*Ec*Ig = 2.3369E+013

factor = 0.30

Ag = 196349.541

Mean concrete strength: fc' = (fc'_jacket*Area_jacket + fc'_core*Area_core)/Area_section = 27.84

N = 7387.347

Ec*Ig = Ec_jacket*Ig_jacket + Ec_core*Ig_core = 7.7898E+013

Calculation of Yielding Moment My

Calculation of $\frac{V_s}{V_y}$ and My according to (7) - (8) in Biskinis and Fardis

My = Min(My_ten, My_com) = 4.4260E+008

y ((10a) or (10b)) = 1.3430729E-005

My_ten (8a) = 4.4260E+008

_ten (7a) = 65.19069

error of function (7a) = 0.00234593

My_com (8b) = 7.6083E+008

_com (7b) = 64.49917

error of function (7b) = -0.0073398

with ey = 0.003125

eco = 0.002

apl = 0.45 ((9c) in Biskinis and Fardis for FRP Wrap)

d1 = 44.00

R = 250.00

v = 0.0011297

N = 7387.347

Ac = 196349.541

= 0.29185858

with fc' ((12.3), ACI 440) = 33.3038

fc = 30.00

fl = 1.05384

k = 1

Effective FRP thickness, tf = NL*t*Cos(b1) = 1.016

efe ((12.5) and (12.7)) = 0.004

Ef = 64828.00

Calculation of ratio l_b/l_d

Adequate Lap Length: $l_b/l_d \geq 1$

End Of Calculation of Shear Capacity for element: column JCC1 of floor 1

At local axis: 3

Integration Section: (a)

Calculation No. 12

column C1, Floor 1

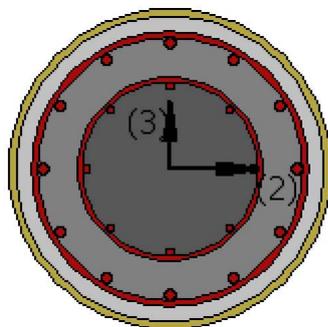
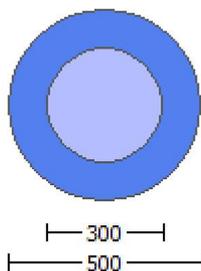
Limit State: Life Safety (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity (θ)

Edge: Start

Local Axis: (3)



Start Of Calculation of Shear Capacity ratio for element: column JCC1 of floor 1

At Shear local axis: 3

(Bending local axis: 2)

Section Type: rcjcs

Constant Properties

Knowledge Factor, $\gamma = 1.00$

Mean strength values are used for both shear and moment calculations.

Consequently:

Jacket

New material of Primary Member: Concrete Strength, $f_c = f_{cm} = 30.00$

New material of Primary Member: Steel Strength, $f_s = f_{sm} = 625.00$

Concrete Elasticity, $E_c = 25742.96$

Steel Elasticity, $E_s = 200000.00$

Existing Column

Existing material of Primary Member: Concrete Strength, $f_c = f_{cm} = 24.00$

Existing material of Primary Member: Steel Strength, $f_s = f_{sm} = 525.00$
Concrete Elasticity, $E_c = 23025.204$
Steel Elasticity, $E_s = 200000.00$

Note: Especially for the calculation of moment strengths,
the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14
Jacket
New material: Steel Strength, $f_s = 1.25 \cdot f_{sm} = 781.25$
Existing Column
Existing material: Steel Strength, $f_s = 1.25 \cdot f_{sm} = 656.25$

External Diameter, $D = 500.00$
Internal Diameter, $D = 300.00$
Cover Thickness, $c = 25.00$
Mean Confinement Factor overall section = 1.50688
Element Length, $L = 3000.00$
Primary Member
Smooth Bars
Ductile Steel
With Detailing for Earthquake Resistance (including stirrups closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
Adequate Lap Length ($l_o/l_{ou, min} > 1$)
FRP Wrapping Data
Type: Carbon
Cured laminate properties (design values)
Thickness, $t = 1.016$
Tensile Strength, $f_{fu} = 1055.00$
Tensile Modulus, $E_f = 64828.00$
Elongation, $e_{fu} = 0.01$
Number of directions, $N_{oDir} = 1$
Fiber orientations, $b_i: 0.00^\circ$
Number of layers, $N_L = 1$
Radius of rounding corners, $R = 40.00$

Stepwise Properties

At local axis: 3
EDGE -A-
Shear Force, $V_a = 4.1010657E-031$
EDGE -B-
Shear Force, $V_b = -4.1010657E-031$
BOTH EDGES
Axial Force, $F = -7389.214$
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: $A_{sl,t} = 0.00$
-Compression: $A_{sl,c} = 3053.628$
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension: $A_{sl,ten} = 1017.876$
-Compression: $A_{sl,com} = 1017.876$
-Middle: $A_{sl,mid} = 1017.876$

Calculation of Shear Capacity ratio, $V_e/V_r = 0.45961884$
Member Controlled by Flexure ($V_e/V_r < 1$)
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 298019.298$
with
 $M_{pr1} = \text{Max}(M_{u1+}, M_{u1-}) = 4.4703E+008$
 $M_{u1+} = 4.4703E+008$, is the ultimate moment strength at the edge 1 of the member in the actual moment direction
which is defined for the static loading combination
 $M_{u1-} = 4.4703E+008$, is the ultimate moment strength at the edge 1 of the member in the opposite moment
direction which is defined for the static loading combination
 $M_{pr2} = \text{Max}(M_{u2+}, M_{u2-}) = 4.4703E+008$
 $M_{u2+} = 4.4703E+008$, is the ultimate moment strength at the edge 2 of the member in the actual moment direction
which is defined for the the static loading combination

Mu2- = 4.4703E+008, is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the the static loading combination

Calculation of Mu1+

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), Mu
Mu = 4.4703E+008

= 0.97738438
' = 0.86668818
error of function (3.68), Biskinis Phd = 40566.604
From 5A.2, TBDY: fcc = fc* c = 45.20626
conf. factor c = 1.50688
fc = 30.00
From 10.3.5, ASCE 41-17, Final value of fy: fy*Min(1,1.25*(lb/d)^ 2/3) = 781.25
lb/d = 1.00
d1 = 44.00
R = 250.00
v = 0.00112412
N = 7389.214
Ac = 196349.541
= *Min(1,1.25*(lb/d)^ 2/3) = 0.36292832

Calculation of ratio lb/d

Adequate Lap Length: lb/d >= 1

Calculation of Mu1-

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), Mu
Mu = 4.4703E+008

= 0.97738438
' = 0.86668818
error of function (3.68), Biskinis Phd = 40566.604
From 5A.2, TBDY: fcc = fc* c = 45.20626
conf. factor c = 1.50688
fc = 30.00
From 10.3.5, ASCE 41-17, Final value of fy: fy*Min(1,1.25*(lb/d)^ 2/3) = 781.25
lb/d = 1.00
d1 = 44.00
R = 250.00
v = 0.00112412
N = 7389.214
Ac = 196349.541
= *Min(1,1.25*(lb/d)^ 2/3) = 0.36292832

Calculation of ratio lb/d

Adequate Lap Length: lb/d >= 1

Calculation of Mu2+

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), Mu

$$\mu = 4.4703E+008$$

$$= 0.97738438$$

$$\lambda = 0.86668818$$

error of function (3.68), Biskinis Phd = 40566.604

From 5A.2, TBDY: $f_{cc} = f_c \cdot c = 45.20626$

conf. factor $c = 1.50688$

$$f_c = 30.00$$

From 10.3.5, ASCE 41-17, Final value of f_y : $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 781.25$

$$l_b/d = 1.00$$

$$d_1 = 44.00$$

$$R = 250.00$$

$$v = 0.00112412$$

$$N = 7389.214$$

$$A_c = 196349.541$$

$$= \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.36292832$$

Calculation of ratio l_b/d

Adequate Lap Length: $l_b/d \geq 1$

Calculation of μ_2

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), μ

$$\mu = 4.4703E+008$$

$$= 0.97738438$$

$$\lambda = 0.86668818$$

error of function (3.68), Biskinis Phd = 40566.604

From 5A.2, TBDY: $f_{cc} = f_c \cdot c = 45.20626$

conf. factor $c = 1.50688$

$$f_c = 30.00$$

From 10.3.5, ASCE 41-17, Final value of f_y : $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 781.25$

$$l_b/d = 1.00$$

$$d_1 = 44.00$$

$$R = 250.00$$

$$v = 0.00112412$$

$$N = 7389.214$$

$$A_c = 196349.541$$

$$= \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.36292832$$

Calculation of ratio l_b/d

Adequate Lap Length: $l_b/d \geq 1$

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 648405.308$

Calculation of Shear Strength at edge 1, $V_{r1} = 648405.308$

$V_{r1} = V_{Co1}$ ((10.3), ASCE 41-17) = $k_{nl} \cdot V_{Co10}$

$$V_{Co10} = 648405.308$$

$k_{nl} = 1$ (zero step-static loading)

NOTE: In expression (10-3) ' $V_s = A_v \cdot f_y \cdot d/s$ ' is replaced by ' $V_{s+} = f \cdot V_f$ '

where V_f is the contribution of FRPs (11.3), ACI 440).

$f = 1$ (normal-weight concrete)

Mean concrete strength: $f_c' = (f_c'_{\text{jacket}} \cdot \text{Area}_{\text{jacket}} + f_c'_{\text{core}} \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 27.84$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$
 $\mu_u = 2.1425332E-011$
 $V_u = 4.1010657E-031$
 $d = 0.8 \cdot D = 400.00$
 $N_u = 7389.214$
 $A_g = 196349.541$
 From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 308425.138$
 $V_{s1} = 308425.138$ is calculated for jacket, with:
 $A_v = \sqrt{2} \cdot A_{stirrup} = 123370.055$
 $f_y = 625.00$
 $s = 100.00$
 V_{s1} is multiplied by $Col1 = 1.00$
 $s/d = 0.25$
 $V_{s2} = 0.00$ is calculated for core, with:
 $A_v = \sqrt{2} \cdot A_{stirrup} = 78956.835$
 $f_y = 525.00$
 $s = 250.00$
 V_{s2} is multiplied by $Col2 = 0.00$
 $s/d = 1.04167$
 V_f ((11-3)-(11.4), ACI 440) = 247653.332
 $f = 0.95$, for fully-wrapped sections
 $w_f/s_f = 1$ (FRP strips adjacent to one another).
 In (11.3) $\sin \theta + \cos \theta$ is replaced with $(\cot \theta + \csc \theta) \sin \alpha$ which is more a generalised expression,
 where θ is the angle of the crack direction (see KANEPE).
 This later relation, considered as a function $V_f(\theta, \alpha)$, is implemented for every different fiber orientation α_i ,
 as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.
 orientation 1: $\theta = 45^\circ$
 $V_f = \text{Min}(|V_f(45, \alpha_1)|, |V_f(-45, \alpha_1)|)$, 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: $V_s + V_f \leq 440464.828$
 $b_w \cdot d = \sqrt{4} \cdot V_s = 125663.706$

Calculation of Shear Strength at edge 2, $V_{r2} = 648405.308$
 $V_{r2} = V_{Col}$ ((10.3), ASCE 41-17) = $k_{nl} \cdot V_{Col0}$
 $V_{Col0} = 648405.308$
 $k_{nl} = 1$ (zero step-static loading)

NOTE: In expression (10-3) ' $V_s = A_v \cdot f_y \cdot d / s$ ' is replaced by ' $V_s + f \cdot V_f$ '
 where V_f is the contribution of FRPs ((11.3), ACI 440).

$\lambda = 1$ (normal-weight concrete)
 Mean concrete strength: $f_c' = (f_c'_{jacket} \cdot Area_{jacket} + f_c'_{core} \cdot Area_{core}) / Area_{section} = 27.84$, but $f_c'^{0.5} \leq 8.3$
 MPa (22.5.3.1, ACI 318-14)
 $M/Vd = 2.00$
 $\mu_u = 2.1425332E-011$
 $V_u = 4.1010657E-031$
 $d = 0.8 \cdot D = 400.00$
 $N_u = 7389.214$
 $A_g = 196349.541$
 From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 308425.138$
 $V_{s1} = 308425.138$ is calculated for jacket, with:
 $A_v = \sqrt{2} \cdot A_{stirrup} = 123370.055$
 $f_y = 625.00$
 $s = 100.00$
 V_{s1} is multiplied by $Col1 = 1.00$
 $s/d = 0.25$
 $V_{s2} = 0.00$ is calculated for core, with:
 $A_v = \sqrt{2} \cdot A_{stirrup} = 78956.835$
 $f_y = 525.00$
 $s = 250.00$
 V_{s2} is multiplied by $Col2 = 0.00$

$$s/d = 1.04167$$

$$V_f((11-3)-(11.4), \text{ACI 440}) = 247653.332$$

$$f = 0.95, \text{ for fully-wrapped sections}$$

$$w_f/s_f = 1 \text{ (FRP strips adjacent to one another).}$$

In (11.3) $\sin + \cos$ is replaced with $(\cot + \cot\alpha)\sin\alpha$ which is more a generalised expression, where α is the angle of the crack direction (see KANEPE).

This later relation, considered as a function $V_f(\alpha)$, is implemented for every different fiber orientation α_i , as well as for 2 crack directions, $\alpha = 45^\circ$ and $\alpha = -45^\circ$ to take into consideration the cyclic seismic loading.

$$\text{orientation 1: } \alpha = b1 + 90^\circ = 90.00$$

$$V_f = \text{Min}(|V_f(45, 1)|, |V_f(-45, a1)|), \text{ with:}$$

$$\text{total thickness per orientation, } t_{f1} = NL * t / \text{NoDir} = 1.016$$

$$d_{fv} = d \text{ (figure 11.2, ACI 440)} = 470.00$$

$$f_{fe}((11-5), \text{ACI 440}) = 259.312$$

$$E_f = 64828.00$$

$$f_e = 0.004, \text{ from (11.6a), ACI 440}$$

$$\text{with } f_u = 0.01$$

$$\text{From (11-11), ACI 440: } V_s + V_f \leq 440464.828$$

$$b_w * d = \frac{A_s * d}{4} = 125663.706$$

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

$$\text{Knowledge Factor, } \phi = 1.00$$

Mean strength values are used for both shear and moment calculations.

Consequently:

Jacket

$$\text{New material of Primary Member: Concrete Strength, } f_c = f_{cm} = 30.00$$

$$\text{New material of Primary Member: Steel Strength, } f_s = f_{sm} = 625.00$$

$$\text{Concrete Elasticity, } E_c = 25742.96$$

$$\text{Steel Elasticity, } E_s = 200000.00$$

Existing Column

$$\text{Existing material of Primary Member: Concrete Strength, } f_c = f_{cm} = 24.00$$

$$\text{Existing material of Primary Member: Steel Strength, } f_s = f_{sm} = 525.00$$

$$\text{Concrete Elasticity, } E_c = 23025.204$$

$$\text{Steel Elasticity, } E_s = 200000.00$$

#####

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

$$\text{New material: Steel Strength, } f_s = 1.25 * f_{sm} = 781.25$$

Existing Column

$$\text{Existing material: Steel Strength, } f_s = 1.25 * f_{sm} = 656.25$$

#####

$$\text{External Diameter, } D = 500.00$$

$$\text{Internal Diameter, } D = 300.00$$

$$\text{Cover Thickness, } c = 25.00$$

$$\text{Mean Confinement Factor overall section} = 1.50688$$

$$\text{Element Length, } L = 3000.00$$

Primary Member

Smooth Bars

Ductile Steel

With Detailing for Earthquake Resistance (including stirrups closed at 135°)

Longitudinal Bars With Ends Lapped Starting at the End Sections

Adequate Lap Length ($l_o/l_{ou, \min} \geq 1$)

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $e_{fu} = 0.01$

Number of directions, $NoDir = 1$

Fiber orientations, $b_i = 0.00^\circ$

Number of layers, $NL = 1$

Radius of rounding corners, $R = 40.00$

Stepwise Properties

At local axis: 2

EDGE -A-

Shear Force, $V_a = -2.5110955E-047$

EDGE -B-

Shear Force, $V_b = 2.5110955E-047$

BOTH EDGES

Axial Force, $F = -7389.214$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: $As_t = 0.00$

-Compression: $As_c = 3053.628$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension: $As_{t,ten} = 1017.876$

-Compression: $As_{l,com} = 1017.876$

-Middle: $As_{l,mid} = 1017.876$

Calculation of Shear Capacity ratio, $V_e/V_r = 0.45961884$

Member Controlled by Flexure ($V_e/V_r < 1$)

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 298019.298$

with

$M_{pr1} = \text{Max}(Mu_{1+}, Mu_{1-}) = 4.4703E+008$

$Mu_{1+} = 4.4703E+008$, is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination

$Mu_{1-} = 4.4703E+008$, is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination

$M_{pr2} = \text{Max}(Mu_{2+}, Mu_{2-}) = 4.4703E+008$

$Mu_{2+} = 4.4703E+008$, is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the the static loading combination

$Mu_{2-} = 4.4703E+008$, is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the the static loading combination

Calculation of Mu_{1+}

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), Mu

$Mu = 4.4703E+008$

= 0.97738438

' = 0.86668818

error of function (3.68), Biskinis Phd = 40566.604

From 5A.2, TBDY: $f_{cc} = f_c^* c = 45.20626$

conf. factor $c = 1.50688$

$f_c = 30.00$

From 10.3.5, ASCE 41-17, Final value of f_y : $f_y * \text{Min}(1, 1.25 * (l_b/d)^{2/3}) = 781.25$

$l_b/d = 1.00$

$d_1 = 44.00$

$R = 250.00$

$v = 0.00112412$

$N = 7389.214$

$Ac = 196349.541$

$$= \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.36292832$$

Calculation of ratio l_b/d

Adequate Lap Length: $l_b/d \geq 1$

Calculation of μ_{1-}

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), μ
 $\mu = 4.4703E+008$

$$= 0.97738438$$

$$\lambda = 0.86668818$$

error of function (3.68), Biskinis Phd = 40566.604

From 5A.2, TBDY: $f_{cc} = f_c \cdot c = 45.20626$

conf. factor $c = 1.50688$

$f_c = 30.00$

From 10.3.5, ASCE 41-17, Final value of f_y : $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 781.25$

$$l_b/d = 1.00$$

$$d_1 = 44.00$$

$$R = 250.00$$

$$v = 0.00112412$$

$$N = 7389.214$$

$$A_c = 196349.541$$

$$= \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.36292832$$

Calculation of ratio l_b/d

Adequate Lap Length: $l_b/d \geq 1$

Calculation of μ_{2+}

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), μ
 $\mu = 4.4703E+008$

$$= 0.97738438$$

$$\lambda = 0.86668818$$

error of function (3.68), Biskinis Phd = 40566.604

From 5A.2, TBDY: $f_{cc} = f_c \cdot c = 45.20626$

conf. factor $c = 1.50688$

$f_c = 30.00$

From 10.3.5, ASCE 41-17, Final value of f_y : $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 781.25$

$$l_b/d = 1.00$$

$$d_1 = 44.00$$

$$R = 250.00$$

$$v = 0.00112412$$

$$N = 7389.214$$

$$A_c = 196349.541$$

$$= \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.36292832$$

Calculation of ratio l_b/d

Adequate Lap Length: $l_b/d \geq 1$

Calculation of Mu2-

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), Mu
Mu = 4.4703E+008

$$= 0.97738438$$

$$' = 0.86668818$$

error of function (3.68), Biskinis Phd = 40566.604

From 5A.2, TBDY: $f_{cc} = f_c \cdot c = 45.20626$

$$\text{conf. factor } c = 1.50688$$

$$f_c = 30.00$$

From 10.3.5, ASCE 41-17, Final value of fy: $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 781.25$

$$l_b/d = 1.00$$

$$d1 = 44.00$$

$$R = 250.00$$

$$v = 0.00112412$$

$$N = 7389.214$$

$$A_c = 196349.541$$

$$= \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.36292832$$

Calculation of ratio lb/d

Adequate Lap Length: $l_b/d \geq 1$

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 648405.308$

Calculation of Shear Strength at edge 1, $V_{r1} = 648405.308$

$V_{r1} = V_{Col}$ ((10.3), ASCE 41-17) = $k_{nl} \cdot V_{Col0}$

$$V_{Col0} = 648405.308$$

$$k_{nl} = 1 \text{ (zero step-static loading)}$$

NOTE: In expression (10-3) ' $V_s = A_v \cdot f_y \cdot d/s$ ' is replaced by ' $V_s + f \cdot V_f$ ' where V_f is the contribution of FRPs (11.3), ACI 440).

$$= 1 \text{ (normal-weight concrete)}$$

Mean concrete strength: $f_c' = (f_c'_{jacket} \cdot \text{Area}_{jacket} + f_c'_{core} \cdot \text{Area}_{core}) / \text{Area}_{section} = 27.84$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$$M/d = 2.00$$

$$Mu = 2.0093280E-011$$

$$Vu = 2.5110955E-047$$

$$d = 0.8 \cdot D = 400.00$$

$$Nu = 7389.214$$

$$Ag = 196349.541$$

From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 308425.138$

$V_{s1} = 308425.138$ is calculated for jacket, with:

$$A_v = \sqrt{2} \cdot A_{stirrup} = 123370.055$$

$$f_y = 625.00$$

$$s = 100.00$$

V_{s1} is multiplied by $Col1 = 1.00$

$$s/d = 0.25$$

$V_{s2} = 0.00$ is calculated for core, with:

$$A_v = \sqrt{2} \cdot A_{stirrup} = 78956.835$$

$$f_y = 525.00$$

$$s = 250.00$$

V_{s2} is multiplied by $Col2 = 0.00$

$$s/d = 1.04167$$

V_f ((11-3)-(11.4), ACI 440) = 247653.332

$$f = 0.95, \text{ for fully-wrapped sections}$$

$w_f/s_f = 1$ (FRP strips adjacent to one another).

In (11.3) $\sin \theta + \cos \theta$ is replaced with $(\cot \theta + \cot \alpha) \sin \alpha$ which is more a generalised expression, where θ is the angle of the crack direction (see KANEPE).

This later relation, considered as a function $V_f(\theta)$, is implemented for every different fiber orientation θ_i , as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.

orientation 1: $\theta = 90^\circ = 90.00$

$V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, \theta)|)$, 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: $V_s + V_f \leq 440464.828$

$b_w \cdot d = \frac{1}{4} \cdot d^2 = 125663.706$

Calculation of Shear Strength at edge 2, $V_{r2} = 648405.308$

$V_{r2} = V_{Co1}$ ((10.3), ASCE 41-17) = $k_{nl} \cdot V_{Co10}$

$V_{Co10} = 648405.308$

$k_{nl} = 1$ (zero step-static loading)

NOTE: In expression (10-3) ' $V_s = A_v \cdot f_y \cdot d / s$ ' is replaced by ' $V_s + f \cdot V_f$ ' where V_f is the contribution of FRPs (11.3), ACI 440).

$\lambda = 1$ (normal-weight concrete)

Mean concrete strength: $f_c' = (f_c'_{\text{jacket}} \cdot \text{Area}_{\text{jacket}} + f_c'_{\text{core}} \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 27.84$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M / Vd = 2.00$

$\mu_u = 2.0093280E-011$

$\nu_u = 2.5110955E-047$

$d = 0.8 \cdot D = 400.00$

$N_u = 7389.214$

$A_g = 196349.541$

From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 308425.138$

$V_{s1} = 308425.138$ is calculated for jacket, with:

$A_v = \frac{1}{2} \cdot A_{\text{stirrup}} = 123370.055$

$f_y = 625.00$

$s = 100.00$

V_{s1} is multiplied by $Col1 = 1.00$

$s/d = 0.25$

$V_{s2} = 0.00$ is calculated for core, with:

$A_v = \frac{1}{2} \cdot A_{\text{stirrup}} = 78956.835$

$f_y = 525.00$

$s = 250.00$

V_{s2} is multiplied by $Col2 = 0.00$

$s/d = 1.04167$

V_f ((11-3)-(11.4), ACI 440) = 247653.332

$f = 0.95$, for fully-wrapped sections

$w_f / s_f = 1$ (FRP strips adjacent to one another).

In (11.3) $\sin \theta + \cos \theta$ is replaced with $(\cot \theta + \csc \theta) \sin \alpha$ which is more a generalised expression,

where θ is the angle of the crack direction (see KANEPE).

This later relation, considered as a function $V_f(\theta)$, is implemented for every different fiber orientation θ_i , as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.

orientation 1: $\theta = 90^\circ = 90.00$

$V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, \theta)|)$, 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: $V_s + V_f \leq 440464.828$

$b_w \cdot d = \frac{1}{4} \cdot d^2 = 125663.706$

End Of Calculation of Shear Capacity ratio for element: column JCC1 of floor 1

At local axis: 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, $k = 1.00$

Chord Rotation is generally considered as Deformation-Controlled Action according to Table C7-1, ASCE 41-17.

Mean strengths are used for Deformation-Controlled Actions according to 7.5.1.3, ASCE 41-17

Consequently:

Jacket

New material of Primary Member: Concrete Strength, $f_c = f_{cm} = 30.00$

New material of Primary Member: Steel Strength, $f_s = f_{sm} = 625.00$

Concrete Elasticity, $E_c = 25742.96$

Steel Elasticity, $E_s = 200000.00$

Existing Column

Existing material of Primary Member: Concrete Strength, $f_c = f_{cm} = 24.00$

Existing material of Primary Member: Steel Strength, $f_s = f_{sm} = 525.00$

Concrete Elasticity, $E_c = 23025.204$

Steel Elasticity, $E_s = 200000.00$

External Diameter, $D = 500.00$

Internal Diameter, $D = 300.00$

Cover Thickness, $c = 25.00$

Element Length, $L = 3000.00$

Primary Member

Smooth Bars

Ductile Steel

With Detailing for Earthquake Resistance (including stirrups closed at 135°)

Longitudinal Bars With Ends Lapped Starting at the End Sections

Adequate Lap Length ($l_b/d >= 1$)

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $e_{fu} = 0.01$

Number of directions, $N_{oDir} = 1$

Fiber orientations, $b_i = 0.00^\circ$

Number of layers, $N_L = 1$

Radius of rounding corners, $R = 40.00$

Stepwise Properties

Bending Moment, $M = -1.4007E+007$

Shear Force, $V_2 = -4667.709$

Shear Force, $V_3 = -1.6819047E-013$

Axial Force, $F = -7387.347$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: $A_{sl,t} = 0.00$

-Compression: $A_{sl,c} = 3053.628$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension: $A_{sl,ten} = 1017.876$

-Compression: $A_{sl,com} = 1017.876$

-Middle: $A_{sl,mid} = 1017.876$

Mean Diameter of Tension Reinforcement, $D_{bL} = 18.00$

Existing component: From table 7-7, ASCE 41_17: Final chord rotation Capacity $u_{,R} = * u = 0.06937825$

$u = y + p = 0.06937825$

- Calculation of ρ_y -

$$\rho_y = (M_y * L_s / 3) / E_{eff} = 0.0189444 \text{ ((4.29), Biskinis Phd)}$$

$$M_y = 4.4260E+008$$

$$L_s = M/V \text{ (with } L_s > 0.1 * L \text{ and } L_s < 2 * L) = 3000.779$$

$$\text{From table 10.5, ASCE 41_17: } E_{eff} = \text{factor} * E_c * I_g = 2.3369E+013$$

$$\text{factor} = 0.30$$

$$A_g = 196349.541$$

$$\text{Mean concrete strength: } f_c' = (f_c'_{\text{jacket}} * A_{\text{jacket}} + f_c'_{\text{core}} * A_{\text{core}}) / A_{\text{section}} = 27.84$$

$$N = 7387.347$$

$$E_c * I_g = E_{c_{\text{jacket}}} * I_{g_{\text{jacket}}} + E_{c_{\text{core}}} * I_{g_{\text{core}}} = 7.7898E+013$$

Calculation of Yielding Moment M_y

Calculation of ρ_y and M_y according to (7) - (8) in Biskinis and Fardis

$$M_y = \text{Min}(M_{y_{\text{ten}}}, M_{y_{\text{com}}}) = 4.4260E+008$$

$$\rho_y \text{ ((10a) or (10b))} = 1.3430729E-005$$

$$M_{y_{\text{ten}}} \text{ (8a)} = 4.4260E+008$$

$$\rho_{y_{\text{ten}}} \text{ (7a)} = 65.19069$$

$$\text{error of function (7a)} = 0.00234593$$

$$M_{y_{\text{com}}} \text{ (8b)} = 7.6083E+008$$

$$\rho_{y_{\text{com}}} \text{ (7b)} = 64.49917$$

$$\text{error of function (7b)} = -0.0073398$$

$$\text{with } e_y = 0.003125$$

$$e_{c0} = 0.002$$

$$a_{pl} = 0.45 \text{ ((9c) in Biskinis and Fardis for FRP Wrap)}$$

$$d_1 = 44.00$$

$$R = 250.00$$

$$v = 0.0011297$$

$$N = 7387.347$$

$$A_c = 196349.541$$

$$= 0.29185858$$

$$\text{with } f_c' \text{ ((12.3), ACI 440)} = 33.3038$$

$$f_c = 30.00$$

$$f_l = 1.05384$$

$$k = 1$$

$$\text{Effective FRP thickness, } t_f = N L * t * \text{Cos}(b_1) = 1.016$$

$$e_{fe} \text{ ((12.5) and (12.7))} = 0.004$$

$$E_f = 64828.00$$

Calculation of ratio l_b/d

Adequate Lap Length: $l_b/d \geq 1$

- Calculation of ρ_p -

$$\text{From table 10-9: } \rho_p = 0.05043385$$

with:

- Columns not controlled by inadequate development or splicing along the clear height because $l_b/d \geq 1$

$$\text{shear control ratio } V_y E / V_{Co} I_{OE} = 0.45961884$$

$$d = d_{\text{external}} = 0.00$$

$$s = s_{\text{external}} = 0.00$$

$$t = s_1 + s_2 + 2 * t_f / b_w * (f_{fe} / f_s) = 0.00660658$$

$$\text{jacket: } s_1 = A_{v1} * (D_{c1} / 2) / (s_1 * A_g) = 0.0027646$$

$$A_{v1} = 78.53982, \text{ is the area of stirrup}$$

$$D_{c1} = D_{\text{ext}} - 2 * \text{cover} - \text{External Hoop Diameter} = 440.00, \text{ is the total Length of all stirrups parallel to loading}$$

(shear) direction

$$s_1 = 100.00$$

$$\text{core: } s_2 = A_{v2} * (D_{c2} / 2) / (s_2 * A_g) = 0.00046968$$

$$A_{v2} = 50.26548, \text{ is the area of stirrup}$$

$$D_{c2} = D_{\text{int}} - \text{Internal Hoop Diameter} = 292.00, \text{ is the total Length of all stirrups parallel to loading (shear)}$$

direction

$$s_2 = 250.00$$

The term $2 \cdot t_f / b_w \cdot (f_{fe} / f_s)$ is implemented to account for FRP contribution where $f = 2 \cdot t_f / b_w$ is FRP ratio (EC8 - 3, A.4.4.3(6)) and f_{fe} / f_s normalises f to steel strength. All these variables have already been given in Shear control ratio calculation.

For the normalisation f_s of jacket is used.

$$N_{UD} = 7387.347$$

$$A_g = 196349.541$$

$$f_{cE} = (f_{c_jacket} \cdot Area_{jacket} + f_{c_core} \cdot Area_{core}) / section_area = 27.84$$

$$f_{yIE} = (f_{y_ext_Long_Reinf} \cdot Area_{ext_Long_Reinf} + f_{y_int_Long_Reinf} \cdot Area_{int_Long_Reinf}) / Area_{Tot_Long_Rein} = 2.1219958E-314$$

$$f_{yTE} = (f_{y_ext_Trans_Reinf} \cdot Area_{ext_Trans_Reinf} + f_{y_int_Trans_Reinf} \cdot Area_{int_Trans_Reinf}) / Area_{Tot_Trans_Rein} = 610.4781$$

$$\rho_l = Area_{Tot_Long_Rein} / (A_g) = 0.015552$$

$$f_{cE} = 27.84$$

End Of Calculation of Chord Rotation Capacity for element: column JCC1 of floor 1

At local axis: 3

Integration Section: (a)

Calculation No. 13

column C1, Floor 1

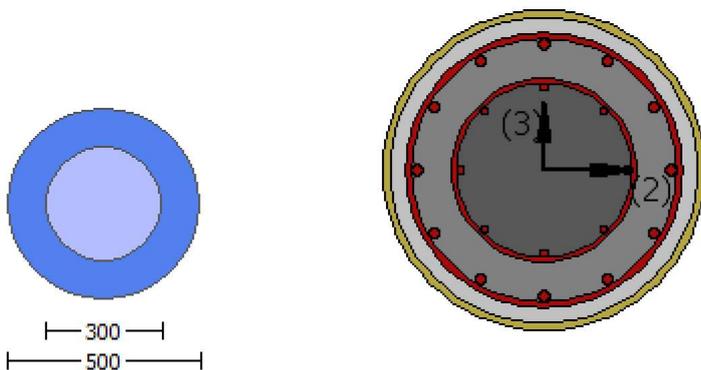
Limit State: Life Safety (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Shear capacity V_{Rd}

Edge: End

Local Axis: (2)



Start Of Calculation of Shear Capacity for element: column JCC1 of floor 1

At local axis: 2

Integration Section: (b)

Section Type: rcjcs

Constant Properties

```

Knowledge Factor,  $\gamma = 1.00$ 
Member Shear Force is generally considered as Force-Controlled Action according to Table C7-1, ASCE 41-17.
Lower-bound strengths are used for Force-Controlled Actions according to 7.5.1.3, ASCE 41-17
Consequently:
Jacket
New material of Primary Member: Concrete Strength,  $f_c = f_{c\_lower\_bound} = 20.00$ 
New material of Primary Member: Steel Strength,  $f_s = f_{s\_lower\_bound} = 500.00$ 
Concrete Elasticity,  $E_c = 25742.96$ 
Steel Elasticity,  $E_s = 200000.00$ 
Existing Column
Existing material of Primary Member: Concrete Strength,  $f_c = f_{c\_lower\_bound} = 16.00$ 
Existing material of Primary Member: Steel Strength,  $f_s = f_{s\_lower\_bound} = 420.00$ 
Concrete Elasticity,  $E_c = 23025.204$ 
Steel Elasticity,  $E_s = 200000.00$ 
#####
Note: Especially for the calculation of  $\gamma$  for displacement ductility demand,
the expected (mean value) strengths are used (7.5.1.3, ASCE 41-17) because bending is considered as
Deformation-Controlled Action (Table C7-1, ASCE 41-17).
Jacket
New material: Concrete Strength,  $f_c = f_{cm} = 30.00$ 
New material: Steel Strength,  $f_s = f_{sm} = 625.00$ 
Existing Column
Existing material: Concrete Strength,  $f_c = f_{cm} = 24.00$ 
Existing material: Steel Strength,  $f_s = f_{sm} = 525.00$ 
#####
External Diameter,  $D = 500.00$ 
Internal Diameter,  $D = 300.00$ 
Cover Thickness,  $c = 25.00$ 
Element Length,  $L = 3000.00$ 
Primary Member
Smooth Bars
Ductile Steel
With Detailing for Earthquake Resistance (including stirrups closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
Adequate Lap Length ( $l_o/l_{ou,min} = l_b/l_d \geq 1$ )
FRP Wrapping Data
Type: Carbon
Cured laminate properties (design values)
Thickness,  $t = 1.016$ 
Tensile Strength,  $f_{fu} = 1055.00$ 
Tensile Modulus,  $E_f = 64828.00$ 
Elongation,  $e_{fu} = 0.01$ 
Number of directions,  $NoDir = 1$ 
Fiber orientations,  $b_i: 0.00^\circ$ 
Number of layers,  $NL = 1$ 
Radius of rounding corners,  $R = 40.00$ 
-----

Stepwise Properties
-----
EDGE -A-
Bending Moment,  $M_a = -1.4007E+007$ 
Shear Force,  $V_a = -4667.709$ 
EDGE -B-
Bending Moment,  $M_b = 0.10299595$ 
Shear Force,  $V_b = 4667.709$ 
BOTH EDGES
Axial Force,  $F = -7387.347$ 
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension:  $As_t = 0.00$ 
-Compression:  $As_c = 3053.628$ 
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension:  $As_{l,ten} = 1017.876$ 
-Compression:  $As_{l,com} = 1017.876$ 
-Middle:  $As_{l,mid} = 1017.876$ 
Mean Diameter of Tension Reinforcement,  $Db_{L,ten} = 18.00$ 
-----

```

Existing component: From table 7-7, ASCE 41_17: Final Shear Capacity $V_R = V_n = 529689.402$
 V_n ((10.3), ASCE 41-17) = $k_n V_{CoI} = 529689.402$
 $V_{CoI} = 529689.402$
 $k_n = 1.00$
displacement_ductility_demand = 0.04746465

NOTE: In expression (10-3) ' $V_s = A_v f_y d/s$ ' is replaced by ' $V_s + f V_f$ '
where V_f is the contribution of FRPs (11.3), ACI 440).

= 1 (normal-weight concrete)
Mean concrete strength: $f'_c = (f'_{c_jacket} \text{Area}_{jacket} + f'_{c_core} \text{Area}_{core}) / \text{Area}_{section} = 18.56$, but $f'_c^{0.5} \leq 8.3$
MPa (22.5.3.1, ACI 318-14)
 $M/Vd = 2.00$
 $\mu_u = 0.10299595$
 $V_u = 4667.709$
 $d = 0.8 \cdot D = 400.00$
 $N_u = 7387.347$
 $A_g = 196349.541$
From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 246740.11$
 $V_{s1} = 246740.11$ is calculated for jacket, with:
 $A_v = \sqrt{2} A_{stirrup} = 123370.055$
 $f_y = 500.00$
 $s = 100.00$
 V_{s1} is multiplied by $Col1 = 1.00$
 $s/d = 0.25$
 $V_{s2} = 0.00$ is calculated for core, with:
 $A_v = \sqrt{2} A_{stirrup} = 78956.835$
 $f_y = 420.00$
 $s = 250.00$
 V_{s2} is multiplied by $Col2 = 0.00$
 $s/d = 1.04167$
 V_f ((11-3)-(11.4), ACI 440) = 247653.332
 $f = 0.95$, for fully-wrapped sections
 $w_f/s_f = 1$ (FRP strips adjacent to one another).
In (11.3) $\sin + \cos$ is replaced with $(\cot + \cot_a) \sin a$ which is more a generalised expression,
where a is the angle of the crack direction (see KANEPE).
This later relation, considered as a function $V_f(a)$, is implemented for every different fiber orientation a_i ,
as well as for 2 crack directions, $a = 45^\circ$ and $a = -45^\circ$ to take into consideration the cyclic seismic loading.
orientation 1: $a = b1 + 90^\circ = 90.00$
 $V_f = \text{Min}(|V_f(45, a)|, |V_f(-45, a)|)$, 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: $V_s + V_f \leq 359638.026$
 $b_w \cdot d = V_n \cdot d / 4 = 125663.706$

displacement_ductility_demand is calculated as δ / y

- Calculation of δ / y for END B -
for rotation axis 3 and integ. section (b)

From analysis, chord rotation $\theta = 8.9895615E-005$
 $y = (M_y \cdot L_s / 3) / E_{eff} = 0.00189395$ ((4.29), Biskinis Phd)
 $M_y = 4.4260E+008$
 $L_s = M/V$ (with $L_s > 0.1 \cdot L$ and $L_s < 2 \cdot L$) = 300.00
From table 10.5, ASCE 41_17: $E_{eff} = \text{factor} \cdot E_c \cdot I_g = 2.3369E+013$
factor = 0.30
 $A_g = 196349.541$
Mean concrete strength: $f'_c = (f'_{c_jacket} \text{Area}_{jacket} + f'_{c_core} \text{Area}_{core}) / \text{Area}_{section} = 27.84$

$$N = 7387.347$$
$$E_c \cdot I_g = E_{c_jacket} \cdot I_{g_jacket} + E_{c_core} \cdot I_{g_core} = 7.7898E+013$$

Calculation of Yielding Moment M_y

Calculation of ρ_y and M_y according to (7) - (8) in Biskinis and Fardis

$$M_y = \min(M_{y_ten}, M_{y_com}) = 4.4260E+008$$
$$\rho_y \text{ ((10a) or (10b))} = 1.3430729E-005$$
$$M_{y_ten} \text{ (8a)} = 4.4260E+008$$
$$\rho_{y_ten} \text{ (7a)} = 65.19069$$
$$\text{error of function (7a)} = 0.00234593$$
$$M_{y_com} \text{ (8b)} = 7.6083E+008$$
$$\rho_{y_com} \text{ (7b)} = 64.49917$$
$$\text{error of function (7b)} = -0.0073398$$

with $e_y = 0.003125$

$$e_{co} = 0.002$$
$$a_{pl} = 0.45 \text{ ((9c) in Biskinis and Fardis for FRP Wrap)}$$
$$d_1 = 44.00$$
$$R = 250.00$$
$$v = 0.0011297$$
$$N = 7387.347$$
$$A_c = 196349.541$$
$$= 0.29185858$$

with f_c^* ((12.3), ACI 440) = 33.3038

$$f_c = 30.00$$
$$f_l = 1.05384$$
$$k = 1$$
$$\text{Effective FRP thickness, } t_f = NL \cdot t \cdot \cos(b_1) = 1.016$$
$$e_{fe} \text{ ((12.5) and (12.7))} = 0.004$$
$$E_f = 64828.00$$

Calculation of ratio l_b/d

Adequate Lap Length: $l_b/d \geq 1$

End Of Calculation of Shear Capacity for element: column JCC1 of floor 1

At local axis: 2

Integration Section: (b)

Calculation No. 14

column C1, Floor 1

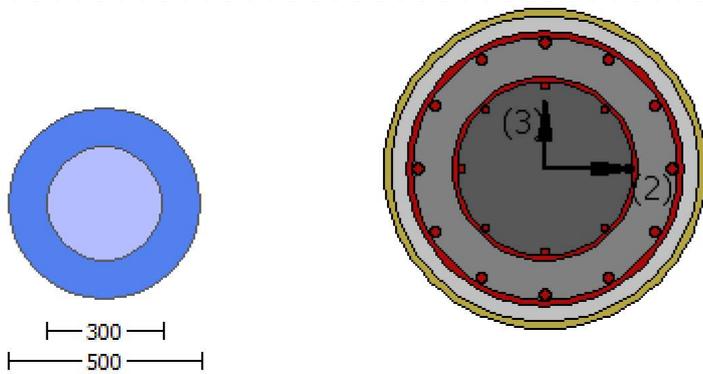
Limit State: Life Safety (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity (θ_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 Primary Member: Concrete Strength, $f_c = f_{cm} = 30.00$
 New material of Primary Member: Steel Strength, $f_s = f_{sm} = 625.00$
 Concrete Elasticity, $E_c = 25742.96$
 Steel Elasticity, $E_s = 200000.00$

Existing Column

Existing material of Primary Member: Concrete Strength, $f_c = f_{cm} = 24.00$
 Existing material of Primary Member: Steel Strength, $f_s = f_{sm} = 525.00$
 Concrete Elasticity, $E_c = 23025.204$
 Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,
 the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14

Jacket

New material: Steel Strength, $f_s = 1.25 \cdot f_{sm} = 781.25$

Existing Column

Existing material: Steel Strength, $f_s = 1.25 \cdot f_{sm} = 656.25$

#####

External Diameter, $D = 500.00$

Internal Diameter, $D = 300.00$

Cover Thickness, $c = 25.00$

Mean Confinement Factor overall section = 1.50688

Element Length, $L = 3000.00$

Primary Member

Smooth Bars

Ductile Steel

With Detailing for Earthquake Resistance (including stirrups closed at 135°)

Longitudinal Bars With Ends Lapped Starting at the End Sections

Adequate Lap Length ($l_o/l_{ou, \min} >= 1$)

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $e_{fu} = 0.01$

Number of directions, $NoDir = 1$

Fiber orientations, $b_i = 0.00^\circ$

Number of layers, $NL = 1$

Radius of rounding corners, $R = 40.00$

Stepwise Properties

At local axis: 3

EDGE -A-

Shear Force, $V_a = 4.1010657E-031$

EDGE -B-

Shear Force, $V_b = -4.1010657E-031$

BOTH EDGES

Axial Force, $F = -7389.214$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: $A_{st} = 0.00$

-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: $A_{s,mid} = 1017.876$

Calculation of Shear Capacity ratio, $V_e/V_r = 0.45961884$

Member Controlled by Flexure ($V_e/V_r < 1$)

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 298019.298$

with

$M_{pr1} = \text{Max}(M_{u1+}, M_{u1-}) = 4.4703E+008$

$M_{u1+} = 4.4703E+008$, is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination

$M_{u1-} = 4.4703E+008$, is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination

$M_{pr2} = \text{Max}(M_{u2+}, M_{u2-}) = 4.4703E+008$

$M_{u2+} = 4.4703E+008$, is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the the static loading combination

$M_{u2-} = 4.4703E+008$, is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the the static loading combination

Calculation of M_{u1+}

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), M_u

$M_u = 4.4703E+008$

$\phi = 0.97738438$

$\phi' = 0.86668818$

error of function (3.68), Biskinis Phd = 40566.604

From 5A.2, TBDY: $f_{cc} = f_c \cdot c = 45.20626$

conf. factor $c = 1.50688$

$f_c = 30.00$

From 10.3.5, ASCE 41-17, Final value of f_y : $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 781.25$

$l_b/d = 1.00$

$d_1 = 44.00$

$R = 250.00$

$v = 0.00112412$

$N = 7389.214$

$A_c = 196349.541$

$\phi' \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.36292832$

Calculation of ratio l_b/d

Adequate Lap Length: $l_b/d \geq 1$

Calculation of M_{u1-}

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), Mu

Mu = 4.4703E+008

= 0.97738438

' = 0.86668818

error of function (3.68), Biskinis Phd = 40566.604

From 5A.2, TBDY: $f_{cc} = f_c \cdot c = 45.20626$

conf. factor $c = 1.50688$

$f_c = 30.00$

From 10.3.5, ASCE 41-17, Final value of f_y : $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 781.25$

$l_b/d = 1.00$

$d_1 = 44.00$

$R = 250.00$

$v = 0.00112412$

$N = 7389.214$

$Ac = 196349.541$

= $\cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.36292832$

Calculation of ratio l_b/d

Adequate Lap Length: $l_b/d \geq 1$

Calculation of Mu2+

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), Mu

Mu = 4.4703E+008

= 0.97738438

' = 0.86668818

error of function (3.68), Biskinis Phd = 40566.604

From 5A.2, TBDY: $f_{cc} = f_c \cdot c = 45.20626$

conf. factor $c = 1.50688$

$f_c = 30.00$

From 10.3.5, ASCE 41-17, Final value of f_y : $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 781.25$

$l_b/d = 1.00$

$d_1 = 44.00$

$R = 250.00$

$v = 0.00112412$

$N = 7389.214$

$Ac = 196349.541$

= $\cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.36292832$

Calculation of ratio l_b/d

Adequate Lap Length: $l_b/d \geq 1$

Calculation of Mu2-

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), Mu

Mu = 4.4703E+008

= 0.97738438

' = 0.86668818

error of function (3.68), Biskinis Phd = 40566.604

From 5A.2, TBDY: $f_{cc} = f_c \cdot c = 45.20626$

conf. factor $c = 1.50688$

$f_c = 30.00$

From 10.3.5, ASCE 41-17, Final value of f_y : $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 781.25$

$l_b/d = 1.00$

$d_1 = 44.00$

$R = 250.00$

$v = 0.00112412$

$N = 7389.214$

$A_c = 196349.541$

$= \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.36292832$

Calculation of ratio l_b/d

Adequate Lap Length: $l_b/d \geq 1$

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 648405.308$

Calculation of Shear Strength at edge 1, $V_{r1} = 648405.308$

$V_{r1} = V_{\text{Col}} ((10.3), \text{ASCE 41-17}) = k_{n1} \cdot V_{\text{Col}0}$

$V_{\text{Col}0} = 648405.308$

$k_{n1} = 1$ (zero step-static loading)

NOTE: In expression (10-3) ' $V_s = A_v \cdot f_y \cdot d/s$ ' is replaced by ' $V_s + f \cdot V_f$ ' where V_f is the contribution of FRPs (11.3), ACI 440).

$= 1$ (normal-weight concrete)

Mean concrete strength: $f'_c = (f'_c \cdot \text{jacket} \cdot \text{Area}_{\text{jacket}} + f'_c \cdot \text{core} \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 27.84$, but $f_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/d = 2.00$

$\mu_u = 2.1425332E-011$

$\nu_u = 4.1010657E-031$

$d = 0.8 \cdot D = 400.00$

$N_u = 7389.214$

$A_g = 196349.541$

From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 308425.138$

$V_{s1} = 308425.138$ is calculated for jacket, with:

$A_v = \sqrt{2} \cdot A_{\text{stirrup}} = 123370.055$

$f_y = 625.00$

$s = 100.00$

V_{s1} is multiplied by $\text{Col}1 = 1.00$

$s/d = 0.25$

$V_{s2} = 0.00$ is calculated for core, with:

$A_v = \sqrt{2} \cdot A_{\text{stirrup}} = 78956.835$

$f_y = 525.00$

$s = 250.00$

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 θ is the angle of the crack direction (see KANEPE).

This later relation, considered as a function $V_f(\theta, \alpha)$, is implemented for every different fiber orientation α_i , as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.

orientation 1: $\theta = 45^\circ + 90^\circ = 135^\circ$

$V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, \alpha)|)$, 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: $V_s + V_f \leq 440464.828$

$$b_w*d = *d*d/4 = 125663.706$$

Calculation of Shear Strength at edge 2, $V_{r2} = 648405.308$

$$V_{r2} = V_{CoI} \text{ ((10.3), ASCE 41-17)} = k_n I * V_{CoI0}$$

$$V_{CoI0} = 648405.308$$

$k_n I = 1$ (zero step-static loading)

NOTE: In expression (10-3) ' $V_s = A_v * f_y * d / s$ ' is replaced by ' $V_s + f * V_f$ ' where V_f is the contribution of FRPs (11.3), ACI 440).

$= 1$ (normal-weight concrete)

Mean concrete strength: $f_c' = (f_c'_{jacket} * Area_{jacket} + f_c'_{core} * Area_{core}) / Area_{section} = 27.84$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$$M/Vd = 2.00$$

$$\mu_u = 2.1425332E-011$$

$$\nu_u = 4.1010657E-031$$

$$d = 0.8 * D = 400.00$$

$$N_u = 7389.214$$

$$A_g = 196349.541$$

From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 308425.138$

$V_{s1} = 308425.138$ is calculated for jacket, with:

$$A_v = /2 * A_{stirrup} = 123370.055$$

$$f_y = 625.00$$

$$s = 100.00$$

V_{s1} is multiplied by $Col1 = 1.00$

$$s/d = 0.25$$

$V_{s2} = 0.00$ is calculated for core, with:

$$A_v = /2 * A_{stirrup} = 78956.835$$

$$f_y = 525.00$$

$$s = 250.00$$

V_{s2} is multiplied by $Col2 = 0.00$

$$s/d = 1.04167$$

V_f ((11-3)-(11.4), ACI 440) = 247653.332

$f = 0.95$, for fully-wrapped sections

$w_f/s_f = 1$ (FRP strips adjacent to one another).

In (11.3) $\sin + \cos$ is replaced with $(\cot + \cot a) \sin a$ which is more a generalised expression, where θ is the angle of the crack direction (see KANEPE).

This later relation, considered as a function $V_f(\theta, a)$, is implemented for every different fiber orientation a_i , as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.

orientation 1: $\theta = b1 + 90^\circ = 90.00$

$V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, a1)|)$, with:

total thickness per orientation, $t_{f1} = N_L * t / N_{oDir} = 1.016$

$d_{fv} = d$ (figure 11.2, ACI 440) = 470.00

f_{fe} ((11-5), ACI 440) = 259.312

$$E_f = 64828.00$$

$$f_e = 0.004, \text{ from (11.6a), ACI 440}$$

$$\text{with } f_u = 0.01$$

From (11-11), ACI 440: $V_s + V_f \leq 440464.828$

$$b_w*d = *d*d/4 = 125663.706$$

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, $\phi = 1.00$

Mean strength values are used for both shear and moment calculations.

Consequently:

Jacket

New material of Primary Member: Concrete Strength, $f_c = f_{cm} = 30.00$

New material of Primary Member: Steel Strength, $f_s = f_{sm} = 625.00$

Concrete Elasticity, $E_c = 25742.96$

Steel Elasticity, $E_s = 200000.00$

Existing Column

Existing material of Primary Member: Concrete Strength, $f_c = f_{cm} = 24.00$

Existing material of Primary Member: Steel Strength, $f_s = f_{sm} = 525.00$

Concrete Elasticity, $E_c = 23025.204$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14

Jacket

New material: Steel Strength, $f_s = 1.25 \cdot f_{sm} = 781.25$

Existing Column

Existing material: Steel Strength, $f_s = 1.25 \cdot f_{sm} = 656.25$

#####

External Diameter, $D = 500.00$

Internal Diameter, $D = 300.00$

Cover Thickness, $c = 25.00$

Mean Confinement Factor overall section = 1.50688

Element Length, $L = 3000.00$

Primary Member

Smooth Bars

Ductile Steel

With Detailing for Earthquake Resistance (including stirrups closed at 135°)

Longitudinal Bars With Ends Lapped Starting at the End Sections

Adequate Lap Length ($l_o/l_{ou}, \min >= 1$)

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $e_{fu} = 0.01$

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, $V_a = -2.5110955E-047$

EDGE -B-

Shear Force, $V_b = 2.5110955E-047$

BOTH EDGES

Axial Force, $F = -7389.214$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: $A_{sl,t} = 0.00$

-Compression: $A_{sl,c} = 3053.628$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension: $A_{sl,ten} = 1017.876$

-Compression: $A_{sl,com} = 1017.876$

-Middle: $A_{sl,mid} = 1017.876$

Calculation of Shear Capacity ratio, $V_e/V_r = 0.45961884$

Member Controlled by Flexure ($V_e/V_r < 1$)

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 298019.298$

with

$$Mpr1 = \text{Max}(Mu1+, Mu1-) = 4.4703E+008$$

Mu1+ = 4.4703E+008, is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination

Mu1- = 4.4703E+008, is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination

$$Mpr2 = \text{Max}(Mu2+, Mu2-) = 4.4703E+008$$

Mu2+ = 4.4703E+008, is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the the static loading combination

Mu2- = 4.4703E+008, is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the the static loading combination

Calculation of Mu1+

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), Mu
Mu = 4.4703E+008

$$= 0.97738438$$

$$' = 0.86668818$$

error of function (3.68), Biskinis Phd = 40566.604

From 5A.2, TBDY: $f_{cc} = f_c \cdot c = 45.20626$

conf. factor $c = 1.50688$

$$f_c = 30.00$$

From 10.3.5, ASCE 41-17, Final value of f_y : $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 781.25$

$$l_b/d = 1.00$$

$$d1 = 44.00$$

$$R = 250.00$$

$$v = 0.00112412$$

$$N = 7389.214$$

$$A_c = 196349.541$$

$$= \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.36292832$$

Calculation of ratio l_b/d

Adequate Lap Length: $l_b/d \geq 1$

Calculation of Mu1-

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), Mu
Mu = 4.4703E+008

$$= 0.97738438$$

$$' = 0.86668818$$

error of function (3.68), Biskinis Phd = 40566.604

From 5A.2, TBDY: $f_{cc} = f_c \cdot c = 45.20626$

conf. factor $c = 1.50688$

$$f_c = 30.00$$

From 10.3.5, ASCE 41-17, Final value of f_y : $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 781.25$

$$l_b/d = 1.00$$

$$d1 = 44.00$$

$$R = 250.00$$

$$v = 0.00112412$$

$$N = 7389.214$$

$$A_c = 196349.541$$

$$= \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.36292832$$

Calculation of ratio l_b/d

Adequate Lap Length: $l_b/d \geq 1$

Calculation of Mu2+

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), Mu
Mu = 4.4703E+008

= 0.97738438
' = 0.86668818
error of function (3.68), Biskinis Phd = 40566.604
From 5A.2, TBDY: fcc = fc* c = 45.20626
conf. factor c = 1.50688
fc = 30.00
From 10.3.5, ASCE 41-17, Final value of fy: fy*Min(1,1.25*(lb/d)^ 2/3) = 781.25
lb/d = 1.00
d1 = 44.00
R = 250.00
v = 0.00112412
N = 7389.214
Ac = 196349.541
= *Min(1,1.25*(lb/d)^ 2/3) = 0.36292832

Calculation of ratio lb/d

Adequate Lap Length: lb/d >= 1

Calculation of Mu2-

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), Mu
Mu = 4.4703E+008

= 0.97738438
' = 0.86668818
error of function (3.68), Biskinis Phd = 40566.604
From 5A.2, TBDY: fcc = fc* c = 45.20626
conf. factor c = 1.50688
fc = 30.00
From 10.3.5, ASCE 41-17, Final value of fy: fy*Min(1,1.25*(lb/d)^ 2/3) = 781.25
lb/d = 1.00
d1 = 44.00
R = 250.00
v = 0.00112412
N = 7389.214
Ac = 196349.541
= *Min(1,1.25*(lb/d)^ 2/3) = 0.36292832

Calculation of ratio lb/d

Adequate Lap Length: lb/d >= 1

Calculation of Shear Strength Vr = Min(Vr1,Vr2) = 648405.308

Calculation of Shear Strength at edge 1, Vr1 = 648405.308
Vr1 = VCol ((10.3), ASCE 41-17) = knl*VColO
VColO = 648405.308

$k_{nl} = 1$ (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: $f'_c = (f'_{c_jacket} \cdot Area_jacket + f'_{c_core} \cdot Area_core) / Area_section = 27.84$, but $f_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$\mu_u = 2.0093280E-011$

$\nu_u = 2.5110955E-047$

$d = 0.8 \cdot D = 400.00$

$N_u = 7389.214$

$A_g = 196349.541$

From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 308425.138$

$V_{s1} = 308425.138$ is calculated for jacket, with:

$A_v = \sqrt{2} \cdot A_{stirrup} = 123370.055$

$f_y = 625.00$

$s = 100.00$

V_{s1} is multiplied by $Col1 = 1.00$

$s/d = 0.25$

$V_{s2} = 0.00$ is calculated for core, with:

$A_v = \sqrt{2} \cdot A_{stirrup} = 78956.835$

$f_y = 525.00$

$s = 250.00$

V_{s2} is multiplied by $Col2 = 0.00$

$s/d = 1.04167$

V_f ((11-3)-(11.4), ACI 440) = 247653.332

$f = 0.95$, for fully-wrapped sections

$w_f/s_f = 1$ (FRP strips adjacent to one another).

In (11.3) $\sin \theta + \cos \theta$ is replaced with $(\cot \theta + \csc \theta) \sin \alpha$ which is more a generalised expression, where θ is the angle of the crack direction (see KANEPE).

This later relation, considered as a function $V_f(\theta, \alpha)$, is implemented for every different fiber orientation α_i , as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.

orientation 1: $\theta = b_1 + 90^\circ = 90.00$

$V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, \theta)|)$, 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: $V_s + V_f \leq 440464.828$

$b_w \cdot d = \sqrt{4} \cdot d^2 = 125663.706$

Calculation of Shear Strength at edge 2, $V_{r2} = 648405.308$

$V_{r2} = V_{Col}$ ((10.3), ASCE 41-17) = $k_{nl} \cdot V_{Col0}$

$V_{Col0} = 648405.308$

$k_{nl} = 1$ (zero step-static loading)

NOTE: In expression (10-3) ' $V_s = A_v \cdot f_y \cdot d / s$ ' is replaced by ' $V_s + f \cdot V_f$ ' where V_f is the contribution of FRPs (11.3), ACI 440).

$\lambda = 1$ (normal-weight concrete)

Mean concrete strength: $f'_c = (f'_{c_jacket} \cdot Area_jacket + f'_{c_core} \cdot Area_core) / Area_section = 27.84$, but $f_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$\mu_u = 2.0093280E-011$

$\nu_u = 2.5110955E-047$

$d = 0.8 \cdot D = 400.00$

$N_u = 7389.214$

$A_g = 196349.541$

From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 308425.138$

$V_{s1} = 308425.138$ is calculated for jacket, with:

$A_v = \sqrt{2} \cdot A_{stirrup} = 123370.055$

$f_y = 625.00$

$s = 100.00$
 V_{s1} is multiplied by $Col1 = 1.00$
 $s/d = 0.25$
 $V_{s2} = 0.00$ is calculated for core, with:
 $A_v = \sqrt{2} * A_{stirrup} = 78956.835$
 $f_y = 525.00$
 $s = 250.00$
 V_{s2} is multiplied by $Col2 = 0.00$
 $s/d = 1.04167$
 $V_f ((11-3)-(11.4), ACI 440) = 247653.332$
 $f = 0.95$, for fully-wrapped sections
 $w_f/s_f = 1$ (FRP strips adjacent to one another).
 In (11.3) $\sin \theta + \cos \theta$ is replaced with $(\cot \theta + \csc \theta) \sin \alpha$ which is more a generalised expression,
 where θ is the angle of the crack direction (see KANEPE).
 This later relation, considered as a function $V_f(\theta, \alpha)$, is implemented for every different fiber orientation α_i ,
 as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.
 orientation 1: $\theta = b1 + 90^\circ = 90.00$
 $V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, \theta)|)$, with:
 total thickness per orientation, $tf1 = NL * t / NoDir = 1.016$
 $df_v = d$ (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: $V_s + V_f \leq 440464.828$
 $bw * d = \sqrt{V_s + V_f} * d / 4 = 125663.706$

 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: 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 Primary Member: Concrete Strength, $f_c = f_{cm} = 30.00$
 New material of Primary Member: Steel Strength, $f_s = f_{sm} = 625.00$
 Concrete Elasticity, $E_c = 25742.96$
 Steel Elasticity, $E_s = 200000.00$
 Existing Column
 Existing material of Primary Member: Concrete Strength, $f_c = f_{cm} = 24.00$
 Existing material of Primary Member: Steel Strength, $f_s = f_{sm} = 525.00$
 Concrete Elasticity, $E_c = 23025.204$
 Steel Elasticity, $E_s = 200000.00$
 External Diameter, $D = 500.00$
 Internal Diameter, $D = 300.00$
 Cover Thickness, $c = 25.00$
 Element Length, $L = 3000.00$
 Primary Member
 Smooth Bars
 Ductile Steel
 With Detailing for Earthquake Resistance (including stirrups closed at 135°)
 Longitudinal Bars With Ends Lapped Starting at the End Sections
 Adequate Lap Length ($l_b/d \geq 1$)
 FRP Wrapping Data
 Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $e_{fu} = 0.01$

Number of directions, $N_{oDir} = 1$

Fiber orientations, $b_i = 0.00^\circ$

Number of layers, $N_L = 1$

Radius of rounding corners, $R = 40.00$

Stepwise Properties

Bending Moment, $M = -1.3314306E-010$

Shear Force, $V_2 = 4667.709$

Shear Force, $V_3 = 1.6819047E-013$

Axial Force, $F = -7387.347$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: $A_{sl,t} = 0.00$

-Compression: $A_{sl,c} = 3053.628$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension: $A_{sl,ten} = 1017.876$

-Compression: $A_{sl,com} = 1017.876$

-Middle: $A_{sl,mid} = 1017.876$

Mean Diameter of Tension Reinforcement, $D_{bL} = 18.00$

Existing component: From table 7-7, ASCE 41_17: Final chord rotation Capacity $u_{,R} = * u = 0.05990359$

$u = y + p = 0.05990359$

- Calculation of y -

$y = (M_y * L_s / 3) / E_{eff} = 0.00946974$ ((4.29), Biskinis Phd)

$M_y = 4.4260E+008$

$L_s = M/V$ (with $L_s > 0.1 * L$ and $L_s < 2 * L$) = 1500.00

From table 10.5, ASCE 41_17: $E_{eff} = factor * E_c * I_g = 2.3369E+013$

factor = 0.30

$A_g = 196349.541$

Mean concrete strength: $f_c' = (f_c'_{jacket} * Area_{jacket} + f_c'_{core} * Area_{core}) / Area_{section} = 27.84$

$N = 7387.347$

$E_c * I_g = E_c * I_{g,jacket} + E_c * I_{g,core} = 7.7898E+013$

Calculation of Yielding Moment M_y

Calculation of y and M_y according to (7) - (8) in Biskinis and Fardis

$M_y = \text{Min}(M_{y,ten}, M_{y,com}) = 4.4260E+008$

y ((10a) or (10b)) = 1.3430729E-005

$M_{y,ten}$ (8a) = 4.4260E+008

y_{ten} (7a) = 65.19069

error of function (7a) = 0.00234593

$M_{y,com}$ (8b) = 7.6083E+008

y_{com} (7b) = 64.49917

error of function (7b) = -0.0073398

with $e_y = 0.003125$

$e_{co} = 0.002$

$a_{pl} = 0.45$ ((9c) in Biskinis and Fardis for FRP Wrap)

$d_1 = 44.00$

$R = 250.00$

$v = 0.0011297$

$N = 7387.347$

$A_c = 196349.541$

$= 0.29185858$
 with f_c^* ((12.3), ACI 440) = 33.3038
 $f_c = 30.00$
 $f_l = 1.05384$
 $k = 1$
 Effective FRP thickness, $t_f = NL \cdot t \cdot \cos(b_1) = 1.016$
 e_{fe} ((12.5) and (12.7)) = 0.004
 $E_f = 64828.00$

 Calculation of ratio l_b/l_d

 Adequate Lap Length: $l_b/l_d \geq 1$

 - Calculation of p -

 From table 10-9: $p = 0.05043385$

with:

- Columns not controlled by inadequate development or splicing along the clear height because $l_b/l_d \geq 1$

shear control ratio $V_y E / V_{col} O E = 0.45961884$

$d = d_{external} = 0.00$

$s = s_{external} = 0.00$

$t = s_1 + s_2 + 2 \cdot t_f / b_w \cdot (f_{fe} / f_s) = 0.00660658$

jacket: $s_1 = A_{v1} \cdot (D_{c1} / 2) / (s_1 \cdot A_g) = 0.0027646$

$A_{v1} = 78.53982$, is the area of stirrup

$D_{c1} = D_{ext} - 2 \cdot cover$ - External Hoop Diameter = 440.00, is the total Length of all stirrups parallel to loading

(shear) direction

$s_1 = 100.00$

core: $s_2 = A_{v2} \cdot (D_{c2} / 2) / (s_2 \cdot A_g) = 0.00046968$

$A_{v2} = 50.26548$, is the area of stirrup

$D_{c2} = D_{int}$ - Internal Hoop Diameter = 292.00, is the total Length of all stirrups parallel to loading (shear)

direction

$s_2 = 250.00$

The term $2 \cdot t_f / b_w \cdot (f_{fe} / f_s)$ is implemented to account for FRP contribution

where $f = 2 \cdot t_f / b_w$ is FRP ratio (EC8 - 3, A.4.4.3(6)) and f_{fe} / f_s normalises f to steel strength

All these variables have already been given in Shear control ratio calculation.

For the normalisation f_s of jacket is used.

$NUD = 7387.347$

$A_g = 196349.541$

$f_{cE} = (f_{c,jacket} \cdot Area_{jacket} + f_{c,core} \cdot Area_{core}) / section_area = 27.84$

$f_{yIE} = (f_{y,ext_Long_Reinf} \cdot Area_{ext_Long_Reinf} + f_{y,int_Long_Reinf} \cdot Area_{int_Long_Reinf}) / Area_{Tot_Long_Rein} = 2.1219958E-314$

$f_{yTE} = (f_{y,ext_Trans_Reinf} \cdot Area_{ext_Trans_Reinf} + f_{y,int_Trans_Reinf} \cdot Area_{int_Trans_Reinf}) / Area_{Tot_Trans_Rein} = 610.4781$

$p_l = Area_{Tot_Long_Rein} / (A_g) = 0.015552$

$f_{cE} = 27.84$

 End Of Calculation of Chord Rotation Capacity for element: column JCC1 of floor 1

At local axis: 2

Integration Section: (b)

Calculation No. 15

column C1, Floor 1

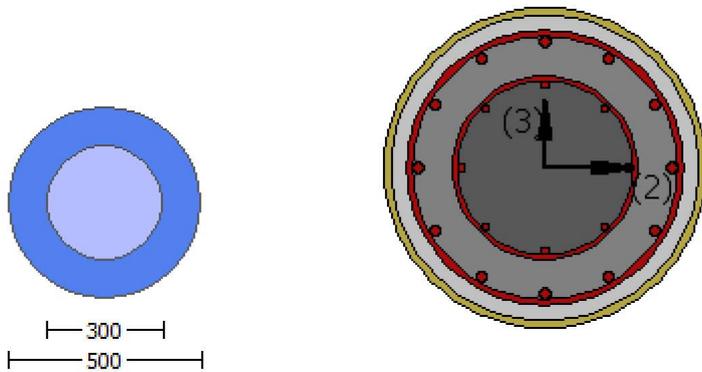
Limit State: Life Safety (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Shear capacity VRd

Edge: End

Local Axis: (3)



Start Of Calculation of Shear Capacity for element: column JCC1 of floor 1

At local axis: 3

Integration Section: (b)

Section Type: rcjcs

Constant Properties

Knowledge Factor, = 1.00

Member Shear Force is generally considered as Force-Controlled Action according to Table C7-1, ASCE 41-17.

Lower-bound strengths are used for Force-Controlled Actions according to 7.5.1.3, ASCE 41-17

Consequently:

Jacket

New material of Primary Member: Concrete Strength, $f_c = f_{c_lower_bound} = 20.00$

New material of Primary Member: Steel Strength, $f_s = f_{s_lower_bound} = 500.00$

Concrete Elasticity, $E_c = 25742.96$

Steel Elasticity, $E_s = 200000.00$

Existing Column

Existing material of Primary Member: Concrete Strength, $f_c = f_{c_lower_bound} = 16.00$

Existing material of Primary Member: Steel Strength, $f_s = f_{s_lower_bound} = 420.00$

Concrete Elasticity, $E_c = 23025.204$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of γ for displacement ductility demand, the expected (mean value) strengths are used (7.5.1.3, ASCE 41-17) because bending is considered as Deformation-Controlled Action (Table C7-1, ASCE 41-17).

Jacket

New material: Concrete Strength, $f_c = f_{cm} = 30.00$

New material: Steel Strength, $f_s = f_{sm} = 625.00$

Existing Column

Existing material: Concrete Strength, $f_c = f_{cm} = 24.00$

Existing material: Steel Strength, $f_s = f_{sm} = 525.00$

#####

External Diameter, $D = 500.00$

Internal Diameter, $D = 300.00$

Cover Thickness, $c = 25.00$

Element Length, $L = 3000.00$

Primary Member

Smooth Bars

Ductile Steel

With Detailing for Earthquake Resistance (including stirrups closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
Adequate Lap Length ($l_o/l_{ou,min} = l_b/l_d \geq 1$)
FRP Wrapping Data
Type: Carbon
Cured laminate properties (design values)
Thickness, $t = 1.016$
Tensile Strength, $f_{fu} = 1055.00$
Tensile Modulus, $E_f = 64828.00$
Elongation, $e_{fu} = 0.01$
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, $M_a = 6.3791133E-010$
Shear Force, $V_a = -1.6819047E-013$
EDGE -B-
Bending Moment, $M_b = -1.3314306E-010$
Shear Force, $V_b = 1.6819047E-013$
BOTH EDGES
Axial Force, $F = -7387.347$
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: $As_t = 0.00$
-Compression: $As_c = 3053.628$
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension: $As_{t,ten} = 1017.876$
-Compression: $As_{c,com} = 1017.876$
-Middle: $As_{c,mid} = 1017.876$
Mean Diameter of Tension Reinforcement, $Db_{L,ten} = 18.00$

Existing component: From table 7-7, ASCE 41-17: Final Shear Capacity $V_R = \phi V_n = 529689.402$
 V_n ((10.3), ASCE 41-17) = $k_n \phi V_{CoI} = 529689.402$
 $V_{CoI} = 529689.402$
 $k_n = 1.00$
 $displacement_ductility_demand = 0.00$

NOTE: In expression (10-3) ' $V_s = A_v \cdot f_y \cdot d / s$ ' is replaced by ' $V_{s+} = \phi \cdot V_f$ '
where V_f is the contribution of FRPs (11.3), ACI 440).

= 1 (normal-weight concrete)
Mean concrete strength: $f'_c = (f'_{c,jacket} \cdot Area_{jacket} + f'_{c,core} \cdot Area_{core}) / Area_{section} = 18.56$, but $f'_c^{0.5} \leq 8.3$
MPa (22.5.3.1, ACI 318-14)
 $M/d = 2.00$
 $M_u = 1.3314306E-010$
 $V_u = 1.6819047E-013$
 $d = 0.8 \cdot D = 400.00$
 $N_u = 7387.347$
 $A_g = 196349.541$
From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 246740.11$
 $V_{s1} = 246740.11$ is calculated for jacket, with:
 $A_v = \phi / 2 \cdot A_{stirrup} = 123370.055$
 $f_y = 500.00$
 $s = 100.00$
 V_{s1} is multiplied by $Col1 = 1.00$
 $s/d = 0.25$
 $V_{s2} = 0.00$ is calculated for core, with:
 $A_v = \phi / 2 \cdot A_{stirrup} = 78956.835$
 $f_y = 420.00$
 $s = 250.00$

V_{s2} is multiplied by $Col2 = 0.00$
 $s/d = 1.04167$
 V_f ((11-3)-(11.4), ACI 440) = 247653.332
 $f = 0.95$, for fully-wrapped sections
 $wf/sf = 1$ (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 θ 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, $tf1 = NL * t / NoDir = 1.016$
 $d_{fv} = d$ (figure 11.2, ACI 440) = 470.00
 f_{fe} ((11-5), ACI 440) = 259.312
 $E_f = 64828.00$
 $f_e = 0.004$, from (11.6a), ACI 440
 with $f_u = 0.01$
 From (11-11), ACI 440: $V_s + V_f \leq 359638.026$
 $b_w * d = \rho * d^2 / 4 = 125663.706$

displacement_ductility_demand is calculated as δ / y

- Calculation of δ / y for END B -
 for rotation axis 2 and integ. section (b)

From analysis, chord rotation $\theta = 5.3113353E-021$
 $y = (M_y * L_s / 3) / E_{eff} = 0.00946974$ ((4.29), Biskinis Phd)
 $M_y = 4.4260E+008$
 $L_s = M/V$ (with $L_s > 0.1 * L$ and $L_s < 2 * L$) = 1500.00
 From table 10.5, ASCE 41_17: $E_{eff} = \text{factor} * E_c * I_g = 2.3369E+013$
 $\text{factor} = 0.30$
 $A_g = 196349.541$
 Mean concrete strength: $f'_c = (f'_{c_jacket} * \text{Area}_{jacket} + f'_{c_core} * \text{Area}_{core}) / \text{Area}_{section} = 27.84$
 $N = 7387.347$
 $E_c * I_g = E_{c_jacket} * I_{g_jacket} + E_{c_core} * I_{g_core} = 7.7898E+013$

Calculation of Yielding Moment M_y

Calculation of δ / y and M_y according to (7) - (8) in Biskinis and Fardis

$M_y = \text{Min}(M_{y_ten}, M_{y_com}) = 4.4260E+008$
 y ((10a) or (10b)) = 1.3430729E-005
 M_{y_ten} (8a) = 4.4260E+008
 δ_{ten} (7a) = 65.19069
 error of function (7a) = 0.00234593
 M_{y_com} (8b) = 7.6083E+008
 δ_{com} (7b) = 64.49917
 error of function (7b) = -0.0073398
 with $e_y = 0.003125$
 $e_{co} = 0.002$
 $a_{pl} = 0.45$ ((9c) in Biskinis and Fardis for FRP Wrap)
 $d1 = 44.00$
 $R = 250.00$
 $v = 0.0011297$
 $N = 7387.347$
 $A_c = 196349.541$
 $\rho = 0.29185858$
 with f'_c ((12.3), ACI 440) = 33.3038
 $f_c = 30.00$
 $f_l = 1.05384$
 $k = 1$
 Effective FRP thickness, $tf = NL * t * \text{Cos}(b1) = 1.016$
 e_{fe} ((12.5) and (12.7)) = 0.004

Ef = 64828.00

Calculation of ratio lb/d

Adequate Lap Length: lb/d \geq 1

End Of Calculation of Shear Capacity for element: column JCC1 of floor 1

At local axis: 3

Integration Section: (b)

Calculation No. 16

column C1, Floor 1

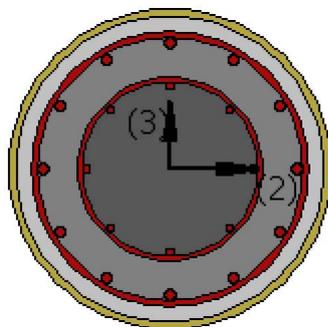
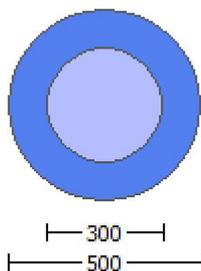
Limit State: Life Safety (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity (θ)

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, γ = 1.00

Mean strength values are used for both shear and moment calculations.

Consequently:

Jacket

New material of Primary Member: Concrete Strength, $f_c = f_{cm} = 30.00$

New material of Primary Member: Steel Strength, $f_s = f_{sm} = 625.00$

Concrete Elasticity, $E_c = 25742.96$

Steel Elasticity, $E_s = 200000.00$

Existing Column

Existing material of Primary Member: Concrete Strength, $f_c = f_{cm} = 24.00$

Existing material of Primary Member: Steel Strength, $f_s = f_{sm} = 525.00$
Concrete Elasticity, $E_c = 23025.204$
Steel Elasticity, $E_s = 200000.00$

Note: Especially for the calculation of moment strengths,
the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14

Jacket
New material: Steel Strength, $f_s = 1.25 \cdot f_{sm} = 781.25$
Existing Column
Existing material: Steel Strength, $f_s = 1.25 \cdot f_{sm} = 656.25$

External Diameter, $D = 500.00$
Internal Diameter, $D = 300.00$
Cover Thickness, $c = 25.00$
Mean Confinement Factor overall section = 1.50688
Element Length, $L = 3000.00$
Primary Member
Smooth Bars
Ductile Steel
With Detailing for Earthquake Resistance (including stirrups closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
Adequate Lap Length ($l_o/l_{ou, min} > 1$)
FRP Wrapping Data
Type: Carbon
Cured laminate properties (design values)
Thickness, $t = 1.016$
Tensile Strength, $f_{fu} = 1055.00$
Tensile Modulus, $E_f = 64828.00$
Elongation, $e_{fu} = 0.01$
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, $V_a = 4.1010657E-031$
EDGE -B-
Shear Force, $V_b = -4.1010657E-031$
BOTH EDGES
Axial Force, $F = -7389.214$
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: $A_{sl} = 0.00$
-Compression: $A_{slc} = 3053.628$
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension: $A_{sl, ten} = 1017.876$
-Compression: $A_{sl, com} = 1017.876$
-Middle: $A_{sl, mid} = 1017.876$

Calculation of Shear Capacity ratio, $V_e/V_r = 0.45961884$
Member Controlled by Flexure ($V_e/V_r < 1$)
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 298019.298$
with
 $M_{pr1} = \text{Max}(M_{u1+}, M_{u1-}) = 4.4703E+008$
 $M_{u1+} = 4.4703E+008$, is the ultimate moment strength at the edge 1 of the member in the actual moment direction
which is defined for the static loading combination
 $M_{u1-} = 4.4703E+008$, is the ultimate moment strength at the edge 1 of the member in the opposite moment
direction which is defined for the static loading combination
 $M_{pr2} = \text{Max}(M_{u2+}, M_{u2-}) = 4.4703E+008$
 $M_{u2+} = 4.4703E+008$, is the ultimate moment strength at the edge 2 of the member in the actual moment direction
which is defined for the the static loading combination

Mu2- = 4.4703E+008, is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the the static loading combination

Calculation of Mu1+

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), Mu
Mu = 4.4703E+008

= 0.97738438
' = 0.86668818
error of function (3.68), Biskinis Phd = 40566.604
From 5A.2, TBDY: fcc = fc* c = 45.20626
conf. factor c = 1.50688
fc = 30.00
From 10.3.5, ASCE 41-17, Final value of fy: fy*Min(1,1.25*(lb/d)^ 2/3) = 781.25
lb/d = 1.00
d1 = 44.00
R = 250.00
v = 0.00112412
N = 7389.214
Ac = 196349.541
= *Min(1,1.25*(lb/d)^ 2/3) = 0.36292832

Calculation of ratio lb/d

Adequate Lap Length: lb/d >= 1

Calculation of Mu1-

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), Mu
Mu = 4.4703E+008

= 0.97738438
' = 0.86668818
error of function (3.68), Biskinis Phd = 40566.604
From 5A.2, TBDY: fcc = fc* c = 45.20626
conf. factor c = 1.50688
fc = 30.00
From 10.3.5, ASCE 41-17, Final value of fy: fy*Min(1,1.25*(lb/d)^ 2/3) = 781.25
lb/d = 1.00
d1 = 44.00
R = 250.00
v = 0.00112412
N = 7389.214
Ac = 196349.541
= *Min(1,1.25*(lb/d)^ 2/3) = 0.36292832

Calculation of ratio lb/d

Adequate Lap Length: lb/d >= 1

Calculation of Mu2+

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), Mu

$$\mu = 4.4703E+008$$

$$= 0.97738438$$

$$\lambda = 0.86668818$$

error of function (3.68), Biskinis Phd = 40566.604

From 5A.2, TBDY: $f_{cc} = f_c \cdot c = 45.20626$

$$\text{conf. factor } c = 1.50688$$

$$f_c = 30.00$$

From 10.3.5, ASCE 41-17, Final value of f_y : $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 781.25$

$$l_b/d = 1.00$$

$$d_1 = 44.00$$

$$R = 250.00$$

$$v = 0.00112412$$

$$N = 7389.214$$

$$A_c = 196349.541$$

$$= \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.36292832$$

Calculation of ratio l_b/d

Adequate Lap Length: $l_b/d \geq 1$

Calculation of μ_2

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), μ

$$\mu = 4.4703E+008$$

$$= 0.97738438$$

$$\lambda = 0.86668818$$

error of function (3.68), Biskinis Phd = 40566.604

From 5A.2, TBDY: $f_{cc} = f_c \cdot c = 45.20626$

$$\text{conf. factor } c = 1.50688$$

$$f_c = 30.00$$

From 10.3.5, ASCE 41-17, Final value of f_y : $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 781.25$

$$l_b/d = 1.00$$

$$d_1 = 44.00$$

$$R = 250.00$$

$$v = 0.00112412$$

$$N = 7389.214$$

$$A_c = 196349.541$$

$$= \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.36292832$$

Calculation of ratio l_b/d

Adequate Lap Length: $l_b/d \geq 1$

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 648405.308$

Calculation of Shear Strength at edge 1, $V_{r1} = 648405.308$

$V_{r1} = V_{Co1}$ ((10.3), ASCE 41-17) = $k_{nl} \cdot V_{Co10}$

$$V_{Co10} = 648405.308$$

$$k_{nl} = 1 \text{ (zero step-static loading)}$$

NOTE: In expression (10-3) ' $V_s = A_v \cdot f_y \cdot d/s$ ' is replaced by ' $V_{s+} = f \cdot V_f$ '

where V_f is the contribution of FRPs (11.3), ACI 440).

$$= 1 \text{ (normal-weight concrete)}$$

Mean concrete strength: $f_c' = (f_c'_{\text{jacket}} \cdot \text{Area}_{\text{jacket}} + f_c'_{\text{core}} \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 27.84$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$
 $\mu_u = 2.1425332E-011$
 $V_u = 4.1010657E-031$
 $d = 0.8 \cdot D = 400.00$
 $N_u = 7389.214$
 $A_g = 196349.541$
 From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 308425.138$
 $V_{s1} = 308425.138$ is calculated for jacket, with:
 $A_v = \sqrt{2} \cdot A_{stirrup} = 123370.055$
 $f_y = 625.00$
 $s = 100.00$
 V_{s1} is multiplied by $Col1 = 1.00$
 $s/d = 0.25$
 $V_{s2} = 0.00$ is calculated for core, with:
 $A_v = \sqrt{2} \cdot A_{stirrup} = 78956.835$
 $f_y = 525.00$
 $s = 250.00$
 V_{s2} is multiplied by $Col2 = 0.00$
 $s/d = 1.04167$
 V_f ((11-3)-(11.4), ACI 440) = 247653.332
 $f = 0.95$, for fully-wrapped sections
 $w_f/s_f = 1$ (FRP strips adjacent to one another).
 In (11.3) $\sin \theta + \cos \theta$ is replaced with $(\cot \theta + \csc \theta) \sin \alpha$ which is more a generalised expression,
 where θ is the angle of the crack direction (see KANEPE).
 This later relation, considered as a function $V_f(\theta, \alpha)$, is implemented for every different fiber orientation α_i ,
 as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.
 orientation 1: $\theta = 45^\circ$
 $V_f = \text{Min}(|V_f(45, \alpha_1)|, |V_f(-45, \alpha_1)|)$, 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: $V_s + V_f \leq 440464.828$
 $b_w \cdot d = \sqrt{4} \cdot V_f = 125663.706$

Calculation of Shear Strength at edge 2, $V_{r2} = 648405.308$
 $V_{r2} = V_{Col}$ ((10.3), ASCE 41-17) = $k_{nl} \cdot V_{Col0}$
 $V_{Col0} = 648405.308$
 $k_{nl} = 1$ (zero step-static loading)

NOTE: In expression (10-3) ' $V_s = A_v \cdot f_y \cdot d / s$ ' is replaced by ' $V_s + f \cdot V_f$ '
 where V_f is the contribution of FRPs (11.3), ACI 440).

$k_c = 1$ (normal-weight concrete)
 Mean concrete strength: $f_c' = (f_c'_{jacket} \cdot Area_{jacket} + f_c'_{core} \cdot Area_{core}) / Area_{section} = 27.84$, but $f_c'^{0.5} \leq 8.3$
 MPa (22.5.3.1, ACI 318-14)
 $M/Vd = 2.00$
 $\mu_u = 2.1425332E-011$
 $V_u = 4.1010657E-031$
 $d = 0.8 \cdot D = 400.00$
 $N_u = 7389.214$
 $A_g = 196349.541$
 From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 308425.138$
 $V_{s1} = 308425.138$ is calculated for jacket, with:
 $A_v = \sqrt{2} \cdot A_{stirrup} = 123370.055$
 $f_y = 625.00$
 $s = 100.00$
 V_{s1} is multiplied by $Col1 = 1.00$
 $s/d = 0.25$
 $V_{s2} = 0.00$ is calculated for core, with:
 $A_v = \sqrt{2} \cdot A_{stirrup} = 78956.835$
 $f_y = 525.00$
 $s = 250.00$
 V_{s2} is multiplied by $Col2 = 0.00$

s/d = 1.04167

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 $(\cot \theta + \cot \alpha) \sin \alpha$ which is more a generalised expression, where θ is the angle of the crack direction (see KANEPE).

This later relation, considered as a function Vf(θ , α), 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: $\theta = \theta_1 + 90^\circ = 90.00$

Vf = Min(|Vf(45, θ_1)|, |Vf(-45, θ_1)|), with:

total thickness per orientation, $t_{f1} = NL * t / NoDir = 1.016$

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 <= 440464.828

bw*d = $\rho_s * d^2 / 4 = 125663.706$

End Of Calculation of Shear Capacity ratio for element: column JCC1 of floor 1
At local axis: 3

Start Of Calculation of Shear Capacity ratio for element: column JCC1 of floor 1
At Shear local axis: 2
(Bending local axis: 3)
Section Type: rcjcs

Constant Properties

Knowledge Factor, $\gamma = 1.00$

Mean strength values are used for both shear and moment calculations.

Consequently:

Jacket

New material of Primary Member: Concrete Strength, $f_c = f_{cm} = 30.00$

New material of Primary Member: Steel Strength, $f_s = f_{sm} = 625.00$

Concrete Elasticity, $E_c = 25742.96$

Steel Elasticity, $E_s = 200000.00$

Existing Column

Existing material of Primary Member: Concrete Strength, $f_c = f_{cm} = 24.00$

Existing material of Primary Member: Steel Strength, $f_s = f_{sm} = 525.00$

Concrete Elasticity, $E_c = 23025.204$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14

Jacket

New material: Steel Strength, $f_s = 1.25 * f_{sm} = 781.25$

Existing Column

Existing material: Steel Strength, $f_s = 1.25 * f_{sm} = 656.25$

#####

External Diameter, D = 500.00

Internal Diameter, D = 300.00

Cover Thickness, c = 25.00

Mean Confinement Factor overall section = 1.50688

Element Length, L = 3000.00

Primary Member

Smooth Bars

Ductile Steel

With Detailing for Earthquake Resistance (including stirrups closed at 135°)

Longitudinal Bars With Ends Lapped Starting at the End Sections

Adequate Lap Length ($l_o / l_{ou, min} >= 1$)

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $e_{fu} = 0.01$

Number of directions, $NoDir = 1$

Fiber orientations, $b_i = 0.00^\circ$

Number of layers, $NL = 1$

Radius of rounding corners, $R = 40.00$

Stepwise Properties

At local axis: 2

EDGE -A-

Shear Force, $V_a = -2.5110955E-047$

EDGE -B-

Shear Force, $V_b = 2.5110955E-047$

BOTH EDGES

Axial Force, $F = -7389.214$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: $As_t = 0.00$

-Compression: $As_c = 3053.628$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension: $As_{t,ten} = 1017.876$

-Compression: $As_{l,com} = 1017.876$

-Middle: $As_{l,mid} = 1017.876$

Calculation of Shear Capacity ratio, $V_e/V_r = 0.45961884$

Member Controlled by Flexure ($V_e/V_r < 1$)

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 298019.298$

with

$M_{pr1} = \text{Max}(Mu_{1+}, Mu_{1-}) = 4.4703E+008$

$Mu_{1+} = 4.4703E+008$, is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination

$Mu_{1-} = 4.4703E+008$, is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination

$M_{pr2} = \text{Max}(Mu_{2+}, Mu_{2-}) = 4.4703E+008$

$Mu_{2+} = 4.4703E+008$, is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the the static loading combination

$Mu_{2-} = 4.4703E+008$, is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the the static loading combination

Calculation of Mu_{1+}

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), Mu

$Mu = 4.4703E+008$

 $\lambda = 0.97738438$

$\lambda' = 0.86668818$

error of function (3.68), Biskinis Phd = 40566.604

From 5A.2, TBDY: $f_{cc} = f_c^* \quad c = 45.20626$

conf. factor $c = 1.50688$

$f_c = 30.00$

From 10.3.5, ASCE 41-17, Final value of f_y : $f_y * \text{Min}(1, 1.25 * (l_b/d)^{2/3}) = 781.25$

$l_b/d = 1.00$

$d_1 = 44.00$

$R = 250.00$

$v = 0.00112412$

$N = 7389.214$

$Ac = 196349.541$

$$= \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.36292832$$

Calculation of ratio l_b/d

Adequate Lap Length: $l_b/d \geq 1$

Calculation of μ_{1-}

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), μ
 $\mu = 4.4703E+008$

$$= 0.97738438$$

$$\lambda = 0.86668818$$

error of function (3.68), Biskinis Phd = 40566.604

From 5A.2, TBDY: $f_{cc} = f_c \cdot c = 45.20626$

conf. factor $c = 1.50688$

$f_c = 30.00$

From 10.3.5, ASCE 41-17, Final value of f_y : $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 781.25$

$$l_b/d = 1.00$$

$$d_1 = 44.00$$

$$R = 250.00$$

$$v = 0.00112412$$

$$N = 7389.214$$

$$A_c = 196349.541$$

$$= \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.36292832$$

Calculation of ratio l_b/d

Adequate Lap Length: $l_b/d \geq 1$

Calculation of μ_{2+}

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), μ
 $\mu = 4.4703E+008$

$$= 0.97738438$$

$$\lambda = 0.86668818$$

error of function (3.68), Biskinis Phd = 40566.604

From 5A.2, TBDY: $f_{cc} = f_c \cdot c = 45.20626$

conf. factor $c = 1.50688$

$f_c = 30.00$

From 10.3.5, ASCE 41-17, Final value of f_y : $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 781.25$

$$l_b/d = 1.00$$

$$d_1 = 44.00$$

$$R = 250.00$$

$$v = 0.00112412$$

$$N = 7389.214$$

$$A_c = 196349.541$$

$$= \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.36292832$$

Calculation of ratio l_b/d

Adequate Lap Length: $l_b/d \geq 1$

Calculation of Mu2-

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), Mu

Mu = 4.4703E+008

= 0.97738438

' = 0.86668818

error of function (3.68), Biskinis Phd = 40566.604

From 5A.2, TBDY: $f_{cc} = f_c \cdot c = 45.20626$

conf. factor $c = 1.50688$

$f_c = 30.00$

From 10.3.5, ASCE 41-17, Final value of fy: $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 781.25$

$l_b/d = 1.00$

$d_1 = 44.00$

$R = 250.00$

$v = 0.00112412$

$N = 7389.214$

$A_c = 196349.541$

= $\cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.36292832$

Calculation of ratio l_b/d

Adequate Lap Length: $l_b/d \geq 1$

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 648405.308$

Calculation of Shear Strength at edge 1, $V_{r1} = 648405.308$

$V_{r1} = V_{Col}$ ((10.3), ASCE 41-17) = $k_{nl} \cdot V_{Col0}$

$V_{Col0} = 648405.308$

$k_{nl} = 1$ (zero step-static loading)

NOTE: In expression (10-3) ' $V_s = A_v \cdot f_y \cdot d/s$ ' is replaced by ' $V_s + f \cdot V_f$ ' where V_f is the contribution of FRPs (11.3), ACI 440).

= 1 (normal-weight concrete)

Mean concrete strength: $f_c' = (f_c'_{jacket} \cdot \text{Area}_{jacket} + f_c'_{core} \cdot \text{Area}_{core}) / \text{Area}_{section} = 27.84$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/d = 2.00$

$M_u = 2.0093280E-011$

$V_u = 2.5110955E-047$

$d = 0.8 \cdot D = 400.00$

$N_u = 7389.214$

$A_g = 196349.541$

From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 308425.138$

$V_{s1} = 308425.138$ is calculated for jacket, with:

$A_v = \sqrt{2} \cdot A_{stirrup} = 123370.055$

$f_y = 625.00$

$s = 100.00$

V_{s1} is multiplied by $Col1 = 1.00$

$s/d = 0.25$

$V_{s2} = 0.00$ is calculated for core, with:

$A_v = \sqrt{2} \cdot A_{stirrup} = 78956.835$

$f_y = 525.00$

$s = 250.00$

V_{s2} is multiplied by $Col2 = 0.00$

$s/d = 1.04167$

V_f ((11-3)-(11.4), ACI 440) = 247653.332

$f = 0.95$, for fully-wrapped sections

$w_f/s_f = 1$ (FRP strips adjacent to one another).

In (11.3) $\sin \theta + \cos \theta$ is replaced with $(\cot \theta + \csc \theta) \sin \alpha$ which is more a generalised expression, where θ is the angle of the crack direction (see KANEPE).

This later relation, considered as a function $V_f(\theta)$, is implemented for every different fiber orientation θ_i , as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.

orientation 1: $\theta = 90^\circ = 90.00$

$V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, \theta)|)$, 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: $V_s + V_f \leq 440464.828$

$b_w \cdot d = \frac{b \cdot d}{4} = 125663.706$

Calculation of Shear Strength at edge 2, $V_{r2} = 648405.308$

$V_{r2} = V_{Co1}$ ((10.3), ASCE 41-17) = $k_{nl} \cdot V_{Co10}$

$V_{Co10} = 648405.308$

$k_{nl} = 1$ (zero step-static loading)

NOTE: In expression (10-3) ' $V_s = A_v \cdot f_y \cdot d / s$ ' is replaced by ' $V_s + f \cdot V_f$ ' where V_f is the contribution of FRPs (11.3), ACI 440).

$\lambda = 1$ (normal-weight concrete)

Mean concrete strength: $f_c' = (f_c'_{\text{jacket}} \cdot \text{Area}_{\text{jacket}} + f_c'_{\text{core}} \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 27.84$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M / Vd = 2.00$

$\mu_u = 2.0093280E-011$

$\nu_u = 2.5110955E-047$

$d = 0.8 \cdot D = 400.00$

$N_u = 7389.214$

$A_g = 196349.541$

From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 308425.138$

$V_{s1} = 308425.138$ is calculated for jacket, with:

$A_v = \frac{1}{2} \cdot A_{\text{stirrup}} = 123370.055$

$f_y = 625.00$

$s = 100.00$

V_{s1} is multiplied by $Col1 = 1.00$

$s/d = 0.25$

$V_{s2} = 0.00$ is calculated for core, with:

$A_v = \frac{1}{2} \cdot A_{\text{stirrup}} = 78956.835$

$f_y = 525.00$

$s = 250.00$

V_{s2} is multiplied by $Col2 = 0.00$

$s/d = 1.04167$

V_f ((11-3)-(11.4), ACI 440) = 247653.332

$f = 0.95$, for fully-wrapped sections

$w_f / s_f = 1$ (FRP strips adjacent to one another).

In (11.3) $\sin \theta + \cos \theta$ is replaced with $(\cot \theta + \csc \theta) \sin \alpha$ which is more a generalised expression,

where θ is the angle of the crack direction (see KANEPE).

This later relation, considered as a function $V_f(\theta)$, is implemented for every different fiber orientation θ_i , as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.

orientation 1: $\theta = 90^\circ = 90.00$

$V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, \theta)|)$, 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: $V_s + V_f \leq 440464.828$

$b_w \cdot d = \frac{b \cdot d}{4} = 125663.706$

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: (b)

Section Type: rcjcs

Constant Properties

Knowledge Factor, $\gamma = 1.00$

Chord Rotation is generally considered as Deformation-Controlled Action according to Table C7-1, ASCE 41-17.

Mean strengths are used for Deformation-Controlled Actions according to 7.5.1.3, ASCE 41-17

Consequently:

Jacket

New material of Primary Member: Concrete Strength, $f_c = f_{cm} = 30.00$

New material of Primary Member: Steel Strength, $f_s = f_{sm} = 625.00$

Concrete Elasticity, $E_c = 25742.96$

Steel Elasticity, $E_s = 200000.00$

Existing Column

Existing material of Primary Member: Concrete Strength, $f_c = f_{cm} = 24.00$

Existing material of Primary Member: Steel Strength, $f_s = f_{sm} = 525.00$

Concrete Elasticity, $E_c = 23025.204$

Steel Elasticity, $E_s = 200000.00$

External Diameter, $D = 500.00$

Internal Diameter, $D = 300.00$

Cover Thickness, $c = 25.00$

Element Length, $L = 3000.00$

Primary Member

Smooth Bars

Ductile Steel

With Detailing for Earthquake Resistance (including stirrups closed at 135°)

Longitudinal Bars With Ends Lapped Starting at the End Sections

Adequate Lap Length ($l_b/d >= 1$)

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $e_{fu} = 0.01$

Number of directions, $N_{oDir} = 1$

Fiber orientations, $b_i = 0.00^\circ$

Number of layers, $N_L = 1$

Radius of rounding corners, $R = 40.00$

Stepwise Properties

Bending Moment, $M = 0.10299595$

Shear Force, $V_2 = 4667.709$

Shear Force, $V_3 = 1.6819047E-013$

Axial Force, $F = -7387.347$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: $A_{slt} = 0.00$

-Compression: $A_{slc} = 3053.628$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension: $A_{sl,ten} = 1017.876$

-Compression: $A_{sl,com} = 1017.876$

-Middle: $A_{sl,mid} = 1017.876$

Mean Diameter of Tension Reinforcement, $D_{bL} = 18.00$

Existing component: From table 7-7, ASCE 41_17: Final chord rotation Capacity $u_{,R} = * u = 0.0523278$

$u = y + p = 0.0523278$

- Calculation of ρ_y -

$$\rho_y = (M_y * L_s / 3) / E_{eff} = 0.00189395 \text{ ((4.29), Biskinis Phd)}$$

$$M_y = 4.4260E+008$$

$$L_s = M/V \text{ (with } L_s > 0.1 * L \text{ and } L_s < 2 * L) = 300.00$$

$$\text{From table 10.5, ASCE 41_17: } E_{eff} = \text{factor} * E_c * I_g = 2.3369E+013$$

$$\text{factor} = 0.30$$

$$A_g = 196349.541$$

$$\text{Mean concrete strength: } f_c' = (f_c'_{\text{jacket}} * A_{\text{jacket}} + f_c'_{\text{core}} * A_{\text{core}}) / A_{\text{section}} = 27.84$$

$$N = 7387.347$$

$$E_c * I_g = E_{c_{\text{jacket}}} * I_{g_{\text{jacket}}} + E_{c_{\text{core}}} * I_{g_{\text{core}}} = 7.7898E+013$$

Calculation of Yielding Moment M_y

Calculation of ρ_y and M_y according to (7) - (8) in Biskinis and Fardis

$$M_y = \text{Min}(M_{y_{\text{ten}}}, M_{y_{\text{com}}}) = 4.4260E+008$$

$$\rho_y \text{ ((10a) or (10b))} = 1.3430729E-005$$

$$M_{y_{\text{ten}}} \text{ (8a)} = 4.4260E+008$$

$$\rho_{y_{\text{ten}}} \text{ (7a)} = 65.19069$$

$$\text{error of function (7a)} = 0.00234593$$

$$M_{y_{\text{com}}} \text{ (8b)} = 7.6083E+008$$

$$\rho_{y_{\text{com}}} \text{ (7b)} = 64.49917$$

$$\text{error of function (7b)} = -0.0073398$$

$$\text{with } e_y = 0.003125$$

$$e_{co} = 0.002$$

$$a_{pl} = 0.45 \text{ ((9c) in Biskinis and Fardis for FRP Wrap)}$$

$$d_1 = 44.00$$

$$R = 250.00$$

$$v = 0.0011297$$

$$N = 7387.347$$

$$A_c = 196349.541$$

$$= 0.29185858$$

$$\text{with } f_c' \text{ ((12.3), ACI 440)} = 33.3038$$

$$f_c = 30.00$$

$$f_l = 1.05384$$

$$k = 1$$

$$\text{Effective FRP thickness, } t_f = NL * t * \text{Cos}(b_1) = 1.016$$

$$e_{fe} \text{ ((12.5) and (12.7))} = 0.004$$

$$E_f = 64828.00$$

Calculation of ratio l_b/d

Adequate Lap Length: $l_b/d \geq 1$

- Calculation of ρ_p -

From table 10-9: $\rho_p = 0.05043385$

with:

- Columns not controlled by inadequate development or splicing along the clear height because $l_b/d \geq 1$

$$\text{shear control ratio } V_y E / V_{co} I_{OE} = 0.45961884$$

$$d = d_{\text{external}} = 0.00$$

$$s = s_{\text{external}} = 0.00$$

$$t = s_1 + s_2 + 2 * t_f / b_w * (f_{fe} / f_s) = 0.00660658$$

$$\text{jacket: } s_1 = A_{v1} * (D_{c1} / 2) / (s_1 * A_g) = 0.0027646$$

$$A_{v1} = 78.53982, \text{ is the area of stirrup}$$

$$D_{c1} = D_{\text{ext}} - 2 * \text{cover} - \text{External Hoop Diameter} = 440.00, \text{ is the total Length of all stirrups parallel to loading}$$

(shear) direction

$$s_1 = 100.00$$

$$\text{core: } s_2 = A_{v2} * (D_{c2} / 2) / (s_2 * A_g) = 0.00046968$$

$$A_{v2} = 50.26548, \text{ is the area of stirrup}$$

$$D_{c2} = D_{\text{int}} - \text{Internal Hoop Diameter} = 292.00, \text{ is the total Length of all stirrups parallel to loading (shear)}$$

direction

$$s_2 = 250.00$$

The term $2 \cdot t_f / b_w \cdot (f_{fe} / f_s)$ is implemented to account for FRP contribution where $f = 2 \cdot t_f / b_w$ is FRP ratio (EC8 - 3, A.4.4.3(6)) and f_{fe} / f_s normalises f to steel strength. All these variables have already been given in Shear control ratio calculation.

For the normalisation f_s of jacket is used.

$$N_{UD} = 7387.347$$

$$A_g = 196349.541$$

$$f_{cE} = (f_{c_jacket} \cdot Area_jacket + f_{c_core} \cdot Area_core) / section_area = 27.84$$

$$f_{yIE} = (f_{y_ext_Long_Reinf} \cdot Area_ext_Long_Reinf + f_{y_int_Long_Reinf} \cdot Area_int_Long_Reinf) / Area_Tot_Long_Rein = 2.1219958E-314$$

$$f_{yTE} = (f_{y_ext_Trans_Reinf} \cdot Area_ext_Trans_Reinf + f_{y_int_Trans_Reinf} \cdot Area_int_Trans_Reinf) / Area_Tot_Trans_Rein = 610.4781$$

$$p_l = Area_Tot_Long_Rein / (A_g) = 0.015552$$

$$f_{cE} = 27.84$$

End Of Calculation of Chord Rotation Capacity for element: column JCC1 of floor 1

At local axis: 3

Integration Section: (b)
