

Detailed Member Calculations

Units: N&mm

Regulation: ASCE 41-17

Calculation No. 1

column C1, Floor 1

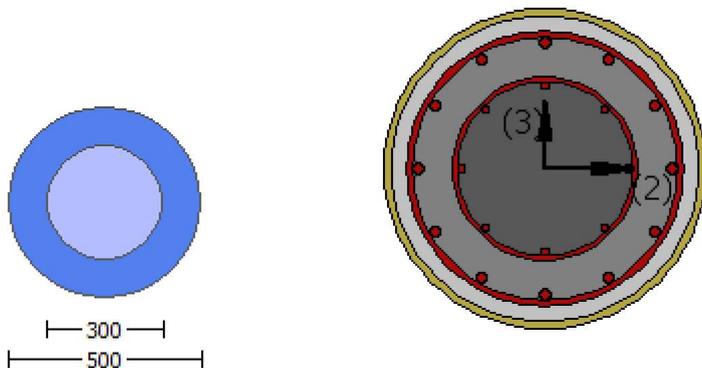
Limit State: Immediate Occupancy (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Shear capacity 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, $f_c = f_{c_lower_bound} = 25.00$

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

Concrete Elasticity, $E_c = 26999.444$
 Steel Elasticity, $E_s = 200000.00$
 Existing Column
 Existing material of Primary Member: Concrete Strength, $f_c = f_{c_lower_bound} = 16.00$
 Existing material of Primary Member: Steel Strength, $f_s = f_{s_lower_bound} = 400.00$
 Concrete Elasticity, $E_c = 21019.039$
 Steel Elasticity, $E_s = 200000.00$
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 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, $f_c = f_{cm} = 33.00$
 New material: Steel Strength, $f_s = f_{sm} = 555.56$
 Existing Column
 Existing material: Concrete Strength, $f_c = f_{cm} = 20.00$
 Existing material: Steel Strength, $f_s = f_{sm} = 444.44$
 #####
 External Diameter, $D = 500.00$
 Internal Diameter, $D = 300.00$
 Cover Thickness, $c = 25.00$
 Element Length, $L = 3000.00$
 Primary Member
 Ribbed Bars
 Ductile Steel
 Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
 Longitudinal Bars With Ends Lapped Starting at the End Sections
 Lap Length $l_o = l_b = 300.00$
 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, $M_a = -1.7582E+007$
 Shear Force, $V_a = -5859.331$
 EDGE -B-
 Bending Moment, $M_b = 0.08058394$
 Shear Force, $V_b = 5859.331$
 BOTH EDGES
 Axial Force, $F = -7386.87$
 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 $V_R = *V_n = 396407.336$
 $V_n ((10.3), ASCE 41-17) = knl * V_{CoIo} = 396407.336$
 $V_{CoI} = 396407.336$
 $knl = 1.00$

displacement_ductility_demand = 0.01967484

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: $f_c' = (f_c'_{\text{jacket}} \cdot \text{Area}_{\text{jacket}} + f_c'_{\text{core}} \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 21.76$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 4.00$

$\mu_u = 1.7582E+007$

$V_u = 5859.331$

$d = 0.8 \cdot D = 400.00$

$N_u = 7386.87$

$A_g = 196349.541$

From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 68808.56$

$V_{s1} = 43542.372$ is calculated for jacket, with:

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

$f_y = 500.00$

$s = 340.00$

V_{s1} is multiplied by $\text{Col1} = 0.60$

$s/d = 0.85$

$V_{s2} = 25266.187$ is calculated for core, with:

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

$f_y = 400.00$

$s = 200.00$

V_{s2} is multiplied by $\text{Col2} = 0.66666667$

$s/d = 0.83333333$

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

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

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

$d_{fv} = d$ (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: $V_s + V_f \leq 389409.072$

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

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 $\theta = 0.00020101$

$y = (M_y \cdot L_s / 3) / E_{\text{eff}} = 0.01021672$ ((4.29), Biskinis Phd)

$M_y = 2.4653E+008$

$L_s = M/V$ (with $L_s > 0.1 \cdot L$ and $L_s < 2 \cdot L$) = 3000.756

From table 10.5, ASCE 41_17: $E_{\text{eff}} = \text{factor} \cdot E_c \cdot I_g = 2.4137E+013$

factor = 0.30

$A_g = 196349.541$

Mean concrete strength: $f_c' = (f_c'_{\text{jacket}} \cdot \text{Area}_{\text{jacket}} + f_c'_{\text{core}} \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 28.32$

$N = 7386.87$

$E_c \cdot I_g = E_c \cdot I_{g_{\text{jacket}}} + E_c \cdot I_{g_{\text{core}}} = 8.0455E+013$

Calculation of Yielding Moment M_y

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

$$M_y = \text{Min}(M_{y_ten}, M_{y_com}) = 2.4653E+008$$

$$\phi_y = 7.1028705E-006$$

$$M_{y_ten} (8c) = 2.4653E+008$$

$$\phi_{y_ten} (7c) = 62.22249$$

$$\text{error of function (7c)} = 0.00021692$$

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

$$\phi_{y_com} (7d) = 63.84406$$

$$\text{error of function (7d)} = -0.00846594$$

$$\text{with } ((10.1), \text{ASCE 41-17}) \phi_y = \text{Min}(\phi_y, 1.25 \cdot \phi_y \cdot (l_b/d)^{2/3}) = 0.0027778$$

$$\phi_{co} = 0.002$$

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

$$d_1 = 44.00$$

$$R = 250.00$$

$$v = 0.00103628$$

$$N = 7386.87$$

$$A_c = 196349.541$$

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

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

$$\phi_c = 33.00$$

$$\phi_l = 1.05384$$

$$k = 1$$

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

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

$$\phi_u = 0.01$$

$$E_f = 64828.00$$

Calculation of ratio l_b/d

$$\text{Lap Length: } l_b/d, \text{min} = 0.34503556$$

$$l_b = 300.00$$

$$l_d = 869.4756$$

Calculation of l according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

$$= 1$$

$$d_b = 18.00$$

$$\text{Mean strength value of all re-bars: } f_y = 555.56$$

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

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 25.00$$

$$K_{tr} = 1.20951$$

$$A_{tr} = \frac{1}{2} \cdot \text{Area of external stirrup} = 123.3701$$

$$s = s_{\text{external}} = 340.00$$

$$n = 12.00$$

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

At local axis: 2

Integration Section: (a)

Calculation No. 2

column C1, Floor 1

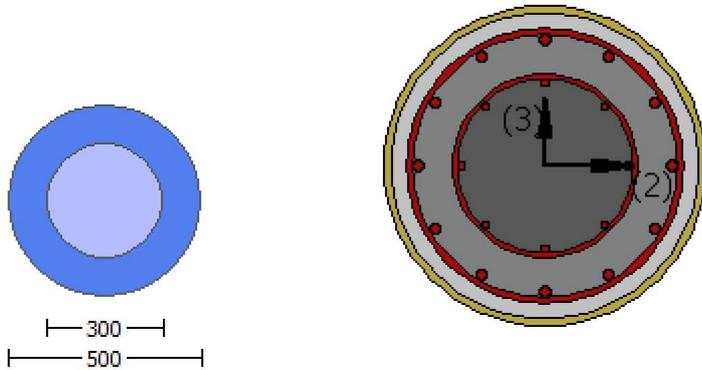
Limit State: Immediate Occupancy (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity (θ)

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, $f_c = f_{cm} = 33.00$

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

Concrete Elasticity, $E_c = 26999.444$

Steel Elasticity, $E_s = 200000.00$

Existing Column

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

Existing material of Primary Member: Steel Strength, $f_s = f_{sm} = 444.44$

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

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Note: Especially for the calculation of moment strengths,

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

Jacket

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

Existing Column

Existing material: Steel Strength, $f_s = 1.25 \cdot f_{sm} = 555.55$

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External Diameter, $D = 500.00$

Internal Diameter, $D = 300.00$

Cover Thickness, $c = 25.00$

Mean Confinement Factor overall section = 1.46748

Element Length, $L = 3000.00$

Primary Member

Ribbed Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

Lap Length $l_o = 300.00$

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $\epsilon_{fu} = 0.01$

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

Fiber orientations, $b_i = 0.00^\circ$

Number of layers, $N_L = 1$

Radius of rounding corners, $R = 40.00$

Stepwise Properties

At local axis: 3

EDGE -A-

Shear Force, $V_a = 4.1704511E-031$

EDGE -B-

Shear Force, $V_b = -4.1704511E-031$

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, $V_e/V_r = 0.29814229$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 155683.418$

with

$M_{pr1} = \text{Max}(M_{u1+}, M_{u1-}) = 2.3353E+008$

$M_{u1+} = 2.3353E+008$, is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination

$M_{u1-} = 2.3353E+008$, is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination

$M_{pr2} = \text{Max}(M_{u2+}, M_{u2-}) = 2.3353E+008$

$M_{u2+} = 2.3353E+008$, is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the static loading combination

$M_{u2-} = 2.3353E+008$, is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the static loading combination

Calculation of M_{u1+}

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

$M_u = 2.3353E+008$

$\phi = 0.80285146$

$\lambda = 0.71403327$

error of function (3.68), Biskinis Phd = 40102.185

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

conf. factor $c = 1.46748$

$f_c = 33.00$

From 10.3.5, ASCE 41-17, Final value of f_y : $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3}) = 368.0049$

$l_b/l_d = 0.27602844$

$d_1 = 44.00$

$R = 250.00$

$v = 0.00103167$

$$N = 7389.214$$

$$Ac = 196349.541$$

$$= *Min(1,1.25*(lb/d)^{2/3}) = 0.15689624$$

Calculation of ratio lb/d

$$\text{Lap Length: } lb/d = 0.27602844$$

$$lb = 300.00$$

$$ld = 1086.845$$

Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

$$= 1$$

$$db = 18.00$$

$$\text{Mean strength value of all re-bars: } fy = 694.45$$

$$\text{Mean concrete strength: } fc' = (fc'_{\text{jacket}} * Area_{\text{jacket}} + fc'_{\text{core}} * Area_{\text{core}}) / Area_{\text{section}} = 33.00, \text{ but } fc'^{0.5} \leq 8.3$$

MPa (22.5.3.1, ACI 318-14)

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$cb = 25.00$$

$$Ktr = 1.20951$$

$$Atr = /2 * \text{Area of external stirrup} = 123.3701$$

$$s = s_{\text{external}} = 340.00$$

$$n = 12.00$$

Calculation of Mu1-

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

$$Mu = 2.3353E+008$$

$$= 0.80285146$$

$$' = 0.71403327$$

error of function (3.68), Biskinis Phd = 40102.185

From 5A.2, TBDY: $f_{cc} = fc' * c = 48.42699$

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

$$fc = 33.00$$

From 10.3.5, ASCE 41-17, Final value of fy: $fy * Min(1,1.25*(lb/d)^{2/3}) = 368.0049$

$$lb/d = 0.27602844$$

$$d1 = 44.00$$

$$R = 250.00$$

$$v = 0.00103167$$

$$N = 7389.214$$

$$Ac = 196349.541$$

$$= *Min(1,1.25*(lb/d)^{2/3}) = 0.15689624$$

Calculation of ratio lb/d

$$\text{Lap Length: } lb/d = 0.27602844$$

$$lb = 300.00$$

$$ld = 1086.845$$

Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

$$= 1$$

$$db = 18.00$$

$$\text{Mean strength value of all re-bars: } fy = 694.45$$

$$\text{Mean concrete strength: } fc' = (fc'_{\text{jacket}} * Area_{\text{jacket}} + fc'_{\text{core}} * Area_{\text{core}}) / Area_{\text{section}} = 33.00, \text{ but } fc'^{0.5} \leq 8.3$$

MPa (22.5.3.1, ACI 318-14)

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$cb = 25.00$$

$$Ktr = 1.20951$$

$$Atr = /2 * \text{Area of external stirrup} = 123.3701$$

s = s_external = 340.00
n = 12.00

Calculation of Mu2+

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), Mu
Mu = 2.3353E+008

= 0.80285146
' = 0.71403327
error of function (3.68), Biskinis Phd = 40102.185
From 5A.2, TBDY: fcc = fc* c = 48.42699
conf. factor c = 1.46748
fc = 33.00
From 10.3.5, ASCE 41-17, Final value of fy: fy*Min(1,1.25*(lb/d)^ 2/3) = 368.0049
lb/d = 0.27602844
d1 = 44.00
R = 250.00
v = 0.00103167
N = 7389.214
Ac = 196349.541
= *Min(1,1.25*(lb/d)^ 2/3) = 0.15689624

Calculation of ratio lb/d

Lap Length: lb/d = 0.27602844
lb = 300.00
ld = 1086.845
Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
= 1
db = 18.00
Mean strength value of all re-bars: fy = 694.45
Mean concrete strength: fc' = (fc'_jacket*Area_jacket + fc'_core*Area_core)/Area_section = 33.00, but fc'^0.5 <= 8.3
MPa (22.5.3.1, ACI 318-14)
t = 1.00
s = 0.80
e = 1.00
cb = 25.00
Ktr = 1.20951
Atr = /2 * Area of external stirrup = 123.3701
s = s_external = 340.00
n = 12.00

Calculation of Mu2-

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), Mu
Mu = 2.3353E+008

= 0.80285146
' = 0.71403327
error of function (3.68), Biskinis Phd = 40102.185
From 5A.2, TBDY: fcc = fc* c = 48.42699
conf. factor c = 1.46748
fc = 33.00
From 10.3.5, ASCE 41-17, Final value of fy: fy*Min(1,1.25*(lb/d)^ 2/3) = 368.0049
lb/d = 0.27602844
d1 = 44.00
R = 250.00

$$v = 0.00103167$$

$$N = 7389.214$$

$$Ac = 196349.541$$

$$= *Min(1, 1.25*(lb/ld)^{2/3}) = 0.15689624$$

 Calculation of ratio lb/ld

 Lap Length: lb/ld = 0.27602844

lb = 300.00

ld = 1086.845

Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

= 1

db = 18.00

Mean strength value of all re-bars: fy = 694.45

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

t = 1.00

s = 0.80

e = 1.00

cb = 25.00

Ktr = 1.20951

Atr = /2 * Area of external stirrup = 123.3701

s = s_external = 340.00

n = 12.00

 Calculation of Shear Strength Vr = Min(Vr1, Vr2) = 522178.241

 Calculation of Shear Strength at edge 1, Vr1 = 522178.241

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

VColO = 522178.241

knl = 1 (zero step-static loading)

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

 = 1 (normal-weight concrete)

Mean concrete strength: fc' = (fc'_jacket*Area_jacket + fc'_core*Area_core)/Area_section = 28.32, but fc'^0.5 <= 8.3 MPa (22.5.3.1, ACI 318-14)

M/Vd = 2.00

Mu = 2.3891386E-011

Vu = 4.1704511E-031

d = 0.8*D = 400.00

Nu = 7389.214

Ag = 196349.541

From (11.5.4.8), ACI 318-14: Vs = Vs1 + Vs2 = 76454.061

Vs1 = 48380.801 is calculated for jacket, with:

Av = /2*A_stirrup = 123370.055

fy = 555.56

s = 340.00

Vs1 is multiplied by Col1 = 0.60

s/d = 0.85

Vs2 = 28073.261 is calculated for core, with:

Av = /2*A_stirrup = 78956.835

fy = 444.44

s = 200.00

Vs2 is multiplied by Col2 = 0.66666667

s/d = 0.83333333

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

f = 0.95, for fully-wrapped sections

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

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

This later relation, considered as a function Vf(,), is implemented for every different fiber orientation ai,

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

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

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

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

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

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

$E_f = 64828.00$

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

with $f_u = 0.01$

From (11-11), ACI 440: $V_s + V_f \leq 444245.712$

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

Calculation of Shear Strength at edge 2, $V_{r2} = 522178.241$

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

$V_{Col0} = 522178.241$

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

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

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

Mean concrete strength: $f'_c = (f'_{c,jacket} \cdot \text{Area}_{jacket} + f'_{c,core} \cdot \text{Area}_{core}) / \text{Area}_{section} = 28.32$, but $f'_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$\mu_u = 2.3891386E-011$

$\nu_u = 4.1704511E-031$

$d = 0.8 \cdot D = 400.00$

$N_u = 7389.214$

$A_g = 196349.541$

From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 76454.061$

$V_{s1} = 48380.801$ is calculated for jacket, with:

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

$f_y = 555.56$

$s = 340.00$

V_{s1} is multiplied by $\text{Col1} = 0.60$

$s/d = 0.85$

$V_{s2} = 28073.261$ is calculated for core, with:

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

$f_y = 444.44$

$s = 200.00$

V_{s2} is multiplied by $\text{Col2} = 0.66666667$

$s/d = 0.83333333$

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

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

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

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

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

$E_f = 64828.00$

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

with $f_u = 0.01$

From (11-11), ACI 440: $V_s + V_f \leq 444245.712$

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

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

At local axis: 3

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

At Shear local axis: 2

(Bending local axis: 3)

Section Type: rcjcs

Constant Properties

Knowledge Factor, $\gamma = 1.00$

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

Consequently:

Jacket

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

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

Concrete Elasticity, $E_c = 26999.444$

Steel Elasticity, $E_s = 200000.00$

Existing Column

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

Existing material of Primary Member: Steel Strength, $f_s = f_{sm} = 444.44$

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

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

Jacket

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

Existing Column

Existing material: Steel Strength, $f_s = 1.25 \cdot f_{sm} = 555.55$

#####

External Diameter, $D = 500.00$

Internal Diameter, $D = 300.00$

Cover Thickness, $c = 25.00$

Mean Confinement Factor overall section = 1.46748

Element Length, $L = 3000.00$

Primary Member

Ribbed Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

Lap Length $l_o = 300.00$

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, $V_a = -2.5535805E-047$

EDGE -B-

Shear Force, $V_b = 2.5535805E-047$

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: $Asl,com = 1017.876$
-Middle: $Asl,mid = 1017.876$

Calculation of Shear Capacity ratio, $V_e/V_r = 0.29814229$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 155683.418$

with
 $M_{pr1} = \text{Max}(Mu_{1+}, Mu_{1-}) = 2.3353E+008$
 $Mu_{1+} = 2.3353E+008$, is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination
 $Mu_{1-} = 2.3353E+008$, is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination
 $M_{pr2} = \text{Max}(Mu_{2+}, Mu_{2-}) = 2.3353E+008$
 $Mu_{2+} = 2.3353E+008$, 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
 $Mu_{2-} = 2.3353E+008$, 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
 $Mu = 2.3353E+008$

$= 0.80285146$

$' = 0.71403327$

error of function (3.68), Biskinis Phd = 40102.185

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

conf. factor $c = 1.46748$

$f_c = 33.00$

From 10.3.5, ASCE 41-17, Final value of f_y : $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3}) = 368.0049$

$l_b/l_d = 0.27602844$

$d_1 = 44.00$

$R = 250.00$

$v = 0.00103167$

$N = 7389.214$

$A_c = 196349.541$

$= \cdot \text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3}) = 0.15689624$

Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.27602844$

$l_b = 300.00$

$l_d = 1086.845$

Calculation of l_b, \min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

$= 1$

$d_b = 18.00$

Mean strength value of all re-bars: $f_y = 694.45$

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

$t = 1.00$

$s = 0.80$

$e = 1.00$

$c_b = 25.00$

$K_{tr} = 1.20951$

$A_{tr} = \sqrt{2} \cdot \text{Area of external stirrup} = 123.3701$

$s = s_{external} = 340.00$

$n = 12.00$

Calculation of Mu1-

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

$$\text{Mu} = 2.3353\text{E}+008$$

$$= 0.80285146$$

$$' = 0.71403327$$

error of function (3.68), Biskinis Phd = 40102.185

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

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

$$f_c = 33.00$$

From 10.3.5, ASCE 41-17, Final value of f_y : $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 368.0049$

$$l_b/d = 0.27602844$$

$$d_1 = 44.00$$

$$R = 250.00$$

$$v = 0.00103167$$

$$N = 7389.214$$

$$A_c = 196349.541$$

$$= \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.15689624$$

Calculation of ratio l_b/d

Lap Length: $l_b/d = 0.27602844$

$$l_b = 300.00$$

$$l_d = 1086.845$$

Calculation of l_b , min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

$$= 1$$

$$d_b = 18.00$$

Mean strength value of all re-bars: $f_y = 694.45$

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

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 25.00$$

$$K_{tr} = 1.20951$$

$$A_{tr} = \sqrt{2} \cdot \text{Area of external stirrup} = 123.3701$$

$$s = s_{\text{external}} = 340.00$$

$$n = 12.00$$

Calculation of Mu2+

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

$$\text{Mu} = 2.3353\text{E}+008$$

$$= 0.80285146$$

$$' = 0.71403327$$

error of function (3.68), Biskinis Phd = 40102.185

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

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

$$f_c = 33.00$$

From 10.3.5, ASCE 41-17, Final value of f_y : $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 368.0049$

$$l_b/d = 0.27602844$$

$$d_1 = 44.00$$

$$R = 250.00$$

$$v = 0.00103167$$

$$N = 7389.214$$

$$A_c = 196349.541$$

$$= \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.15689624$$

Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.27602844$

$l_b = 300.00$

$l_d = 1086.845$

Calculation of l_b, \min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

$= 1$

$db = 18.00$

Mean strength value of all re-bars: $f_y = 694.45$

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

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 1.20951$

$A_{tr} = \pi/2 \cdot \text{Area of external stirrup} = 123.3701$

$s = s_{\text{external}} = 340.00$

$n = 12.00$

Calculation of μ_2

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

$\mu = 2.3353E+008$

$= 0.80285146$

$' = 0.71403327$

error of function (3.68), Biskinis Phd = 40102.185

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

conf. factor $c = 1.46748$

$f_c = 33.00$

From 10.3.5, ASCE 41-17, Final value of f_y : $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3}) = 368.0049$

$l_b/l_d = 0.27602844$

$d_1 = 44.00$

$R = 250.00$

$v = 0.00103167$

$N = 7389.214$

$A_c = 196349.541$

$= \text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3}) = 0.15689624$

Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.27602844$

$l_b = 300.00$

$l_d = 1086.845$

Calculation of l_b, \min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

$= 1$

$db = 18.00$

Mean strength value of all re-bars: $f_y = 694.45$

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

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 1.20951$

$A_{tr} = \pi/2 \cdot \text{Area of external stirrup} = 123.3701$

$s = s_{\text{external}} = 340.00$

$n = 12.00$

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 522178.241$

Calculation of Shear Strength at edge 1, $V_{r1} = 522178.241$

$V_{r1} = V_{Co1} \text{ ((10.3), ASCE 41-17)} = knl * V_{Co10}$

$V_{Co10} = 522178.241$

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

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

$= 1$ (normal-weight concrete)

Mean concrete strength: $f_c' = (f_c'_{jacket} * Area_{jacket} + f_c'_{core} * Area_{core}) / Area_{section} = 28.32$, but $f_c'^{0.5} \leq 8.3$
MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$M_u = 2.0433236E-011$

$V_u = 2.5535805E-047$

$d = 0.8 * D = 400.00$

$N_u = 7389.214$

$A_g = 196349.541$

From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 76454.061$

$V_{s1} = 48380.801$ is calculated for jacket, with:

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

$f_y = 555.56$

$s = 340.00$

V_{s1} is multiplied by $Col1 = 0.60$

$s/d = 0.85$

$V_{s2} = 28073.261$ is calculated for core, with:

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

$f_y = 444.44$

$s = 200.00$

V_{s2} is multiplied by $Col2 = 0.66666667$

$s/d = 0.83333333$

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

$f = 0.95$, for fully-wrapped sections

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

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

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

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

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

$E_f = 64828.00$

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

with $f_u = 0.01$

From (11-11), ACI 440: $V_s + V_f \leq 444245.712$

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

Calculation of Shear Strength at edge 2, $V_{r2} = 522178.241$

$V_{r2} = V_{Co2} \text{ ((10.3), ASCE 41-17)} = knl * V_{Co10}$

$V_{Co10} = 522178.241$

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

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

$= 1$ (normal-weight concrete)

Mean concrete strength: $f_c' = (f_c'_{jacket} * Area_{jacket} + f_c'_{core} * Area_{core}) / Area_{section} = 28.32$, but $f_c'^{0.5} \leq 8.3$
MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$M_u = 2.0433236E-011$

$V_u = 2.5535805E-047$

$d = 0.8 \cdot D = 400.00$
 $Nu = 7389.214$
 $Ag = 196349.541$
 From (11.5.4.8), ACI 318-14: $Vs = Vs1 + Vs2 = 76454.061$
 $Vs1 = 48380.801$ is calculated for jacket, with:
 $Av = \sqrt{2} \cdot A_{stirrup} = 123370.055$
 $fy = 555.56$
 $s = 340.00$
 $Vs1$ is multiplied by $Col1 = 0.60$
 $s/d = 0.85$
 $Vs2 = 28073.261$ is calculated for core, with:
 $Av = \sqrt{2} \cdot A_{stirrup} = 78956.835$
 $fy = 444.44$
 $s = 200.00$
 $Vs2$ is multiplied by $Col2 = 0.66666667$
 $s/d = 0.83333333$
 Vf ((11-3)-(11.4), ACI 440) = 247653.332
 $f = 0.95$, for fully-wrapped sections
 $wf/sf = 1$ (FRP strips adjacent to one another).
 In (11.3) $\sin + \cos$ is replaced with $(\cot + \cot a) \sin a$ which is more a generalised expression,
 where a is the angle of the crack direction (see KANEPE).
 This later relation, considered as a function $Vf(\theta, a)$, is implemented for every different fiber orientation a_i ,
 as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.
 orientation 1: $\theta = b1 + 90^\circ = 90.00$
 $Vf = \text{Min}(|Vf(45, \theta)|, |Vf(-45, a1)|)$, with:
 total thickness per orientation, $tf1 = NL \cdot t / NoDir = 1.016$
 $dfv = d$ (figure 11.2, ACI 440) = 470.00
 ffe ((11-5), ACI 440) = 259.312
 $Ef = 64828.00$
 $fe = 0.004$, from (11.6a), ACI 440
 with $fu = 0.01$
 From (11-11), ACI 440: $Vs + Vf \leq 444245.712$
 $bw \cdot d = \sqrt{2} \cdot d \cdot d / 4 = 125663.706$

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

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

Constant Properties

 Knowledge Factor, $\gamma = 1.00$
 Chord Rotation is generally considered as Deformation-Controlled Action according to Table C7-1, ASCE 41-17.
 Mean strengths are used for Deformation-Controlled Actions according to 7.5.1.3, ASCE 41-17
 Consequently:
 Jacket
 New material of Primary Member: Concrete Strength, $fc = f_{cm} = 33.00$
 New material of Primary Member: Steel Strength, $fs = f_{sm} = 555.56$
 Concrete Elasticity, $Ec = 26999.444$
 Steel Elasticity, $Es = 200000.00$
 Existing Column
 Existing material of Primary Member: Concrete Strength, $fc = f_{cm} = 20.00$
 Existing material of Primary Member: Steel Strength, $fs = f_{sm} = 444.44$
 Concrete Elasticity, $Ec = 21019.039$
 Steel Elasticity, $Es = 200000.00$
 External Diameter, $D = 500.00$
 Internal Diameter, $D = 300.00$
 Cover Thickness, $c = 25.00$
 Element Length, $L = 3000.00$
 Primary Member

Ribbed Bars
 Ductile Steel
 Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
 Longitudinal Bars With Ends Lapped Starting at the End Sections
 Lap Length $l_b = 300.00$
 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, $N_L = 1$
 Radius of rounding corners, $R = 40.00$

 Stepwise Properties

 Bending Moment, $M = 1.1931952E-009$
 Shear Force, $V_2 = -5859.331$
 Shear Force, $V_3 = -4.1350384E-013$
 Axial Force, $F = -7386.87$
 Longitudinal Reinforcement Area Distribution (in 2 divisions)
 -Tension: $As_t = 1272.345$
 -Compression: $As_c = 1781.283$
 Longitudinal Reinforcement Area Distribution (in 3 divisions)
 -Tension: $As_{,ten} = 1017.876$
 -Compression: $As_{,com} = 1017.876$
 -Middle: $As_{,mid} = 1017.876$
 Mean Diameter of Tension Reinforcement, $Db_L = 18.00$

 Existing component: From table 7-7, ASCE 41_17: Final chord rotation Capacity $u_{,R} = u = 0.00510707$
 $u = y + p = 0.00510707$

 - Calculation of y -

 $y = (M_y * L_s / 3) / E_{eff} = 0.00510707$ ((4.29), Biskinis Phd))
 $M_y = 2.4653E+008$
 $L_s = M/V$ (with $L_s > 0.1 * L$ and $L_s < 2 * L$) = 1500.00
 From table 10.5, ASCE 41_17: $E_{eff} = factor * E_c * I_g = 2.4137E+013$
 $factor = 0.30$
 $A_g = 196349.541$
 Mean concrete strength: $f'_c = (f'_{c,jacket} * Area_{jacket} + f'_{c,core} * Area_{core}) / Area_{section} = 28.32$
 $N = 7386.87$
 $E_c * I_g = E_{c,jacket} * I_{g,jacket} + E_{c,core} * I_{g,core} = 8.0455E+013$

 Calculation of Yielding Moment M_y

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

 $M_y = \text{Min}(M_{y,ten}, M_{y,com}) = 2.4653E+008$
 $y = 7.1028705E-006$
 $M_{y,ten}$ (8c) = 2.4653E+008
 $_{ten}$ (7c) = 62.22249
 error of function (7c) = 0.00021692
 $M_{y,com}$ (8d) = 8.0674E+008
 $_{com}$ (7d) = 63.84406
 error of function (7d) = -0.00846594
 with ((10.1), ASCE 41-17) $e_y = \text{Min}(e_y, 1.25 * e_y * (l_b / l_d)^{2/3}) = 0.0027778$

$\epsilon_{co} = 0.002$
 $a_{pl} = 0.45$ ((9c) in Biskinis and Fardis for FRP Wrap)
 $d_1 = 44.00$
 $R = 250.00$
 $v = 0.00103628$
 $N = 7386.87$
 $A_c = 196349.541$
 $((10.1), ASCE 41-17) = \text{Min}(, 1.25 * (l_b/d)^{2/3}) = 0.23799351$
 with f_c^* ((12.3), ACI 440) = 36.3038
 $f_c = 33.00$
 $f_l = 1.05384$
 $k = 1$
 Effective FRP thickness, $t_f = NL * t * \text{Cos}(b_1) = 1.016$
 e_{fe} ((12.5) and (12.7)) = 0.004
 $f_u = 0.01$
 $E_f = 64828.00$

 Calculation of ratio l_b/d

Lap Length: $l_d/d, \text{min} = 0.34503556$

$l_b = 300.00$

$l_d = 869.4756$

Calculation of l according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

$= 1$

$d_b = 18.00$

Mean strength value of all re-bars: $f_y = 555.56$

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

$t = 1.00$

$s = 0.80$

$e = 1.00$

$c_b = 25.00$

$K_{tr} = 1.20951$

$A_{tr} = \sqrt{2} * \text{Area of external stirrup} = 123.3701$

$s = s_{\text{external}} = 340.00$

$n = 12.00$

 - Calculation of ρ_p -

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

with:

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

shear control ratio $V_y E / V_{CoI OE} = 0.29814229$

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

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

$t = s_1 + s_2 + 2 * t_f / b_w * (f_{fe} / f_s) = 0.00519403$

jacket: $s_1 = A_{v1} * (D_{c1} / 2) / (s_1 * A_g) = 0.00081312$

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

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

(shear) direction

$s_1 = 340.00$

core: $s_2 = A_{v2} * (D_{c2} / 2) / (s_2 * A_g) = 0.0005871$

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

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

direction

$s_2 = 200.00$

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

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

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

For the normalisation f_s of jacket is used.

$N_{UD} = 7386.87$

$A_g = 196349.541$

$f_c E = (f_c'_{\text{jacket}} * \text{Area}_{\text{jacket}} + f_c'_{\text{core}} * \text{Area}_{\text{core}}) / \text{section_area} = 28.32$

$f_y E = (f_y_{\text{ext_Long_Reinf}} * \text{Area}_{\text{ext_Long_Reinf}} + f_y_{\text{int_Long_Reinf}} * \text{Area}_{\text{int_Long_Reinf}}) / \text{Area}_{\text{Tot_Long_Rein}} =$

2.1219958E-314

$$f_{tE} = (f_{y_ext_Trans_Reinf} * s_1 + f_{y_int_Trans_Reinf} * s_2) / (s_1 + s_2) = 508.9683$$

$$p_l = \text{Area_Tot_Long_Rein} / (A_g) = 0.015552$$

$$f_{cE} = 28.32$$

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

At local axis: 2

Integration Section: (a)

Calculation No. 3

column C1, Floor 1

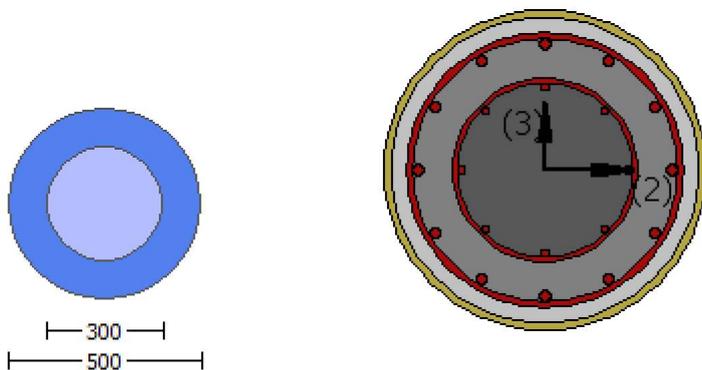
Limit State: Immediate Occupancy (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Shear capacity V_{Rd}

Edge: Start

Local Axis: (3)



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

At local axis: 3

Integration Section: (a)

Section Type: rcjcs

Constant Properties

Knowledge Factor, = 1.00

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

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

Consequently:

Jacket

New material of Primary Member: Concrete Strength, $f_c = f_{c_lower_bound} = 25.00$

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

Concrete Elasticity, $E_c = 26999.444$

Steel Elasticity, $E_s = 200000.00$

Existing Column

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

Existing material of Primary Member: Steel Strength, $f_s = f_{s_lower_bound} = 400.00$
Concrete Elasticity, $E_c = 21019.039$
Steel Elasticity, $E_s = 200000.00$

Note: Especially for the calculation of γ for displacement ductility demand,
the expected (mean value) strengths are used (7.5.1.3, ASCE 41-17) because bending is considered as
Deformation-Controlled Action (Table C7-1, ASCE 41-17).
Jacket
New material: Concrete Strength, $f_c = f_{cm} = 33.00$
New material: Steel Strength, $f_s = f_{sm} = 555.56$
Existing Column
Existing material: Concrete Strength, $f_c = f_{cm} = 20.00$
Existing material: Steel Strength, $f_s = f_{sm} = 444.44$

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

Stepwise Properties

EDGE -A-
Bending Moment, $M_a = 1.1931952E-009$
Shear Force, $V_a = -4.1350384E-013$
EDGE -B-
Bending Moment, $M_b = 4.7579891E-011$
Shear Force, $V_b = 4.1350384E-013$
BOTH EDGES
Axial Force, $F = -7386.87$
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: $A_{sl,t} = 1272.345$
-Compression: $A_{sl,c} = 1781.283$
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension: $A_{sl,ten} = 1017.876$
-Compression: $A_{sl,com} = 1017.876$
-Middle: $A_{sl,mid} = 1017.876$
Mean Diameter of Tension Reinforcement, $Db_{L,ten} = 18.00$

Existing component: From table 7-7, ASCE 41_17: Final Shear Capacity $V_R = \phi V_n = 488735.446$
 $V_n ((10.3), ASCE 41-17) = k_n \phi V_{CoI} = 488735.446$
 $V_{CoI} = 488735.446$
 $k_n = 1.00$
displacement_ductility_demand = 0.00

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

= 1 (normal-weight concrete)
 Mean concrete strength: $f'_c = (f'_{c_jacket} \cdot Area_jacket + f'_{c_core} \cdot Area_core) / Area_section = 21.76$, but $f'_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $M/Vd = 2.00$
 $\mu_u = 1.1931952E-009$
 $V_u = 4.1350384E-013$
 $d = 0.8 \cdot D = 400.00$
 $N_u = 7386.87$
 $A_g = 196349.541$
 From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 68808.56$
 $V_{s1} = 43542.372$ is calculated for jacket, with:
 $A_v = \sqrt{2} \cdot A_{stirrup} = 123370.055$
 $f_y = 500.00$
 $s = 340.00$
 V_{s1} is multiplied by $\text{Col1} = 0.60$
 $s/d = 0.85$
 $V_{s2} = 25266.187$ is calculated for core, with:
 $A_v = \sqrt{2} \cdot A_{stirrup} = 78956.835$
 $f_y = 400.00$
 $s = 200.00$
 V_{s2} is multiplied by $\text{Col2} = 0.66666667$
 $s/d = 0.83333333$
 $V_f ((11-3)-(11.4), ACI 440) = 247653.332$
 $f = 0.95$, for fully-wrapped sections
 $w_f/s_f = 1$ (FRP strips adjacent to one another).
 In (11.3) $\sin + \cos$ is replaced with $(\cot + \csc) \sin \alpha$ which is more a generalised expression, where α is the angle of the crack direction (see KANEPE).
 This later relation, considered as a function $V_f(\alpha, a_i)$, is implemented for every different fiber orientation a_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: $\alpha = b_1 + 90^\circ = 90.00$
 $V_f = \text{Min}(|V_f(45, a_1)|, |V_f(-45, a_1)|)$, with:
 total thickness per orientation, $t_{f1} = N_L \cdot t / N_{oDir} = 1.016$
 $d_{fv} = d$ (figure 11.2, ACI 440) = 470.00
 $f_{fe} ((11-5), ACI 440) = 259.312$
 $E_f = 64828.00$
 $f_e = 0.004$, from (11.6a), ACI 440
 with $f_u = 0.01$
 From (11-11), ACI 440: $V_s + V_f \leq 389409.072$
 $b_w \cdot d = \sqrt{2} \cdot d^2 / 4 = 125663.706$

displacement ductility demand is calculated as δ / y

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

From analysis, chord rotation $\theta = 1.1975644E-020$
 $y = (M_y \cdot L_s / 3) / E_{eff} = 0.00510707$ ((4.29), Biskinis Phd)
 $M_y = 2.4653E+008$
 $L_s = M/V$ (with $L_s > 0.1 \cdot L$ and $L_s < 2 \cdot L$) = 1500.00
 From table 10.5, ASCE 41_17: $E_{eff} = \text{factor} \cdot E_c \cdot I_g = 2.4137E+013$
 factor = 0.30
 $A_g = 196349.541$
 Mean concrete strength: $f'_c = (f'_{c_jacket} \cdot Area_jacket + f'_{c_core} \cdot Area_core) / Area_section = 28.32$
 $N = 7386.87$
 $E_c \cdot I_g = E_{c_jacket} \cdot I_{g_jacket} + E_{c_core} \cdot I_{g_core} = 8.0455E+013$

Calculation of Yielding Moment M_y

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

$M_y = \text{Min}(M_{y_ten}, M_{y_com}) = 2.4653E+008$
 $y = 7.1028705E-006$

$M_{y_ten} (8c) = 2.4653E+008$
 $_{ten} (7c) = 62.22249$
error of function (7c) = 0.00021692
 $M_{y_com} (8d) = 8.0674E+008$
 $_{com} (7d) = 63.84406$
error of function (7d) = -0.00846594
with ((10.1), ASCE 41-17) $e_y = \text{Min}(e_y, 1.25 * e_y * (l_b / l_d)^{2/3}) = 0.0027778$
 $e_{co} = 0.002$
 $a_{pl} = 0.45$ ((9c) in Biskinis and Fardis for FRP Wrap)
 $d_1 = 44.00$
 $R = 250.00$
 $v = 0.00103628$
 $N = 7386.87$
 $A_c = 196349.541$
((10.1), ASCE 41-17) $= \text{Min}(, 1.25 * * (l_b / l_d)^{2/3}) = 0.23799351$
with f_c^* ((12.3), ACI 440) = 36.3038
 $f_c = 33.00$
 $f_l = 1.05384$
 $k = 1$
Effective FRP thickness, $t_f = N L * t * \text{Cos}(b_1) = 1.016$
 e_{fe} ((12.5) and (12.7)) = 0.004
 $f_u = 0.01$
 $E_f = 64828.00$

Calculation of ratio l_b / l_d

Lap Length: $l_d / l_d, \text{min} = 0.34503556$

$l_b = 300.00$

$l_d = 869.4756$

Calculation of l according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

$= 1$

$d_b = 18.00$

Mean strength value of all re-bars: $f_y = 555.56$

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

$t = 1.00$

$s = 0.80$

$e = 1.00$

$c_b = 25.00$

$K_{tr} = 1.20951$

$A_{tr} = /2 * \text{Area of external stirrup} = 123.3701$

$s = s_{external} = 340.00$

$n = 12.00$

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

At local axis: 3

Integration Section: (a)

Calculation No. 4

column C1, Floor 1

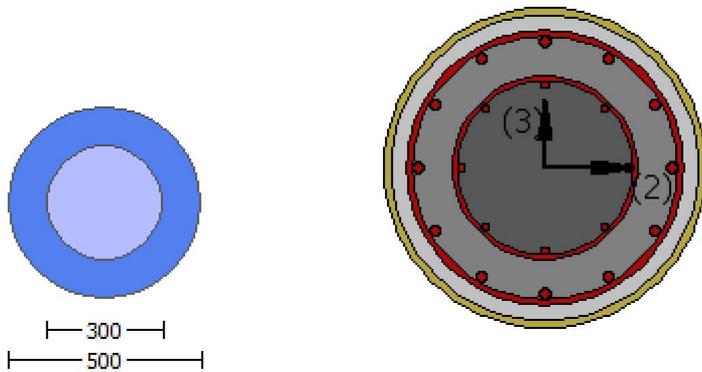
Limit State: Immediate Occupancy (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity (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, $f_c = f_{cm} = 33.00$

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

Concrete Elasticity, $E_c = 26999.444$

Steel Elasticity, $E_s = 200000.00$

Existing Column

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

Existing material of Primary Member: Steel Strength, $f_s = f_{sm} = 444.44$

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

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

Jacket

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

Existing Column

Existing material: Steel Strength, $f_s = 1.25 \cdot f_{sm} = 555.55$

#####

External Diameter, $D = 500.00$

Internal Diameter, $D = 300.00$

Cover Thickness, $c = 25.00$

Mean Confinement Factor overall section = 1.46748

Element Length, $L = 3000.00$

Primary Member

Ribbed Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

Lap Length $l_o = 300.00$

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $\epsilon_{fu} = 0.01$

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

Fiber orientations, $b_i = 0.00^\circ$

Number of layers, $N_L = 1$

Radius of rounding corners, $R = 40.00$

Stepwise Properties

At local axis: 3

EDGE -A-

Shear Force, $V_a = 4.1704511E-031$

EDGE -B-

Shear Force, $V_b = -4.1704511E-031$

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, $V_e/V_r = 0.29814229$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 155683.418$

with

$M_{pr1} = \text{Max}(Mu_{1+}, Mu_{1-}) = 2.3353E+008$

$Mu_{1+} = 2.3353E+008$, is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination

$Mu_{1-} = 2.3353E+008$, is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination

$M_{pr2} = \text{Max}(Mu_{2+}, Mu_{2-}) = 2.3353E+008$

$Mu_{2+} = 2.3353E+008$, is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the static loading combination

$Mu_{2-} = 2.3353E+008$, is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the static loading combination

Calculation of Mu_{1+}

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

$Mu = 2.3353E+008$

$\phi = 0.80285146$

$\phi' = 0.71403327$

error of function (3.68), Biskinis Phd = 40102.185

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

conf. factor $c = 1.46748$

$f_c = 33.00$

From 10.3.5, ASCE 41-17, Final value of f_y : $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3}) = 368.0049$

$l_b/l_d = 0.27602844$

$d_1 = 44.00$

$R = 250.00$

$v = 0.00103167$

$$N = 7389.214$$

$$Ac = 196349.541$$

$$= *Min(1,1.25*(lb/d)^{2/3}) = 0.15689624$$

Calculation of ratio lb/d

$$\text{Lap Length: } lb/d = 0.27602844$$

$$lb = 300.00$$

$$ld = 1086.845$$

Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

$$= 1$$

$$db = 18.00$$

$$\text{Mean strength value of all re-bars: } fy = 694.45$$

$$\text{Mean concrete strength: } fc' = (fc'_{\text{jacket}} * Area_{\text{jacket}} + fc'_{\text{core}} * Area_{\text{core}}) / Area_{\text{section}} = 33.00, \text{ but } fc'^{0.5} \leq 8.3$$

MPa (22.5.3.1, ACI 318-14)

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$cb = 25.00$$

$$Ktr = 1.20951$$

$$Atr = /2 * \text{Area of external stirrup} = 123.3701$$

$$s = s_{\text{external}} = 340.00$$

$$n = 12.00$$

Calculation of Mu1-

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

$$Mu = 2.3353E+008$$

$$= 0.80285146$$

$$' = 0.71403327$$

error of function (3.68), Biskinis Phd = 40102.185

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

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

$$fc = 33.00$$

From 10.3.5, ASCE 41-17, Final value of fy: $fy * Min(1,1.25*(lb/d)^{2/3}) = 368.0049$

$$lb/d = 0.27602844$$

$$d1 = 44.00$$

$$R = 250.00$$

$$v = 0.00103167$$

$$N = 7389.214$$

$$Ac = 196349.541$$

$$= *Min(1,1.25*(lb/d)^{2/3}) = 0.15689624$$

Calculation of ratio lb/d

$$\text{Lap Length: } lb/d = 0.27602844$$

$$lb = 300.00$$

$$ld = 1086.845$$

Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

$$= 1$$

$$db = 18.00$$

$$\text{Mean strength value of all re-bars: } fy = 694.45$$

$$\text{Mean concrete strength: } fc' = (fc'_{\text{jacket}} * Area_{\text{jacket}} + fc'_{\text{core}} * Area_{\text{core}}) / Area_{\text{section}} = 33.00, \text{ but } fc'^{0.5} \leq 8.3$$

MPa (22.5.3.1, ACI 318-14)

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$cb = 25.00$$

$$Ktr = 1.20951$$

$$Atr = /2 * \text{Area of external stirrup} = 123.3701$$

s = s_external = 340.00
n = 12.00

Calculation of Mu2+

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), Mu
Mu = 2.3353E+008

= 0.80285146
' = 0.71403327
error of function (3.68), Biskinis Phd = 40102.185
From 5A.2, TBDY: fcc = fc* c = 48.42699
conf. factor c = 1.46748
fc = 33.00
From 10.3.5, ASCE 41-17, Final value of fy: fy*Min(1,1.25*(lb/d)^ 2/3) = 368.0049
lb/d = 0.27602844
d1 = 44.00
R = 250.00
v = 0.00103167
N = 7389.214
Ac = 196349.541
= *Min(1,1.25*(lb/d)^ 2/3) = 0.15689624

Calculation of ratio lb/d

Lap Length: lb/d = 0.27602844
lb = 300.00
ld = 1086.845
Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
= 1
db = 18.00
Mean strength value of all re-bars: fy = 694.45
Mean concrete strength: fc' = (fc'_jacket*Area_jacket + fc'_core*Area_core)/Area_section = 33.00, but fc'^0.5 <= 8.3
MPa (22.5.3.1, ACI 318-14)
t = 1.00
s = 0.80
e = 1.00
cb = 25.00
Ktr = 1.20951
Atr = /2 * Area of external stirrup = 123.3701
s = s_external = 340.00
n = 12.00

Calculation of Mu2-

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), Mu
Mu = 2.3353E+008

= 0.80285146
' = 0.71403327
error of function (3.68), Biskinis Phd = 40102.185
From 5A.2, TBDY: fcc = fc* c = 48.42699
conf. factor c = 1.46748
fc = 33.00
From 10.3.5, ASCE 41-17, Final value of fy: fy*Min(1,1.25*(lb/d)^ 2/3) = 368.0049
lb/d = 0.27602844
d1 = 44.00
R = 250.00

$$v = 0.00103167$$

$$N = 7389.214$$

$$Ac = 196349.541$$

$$= *Min(1, 1.25*(lb/ld)^{2/3}) = 0.15689624$$

 Calculation of ratio lb/ld

 Lap Length: lb/ld = 0.27602844

lb = 300.00

ld = 1086.845

Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

= 1

db = 18.00

Mean strength value of all re-bars: fy = 694.45

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

t = 1.00

s = 0.80

e = 1.00

cb = 25.00

Ktr = 1.20951

Atr = /2 * Area of external stirrup = 123.3701

s = s_external = 340.00

n = 12.00

 Calculation of Shear Strength Vr = Min(Vr1, Vr2) = 522178.241

 Calculation of Shear Strength at edge 1, Vr1 = 522178.241

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

VColO = 522178.241

knl = 1 (zero step-static loading)

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

 = 1 (normal-weight concrete)

Mean concrete strength: fc' = (fc'_jacket*Area_jacket + fc'_core*Area_core)/Area_section = 28.32, but fc'^0.5 <= 8.3 MPa (22.5.3.1, ACI 318-14)

M/Vd = 2.00

Mu = 2.3891386E-011

Vu = 4.1704511E-031

d = 0.8*D = 400.00

Nu = 7389.214

Ag = 196349.541

From (11.5.4.8), ACI 318-14: Vs = Vs1 + Vs2 = 76454.061

Vs1 = 48380.801 is calculated for jacket, with:

Av = /2*A_stirrup = 123370.055

fy = 555.56

s = 340.00

Vs1 is multiplied by Col1 = 0.60

s/d = 0.85

Vs2 = 28073.261 is calculated for core, with:

Av = /2*A_stirrup = 78956.835

fy = 444.44

s = 200.00

Vs2 is multiplied by Col2 = 0.66666667

s/d = 0.83333333

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

f = 0.95, for fully-wrapped sections

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

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

This later relation, considered as a function Vf(,), is implemented for every different fiber orientation ai,

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

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

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

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

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

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

$E_f = 64828.00$

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

with $fu = 0.01$

From (11-11), ACI 440: $V_s + V_f \leq 444245.712$

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

Calculation of Shear Strength at edge 2, $V_{r2} = 522178.241$

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

$V_{Col0} = 522178.241$

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

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

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

Mean concrete strength: $f'_c = (f'_c \cdot \text{jacket} \cdot \text{Area}_{\text{jacket}} + f'_c \cdot \text{core} \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 28.32$, but $f'_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M / V d = 2.00$

$\mu_u = 2.3891386E-011$

$\nu_u = 4.1704511E-031$

$d = 0.8 \cdot D = 400.00$

$N_u = 7389.214$

$A_g = 196349.541$

From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 76454.061$

$V_{s1} = 48380.801$ is calculated for jacket, with:

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

$f_y = 555.56$

$s = 340.00$

V_{s1} is multiplied by $\text{Col1} = 0.60$

$s/d = 0.85$

$V_{s2} = 28073.261$ is calculated for core, with:

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

$f_y = 444.44$

$s = 200.00$

V_{s2} is multiplied by $\text{Col2} = 0.66666667$

$s/d = 0.83333333$

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

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

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

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

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

$E_f = 64828.00$

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

with $fu = 0.01$

From (11-11), ACI 440: $V_s + V_f \leq 444245.712$

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

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

At local axis: 3

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

At Shear local axis: 2

(Bending local axis: 3)

Section Type: rcjcs

Constant Properties

Knowledge Factor, $\gamma = 1.00$

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

Consequently:

Jacket

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

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

Concrete Elasticity, $E_c = 26999.444$

Steel Elasticity, $E_s = 200000.00$

Existing Column

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

Existing material of Primary Member: Steel Strength, $f_s = f_{sm} = 444.44$

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

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

Jacket

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

Existing Column

Existing material: Steel Strength, $f_s = 1.25 \cdot f_{sm} = 555.55$

#####

External Diameter, $D = 500.00$

Internal Diameter, $D = 300.00$

Cover Thickness, $c = 25.00$

Mean Confinement Factor overall section = 1.46748

Element Length, $L = 3000.00$

Primary Member

Ribbed Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

Lap Length $l_o = 300.00$

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, $V_a = -2.5535805E-047$

EDGE -B-

Shear Force, $V_b = 2.5535805E-047$

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, $V_e/V_r = 0.29814229$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 155683.418$

with
 $M_{pr1} = \text{Max}(M_{u1+}, M_{u1-}) = 2.3353E+008$
 $M_{u1+} = 2.3353E+008$, is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination
 $M_{u1-} = 2.3353E+008$, is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination
 $M_{pr2} = \text{Max}(M_{u2+}, M_{u2-}) = 2.3353E+008$
 $M_{u2+} = 2.3353E+008$, is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the static loading combination
 $M_{u2-} = 2.3353E+008$, is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the static loading combination

Calculation of M_{u1+}

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), M_u
 $M_u = 2.3353E+008$

$\phi = 0.80285146$
 $\lambda = 0.71403327$
error of function (3.68), Biskinis Phd = 40102.185
From 5A.2, TBDY: $f_{cc} = f_c' \cdot \lambda = 48.42699$
conf. factor $\lambda = 1.46748$
 $f_c = 33.00$
From 10.3.5, ASCE 41-17, Final value of f_y : $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3}) = 368.0049$
 $l_b/l_d = 0.27602844$
 $d_1 = 44.00$
 $R = 250.00$
 $v = 0.00103167$
 $N = 7389.214$
 $A_c = 196349.541$
 $\phi \cdot \text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3}) = 0.15689624$

Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.27602844$

$l_b = 300.00$

$l_d = 1086.845$

Calculation of l_b, min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

$\phi = 1$
 $d_b = 18.00$
Mean strength value of all re-bars: $f_y = 694.45$
Mean concrete strength: $f_c' = (f_c'_{\text{jacket}} \cdot \text{Area}_{\text{jacket}} + f_c'_{\text{core}} \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 33.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $t = 1.00$
 $s = 0.80$
 $e = 1.00$
 $cb = 25.00$
 $K_{tr} = 1.20951$
 $A_{tr} = \sqrt{2} \cdot \text{Area of external stirrup} = 123.3701$
 $s = s_{\text{external}} = 340.00$
 $n = 12.00$

Calculation of Mu1-

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

$$\text{Mu} = 2.3353\text{E}+008$$

$$= 0.80285146$$

$$' = 0.71403327$$

error of function (3.68), Biskinis Phd = 40102.185

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

conf. factor $c = 1.46748$

$$f_c = 33.00$$

From 10.3.5, ASCE 41-17, Final value of f_y : $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 368.0049$

$$l_b/d = 0.27602844$$

$$d_1 = 44.00$$

$$R = 250.00$$

$$v = 0.00103167$$

$$N = 7389.214$$

$$A_c = 196349.541$$

$$= \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.15689624$$

Calculation of ratio l_b/d

Lap Length: $l_b/d = 0.27602844$

$$l_b = 300.00$$

$$l_d = 1086.845$$

Calculation of l_b , min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

$$= 1$$

$$d_b = 18.00$$

Mean strength value of all re-bars: $f_y = 694.45$

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

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 25.00$$

$$K_{tr} = 1.20951$$

$$A_{tr} = \sqrt{2} \cdot \text{Area of external stirrup} = 123.3701$$

$$s = s_{\text{external}} = 340.00$$

$$n = 12.00$$

Calculation of Mu2+

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

$$\text{Mu} = 2.3353\text{E}+008$$

$$= 0.80285146$$

$$' = 0.71403327$$

error of function (3.68), Biskinis Phd = 40102.185

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

conf. factor $c = 1.46748$

$$f_c = 33.00$$

From 10.3.5, ASCE 41-17, Final value of f_y : $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 368.0049$

$$l_b/d = 0.27602844$$

$$d_1 = 44.00$$

$$R = 250.00$$

$$v = 0.00103167$$

$$N = 7389.214$$

$$A_c = 196349.541$$

$$= \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.15689624$$

Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.27602844$

$l_b = 300.00$

$l_d = 1086.845$

Calculation of l_b, \min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

$= 1$

$d_b = 18.00$

Mean strength value of all re-bars: $f_y = 694.45$

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

$t = 1.00$

$s = 0.80$

$e = 1.00$

$c_b = 25.00$

$K_{tr} = 1.20951$

$A_{tr} = \pi/2 \cdot \text{Area of external stirrup} = 123.3701$

$s = s_{\text{external}} = 340.00$

$n = 12.00$

Calculation of μ_2

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

$\mu = 2.3353E+008$

$= 0.80285146$

$' = 0.71403327$

error of function (3.68), Biskinis Phd = 40102.185

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

conf. factor $c = 1.46748$

$f_c = 33.00$

From 10.3.5, ASCE 41-17, Final value of f_y : $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3}) = 368.0049$

$l_b/l_d = 0.27602844$

$d_1 = 44.00$

$R = 250.00$

$v = 0.00103167$

$N = 7389.214$

$A_c = 196349.541$

$= \text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3}) = 0.15689624$

Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.27602844$

$l_b = 300.00$

$l_d = 1086.845$

Calculation of l_b, \min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

$= 1$

$d_b = 18.00$

Mean strength value of all re-bars: $f_y = 694.45$

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

$t = 1.00$

$s = 0.80$

$e = 1.00$

$c_b = 25.00$

$K_{tr} = 1.20951$

$A_{tr} = \pi/2 \cdot \text{Area of external stirrup} = 123.3701$

$s = s_{\text{external}} = 340.00$

$n = 12.00$

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 522178.241$

Calculation of Shear Strength at edge 1, $V_{r1} = 522178.241$

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

$V_{Co10} = 522178.241$

$k_{nl} = 1$ (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: $f_c' = (f_c'_{\text{jacket}} * \text{Area}_{\text{jacket}} + f_c'_{\text{core}} * \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 28.32$, but $f_c'^{0.5} \leq 8.3$
MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$M_u = 2.0433236E-011$

$V_u = 2.5535805E-047$

$d = 0.8 * D = 400.00$

$N_u = 7389.214$

$A_g = 196349.541$

From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 76454.061$

$V_{s1} = 48380.801$ is calculated for jacket, with:

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

$f_y = 555.56$

$s = 340.00$

V_{s1} is multiplied by $Col1 = 0.60$

$s/d = 0.85$

$V_{s2} = 28073.261$ is calculated for core, with:

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

$f_y = 444.44$

$s = 200.00$

V_{s2} is multiplied by $Col2 = 0.66666667$

$s/d = 0.83333333$

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

$f = 0.95$, for fully-wrapped sections

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

In (11.3) $\sin + \cos$ is replaced with $(\cot + \csc) \sin \alpha$ which is more a generalised expression,
where 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: $\alpha = 90^\circ = 90.00$

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

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

$d_{fv} = d$ (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: $V_s + V_f \leq 444245.712$

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

Calculation of Shear Strength at edge 2, $V_{r2} = 522178.241$

$V_{r2} = V_{Co2} ((10.3), \text{ASCE } 41-17) = k_{nl} * V_{Co10}$

$V_{Co10} = 522178.241$

$k_{nl} = 1$ (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: $f_c' = (f_c'_{\text{jacket}} * \text{Area}_{\text{jacket}} + f_c'_{\text{core}} * \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 28.32$, but $f_c'^{0.5} \leq 8.3$
MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$M_u = 2.0433236E-011$

$V_u = 2.5535805E-047$

$d = 0.8 \cdot D = 400.00$
 $Nu = 7389.214$
 $Ag = 196349.541$
 From (11.5.4.8), ACI 318-14: $Vs = Vs1 + Vs2 = 76454.061$
 $Vs1 = 48380.801$ is calculated for jacket, with:
 $Av = \sqrt{2} \cdot A_{stirrup} = 123370.055$
 $fy = 555.56$
 $s = 340.00$
 $Vs1$ is multiplied by $Col1 = 0.60$
 $s/d = 0.85$
 $Vs2 = 28073.261$ is calculated for core, with:
 $Av = \sqrt{2} \cdot A_{stirrup} = 78956.835$
 $fy = 444.44$
 $s = 200.00$
 $Vs2$ is multiplied by $Col2 = 0.66666667$
 $s/d = 0.83333333$
 $Vf ((11-3)-(11.4), ACI 440) = 247653.332$
 $f = 0.95$, for fully-wrapped sections
 $wf/sf = 1$ (FRP strips adjacent to one another).
 In (11.3) $\sin + \cos$ is replaced with $(\cot + \cot a) \sin a$ which is more a generalised expression,
 where a is the angle of the crack direction (see KANEPE).
 This later relation, considered as a function $Vf(\theta, a)$, is implemented for every different fiber orientation a_i ,
 as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.
 orientation 1: $\theta = b1 + 90^\circ = 90.00$
 $Vf = \text{Min}(|Vf(45, \theta)|, |Vf(-45, a1)|)$, with:
 total thickness per orientation, $tf1 = NL \cdot t / NoDir = 1.016$
 $dfv = d$ (figure 11.2, ACI 440) = 470.00
 $ffe ((11-5), ACI 440) = 259.312$
 $Ef = 64828.00$
 $fe = 0.004$, from (11.6a), ACI 440
 with $fu = 0.01$
 From (11-11), ACI 440: $Vs + Vf \leq 444245.712$
 $bw \cdot d = \sqrt{2} \cdot d \cdot d / 4 = 125663.706$

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

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

Constant Properties

 Knowledge Factor, $\gamma = 1.00$
 Chord Rotation is generally considered as Deformation-Controlled Action according to Table C7-1, ASCE 41-17.
 Mean strengths are used for Deformation-Controlled Actions according to 7.5.1.3, ASCE 41-17
 Consequently:
 Jacket
 New material of Primary Member: Concrete Strength, $fc = f_{cm} = 33.00$
 New material of Primary Member: Steel Strength, $fs = f_{sm} = 555.56$
 Concrete Elasticity, $Ec = 26999.444$
 Steel Elasticity, $Es = 200000.00$
 Existing Column
 Existing material of Primary Member: Concrete Strength, $fc = f_{cm} = 20.00$
 Existing material of Primary Member: Steel Strength, $fs = f_{sm} = 444.44$
 Concrete Elasticity, $Ec = 21019.039$
 Steel Elasticity, $Es = 200000.00$
 External Diameter, $D = 500.00$
 Internal Diameter, $D = 300.00$
 Cover Thickness, $c = 25.00$
 Element Length, $L = 3000.00$
 Primary Member

Ribbed Bars
 Ductile Steel
 Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
 Longitudinal Bars With Ends Lapped Starting at the End Sections
 Lap Length $l_b = 300.00$
 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

 Bending Moment, $M = -1.7582E+007$
 Shear Force, $V_2 = -5859.331$
 Shear Force, $V_3 = -4.1350384E-013$
 Axial Force, $F = -7386.87$
 Longitudinal Reinforcement Area Distribution (in 2 divisions)
 -Tension: $As_t = 1272.345$
 -Compression: $As_c = 1781.283$
 Longitudinal Reinforcement Area Distribution (in 3 divisions)
 -Tension: $As_{,ten} = 1017.876$
 -Compression: $As_{,com} = 1017.876$
 -Middle: $As_{,mid} = 1017.876$
 Mean Diameter of Tension Reinforcement, $Db_L = 18.00$

 Existing component: From table 7-7, ASCE 41_17: Final chord rotation Capacity $u_{,R} = \gamma + p = 0.01021672$

 - Calculation of γ -

 $\gamma = (M_y * L_s / 3) / E_{eff} = 0.01021672$ ((4.29), Biskinis Phd)
 $M_y = 2.4653E+008$
 $L_s = M/V$ (with $L_s > 0.1 * L$ and $L_s < 2 * L$) = 3000.756
 From table 10.5, ASCE 41_17: $E_{eff} = factor * E_c * I_g = 2.4137E+013$
 $factor = 0.30$
 $A_g = 196349.541$
 Mean concrete strength: $f'_c = (f'_{c,jacket} * Area_{jacket} + f'_{c,core} * Area_{core}) / Area_{section} = 28.32$
 $N = 7386.87$
 $E_c * I_g = E_{c,jacket} * I_{g,jacket} + E_{c,core} * I_{g,core} = 8.0455E+013$

 Calculation of Yielding Moment M_y

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

 $M_y = \text{Min}(M_{y,ten}, M_{y,com}) = 2.4653E+008$
 $\gamma = 7.1028705E-006$
 $M_{y,ten}$ (8c) = $2.4653E+008$
 γ_{ten} (7c) = 62.22249
 error of function (7c) = 0.00021692
 $M_{y,com}$ (8d) = $8.0674E+008$
 γ_{com} (7d) = 63.84406
 error of function (7d) = -0.00846594
 with ((10.1), ASCE 41-17) $e_y = \text{Min}(e_y, 1.25 * e_y * (l_b / l_d)^{2/3}) = 0.0027778$

$\rho_{FRP} = 0.002$
 $\alpha_{FRP} = 0.45$ ((9c) in Biskinis and Fardis for FRP Wrap)
 $d_1 = 44.00$
 $R = 250.00$
 $\nu = 0.00103628$
 $N = 7386.87$
 $A_c = 196349.541$
 $\left(\frac{10.1}{R}, ASCE 41-17\right) = \text{Min}\left(1, 1.25 \cdot \left(\frac{l_b}{l_d}\right)^{2/3}\right) = 0.23799351$
 with $f_c^* \left(\frac{12.3}{R}, ACI 440\right) = 36.3038$
 $f_c = 33.00$
 $\beta_1 = 1.05384$
 $k = 1$
 Effective FRP thickness, $t_f = N \cdot t \cdot \cos(\beta_1) = 1.016$
 $\rho_{FRP} \left(\frac{12.5}{R} \text{ and } \frac{12.7}{R}\right) = 0.004$
 $f_u = 0.01$
 $E_f = 64828.00$

 Calculation of ratio l_b/l_d

Lap Length: $l_d/l_d, \text{min} = 0.34503556$

$l_b = 300.00$

$l_d = 869.4756$

Calculation of l according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

$\beta_1 = 1$

$d_b = 18.00$

Mean strength value of all re-bars: $f_y = 555.56$

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

$t = 1.00$

$s = 0.80$

$e = 1.00$

$c_b = 25.00$

$K_{tr} = 1.20951$

$A_{tr} = \sqrt{2} \cdot \text{Area of external stirrup} = 123.3701$

$s = s_{\text{external}} = 340.00$

$n = 12.00$

 - Calculation of ρ_p -

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

with:

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

shear control ratio $V_y E / V_{CoI} O E = 0.29814229$

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

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

$t = s_1 + s_2 + 2 \cdot t_f / b_w \cdot (f_{fe} / f_s) = 0.00519403$

jacket: $s_1 = A_{v1} \cdot \left(\frac{D_{c1}}{2}\right) / (s_1 \cdot A_g) = 0.00081312$

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

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

(shear) direction

$s_1 = 340.00$

core: $s_2 = A_{v2} \cdot \left(\frac{D_{c2}}{2}\right) / (s_2 \cdot A_g) = 0.0005871$

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

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

direction

$s_2 = 200.00$

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.

$N_{UD} = 7386.87$

$A_g = 196349.541$

$f_c E = (f_c'_{\text{jacket}} \cdot \text{Area}_{\text{jacket}} + f_c'_{\text{core}} \cdot \text{Area}_{\text{core}}) / \text{section_area} = 28.32$

$f_y E = (f_y'_{\text{ext_Long_Reinf}} \cdot \text{Area}_{\text{ext_Long_Reinf}} + f_y'_{\text{int_Long_Reinf}} \cdot \text{Area}_{\text{int_Long_Reinf}}) / \text{Area}_{\text{Tot_Long_Rein}} =$

2.1219958E-314

$$f_{tE} = (f_{y_ext_Trans_Reinf} * s_1 + f_{y_int_Trans_Reinf} * s_2) / (s_1 + s_2) = 508.9683$$

$$p_l = \text{Area_Tot_Long_Rein} / (A_g) = 0.015552$$

$$f_{cE} = 28.32$$

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

At local axis: 3

Integration Section: (a)

Calculation No. 5

column C1, Floor 1

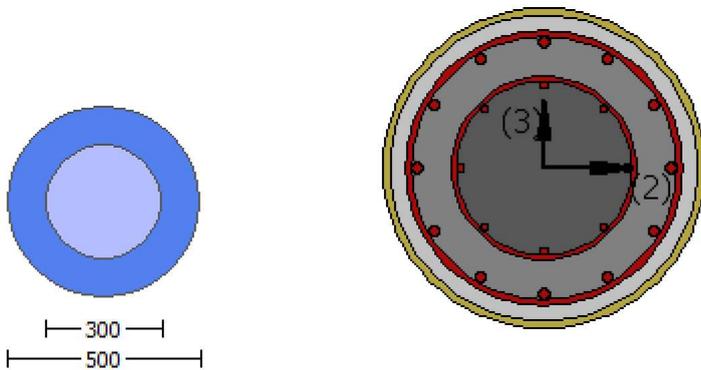
Limit State: Immediate Occupancy (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Shear capacity 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, $f_c = f_{c_lower_bound} = 25.00$

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

Concrete Elasticity, $E_c = 26999.444$

Steel Elasticity, $E_s = 200000.00$

Existing Column

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

Existing material of Primary Member: Steel Strength, $f_s = f_{s_lower_bound} = 400.00$
Concrete Elasticity, $E_c = 21019.039$
Steel Elasticity, $E_s = 200000.00$

Note: Especially for the calculation of γ for displacement ductility demand,
the expected (mean value) strengths are used (7.5.1.3, ASCE 41-17) because bending is considered as
Deformation-Controlled Action (Table C7-1, ASCE 41-17).
Jacket
New material: Concrete Strength, $f_c = f_{cm} = 33.00$
New material: Steel Strength, $f_s = f_{sm} = 555.56$
Existing Column
Existing material: Concrete Strength, $f_c = f_{cm} = 20.00$
Existing material: Steel Strength, $f_s = f_{sm} = 444.44$

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

Stepwise Properties

EDGE -A-
Bending Moment, $M_a = -1.7582E+007$
Shear Force, $V_a = -5859.331$
EDGE -B-
Bending Moment, $M_b = 0.08058394$
Shear Force, $V_b = 5859.331$
BOTH EDGES
Axial Force, $F = -7386.87$
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: $A_{sl,t} = 0.00$
-Compression: $A_{sl,c} = 3053.628$
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension: $A_{sl,ten} = 1017.876$
-Compression: $A_{sl,com} = 1017.876$
-Middle: $A_{sl,mid} = 1017.876$
Mean Diameter of Tension Reinforcement, $Db_{L,ten} = 18.00$

Existing component: From table 7-7, ASCE 41_17: Final Shear Capacity $V_R = \phi V_n = 488735.446$
 $V_n ((10.3), ASCE 41-17) = k_n \phi V_{CoI} = 488735.446$
 $V_{CoI} = 488735.446$
 $k_n = 1.00$
displacement_ductility_demand = 0.10696644

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

= 1 (normal-weight concrete)
Mean concrete strength: $f'_c = (f'_{c_jacket} \cdot Area_jacket + f'_{c_core} \cdot Area_core) / Area_section = 21.76$, but $f'_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $M/Vd = 2.00$
 $\mu_u = 0.08058394$
 $V_u = 5859.331$
 $d = 0.8 \cdot D = 400.00$
 $N_u = 7386.87$
 $A_g = 196349.541$
From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 68808.56$
 $V_{s1} = 43542.372$ is calculated for jacket, with:
 $A_v = \sqrt{2} \cdot A_{stirrup} = 123370.055$
 $f_y = 500.00$
 $s = 340.00$
 V_{s1} is multiplied by $\text{Col1} = 0.60$
 $s/d = 0.85$
 $V_{s2} = 25266.187$ is calculated for core, with:
 $A_v = \sqrt{2} \cdot A_{stirrup} = 78956.835$
 $f_y = 400.00$
 $s = 200.00$
 V_{s2} is multiplied by $\text{Col2} = 0.66666667$
 $s/d = 0.83333333$
 $V_f ((11-3)-(11.4), ACI 440) = 247653.332$
 $f = 0.95$, for fully-wrapped sections
 $w_f/s_f = 1$ (FRP strips adjacent to one another).
In (11.3) $\sin + \cos$ is replaced with $(\cot + \csc) \sin \alpha$ which is more a generalised expression, where α is the angle of the crack direction (see KANEPE).
This later relation, considered as a function $V_f(\alpha, a_i)$, is implemented for every different fiber orientation a_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: $\alpha = b_1 + 90^\circ = 90.00$
 $V_f = \text{Min}(|V_f(45, a_1)|, |V_f(-45, a_1)|)$, with:
total thickness per orientation, $t_{f1} = N_L \cdot t / N_{oDir} = 1.016$
 $d_{fv} = d$ (figure 11.2, ACI 440) = 470.00
 $f_{fe} ((11-5), ACI 440) = 259.312$
 $E_f = 64828.00$
 $f_e = 0.004$, from (11.6a), ACI 440
with $f_u = 0.01$
From (11-11), ACI 440: $V_s + V_f \leq 389409.072$
 $b_w \cdot d = \sqrt{V_s + V_f} \cdot d / 4 = 125663.706$

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 $\theta = 0.00010926$
 $y = (M_y \cdot L_s / 3) / E_{eff} = 0.00102141$ ((4.29), Biskinis Phd)
 $M_y = 2.4653E+008$
 $L_s = M/V$ (with $L_s > 0.1 \cdot L$ and $L_s < 2 \cdot L$) = 300.00
From table 10.5, ASCE 41_17: $E_{eff} = \text{factor} \cdot E_c \cdot I_g = 2.4137E+013$
factor = 0.30
 $A_g = 196349.541$
Mean concrete strength: $f'_c = (f'_{c_jacket} \cdot Area_jacket + f'_{c_core} \cdot Area_core) / Area_section = 28.32$
 $N = 7386.87$
 $E_c \cdot I_g = E_{c_jacket} \cdot I_{g_jacket} + E_{c_core} \cdot I_{g_core} = 8.0455E+013$

Calculation of Yielding Moment M_y

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

$M_y = \text{Min}(M_{y_ten}, M_{y_com}) = 2.4653E+008$
 $y = 7.1028705E-006$

$M_{y_ten} (8c) = 2.4653E+008$
 $_{ten} (7c) = 62.22249$
error of function (7c) = 0.00021692
 $M_{y_com} (8d) = 8.0674E+008$
 $_{com} (7d) = 63.84406$
error of function (7d) = -0.00846594
with ((10.1), ASCE 41-17) $e_y = \text{Min}(e_y, 1.25 * e_y * (l_b / l_d)^{2/3}) = 0.0027778$
 $e_{co} = 0.002$
 $a_{pl} = 0.45$ ((9c) in Biskinis and Fardis for FRP Wrap)
 $d_1 = 44.00$
 $R = 250.00$
 $v = 0.00103628$
 $N = 7386.87$
 $A_c = 196349.541$
((10.1), ASCE 41-17) $= \text{Min}(, 1.25 * * (l_b / l_d)^{2/3}) = 0.23799351$
with f_c^* ((12.3), ACI 440) = 36.3038
 $f_c = 33.00$
 $f_l = 1.05384$
 $k = 1$
Effective FRP thickness, $t_f = N L * t * \text{Cos}(b_1) = 1.016$
 e_{fe} ((12.5) and (12.7)) = 0.004
 $f_u = 0.01$
 $E_f = 64828.00$

Calculation of ratio l_b / l_d

Lap Length: $l_d / l_d, \text{min} = 0.34503556$

$l_b = 300.00$

$l_d = 869.4756$

Calculation of l according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

$= 1$

$d_b = 18.00$

Mean strength value of all re-bars: $f_y = 555.56$

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

$t = 1.00$

$s = 0.80$

$e = 1.00$

$c_b = 25.00$

$K_{tr} = 1.20951$

$A_{tr} = \sqrt{2} * \text{Area of external stirrup} = 123.3701$

$s = s_{external} = 340.00$

$n = 12.00$

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

At local axis: 2

Integration Section: (b)

Calculation No. 6

column C1, Floor 1

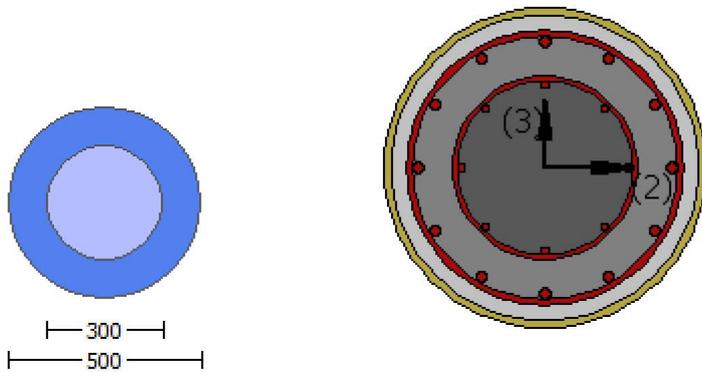
Limit State: Immediate Occupancy (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity (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, $f_c = f_{cm} = 33.00$

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

Concrete Elasticity, $E_c = 26999.444$

Steel Elasticity, $E_s = 200000.00$

Existing Column

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

Existing material of Primary Member: Steel Strength, $f_s = f_{sm} = 444.44$

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

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

Jacket

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

Existing Column

Existing material: Steel Strength, $f_s = 1.25 \cdot f_{sm} = 555.55$

#####

External Diameter, $D = 500.00$

Internal Diameter, $D = 300.00$

Cover Thickness, $c = 25.00$

Mean Confinement Factor overall section = 1.46748

Element Length, $L = 3000.00$

Primary Member

Ribbed Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

Lap Length $l_o = 300.00$

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $\epsilon_{fu} = 0.01$

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

Fiber orientations, $b_i = 0.00^\circ$

Number of layers, $N_L = 1$

Radius of rounding corners, $R = 40.00$

Stepwise Properties

At local axis: 3

EDGE -A-

Shear Force, $V_a = 4.1704511E-031$

EDGE -B-

Shear Force, $V_b = -4.1704511E-031$

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, $V_e/V_r = 0.29814229$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 155683.418$

with

$M_{pr1} = \text{Max}(Mu_{1+}, Mu_{1-}) = 2.3353E+008$

$Mu_{1+} = 2.3353E+008$, is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination

$Mu_{1-} = 2.3353E+008$, is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination

$M_{pr2} = \text{Max}(Mu_{2+}, Mu_{2-}) = 2.3353E+008$

$Mu_{2+} = 2.3353E+008$, is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the static loading combination

$Mu_{2-} = 2.3353E+008$, is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the static loading combination

Calculation of Mu_{1+}

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

$Mu = 2.3353E+008$

$\phi = 0.80285146$

$\lambda = 0.71403327$

error of function (3.68), Biskinis Phd = 40102.185

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

conf. factor $c = 1.46748$

$f_c = 33.00$

From 10.3.5, ASCE 41-17, Final value of f_y : $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3}) = 368.0049$

$l_b/l_d = 0.27602844$

$d_1 = 44.00$

$R = 250.00$

$v = 0.00103167$

$$N = 7389.214$$

$$Ac = 196349.541$$

$$= *Min(1, 1.25*(lb/d)^{2/3}) = 0.15689624$$

 Calculation of ratio lb/d

 Lap Length: lb/d = 0.27602844

lb = 300.00

ld = 1086.845

Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

= 1

db = 18.00

Mean strength value of all re-bars: fy = 694.45

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

t = 1.00

s = 0.80

e = 1.00

cb = 25.00

Ktr = 1.20951

Atr = /2 * Area of external stirrup = 123.3701

s = s_external = 340.00

n = 12.00

 Calculation of Mu1-

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

Mu = 2.3353E+008

 = 0.80285146

' = 0.71403327

error of function (3.68), Biskinis Phd = 40102.185

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

conf. factor c = 1.46748

fc = 33.00

From 10.3.5, ASCE 41-17, Final value of fy: fy*Min(1, 1.25*(lb/d)^{2/3}) = 368.0049

lb/d = 0.27602844

d1 = 44.00

R = 250.00

v = 0.00103167

N = 7389.214

Ac = 196349.541

= *Min(1, 1.25*(lb/d)^{2/3}) = 0.15689624

 Calculation of ratio lb/d

 Lap Length: lb/d = 0.27602844

lb = 300.00

ld = 1086.845

Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

= 1

db = 18.00

Mean strength value of all re-bars: fy = 694.45

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

t = 1.00

s = 0.80

e = 1.00

cb = 25.00

Ktr = 1.20951

Atr = /2 * Area of external stirrup = 123.3701

s = s_external = 340.00
n = 12.00

Calculation of Mu2+

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), Mu
Mu = 2.3353E+008

= 0.80285146
' = 0.71403327
error of function (3.68), Biskinis Phd = 40102.185
From 5A.2, TBDY: fcc = fc* c = 48.42699
conf. factor c = 1.46748
fc = 33.00
From 10.3.5, ASCE 41-17, Final value of fy: fy*Min(1,1.25*(lb/d)^ 2/3) = 368.0049
lb/d = 0.27602844
d1 = 44.00
R = 250.00
v = 0.00103167
N = 7389.214
Ac = 196349.541
= *Min(1,1.25*(lb/d)^ 2/3) = 0.15689624

Calculation of ratio lb/d

Lap Length: lb/d = 0.27602844
lb = 300.00
ld = 1086.845
Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
= 1
db = 18.00
Mean strength value of all re-bars: fy = 694.45
Mean concrete strength: fc' = (fc'_jacket*Area_jacket + fc'_core*Area_core)/Area_section = 33.00, but fc'^0.5 <= 8.3 MPa (22.5.3.1, ACI 318-14)
t = 1.00
s = 0.80
e = 1.00
cb = 25.00
Ktr = 1.20951
Atr = /2 * Area of external stirrup = 123.3701
s = s_external = 340.00
n = 12.00

Calculation of Mu2-

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), Mu
Mu = 2.3353E+008

= 0.80285146
' = 0.71403327
error of function (3.68), Biskinis Phd = 40102.185
From 5A.2, TBDY: fcc = fc* c = 48.42699
conf. factor c = 1.46748
fc = 33.00
From 10.3.5, ASCE 41-17, Final value of fy: fy*Min(1,1.25*(lb/d)^ 2/3) = 368.0049
lb/d = 0.27602844
d1 = 44.00
R = 250.00

$$v = 0.00103167$$

$$N = 7389.214$$

$$Ac = 196349.541$$

$$= *Min(1, 1.25*(lb/ld)^{2/3}) = 0.15689624$$

Calculation of ratio lb/ld

Lap Length: $lb/ld = 0.27602844$

$lb = 300.00$

$ld = 1086.845$

Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

$= 1$

$db = 18.00$

Mean strength value of all re-bars: $fy = 694.45$

Mean concrete strength: $fc' = (fc'_jacket * Area_jacket + fc'_core * Area_core) / Area_section = 33.00$, but $fc'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$Ktr = 1.20951$

$Atr = \sqrt{2} * Area\ of\ external\ stirrup = 123.3701$

$s = s_external = 340.00$

$n = 12.00$

Calculation of Shear Strength $Vr = Min(Vr1, Vr2) = 522178.241$

Calculation of Shear Strength at edge 1, $Vr1 = 522178.241$

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

$VColO = 522178.241$

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

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

$= 1$ (normal-weight concrete)

Mean concrete strength: $fc' = (fc'_jacket * Area_jacket + fc'_core * Area_core) / Area_section = 28.32$, but $fc'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$Mu = 2.3891386E-011$

$Vu = 4.1704511E-031$

$d = 0.8 * D = 400.00$

$Nu = 7389.214$

$Ag = 196349.541$

From (11.5.4.8), ACI 318-14: $Vs = Vs1 + Vs2 = 76454.061$

$Vs1 = 48380.801$ is calculated for jacket, with:

$Av = \sqrt{2} * A_stirrup = 123370.055$

$fy = 555.56$

$s = 340.00$

$Vs1$ is multiplied by $Col1 = 0.60$

$s/d = 0.85$

$Vs2 = 28073.261$ is calculated for core, with:

$Av = \sqrt{2} * A_stirrup = 78956.835$

$fy = 444.44$

$s = 200.00$

$Vs2$ is multiplied by $Col2 = 0.66666667$

$s/d = 0.83333333$

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

$f = 0.95$, for fully-wrapped sections

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

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

This later relation, considered as a function $Vf(\theta, ai)$, 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: $\theta_1 = b_1 + 90^\circ = 90.00$

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

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

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

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

$E_f = 64828.00$

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

with $fu = 0.01$

From (11-11), ACI 440: $V_s + V_f \leq 444245.712$

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

Calculation of Shear Strength at edge 2, $V_{r2} = 522178.241$

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

$V_{Col0} = 522178.241$

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

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

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

Mean concrete strength: $f'_c = (f'_c \text{ jacket} * \text{Area jacket} + f'_c \text{ core} * \text{Area core}) / \text{Area section} = 28.32$, but $f'_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M / V d = 2.00$

$\mu_u = 2.3891386E-011$

$\nu_u = 4.1704511E-031$

$d = 0.8 * D = 400.00$

$N_u = 7389.214$

$A_g = 196349.541$

From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 76454.061$

$V_{s1} = 48380.801$ is calculated for jacket, with:

$A_v = \rho_s / 2 * A_{stirup} = 123370.055$

$f_y = 555.56$

$s = 340.00$

V_{s1} is multiplied by $\text{Col1} = 0.60$

$s/d = 0.85$

$V_{s2} = 28073.261$ is calculated for core, with:

$A_v = \rho_s / 2 * A_{stirup} = 78956.835$

$f_y = 444.44$

$s = 200.00$

V_{s2} is multiplied by $\text{Col2} = 0.66666667$

$s/d = 0.83333333$

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

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

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

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

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

$E_f = 64828.00$

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

with $fu = 0.01$

From (11-11), ACI 440: $V_s + V_f \leq 444245.712$

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

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

At local axis: 3

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

At Shear local axis: 2

(Bending local axis: 3)

Section Type: rcjcs

Constant Properties

Knowledge Factor, $\gamma = 1.00$

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

Consequently:

Jacket

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

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

Concrete Elasticity, $E_c = 26999.444$

Steel Elasticity, $E_s = 200000.00$

Existing Column

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

Existing material of Primary Member: Steel Strength, $f_s = f_{sm} = 444.44$

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

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

Jacket

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

Existing Column

Existing material: Steel Strength, $f_s = 1.25 \cdot f_{sm} = 555.55$

#####

External Diameter, $D = 500.00$

Internal Diameter, $D = 300.00$

Cover Thickness, $c = 25.00$

Mean Confinement Factor overall section = 1.46748

Element Length, $L = 3000.00$

Primary Member

Ribbed Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

Lap Length $l_o = 300.00$

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, $V_a = -2.5535805E-047$

EDGE -B-

Shear Force, $V_b = 2.5535805E-047$

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: $Asl,com = 1017.876$
-Middle: $Asl,mid = 1017.876$

Calculation of Shear Capacity ratio, $V_e/V_r = 0.29814229$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 155683.418$

with

$M_{pr1} = \text{Max}(Mu_{1+}, Mu_{1-}) = 2.3353E+008$

$Mu_{1+} = 2.3353E+008$, is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination

$Mu_{1-} = 2.3353E+008$, is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination

$M_{pr2} = \text{Max}(Mu_{2+}, Mu_{2-}) = 2.3353E+008$

$Mu_{2+} = 2.3353E+008$, is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the static loading combination

$Mu_{2-} = 2.3353E+008$, is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the static loading combination

Calculation of Mu_{1+}

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

$Mu = 2.3353E+008$

$\phi = 0.80285146$

$\lambda = 0.71403327$

error of function (3.68), Biskinis Phd = 40102.185

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

conf. factor $\lambda = 1.46748$

$f_c = 33.00$

From 10.3.5, ASCE 41-17, Final value of f_y : $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3}) = 368.0049$

$l_b/l_d = 0.27602844$

$d_1 = 44.00$

$R = 250.00$

$v = 0.00103167$

$N = 7389.214$

$A_c = 196349.541$

$\phi \cdot \text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3}) = 0.15689624$

Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.27602844$

$l_b = 300.00$

$l_d = 1086.845$

Calculation of l_b, \min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

$\phi = 1$

$d_b = 18.00$

Mean strength value of all re-bars: $f_y = 694.45$

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

$t = 1.00$

$s = 0.80$

$e = 1.00$

$c_b = 25.00$

$K_{tr} = 1.20951$

$A_{tr} = \sqrt{2} \cdot \text{Area of external stirrup} = 123.3701$

$s = s_{\text{external}} = 340.00$

$n = 12.00$

Calculation of Mu1-

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

$$\text{Mu} = 2.3353\text{E}+008$$

$$= 0.80285146$$

$$' = 0.71403327$$

error of function (3.68), Biskinis Phd = 40102.185

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

conf. factor $c = 1.46748$

$$f_c = 33.00$$

From 10.3.5, ASCE 41-17, Final value of f_y : $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 368.0049$

$$l_b/d = 0.27602844$$

$$d_1 = 44.00$$

$$R = 250.00$$

$$v = 0.00103167$$

$$N = 7389.214$$

$$A_c = 196349.541$$

$$= \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.15689624$$

Calculation of ratio lb/d

Lap Length: $l_b/d = 0.27602844$

$$l_b = 300.00$$

$$l_d = 1086.845$$

Calculation of l_b , min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

$$= 1$$

$$d_b = 18.00$$

Mean strength value of all re-bars: $f_y = 694.45$

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

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 25.00$$

$$K_{tr} = 1.20951$$

$$A_{tr} = \sqrt{2} \cdot \text{Area of external stirrup} = 123.3701$$

$$s = s_{\text{external}} = 340.00$$

$$n = 12.00$$

Calculation of Mu2+

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

$$\text{Mu} = 2.3353\text{E}+008$$

$$= 0.80285146$$

$$' = 0.71403327$$

error of function (3.68), Biskinis Phd = 40102.185

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

conf. factor $c = 1.46748$

$$f_c = 33.00$$

From 10.3.5, ASCE 41-17, Final value of f_y : $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 368.0049$

$$l_b/d = 0.27602844$$

$$d_1 = 44.00$$

$$R = 250.00$$

$$v = 0.00103167$$

$$N = 7389.214$$

$$A_c = 196349.541$$

$$= \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.15689624$$

Calculation of ratio l_b/d

Lap Length: $l_b/d = 0.27602844$

$l_b = 300.00$

$l_d = 1086.845$

Calculation of l_b, \min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

$= 1$

$d_b = 18.00$

Mean strength value of all re-bars: $f_y = 694.45$

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

$t = 1.00$

$s = 0.80$

$e = 1.00$

$c_b = 25.00$

$K_{tr} = 1.20951$

$A_{tr} = \pi/2 \cdot \text{Area of external stirrup} = 123.3701$

$s = s_{\text{external}} = 340.00$

$n = 12.00$

Calculation of μ_2

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

$\mu = 2.3353E+008$

$= 0.80285146$

$' = 0.71403327$

error of function (3.68), Biskinis Phd = 40102.185

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

conf. factor $c = 1.46748$

$f_c = 33.00$

From 10.3.5, ASCE 41-17, Final value of f_y : $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 368.0049$

$l_b/d = 0.27602844$

$d_1 = 44.00$

$R = 250.00$

$v = 0.00103167$

$N = 7389.214$

$A_c = 196349.541$

$= \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.15689624$

Calculation of ratio l_b/d

Lap Length: $l_b/d = 0.27602844$

$l_b = 300.00$

$l_d = 1086.845$

Calculation of l_b, \min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

$= 1$

$d_b = 18.00$

Mean strength value of all re-bars: $f_y = 694.45$

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

$t = 1.00$

$s = 0.80$

$e = 1.00$

$c_b = 25.00$

$K_{tr} = 1.20951$

$A_{tr} = \pi/2 \cdot \text{Area of external stirrup} = 123.3701$

$s = s_{\text{external}} = 340.00$

$n = 12.00$

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 522178.241$

Calculation of Shear Strength at edge 1, $V_{r1} = 522178.241$

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

$V_{CoI0} = 522178.241$

$k_{nl} = 1$ (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: $f_c' = (f_c'_{\text{jacket}} * \text{Area}_{\text{jacket}} + f_c'_{\text{core}} * \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 28.32$, but $f_c'^{0.5} \leq 8.3$
MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$\mu_u = 2.0433236E-011$

$\nu_u = 2.5535805E-047$

$d = 0.8 * D = 400.00$

$N_u = 7389.214$

$A_g = 196349.541$

From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 76454.061$

$V_{s1} = 48380.801$ is calculated for jacket, with:

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

$f_y = 555.56$

$s = 340.00$

V_{s1} is multiplied by $Col1 = 0.60$

$s/d = 0.85$

$V_{s2} = 28073.261$ is calculated for core, with:

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

$f_y = 444.44$

$s = 200.00$

V_{s2} is multiplied by $Col2 = 0.66666667$

$s/d = 0.83333333$

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

$f = 0.95$, for fully-wrapped sections

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

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

This later relation, considered as a function $V_f(\alpha, \theta)$, 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, $t_{f1} = N_L * t / N_{oDir} = 1.016$

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

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

$E_f = 64828.00$

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

with $f_u = 0.01$

From (11-11), ACI 440: $V_s + V_f \leq 444245.712$

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

Calculation of Shear Strength at edge 2, $V_{r2} = 522178.241$

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

$V_{CoI0} = 522178.241$

$k_{nl} = 1$ (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: $f_c' = (f_c'_{\text{jacket}} * \text{Area}_{\text{jacket}} + f_c'_{\text{core}} * \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 28.32$, but $f_c'^{0.5} \leq 8.3$
MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$\mu_u = 2.0433236E-011$

$\nu_u = 2.5535805E-047$

$d = 0.8 \cdot D = 400.00$
 $Nu = 7389.214$
 $Ag = 196349.541$
 From (11.5.4.8), ACI 318-14: $Vs = Vs1 + Vs2 = 76454.061$
 $Vs1 = 48380.801$ is calculated for jacket, with:
 $Av = \sqrt{2} \cdot A_{stirrup} = 123370.055$
 $fy = 555.56$
 $s = 340.00$
 $Vs1$ is multiplied by $Col1 = 0.60$
 $s/d = 0.85$
 $Vs2 = 28073.261$ is calculated for core, with:
 $Av = \sqrt{2} \cdot A_{stirrup} = 78956.835$
 $fy = 444.44$
 $s = 200.00$
 $Vs2$ is multiplied by $Col2 = 0.66666667$
 $s/d = 0.83333333$
 $Vf ((11-3)-(11.4), ACI 440) = 247653.332$
 $f = 0.95$, for fully-wrapped sections
 $wf/sf = 1$ (FRP strips adjacent to one another).
 In (11.3) $\sin + \cos$ is replaced with $(\cot + \cot a) \sin a$ which is more a generalised expression,
 where a is the angle of the crack direction (see KANEPE).
 This later relation, considered as a function $Vf(\theta, a)$, is implemented for every different fiber orientation a_i ,
 as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.
 orientation 1: $\theta = b1 + 90^\circ = 90.00$
 $Vf = \text{Min}(|Vf(45, \theta)|, |Vf(-45, a1)|)$, with:
 total thickness per orientation, $tf1 = NL \cdot t / NoDir = 1.016$
 $dfv = d$ (figure 11.2, ACI 440) = 470.00
 $ffe ((11-5), ACI 440) = 259.312$
 $Ef = 64828.00$
 $fe = 0.004$, from (11.6a), ACI 440
 with $fu = 0.01$
 From (11-11), ACI 440: $Vs + Vf \leq 444245.712$
 $bw \cdot d = \sqrt{2} \cdot d^2 / 4 = 125663.706$

 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, $fc = f_{cm} = 33.00$
 New material of Primary Member: Steel Strength, $fs = f_{sm} = 555.56$
 Concrete Elasticity, $Ec = 26999.444$
 Steel Elasticity, $Es = 200000.00$
 Existing Column
 Existing material of Primary Member: Concrete Strength, $fc = f_{cm} = 20.00$
 Existing material of Primary Member: Steel Strength, $fs = f_{sm} = 444.44$
 Concrete Elasticity, $Ec = 21019.039$
 Steel Elasticity, $Es = 200000.00$
 External Diameter, $D = 500.00$
 Internal Diameter, $D = 300.00$
 Cover Thickness, $c = 25.00$
 Element Length, $L = 3000.00$
 Primary Member

Ribbed Bars
 Ductile Steel
 Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
 Longitudinal Bars With Ends Lapped Starting at the End Sections
 Lap Length $l_b = 300.00$
 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

 Bending Moment, $M = 4.7579891E-011$
 Shear Force, $V_2 = 5859.331$
 Shear Force, $V_3 = 4.1350384E-013$
 Axial Force, $F = -7386.87$
 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: $As_{,ten} = 1017.876$
 -Compression: $As_{,com} = 1017.876$
 -Middle: $As_{,mid} = 1017.876$
 Mean Diameter of Tension Reinforcement, $Db_L = 18.00$

 Existing component: From table 7-7, ASCE 41_17: Final chord rotation Capacity $u_{,R} = u = 0.00510707$
 $u = y + p = 0.00510707$

 - Calculation of y -

 $y = (M_y * L_s / 3) / E_{eff} = 0.00510707$ ((4.29), Biskinis Phd))
 $M_y = 2.4653E+008$
 $L_s = M/V$ (with $L_s > 0.1 * L$ and $L_s < 2 * L$) = 1500.00
 From table 10.5, ASCE 41_17: $E_{eff} = factor * E_c * I_g = 2.4137E+013$
 $factor = 0.30$
 $A_g = 196349.541$
 Mean concrete strength: $f'_c = (f'_{c,jacket} * Area_{jacket} + f'_{c,core} * Area_{core}) / Area_{section} = 28.32$
 $N = 7386.87$
 $E_c * I_g = E_{c,jacket} * I_{g,jacket} + E_{c,core} * I_{g,core} = 8.0455E+013$

 Calculation of Yielding Moment M_y

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

 $M_y = \text{Min}(M_{y,ten}, M_{y,com}) = 2.4653E+008$
 $y = 7.1028705E-006$
 $M_{y,ten}$ (8c) = 2.4653E+008
 $_{ten}$ (7c) = 62.22249
 error of function (7c) = 0.00021692
 $M_{y,com}$ (8d) = 8.0674E+008
 $_{com}$ (7d) = 63.84406
 error of function (7d) = -0.00846594
 with ((10.1), ASCE 41-17) $e_y = \text{Min}(e_y, 1.25 * e_y * (l_b / l_d)^{2/3}) = 0.0027778$

$\rho_{FRP} = 0.002$
 $\alpha_{FRP} = 0.45$ ((9c) in Biskinis and Fardis for FRP Wrap)
 $d_1 = 44.00$
 $R = 250.00$
 $\nu = 0.00103628$
 $N = 7386.87$
 $A_c = 196349.541$
 $\left(\frac{10.1}{R}, ASCE 41-17\right) = \text{Min}\left(1, 1.25 \cdot \left(\frac{l_b}{l_d}\right)^{2/3}\right) = 0.23799351$
 with $f_c^* \left(\frac{12.3}{R}, ACI 440\right) = 36.3038$
 $f_c = 33.00$
 $\beta_1 = 1.05384$
 $k = 1$
 Effective FRP thickness, $t_f = N \cdot t \cdot \cos(\beta_1) = 1.016$
 $\rho_{FRP} \left(\frac{12.5}{R} \text{ and } \frac{12.7}{R}\right) = 0.004$
 $f_u = 0.01$
 $E_f = 64828.00$

 Calculation of ratio l_b/l_d

Lap Length: $l_d/l_d, \text{min} = 0.34503556$

$l_b = 300.00$

$l_d = 869.4756$

Calculation of l according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

$\beta_1 = 1$

$d_b = 18.00$

Mean strength value of all re-bars: $f_y = 555.56$

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

$t = 1.00$

$s = 0.80$

$e = 1.00$

$c_b = 25.00$

$K_{tr} = 1.20951$

$A_{tr} = \sqrt{2} \cdot \text{Area of external stirrup} = 123.3701$

$s = s_{\text{external}} = 340.00$

$n = 12.00$

 - Calculation of ρ_p -

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

with:

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

shear control ratio $V_y E / V_{CoI} O E = 0.29814229$

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

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

$t = s_1 + s_2 + 2 \cdot t_f / b_w \cdot (f_{fe} / f_s) = 0.00519403$

jacket: $s_1 = A_{v1} \cdot \left(\frac{D_{c1}}{2}\right) / (s_1 \cdot A_g) = 0.00081312$

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

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

(shear) direction

$s_1 = 340.00$

core: $s_2 = A_{v2} \cdot \left(\frac{D_{c2}}{2}\right) / (s_2 \cdot A_g) = 0.0005871$

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

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

direction

$s_2 = 200.00$

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.

$N_{UD} = 7386.87$

$A_g = 196349.541$

$f_c E = (f_c'_{\text{jacket}} \cdot \text{Area}_{\text{jacket}} + f_c'_{\text{core}} \cdot \text{Area}_{\text{core}}) / \text{section_area} = 28.32$

$f_y E = (f_y_{\text{ext_Long_Reinf}} \cdot \text{Area}_{\text{ext_Long_Reinf}} + f_y_{\text{int_Long_Reinf}} \cdot \text{Area}_{\text{int_Long_Reinf}}) / \text{Area}_{\text{Tot_Long_Rein}} =$

2.1219958E-314

$$f_{tE} = (f_{y_ext_Trans_Reinf} * s_1 + f_{y_int_Trans_Reinf} * s_2) / (s_1 + s_2) = 508.9683$$

$$p_l = Area_Tot_Long_Rein / (A_g) = 0.015552$$

$$f_{cE} = 28.32$$

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

At local axis: 2

Integration Section: (b)

Calculation No. 7

column C1, Floor 1

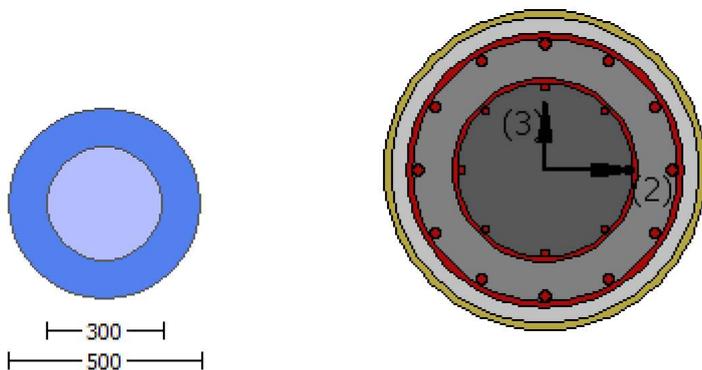
Limit State: Immediate Occupancy (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Shear capacity V_{Rd}

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, $f_c = f_{c_lower_bound} = 25.00$

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

Concrete Elasticity, $E_c = 26999.444$

Steel Elasticity, $E_s = 200000.00$

Existing Column

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

Existing material of Primary Member: Steel Strength, $f_s = f_{s_lower_bound} = 400.00$
Concrete Elasticity, $E_c = 21019.039$
Steel Elasticity, $E_s = 200000.00$

Note: Especially for the calculation of γ for displacement ductility demand,
the expected (mean value) strengths are used (7.5.1.3, ASCE 41-17) because bending is considered as
Deformation-Controlled Action (Table C7-1, ASCE 41-17).
Jacket
New material: Concrete Strength, $f_c = f_{cm} = 33.00$
New material: Steel Strength, $f_s = f_{sm} = 555.56$
Existing Column
Existing material: Concrete Strength, $f_c = f_{cm} = 20.00$
Existing material: Steel Strength, $f_s = f_{sm} = 444.44$

External Diameter, $D = 500.00$
Internal Diameter, $D = 300.00$
Cover Thickness, $c = 25.00$
Element Length, $L = 3000.00$
Primary Member
Ribbed Bars
Ductile Steel
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
Lap Length $l_o = l_b = 300.00$
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, $M_a = 1.1931952E-009$
Shear Force, $V_a = -4.1350384E-013$
EDGE -B-
Bending Moment, $M_b = 4.7579891E-011$
Shear Force, $V_b = 4.1350384E-013$
BOTH EDGES
Axial Force, $F = -7386.87$
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: $As_t = 0.00$
-Compression: $As_c = 3053.628$
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension: $As_{t,ten} = 1017.876$
-Compression: $As_{c,com} = 1017.876$
-Middle: $As_{mid} = 1017.876$
Mean Diameter of Tension Reinforcement, $Db_{L,ten} = 18.00$

Existing component: From table 7-7, ASCE 41_17: Final Shear Capacity $V_R = \phi V_n = 488735.446$
 $V_n ((10.3), ASCE 41-17) = k_n \phi V_{CoI} = 488735.446$
 $V_{CoI} = 488735.446$
 $k_n = 1.00$
displacement_ductility_demand = 0.00

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

= 1 (normal-weight concrete)
 Mean concrete strength: $f_c' = (f_c'_{\text{jacket}} \cdot \text{Area}_{\text{jacket}} + f_c'_{\text{core}} \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 21.76$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $M/Vd = 2.00$
 $\mu_u = 4.7579891E-011$
 $\nu_u = 4.1350384E-013$
 $d = 0.8 \cdot D = 400.00$
 $N_u = 7386.87$
 $A_g = 196349.541$
 From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 68808.56$
 $V_{s1} = 43542.372$ is calculated for jacket, with:
 $A_v = \sqrt{2} \cdot A_{\text{stirrup}} = 123370.055$
 $f_y = 500.00$
 $s = 340.00$
 V_{s1} is multiplied by $\text{Col1} = 0.60$
 $s/d = 0.85$
 $V_{s2} = 25266.187$ is calculated for core, with:
 $A_v = \sqrt{2} \cdot A_{\text{stirrup}} = 78956.835$
 $f_y = 400.00$
 $s = 200.00$
 V_{s2} is multiplied by $\text{Col2} = 0.66666667$
 $s/d = 0.83333333$
 $V_f((11-3)-(11.4), \text{ACI } 440) = 247653.332$
 $f = 0.95$, for fully-wrapped sections
 $w_f/s_f = 1$ (FRP strips adjacent to one another).
 In (11.3) $\sin + \cos$ is replaced with $(\cot + \csc) \sin \alpha$ which is more a generalised expression, where α is the angle of the crack direction (see KANEPE).
 This later relation, considered as a function $V_f(\alpha, a_i)$, is implemented for every different fiber orientation a_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: $\alpha = b_1 + 90^\circ = 90.00$
 $V_f = \text{Min}(|V_f(45, a_1)|, |V_f(-45, a_1)|)$, with:
 total thickness per orientation, $t_{f1} = N_L \cdot t / N_{\text{Dir}} = 1.016$
 $d_{fv} = d$ (figure 11.2, ACI 440) = 470.00
 $f_{fe}((11-5), \text{ACI } 440) = 259.312$
 $E_f = 64828.00$
 $f_e = 0.004$, from (11.6a), ACI 440
 with $f_u = 0.01$
 From (11-11), ACI 440: $V_s + V_f \leq 389409.072$
 $b_w \cdot d = \sqrt{V_s + V_f} \cdot d / 4 = 125663.706$

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 $\theta = 6.4731055E-021$
 $y = (M_y \cdot L_s / 3) / E_{\text{eff}} = 0.00510707$ ((4.29), Biskinis Phd)
 $M_y = 2.4653E+008$
 $L_s = M/V$ (with $L_s > 0.1 \cdot L$ and $L_s < 2 \cdot L$) = 1500.00
 From table 10.5, ASCE 41_17: $E_{\text{eff}} = \text{factor} \cdot E_c \cdot I_g = 2.4137E+013$
 factor = 0.30
 $A_g = 196349.541$
 Mean concrete strength: $f_c' = (f_c'_{\text{jacket}} \cdot \text{Area}_{\text{jacket}} + f_c'_{\text{core}} \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 28.32$
 $N = 7386.87$
 $E_c \cdot I_g = E_{c_{\text{jacket}}} \cdot I_{g_{\text{jacket}}} + E_{c_{\text{core}}} \cdot I_{g_{\text{core}}} = 8.0455E+013$

Calculation of Yielding Moment M_y

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

$M_y = \text{Min}(M_{y_{\text{ten}}}, M_{y_{\text{com}}}) = 2.4653E+008$
 $\delta = 7.1028705E-006$

$M_{y_ten} (8c) = 2.4653E+008$
 $_{ten} (7c) = 62.22249$
error of function (7c) = 0.00021692
 $M_{y_com} (8d) = 8.0674E+008$
 $_{com} (7d) = 63.84406$
error of function (7d) = -0.00846594
with ((10.1), ASCE 41-17) $e_y = \text{Min}(e_y, 1.25 * e_y * (l_b / l_d)^{2/3}) = 0.0027778$
 $e_{co} = 0.002$
 $a_{pl} = 0.45$ ((9c) in Biskinis and Fardis for FRP Wrap)
 $d_1 = 44.00$
 $R = 250.00$
 $v = 0.00103628$
 $N = 7386.87$
 $A_c = 196349.541$
((10.1), ASCE 41-17) $= \text{Min}(, 1.25 * * (l_b / l_d)^{2/3}) = 0.23799351$
with f_c^* ((12.3), ACI 440) = 36.3038
 $f_c = 33.00$
 $f_l = 1.05384$
 $k = 1$
Effective FRP thickness, $t_f = N L * t * \text{Cos}(b_1) = 1.016$
 e_{fe} ((12.5) and (12.7)) = 0.004
 $f_u = 0.01$
 $E_f = 64828.00$

Calculation of ratio l_b / l_d

Lap Length: $l_d / l_d, \text{min} = 0.34503556$

$l_b = 300.00$

$l_d = 869.4756$

Calculation of l according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

$= 1$

$d_b = 18.00$

Mean strength value of all re-bars: $f_y = 555.56$

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

$t = 1.00$

$s = 0.80$

$e = 1.00$

$c_b = 25.00$

$K_{tr} = 1.20951$

$A_{tr} = \sqrt{2} * \text{Area of external stirrup} = 123.3701$

$s = s_{external} = 340.00$

$n = 12.00$

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

At local axis: 3

Integration Section: (b)

Calculation No. 8

column C1, Floor 1

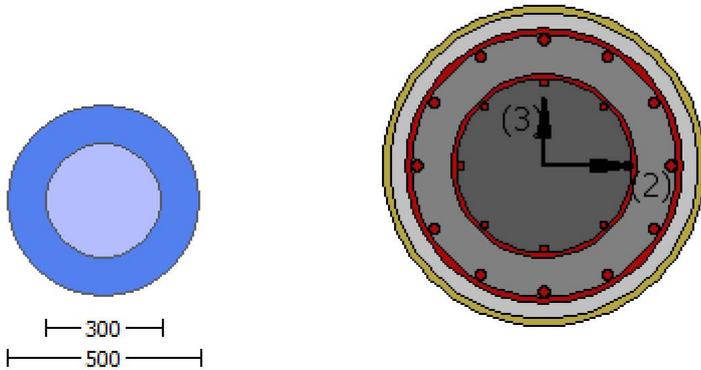
Limit State: Immediate Occupancy (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity (θ_r)

Edge: End

Local Axis: (3)



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

At Shear local axis: 3

(Bending local axis: 2)

Section Type: rcjcs

Constant Properties

Knowledge Factor, $\gamma = 1.00$

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

Consequently:

Jacket

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

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

Concrete Elasticity, $E_c = 26999.444$

Steel Elasticity, $E_s = 200000.00$

Existing Column

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

Existing material of Primary Member: Steel Strength, $f_s = f_{sm} = 444.44$

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

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

Jacket

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

Existing Column

Existing material: Steel Strength, $f_s = 1.25 \cdot f_{sm} = 555.55$

#####

External Diameter, $D = 500.00$

Internal Diameter, $D = 300.00$

Cover Thickness, $c = 25.00$

Mean Confinement Factor overall section = 1.46748

Element Length, $L = 3000.00$

Primary Member

Ribbed Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

Lap Length $l_o = 300.00$

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $\epsilon_{fu} = 0.01$

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

Fiber orientations, $b_i = 0.00^\circ$

Number of layers, $N_L = 1$

Radius of rounding corners, $R = 40.00$

Stepwise Properties

At local axis: 3

EDGE -A-

Shear Force, $V_a = 4.1704511E-031$

EDGE -B-

Shear Force, $V_b = -4.1704511E-031$

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, $V_e/V_r = 0.29814229$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 155683.418$

with

$M_{pr1} = \text{Max}(Mu_{1+}, Mu_{1-}) = 2.3353E+008$

$Mu_{1+} = 2.3353E+008$, is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination

$Mu_{1-} = 2.3353E+008$, is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination

$M_{pr2} = \text{Max}(Mu_{2+}, Mu_{2-}) = 2.3353E+008$

$Mu_{2+} = 2.3353E+008$, is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the static loading combination

$Mu_{2-} = 2.3353E+008$, is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the static loading combination

Calculation of Mu_{1+}

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

$Mu = 2.3353E+008$

$\phi = 0.80285146$

$\lambda = 0.71403327$

error of function (3.68), Biskinis Phd = 40102.185

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

conf. factor $c = 1.46748$

$f_c = 33.00$

From 10.3.5, ASCE 41-17, Final value of f_y : $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3}) = 368.0049$

$l_b/l_d = 0.27602844$

$d_1 = 44.00$

$R = 250.00$

$v = 0.00103167$

$$N = 7389.214$$

$$A_c = 196349.541$$

$$= *Min(1, 1.25 * (l_b / d)^{2/3}) = 0.15689624$$

Calculation of ratio l_b / d

$$\text{Lap Length: } l_b / d = 0.27602844$$

$$l_b = 300.00$$

$$d = 1086.845$$

Calculation of l_b, \min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

$$= 1$$

$$d_b = 18.00$$

$$\text{Mean strength value of all re-bars: } f_y = 694.45$$

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

MPa (22.5.3.1, ACI 318-14)

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 25.00$$

$$K_{tr} = 1.20951$$

$$A_{tr} = /2 * \text{Area of external stirrup} = 123.3701$$

$$s = s_{\text{external}} = 340.00$$

$$n = 12.00$$

Calculation of μ_1

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

$$\mu = 2.3353E+008$$

$$= 0.80285146$$

$$' = 0.71403327$$

error of function (3.68), Biskinis Phd = 40102.185

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

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

$$f_c = 33.00$$

From 10.3.5, ASCE 41-17, Final value of f_y : $f_y * Min(1, 1.25 * (l_b / d)^{2/3}) = 368.0049$

$$l_b / d = 0.27602844$$

$$d_1 = 44.00$$

$$R = 250.00$$

$$v = 0.00103167$$

$$N = 7389.214$$

$$A_c = 196349.541$$

$$= *Min(1, 1.25 * (l_b / d)^{2/3}) = 0.15689624$$

Calculation of ratio l_b / d

$$\text{Lap Length: } l_b / d = 0.27602844$$

$$l_b = 300.00$$

$$d = 1086.845$$

Calculation of l_b, \min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

$$= 1$$

$$d_b = 18.00$$

$$\text{Mean strength value of all re-bars: } f_y = 694.45$$

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

MPa (22.5.3.1, ACI 318-14)

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 25.00$$

$$K_{tr} = 1.20951$$

$$A_{tr} = /2 * \text{Area of external stirrup} = 123.3701$$

s = s_external = 340.00
n = 12.00

Calculation of Mu2+

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), Mu
Mu = 2.3353E+008

= 0.80285146
' = 0.71403327
error of function (3.68), Biskinis Phd = 40102.185
From 5A.2, TBDY: fcc = fc* c = 48.42699
conf. factor c = 1.46748
fc = 33.00
From 10.3.5, ASCE 41-17, Final value of fy: fy*Min(1,1.25*(lb/d)^ 2/3) = 368.0049
lb/d = 0.27602844
d1 = 44.00
R = 250.00
v = 0.00103167
N = 7389.214
Ac = 196349.541
= *Min(1,1.25*(lb/d)^ 2/3) = 0.15689624

Calculation of ratio lb/d

Lap Length: lb/d = 0.27602844
lb = 300.00
ld = 1086.845
Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
= 1
db = 18.00
Mean strength value of all re-bars: fy = 694.45
Mean concrete strength: fc' = (fc'_jacket*Area_jacket + fc'_core*Area_core)/Area_section = 33.00, but fc'^0.5 <= 8.3 MPa (22.5.3.1, ACI 318-14)
t = 1.00
s = 0.80
e = 1.00
cb = 25.00
Ktr = 1.20951
Atr = /2 * Area of external stirrup = 123.3701
s = s_external = 340.00
n = 12.00

Calculation of Mu2-

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), Mu
Mu = 2.3353E+008

= 0.80285146
' = 0.71403327
error of function (3.68), Biskinis Phd = 40102.185
From 5A.2, TBDY: fcc = fc* c = 48.42699
conf. factor c = 1.46748
fc = 33.00
From 10.3.5, ASCE 41-17, Final value of fy: fy*Min(1,1.25*(lb/d)^ 2/3) = 368.0049
lb/d = 0.27602844
d1 = 44.00
R = 250.00

$$v = 0.00103167$$

$$N = 7389.214$$

$$Ac = 196349.541$$

$$= *Min(1, 1.25*(lb/d)^{2/3}) = 0.15689624$$

Calculation of ratio lb/d

Lap Length: $lb/d = 0.27602844$

$lb = 300.00$

$ld = 1086.845$

Calculation of lb_{min} according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

$= 1$

$db = 18.00$

Mean strength value of all re-bars: $f_y = 694.45$

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

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 1.20951$

$A_{tr} = \pi/2 * Area_{external\ stirrup} = 123.3701$

$s_{external} = 340.00$

$n = 12.00$

Calculation of Shear Strength $V_r = Min(V_{r1}, V_{r2}) = 522178.241$

Calculation of Shear Strength at edge 1, $V_{r1} = 522178.241$

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

$V_{Col0} = 522178.241$

$k_{nl} = 1$ (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: $fc' = (fc'_{jacket} * Area_{jacket} + fc'_{core} * Area_{core}) / Area_{section} = 28.32$, but $fc'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/d = 2.00$

$M_u = 2.3891386E-011$

$V_u = 4.1704511E-031$

$d = 0.8 * D = 400.00$

$N_u = 7389.214$

$A_g = 196349.541$

From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 76454.061$

$V_{s1} = 48380.801$ is calculated for jacket, with:

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

$f_y = 555.56$

$s = 340.00$

V_{s1} is multiplied by $Col1 = 0.60$

$s/d = 0.85$

$V_{s2} = 28073.261$ is calculated for core, with:

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

$f_y = 444.44$

$s = 200.00$

V_{s2} is multiplied by $Col2 = 0.66666667$

$s/d = 0.83333333$

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

$f = 0.95$, for fully-wrapped sections

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

In (11.3) $\sin \alpha + \cos \alpha$ is replaced with $(\cot \alpha + \csc \alpha) \sin \alpha$ 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, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.

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

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

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

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

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

$E_f = 64828.00$

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

with $fu = 0.01$

From (11-11), ACI 440: $V_s + V_f \leq 444245.712$

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

Calculation of Shear Strength at edge 2, $V_{r2} = 522178.241$

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

$V_{Col0} = 522178.241$

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

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

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

Mean concrete strength: $f'_c = (f'_c \cdot \text{jacket} \cdot \text{Area}_{\text{jacket}} + f'_c \cdot \text{core} \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 28.32$, but $f'_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$\mu_u = 2.3891386E-011$

$\nu_u = 4.1704511E-031$

$d = 0.8 \cdot D = 400.00$

$N_u = 7389.214$

$A_g = 196349.541$

From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 76454.061$

$V_{s1} = 48380.801$ is calculated for jacket, with:

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

$f_y = 555.56$

$s = 340.00$

V_{s1} is multiplied by $\rho_{Col1} = 0.60$

$s/d = 0.85$

$V_{s2} = 28073.261$ is calculated for core, with:

$A_v = \rho \cdot A_{\text{stirup}} = 78956.835$

$f_y = 444.44$

$s = 200.00$

V_{s2} is multiplied by $\rho_{Col2} = 0.66666667$

$s/d = 0.83333333$

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

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

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

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

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

$E_f = 64828.00$

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

with $fu = 0.01$

From (11-11), ACI 440: $V_s + V_f \leq 444245.712$

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

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

At local axis: 3

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

At Shear local axis: 2

(Bending local axis: 3)

Section Type: rcjcs

Constant Properties

Knowledge Factor, $\gamma = 1.00$

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

Consequently:

Jacket

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

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

Concrete Elasticity, $E_c = 26999.444$

Steel Elasticity, $E_s = 200000.00$

Existing Column

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

Existing material of Primary Member: Steel Strength, $f_s = f_{sm} = 444.44$

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

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

Jacket

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

Existing Column

Existing material: Steel Strength, $f_s = 1.25 \cdot f_{sm} = 555.55$

#####

External Diameter, $D = 500.00$

Internal Diameter, $D = 300.00$

Cover Thickness, $c = 25.00$

Mean Confinement Factor overall section = 1.46748

Element Length, $L = 3000.00$

Primary Member

Ribbed Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

Lap Length $l_o = 300.00$

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, $V_a = -2.5535805E-047$

EDGE -B-

Shear Force, $V_b = 2.5535805E-047$

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: $Asl,com = 1017.876$
-Middle: $Asl,mid = 1017.876$

Calculation of Shear Capacity ratio, $V_e/V_r = 0.29814229$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 155683.418$

with
 $M_{pr1} = \text{Max}(Mu_{1+}, Mu_{1-}) = 2.3353E+008$
 $Mu_{1+} = 2.3353E+008$, is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination
 $Mu_{1-} = 2.3353E+008$, is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination
 $M_{pr2} = \text{Max}(Mu_{2+}, Mu_{2-}) = 2.3353E+008$
 $Mu_{2+} = 2.3353E+008$, 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
 $Mu_{2-} = 2.3353E+008$, 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
 $Mu = 2.3353E+008$

$= 0.80285146$

$' = 0.71403327$

error of function (3.68), Biskinis Phd = 40102.185

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

conf. factor $c = 1.46748$

$f_c = 33.00$

From 10.3.5, ASCE 41-17, Final value of f_y : $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3}) = 368.0049$

$l_b/l_d = 0.27602844$

$d_1 = 44.00$

$R = 250.00$

$v = 0.00103167$

$N = 7389.214$

$A_c = 196349.541$

$= \cdot \text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3}) = 0.15689624$

Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.27602844$

$l_b = 300.00$

$l_d = 1086.845$

Calculation of l_b, \min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

$= 1$

$db = 18.00$

Mean strength value of all re-bars: $f_y = 694.45$

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

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 1.20951$

$A_{tr} = \sqrt{2} \cdot \text{Area of external stirrup} = 123.3701$

$s = s_{external} = 340.00$

$n = 12.00$

Calculation of Mu1-

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

$$\text{Mu} = 2.3353\text{E}+008$$

$$= 0.80285146$$

$$' = 0.71403327$$

error of function (3.68), Biskinis Phd = 40102.185

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

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

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From 10.3.5, ASCE 41-17, Final value of f_y : $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 368.0049$

$$l_b/d = 0.27602844$$

$$d_1 = 44.00$$

$$R = 250.00$$

$$v = 0.00103167$$

$$N = 7389.214$$

$$A_c = 196349.541$$

$$= \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.15689624$$

Calculation of ratio l_b/d

Lap Length: $l_b/d = 0.27602844$

$$l_b = 300.00$$

$$l_d = 1086.845$$

Calculation of l_b , min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

$$= 1$$

$$d_b = 18.00$$

Mean strength value of all re-bars: $f_y = 694.45$

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

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 25.00$$

$$K_{tr} = 1.20951$$

$$A_{tr} = \sqrt{2} \cdot \text{Area of external stirrup} = 123.3701$$

$$s = s_{\text{external}} = 340.00$$

$$n = 12.00$$

Calculation of Mu2+

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

$$\text{Mu} = 2.3353\text{E}+008$$

$$= 0.80285146$$

$$' = 0.71403327$$

error of function (3.68), Biskinis Phd = 40102.185

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

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

$$f_c = 33.00$$

From 10.3.5, ASCE 41-17, Final value of f_y : $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 368.0049$

$$l_b/d = 0.27602844$$

$$d_1 = 44.00$$

$$R = 250.00$$

$$v = 0.00103167$$

$$N = 7389.214$$

$$A_c = 196349.541$$

$$= \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.15689624$$

Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.27602844$

$l_b = 300.00$

$l_d = 1086.845$

Calculation of l_b, \min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

$= 1$

$db = 18.00$

Mean strength value of all re-bars: $f_y = 694.45$

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

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 1.20951$

$A_{tr} = \pi/2 \cdot \text{Area of external stirrup} = 123.3701$

$s = s_{\text{external}} = 340.00$

$n = 12.00$

Calculation of μ_2

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

$\mu = 2.3353E+008$

$= 0.80285146$

$' = 0.71403327$

error of function (3.68), Biskinis Phd = 40102.185

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

conf. factor $c = 1.46748$

$f_c = 33.00$

From 10.3.5, ASCE 41-17, Final value of f_y : $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3}) = 368.0049$

$l_b/l_d = 0.27602844$

$d_1 = 44.00$

$R = 250.00$

$v = 0.00103167$

$N = 7389.214$

$A_c = 196349.541$

$= \text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3}) = 0.15689624$

Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.27602844$

$l_b = 300.00$

$l_d = 1086.845$

Calculation of l_b, \min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

$= 1$

$db = 18.00$

Mean strength value of all re-bars: $f_y = 694.45$

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

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 1.20951$

$A_{tr} = \pi/2 \cdot \text{Area of external stirrup} = 123.3701$

$s = s_{\text{external}} = 340.00$

$n = 12.00$

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 522178.241$

Calculation of Shear Strength at edge 1, $V_{r1} = 522178.241$

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

$V_{Co10} = 522178.241$

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

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

$k_{nl} = 1$ (normal-weight concrete)

Mean concrete strength: $f_c' = (f_c'_{\text{jacket}} * \text{Area}_{\text{jacket}} + f_c'_{\text{core}} * \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 28.32$, but $f_c'^{0.5} \leq 8.3$
MPa (22.5.3.1, ACI 318-14)

$M / Vd = 2.00$

$\mu_u = 2.0433236E-011$

$V_u = 2.5535805E-047$

$d = 0.8 * D = 400.00$

$N_u = 7389.214$

$A_g = 196349.541$

From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 76454.061$

$V_{s1} = 48380.801$ is calculated for jacket, with:

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

$f_y = 555.56$

$s = 340.00$

V_{s1} is multiplied by $Col1 = 0.60$

$s/d = 0.85$

$V_{s2} = 28073.261$ is calculated for core, with:

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

$f_y = 444.44$

$s = 200.00$

V_{s2} is multiplied by $Col2 = 0.66666667$

$s/d = 0.83333333$

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

$f = 0.95$, for fully-wrapped sections

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

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

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

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

$V_f = \text{Min}(|V_f(45, 90)|, |V_f(-45, 90)|)$, with:

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

$d_{fv} = d$ (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: $V_s + V_f \leq 444245.712$

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

Calculation of Shear Strength at edge 2, $V_{r2} = 522178.241$

$V_{r2} = V_{Co2} ((10.3), \text{ASCE } 41-17) = k_{nl} * V_{Co10}$

$V_{Co10} = 522178.241$

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

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

$k_{nl} = 1$ (normal-weight concrete)

Mean concrete strength: $f_c' = (f_c'_{\text{jacket}} * \text{Area}_{\text{jacket}} + f_c'_{\text{core}} * \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 28.32$, but $f_c'^{0.5} \leq 8.3$
MPa (22.5.3.1, ACI 318-14)

$M / Vd = 2.00$

$\mu_u = 2.0433236E-011$

$V_u = 2.5535805E-047$

$d = 0.8 \cdot D = 400.00$
 $Nu = 7389.214$
 $Ag = 196349.541$
 From (11.5.4.8), ACI 318-14: $Vs = Vs1 + Vs2 = 76454.061$
 $Vs1 = 48380.801$ is calculated for jacket, with:
 $Av = \sqrt{2} \cdot A_{stirrup} = 123370.055$
 $fy = 555.56$
 $s = 340.00$
 $Vs1$ is multiplied by $Col1 = 0.60$
 $s/d = 0.85$
 $Vs2 = 28073.261$ is calculated for core, with:
 $Av = \sqrt{2} \cdot A_{stirrup} = 78956.835$
 $fy = 444.44$
 $s = 200.00$
 $Vs2$ is multiplied by $Col2 = 0.66666667$
 $s/d = 0.83333333$
 $Vf ((11-3)-(11.4), ACI 440) = 247653.332$
 $f = 0.95$, for fully-wrapped sections
 $wf/sf = 1$ (FRP strips adjacent to one another).
 In (11.3) $\sin + \cos$ is replaced with $(\cot + \cot a) \sin a$ which is more a generalised expression,
 where a is the angle of the crack direction (see KANEPE).
 This later relation, considered as a function $Vf(\theta, a)$, is implemented for every different fiber orientation a_i ,
 as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.
 orientation 1: $\theta = b1 + 90^\circ = 90.00$
 $Vf = \text{Min}(|Vf(45, \theta)|, |Vf(-45, a1)|)$, with:
 total thickness per orientation, $tf1 = NL \cdot t / NoDir = 1.016$
 $dfv = d$ (figure 11.2, ACI 440) = 470.00
 $ffe ((11-5), ACI 440) = 259.312$
 $Ef = 64828.00$
 $fe = 0.004$, from (11.6a), ACI 440
 with $fu = 0.01$
 From (11-11), ACI 440: $Vs + Vf \leq 444245.712$
 $bw \cdot d = \sqrt{2} \cdot d^2 / 4 = 125663.706$

 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, $fc = f_{cm} = 33.00$
 New material of Primary Member: Steel Strength, $fs = f_{sm} = 555.56$
 Concrete Elasticity, $Ec = 26999.444$
 Steel Elasticity, $Es = 200000.00$
 Existing Column
 Existing material of Primary Member: Concrete Strength, $fc = f_{cm} = 20.00$
 Existing material of Primary Member: Steel Strength, $fs = f_{sm} = 444.44$
 Concrete Elasticity, $Ec = 21019.039$
 Steel Elasticity, $Es = 200000.00$
 External Diameter, $D = 500.00$
 Internal Diameter, $D = 300.00$
 Cover Thickness, $c = 25.00$
 Element Length, $L = 3000.00$
 Primary Member

Ribbed Bars
 Ductile Steel
 Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
 Longitudinal Bars With Ends Lapped Starting at the End Sections
 Lap Length $l_b = 300.00$
 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

 Bending Moment, $M = 0.08058394$
 Shear Force, $V_2 = 5859.331$
 Shear Force, $V_3 = 4.1350384E-013$
 Axial Force, $F = -7386.87$
 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: $As_{,ten} = 1017.876$
 -Compression: $As_{,com} = 1017.876$
 -Middle: $As_{,mid} = 1017.876$
 Mean Diameter of Tension Reinforcement, $Db_L = 18.00$

 Existing component: From table 7-7, ASCE 41_17: Final chord rotation Capacity $u_{,R} = \gamma + p = 0.00102141$

 - Calculation of γ -

 $\gamma = (M_y * L_s / 3) / E_{eff} = 0.00102141$ ((4.29), Biskinis Phd)
 $M_y = 2.4653E+008$
 $L_s = M/V$ (with $L_s > 0.1 * L$ and $L_s < 2 * L$) = 300.00
 From table 10.5, ASCE 41_17: $E_{eff} = factor * E_c * I_g = 2.4137E+013$
 $factor = 0.30$
 $A_g = 196349.541$
 Mean concrete strength: $f'_c = (f'_{c,jacket} * Area_{jacket} + f'_{c,core} * Area_{core}) / Area_{section} = 28.32$
 $N = 7386.87$
 $E_c * I_g = E_{c,jacket} * I_{g,jacket} + E_{c,core} * I_{g,core} = 8.0455E+013$

 Calculation of Yielding Moment M_y

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

 $M_y = \text{Min}(M_{y,ten}, M_{y,com}) = 2.4653E+008$
 $\gamma = 7.1028705E-006$
 $M_{y,ten} (8c) = 2.4653E+008$
 $\gamma_{ten} (7c) = 62.22249$
 error of function (7c) = 0.00021692
 $M_{y,com} (8d) = 8.0674E+008$
 $\gamma_{com} (7d) = 63.84406$
 error of function (7d) = -0.00846594
 with ((10.1), ASCE 41-17) $e_y = \text{Min}(e_y, 1.25 * e_y * (l_b / l_d)^{2/3}) = 0.0027778$

$\rho_{FRP} = 0.002$
 $\alpha_{FRP} = 0.45$ ((9c) in Biskinis and Fardis for FRP Wrap)
 $d_1 = 44.00$
 $R = 250.00$
 $\nu = 0.00103628$
 $N = 7386.87$
 $A_c = 196349.541$
 $\left(\frac{10.1}{\rho_{FRP}}, ASCE 41-17\right) = \text{Min}\left(1, 1.25 \cdot \left(\frac{l_b}{l_d}\right)^{2/3}\right) = 0.23799351$
 with $f_c^* ((12.3), ACI 440) = 36.3038$
 $f_c = 33.00$
 $\beta_1 = 1.05384$
 $k = 1$
 Effective FRP thickness, $t_f = N L \cdot t \cdot \cos(\beta_1) = 1.016$
 $\rho_{FRP} ((12.5) \text{ and } (12.7)) = 0.004$
 $f_u = 0.01$
 $E_f = 64828.00$

 Calculation of ratio l_b/l_d

Lap Length: $l_d/l_d, \text{min} = 0.34503556$

$l_b = 300.00$

$l_d = 869.4756$

Calculation of l according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

$\beta_1 = 1$

$d_b = 18.00$

Mean strength value of all re-bars: $f_y = 555.56$

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

$t = 1.00$

$s = 0.80$

$e = 1.00$

$c_b = 25.00$

$K_{tr} = 1.20951$

$A_{tr} = \sqrt{2} \cdot \text{Area of external stirrup} = 123.3701$

$s = s_{\text{external}} = 340.00$

$n = 12.00$

 - Calculation of ρ_p -

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

with:

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

shear control ratio $V_y E / V_{CoI} O E = 0.29814229$

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

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

$t = s_1 + s_2 + 2 \cdot t_f / b_w \cdot (f_{fe} / f_s) = 0.00519403$

jacket: $s_1 = A_{v1} \cdot \left(\frac{D_{c1}}{2}\right) / (s_1 \cdot A_g) = 0.00081312$

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

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

(shear) direction

$s_1 = 340.00$

core: $s_2 = A_{v2} \cdot \left(\frac{D_{c2}}{2}\right) / (s_2 \cdot A_g) = 0.0005871$

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

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

direction

$s_2 = 200.00$

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.

$N_{UD} = 7386.87$

$A_g = 196349.541$

$f_c E = (f_c'_{\text{jacket}} \cdot \text{Area}_{\text{jacket}} + f_c'_{\text{core}} \cdot \text{Area}_{\text{core}}) / \text{section_area} = 28.32$

$f_y E = (f_y_{\text{ext_Long_Reinf}} \cdot \text{Area}_{\text{ext_Long_Reinf}} + f_y_{\text{int_Long_Reinf}} \cdot \text{Area}_{\text{int_Long_Reinf}}) / \text{Area}_{\text{Tot_Long_Rein}} =$

2.1219958E-314

$$f_{tE} = (f_{y_ext_Trans_Reinf} * s_1 + f_{y_int_Trans_Reinf} * s_2) / (s_1 + s_2) = 508.9683$$

$$p_l = Area_Tot_Long_Rein / (A_g) = 0.015552$$

$$f_{cE} = 28.32$$

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

At local axis: 3

Integration Section: (b)

Calculation No. 9

column C1, Floor 1

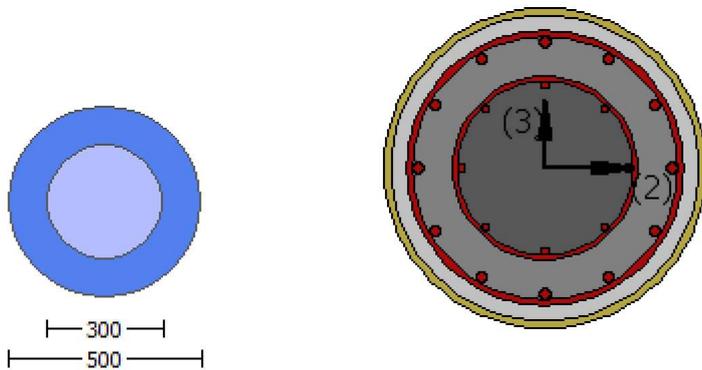
Limit State: Collapse Prevention (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Shear capacity 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, $f_c = f_{c_lower_bound} = 25.00$

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

Concrete Elasticity, $E_c = 26999.444$

Steel Elasticity, $E_s = 200000.00$

Existing Column

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

Existing material of Primary Member: Steel Strength, $f_s = f_{s_lower_bound} = 400.00$
Concrete Elasticity, $E_c = 21019.039$
Steel Elasticity, $E_s = 200000.00$

Note: Especially for the calculation of γ for displacement ductility demand,
the expected (mean value) strengths are used (7.5.1.3, ASCE 41-17) because bending is considered as
Deformation-Controlled Action (Table C7-1, ASCE 41-17).
Jacket
New material: Concrete Strength, $f_c = f_{cm} = 33.00$
New material: Steel Strength, $f_s = f_{sm} = 555.56$
Existing Column
Existing material: Concrete Strength, $f_c = f_{cm} = 20.00$
Existing material: Steel Strength, $f_s = f_{sm} = 444.44$

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

Stepwise Properties

EDGE -A-
Bending Moment, $M_a = -2.6887E+007$
Shear Force, $V_a = -8960.208$
EDGE -B-
Bending Moment, $M_b = 0.1232306$
Shear Force, $V_b = 8960.208$
BOTH EDGES
Axial Force, $F = -7385.629$
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: $As_{lt} = 1272.345$
-Compression: $As_{lc} = 1781.283$
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension: $As_{l,ten} = 1017.876$
-Compression: $As_{l,com} = 1017.876$
-Middle: $As_{l,mid} = 1017.876$
Mean Diameter of Tension Reinforcement, $Db_{L,ten} = 18.00$

Existing component: From table 7-7, ASCE 41_17: Final Shear Capacity $V_R = \phi V_n = 396407.213$
 $V_n ((10.3), ASCE 41-17) = k_n \phi V_{CoI} = 396407.213$
 $V_{CoI} = 396407.213$
 $k_n = 1.00$
displacement_ductility_demand = 0.03008718

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: $f'_c = (f'_{c_jacket} \cdot Area_jacket + f'_{c_core} \cdot Area_core) / Area_section = 21.76$, but $f'_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $M/Vd = 4.00$
 $\mu_u = 2.6887E+007$
 $V_u = 8960.208$
 $d = 0.8 \cdot D = 400.00$
 $N_u = 7385.629$
 $A_g = 196349.541$
 From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 68808.56$
 $V_{s1} = 43542.372$ is calculated for jacket, with:
 $A_v = \sqrt{2} \cdot A_{stirrup} = 123370.055$
 $f_y = 500.00$
 $s = 340.00$
 V_{s1} is multiplied by $\text{Col1} = 0.60$
 $s/d = 0.85$
 $V_{s2} = 25266.187$ is calculated for core, with:
 $A_v = \sqrt{2} \cdot A_{stirrup} = 78956.835$
 $f_y = 400.00$
 $s = 200.00$
 V_{s2} is multiplied by $\text{Col2} = 0.66666667$
 $s/d = 0.83333333$
 $V_f((11-3)-(11.4), ACI 440) = 247653.332$
 $f = 0.95$, for fully-wrapped sections
 $w_f/s_f = 1$ (FRP strips adjacent to one another).
 In (11.3) $\sin + \cos$ is replaced with $(\cot + \csc) \sin \alpha$ which is more a generalised expression, where α is the angle of the crack direction (see KANEPE).
 This later relation, considered as a function $V_f(\alpha, a_i)$, is implemented for every different fiber orientation a_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: $\alpha = b_1 + 90^\circ = 90.00$
 $V_f = \text{Min}(|V_f(45, a_1)|, |V_f(-45, a_1)|)$, with:
 total thickness per orientation, $t_{f1} = N_L \cdot t / N_{oDir} = 1.016$
 $d_{fv} = d$ (figure 11.2, ACI 440) = 470.00
 $f_{fe}((11-5), ACI 440) = 259.312$
 $E_f = 64828.00$
 $f_e = 0.004$, from (11.6a), ACI 440
 with $f_u = 0.01$
 From (11-11), ACI 440: $V_s + V_f \leq 389409.072$
 $b_w \cdot d = \sqrt{2} \cdot d^2 / 4 = 125663.706$

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 $\theta = 0.00030739$
 $y = (M_y \cdot L_s / 3) / E_{eff} = 0.01021671$ ((4.29), Biskinis Phd)
 $M_y = 2.4653E+008$
 $L_s = M/V$ (with $L_s > 0.1 \cdot L$ and $L_s < 2 \cdot L$) = 3000.756
 From table 10.5, ASCE 41_17: $E_{eff} = \text{factor} \cdot E_c \cdot I_g = 2.4137E+013$
 factor = 0.30
 $A_g = 196349.541$
 Mean concrete strength: $f'_c = (f'_{c_jacket} \cdot Area_jacket + f'_{c_core} \cdot Area_core) / Area_section = 28.32$
 $N = 7385.629$
 $E_c \cdot I_g = E_{c_jacket} \cdot I_{g_jacket} + E_{c_core} \cdot I_{g_core} = 8.0455E+013$

Calculation of Yielding Moment M_y

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

$M_y = \text{Min}(M_{y_ten}, M_{y_com}) = 2.4653E+008$
 $\delta / y = 7.1028683E-006$

$M_{y_ten} (8c) = 2.4653E+008$
 $_{ten} (7c) = 62.22247$
 error of function (7c) = 0.00021692
 $M_{y_com} (8d) = 8.0674E+008$
 $_{com} (7d) = 63.84405$
 error of function (7d) = -0.00846596
 with ((10.1), ASCE 41-17) $e_y = \text{Min}(e_y, 1.25 * e_y * (l_b / l_d)^{2/3}) = 0.0027778$
 $e_{co} = 0.002$
 $a_{pl} = 0.45$ ((9c) in Biskinis and Fardis for FRP Wrap)
 $d_1 = 44.00$
 $R = 250.00$
 $v = 0.00103611$
 $N = 7385.629$
 $A_c = 196349.541$
 ((10.1), ASCE 41-17) $= \text{Min}(, 1.25 * * (l_b / l_d)^{2/3}) = 0.23799351$
 with f_c^* ((12.3), ACI 440) = 36.3038
 $f_c = 33.00$
 $f_l = 1.05384$
 $k = 1$
 Effective FRP thickness, $t_f = N L * t * \text{Cos}(b_1) = 1.016$
 e_{fe} ((12.5) and (12.7)) = 0.004
 $f_u = 0.01$
 $E_f = 64828.00$

 Calculation of ratio l_b / l_d

Lap Length: $l_d / l_d, \text{min} = 0.34503556$

$l_b = 300.00$

$l_d = 869.4756$

Calculation of l according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

$= 1$

$d_b = 18.00$

Mean strength value of all re-bars: $f_y = 555.56$

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

$t = 1.00$

$s = 0.80$

$e = 1.00$

$c_b = 25.00$

$K_{tr} = 1.20951$

$A_{tr} = /2 * \text{Area of external stirrup} = 123.3701$

$s = s_{external} = 340.00$

$n = 12.00$

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

At local axis: 2

Integration Section: (a)

Calculation No. 10

column C1, Floor 1

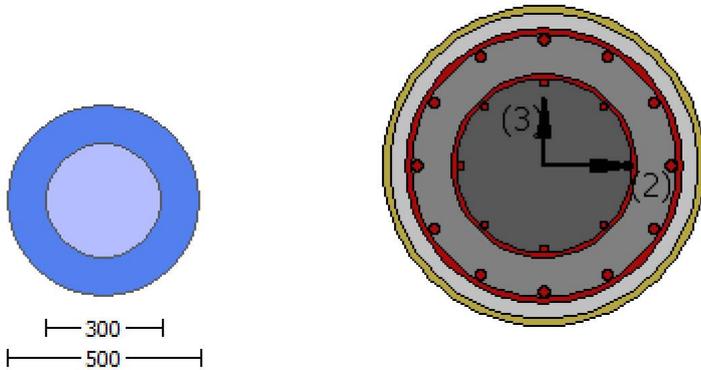
Limit State: Collapse Prevention (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity (θ_r)

Edge: Start

Local Axis: (2)



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

At Shear local axis: 3

(Bending local axis: 2)

Section Type: rcjcs

Constant Properties

Knowledge Factor, $\gamma = 1.00$

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

Consequently:

Jacket

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

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

Concrete Elasticity, $E_c = 26999.444$

Steel Elasticity, $E_s = 200000.00$

Existing Column

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

Existing material of Primary Member: Steel Strength, $f_s = f_{sm} = 444.44$

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

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

Jacket

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

Existing Column

Existing material: Steel Strength, $f_s = 1.25 \cdot f_{sm} = 555.55$

#####

External Diameter, $D = 500.00$

Internal Diameter, $D = 300.00$

Cover Thickness, $c = 25.00$

Mean Confinement Factor overall section = 1.46748

Element Length, $L = 3000.00$

Primary Member

Ribbed Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

Lap Length $l_o = 300.00$

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $\epsilon_{fu} = 0.01$

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

Fiber orientations, $b_i = 0.00^\circ$

Number of layers, $N_L = 1$

Radius of rounding corners, $R = 40.00$

Stepwise Properties

At local axis: 3

EDGE -A-

Shear Force, $V_a = 4.1704511E-031$

EDGE -B-

Shear Force, $V_b = -4.1704511E-031$

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, $V_e/V_r = 0.29814229$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 155683.418$

with

$M_{pr1} = \text{Max}(\mu_{1+}, \mu_{1-}) = 2.3353E+008$

$\mu_{1+} = 2.3353E+008$, is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination

$\mu_{1-} = 2.3353E+008$, is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination

$M_{pr2} = \text{Max}(\mu_{2+}, \mu_{2-}) = 2.3353E+008$

$\mu_{2+} = 2.3353E+008$, is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the static loading combination

$\mu_{2-} = 2.3353E+008$, is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the static loading combination

Calculation of μ_{1+}

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

$\mu_u = 2.3353E+008$

$\phi = 0.80285146$

$\phi' = 0.71403327$

error of function (3.68), Biskinis Phd = 40102.185

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

conf. factor $c = 1.46748$

$f_c = 33.00$

From 10.3.5, ASCE 41-17, Final value of f_y : $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3}) = 368.0049$

$l_b/l_d = 0.27602844$

$d_1 = 44.00$

$R = 250.00$

$v = 0.00103167$

$$N = 7389.214$$

$$Ac = 196349.541$$

$$= *Min(1,1.25*(lb/d)^{2/3}) = 0.15689624$$

 Calculation of ratio lb/d

 Lap Length: lb/d = 0.27602844

lb = 300.00

ld = 1086.845

Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

= 1

db = 18.00

Mean strength value of all re-bars: fy = 694.45

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

t = 1.00

s = 0.80

e = 1.00

cb = 25.00

Ktr = 1.20951

Atr = /2 * Area of external stirrup = 123.3701

s = s_external = 340.00

n = 12.00

 Calculation of Mu1-

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

Mu = 2.3353E+008

 = 0.80285146

' = 0.71403327

error of function (3.68), Biskinis Phd = 40102.185

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

conf. factor c = 1.46748

fc = 33.00

From 10.3.5, ASCE 41-17, Final value of fy: fy*Min(1,1.25*(lb/d)^{2/3}) = 368.0049

lb/d = 0.27602844

d1 = 44.00

R = 250.00

v = 0.00103167

N = 7389.214

Ac = 196349.541

= *Min(1,1.25*(lb/d)^{2/3}) = 0.15689624

 Calculation of ratio lb/d

 Lap Length: lb/d = 0.27602844

lb = 300.00

ld = 1086.845

Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

= 1

db = 18.00

Mean strength value of all re-bars: fy = 694.45

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

t = 1.00

s = 0.80

e = 1.00

cb = 25.00

Ktr = 1.20951

Atr = /2 * Area of external stirrup = 123.3701

s = s_external = 340.00
n = 12.00

Calculation of Mu2+

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), Mu
Mu = 2.3353E+008

= 0.80285146
' = 0.71403327
error of function (3.68), Biskinis Phd = 40102.185
From 5A.2, TBDY: fcc = fc* c = 48.42699
conf. factor c = 1.46748
fc = 33.00
From 10.3.5, ASCE 41-17, Final value of fy: fy*Min(1,1.25*(lb/d)^ 2/3) = 368.0049
lb/d = 0.27602844
d1 = 44.00
R = 250.00
v = 0.00103167
N = 7389.214
Ac = 196349.541
= *Min(1,1.25*(lb/d)^ 2/3) = 0.15689624

Calculation of ratio lb/d

Lap Length: lb/d = 0.27602844
lb = 300.00
ld = 1086.845
Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
= 1
db = 18.00
Mean strength value of all re-bars: fy = 694.45
Mean concrete strength: fc' = (fc'_jacket*Area_jacket + fc'_core*Area_core)/Area_section = 33.00, but fc'^0.5 <= 8.3 MPa (22.5.3.1, ACI 318-14)
t = 1.00
s = 0.80
e = 1.00
cb = 25.00
Ktr = 1.20951
Atr = /2 * Area of external stirrup = 123.3701
s = s_external = 340.00
n = 12.00

Calculation of Mu2-

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), Mu
Mu = 2.3353E+008

= 0.80285146
' = 0.71403327
error of function (3.68), Biskinis Phd = 40102.185
From 5A.2, TBDY: fcc = fc* c = 48.42699
conf. factor c = 1.46748
fc = 33.00
From 10.3.5, ASCE 41-17, Final value of fy: fy*Min(1,1.25*(lb/d)^ 2/3) = 368.0049
lb/d = 0.27602844
d1 = 44.00
R = 250.00

$$v = 0.00103167$$

$$N = 7389.214$$

$$Ac = 196349.541$$

$$= *Min(1, 1.25*(lb/ld)^{2/3}) = 0.15689624$$

Calculation of ratio lb/ld

Lap Length: $lb/ld = 0.27602844$

$lb = 300.00$

$ld = 1086.845$

Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

$= 1$

$db = 18.00$

Mean strength value of all re-bars: $fy = 694.45$

Mean concrete strength: $fc' = (fc'_jacket*Area_jacket + fc'_core*Area_core)/Area_section = 33.00$, but $fc'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$Ktr = 1.20951$

$Atr = \pi/2 * Area\ of\ external\ stirrup = 123.3701$

$s = s_external = 340.00$

$n = 12.00$

Calculation of Shear Strength $Vr = Min(Vr1, Vr2) = 522178.241$

Calculation of Shear Strength at edge 1, $Vr1 = 522178.241$

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

$VColO = 522178.241$

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

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

$= 1$ (normal-weight concrete)

Mean concrete strength: $fc' = (fc'_jacket*Area_jacket + fc'_core*Area_core)/Area_section = 28.32$, but $fc'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$Mu = 2.3891386E-011$

$Vu = 4.1704511E-031$

$d = 0.8*D = 400.00$

$Nu = 7389.214$

$Ag = 196349.541$

From (11.5.4.8), ACI 318-14: $Vs = Vs1 + Vs2 = 76454.061$

$Vs1 = 48380.801$ is calculated for jacket, with:

$Av = \pi/2*A_stirrup = 123370.055$

$fy = 555.56$

$s = 340.00$

$Vs1$ is multiplied by $Col1 = 0.60$

$s/d = 0.85$

$Vs2 = 28073.261$ is calculated for core, with:

$Av = \pi/2*A_stirrup = 78956.835$

$fy = 444.44$

$s = 200.00$

$Vs2$ is multiplied by $Col2 = 0.66666667$

$s/d = 0.83333333$

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

$f = 0.95$, for fully-wrapped sections

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

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

This later relation, considered as a function $Vf(\alpha)$, 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: $\theta_1 = b_1 + 90^\circ = 90.00$

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

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

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

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

$E_f = 64828.00$

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

with $fu = 0.01$

From (11-11), ACI 440: $V_s + V_f \leq 444245.712$

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

Calculation of Shear Strength at edge 2, $V_{r2} = 522178.241$

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

$V_{Col0} = 522178.241$

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

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

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

Mean concrete strength: $f'_c = (f'_{c_jacket} \cdot \text{Area}_{jacket} + f'_{c_core} \cdot \text{Area}_{core}) / \text{Area}_{section} = 28.32$, but $f'_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$\mu_u = 2.3891386E-011$

$\nu_u = 4.1704511E-031$

$d = 0.8 \cdot D = 400.00$

$N_u = 7389.214$

$A_g = 196349.541$

From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 76454.061$

$V_{s1} = 48380.801$ is calculated for jacket, with:

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

$f_y = 555.56$

$s = 340.00$

V_{s1} is multiplied by $\text{Col1} = 0.60$

$s/d = 0.85$

$V_{s2} = 28073.261$ is calculated for core, with:

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

$f_y = 444.44$

$s = 200.00$

V_{s2} is multiplied by $\text{Col2} = 0.66666667$

$s/d = 0.83333333$

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

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

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

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

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

$E_f = 64828.00$

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

with $fu = 0.01$

From (11-11), ACI 440: $V_s + V_f \leq 444245.712$

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

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

At local axis: 3

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

At Shear local axis: 2

(Bending local axis: 3)

Section Type: rcjcs

Constant Properties

Knowledge Factor, $\gamma = 1.00$

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

Consequently:

Jacket

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

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

Concrete Elasticity, $E_c = 26999.444$

Steel Elasticity, $E_s = 200000.00$

Existing Column

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

Existing material of Primary Member: Steel Strength, $f_s = f_{sm} = 444.44$

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

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

Jacket

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

Existing Column

Existing material: Steel Strength, $f_s = 1.25 \cdot f_{sm} = 555.55$

#####

External Diameter, $D = 500.00$

Internal Diameter, $D = 300.00$

Cover Thickness, $c = 25.00$

Mean Confinement Factor overall section = 1.46748

Element Length, $L = 3000.00$

Primary Member

Ribbed Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

Lap Length $l_o = 300.00$

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, $V_a = -2.5535805E-047$

EDGE -B-

Shear Force, $V_b = 2.5535805E-047$

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: $Asl,com = 1017.876$
-Middle: $Asl,mid = 1017.876$

Calculation of Shear Capacity ratio, $V_e/V_r = 0.29814229$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 155683.418$

with

$M_{pr1} = \text{Max}(Mu_{1+}, Mu_{1-}) = 2.3353E+008$

$Mu_{1+} = 2.3353E+008$, is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination

$Mu_{1-} = 2.3353E+008$, is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination

$M_{pr2} = \text{Max}(Mu_{2+}, Mu_{2-}) = 2.3353E+008$

$Mu_{2+} = 2.3353E+008$, is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the static loading combination

$Mu_{2-} = 2.3353E+008$, is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the static loading combination

Calculation of Mu_{1+}

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

$Mu = 2.3353E+008$

$\phi = 0.80285146$

$\lambda = 0.71403327$

error of function (3.68), Biskinis Phd = 40102.185

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

conf. factor $\lambda = 1.46748$

$f_c = 33.00$

From 10.3.5, ASCE 41-17, Final value of f_y : $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3}) = 368.0049$

$l_b/l_d = 0.27602844$

$d_1 = 44.00$

$R = 250.00$

$v = 0.00103167$

$N = 7389.214$

$A_c = 196349.541$

$\phi \cdot \text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3}) = 0.15689624$

Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.27602844$

$l_b = 300.00$

$l_d = 1086.845$

Calculation of l_b, min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

$\phi = 1$

$d_b = 18.00$

Mean strength value of all re-bars: $f_y = 694.45$

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

$t = 1.00$

$s = 0.80$

$e = 1.00$

$c_b = 25.00$

$K_{tr} = 1.20951$

$A_{tr} = \sqrt{2} \cdot \text{Area of external stirrup} = 123.3701$

$s = s_{\text{external}} = 340.00$

$n = 12.00$

Calculation of Mu1-

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

$$\text{Mu} = 2.3353\text{E}+008$$

$$= 0.80285146$$

$$' = 0.71403327$$

error of function (3.68), Biskinis Phd = 40102.185

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

conf. factor $c = 1.46748$

$$f_c = 33.00$$

From 10.3.5, ASCE 41-17, Final value of f_y : $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 368.0049$

$$l_b/d = 0.27602844$$

$$d_1 = 44.00$$

$$R = 250.00$$

$$v = 0.00103167$$

$$N = 7389.214$$

$$A_c = 196349.541$$

$$= \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.15689624$$

Calculation of ratio l_b/d

Lap Length: $l_b/d = 0.27602844$

$$l_b = 300.00$$

$$l_d = 1086.845$$

Calculation of l_b , min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

$$= 1$$

$$d_b = 18.00$$

Mean strength value of all re-bars: $f_y = 694.45$

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

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 25.00$$

$$K_{tr} = 1.20951$$

$$A_{tr} = \sqrt{2} \cdot \text{Area of external stirrup} = 123.3701$$

$$s = s_{\text{external}} = 340.00$$

$$n = 12.00$$

Calculation of Mu2+

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

$$\text{Mu} = 2.3353\text{E}+008$$

$$= 0.80285146$$

$$' = 0.71403327$$

error of function (3.68), Biskinis Phd = 40102.185

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

conf. factor $c = 1.46748$

$$f_c = 33.00$$

From 10.3.5, ASCE 41-17, Final value of f_y : $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 368.0049$

$$l_b/d = 0.27602844$$

$$d_1 = 44.00$$

$$R = 250.00$$

$$v = 0.00103167$$

$$N = 7389.214$$

$$A_c = 196349.541$$

$$= \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.15689624$$

Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.27602844$

$l_b = 300.00$

$l_d = 1086.845$

Calculation of l_b, \min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

$= 1$

$d_b = 18.00$

Mean strength value of all re-bars: $f_y = 694.45$

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

$t = 1.00$

$s = 0.80$

$e = 1.00$

$c_b = 25.00$

$K_{tr} = 1.20951$

$A_{tr} = \pi/2 \cdot \text{Area of external stirrup} = 123.3701$

$s = s_{\text{external}} = 340.00$

$n = 12.00$

Calculation of μ_2

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

$\mu = 2.3353E+008$

$= 0.80285146$

$' = 0.71403327$

error of function (3.68), Biskinis Phd = 40102.185

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

conf. factor $c = 1.46748$

$f_c = 33.00$

From 10.3.5, ASCE 41-17, Final value of f_y : $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3}) = 368.0049$

$l_b/l_d = 0.27602844$

$d_1 = 44.00$

$R = 250.00$

$v = 0.00103167$

$N = 7389.214$

$A_c = 196349.541$

$= \text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3}) = 0.15689624$

Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.27602844$

$l_b = 300.00$

$l_d = 1086.845$

Calculation of l_b, \min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

$= 1$

$d_b = 18.00$

Mean strength value of all re-bars: $f_y = 694.45$

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

$t = 1.00$

$s = 0.80$

$e = 1.00$

$c_b = 25.00$

$K_{tr} = 1.20951$

$A_{tr} = \pi/2 \cdot \text{Area of external stirrup} = 123.3701$

$s = s_{\text{external}} = 340.00$

$n = 12.00$

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 522178.241$

Calculation of Shear Strength at edge 1, $V_{r1} = 522178.241$

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

$V_{Co10} = 522178.241$

$k_{nl} = 1$ (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: $f_c' = (f_c'_{\text{jacket}} * \text{Area}_{\text{jacket}} + f_c'_{\text{core}} * \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 28.32$, but $f_c'^{0.5} \leq 8.3$
MPa (22.5.3.1, ACI 318-14)

$M / Vd = 2.00$

$M_u = 2.0433236E-011$

$V_u = 2.5535805E-047$

$d = 0.8 * D = 400.00$

$N_u = 7389.214$

$A_g = 196349.541$

From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 76454.061$

$V_{s1} = 48380.801$ is calculated for jacket, with:

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

$f_y = 555.56$

$s = 340.00$

V_{s1} is multiplied by $Col1 = 0.60$

$s/d = 0.85$

$V_{s2} = 28073.261$ is calculated for core, with:

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

$f_y = 444.44$

$s = 200.00$

V_{s2} is multiplied by $Col2 = 0.66666667$

$s/d = 0.83333333$

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

$f = 0.95$, for fully-wrapped sections

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

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

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

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

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

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

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

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

$E_f = 64828.00$

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

with $f_u = 0.01$

From (11-11), ACI 440: $V_s + V_f \leq 444245.712$

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

Calculation of Shear Strength at edge 2, $V_{r2} = 522178.241$

$V_{r2} = V_{Co2} \text{ ((10.3), ASCE 41-17)} = k_{nl} * V_{Co10}$

$V_{Co10} = 522178.241$

$k_{nl} = 1$ (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: $f_c' = (f_c'_{\text{jacket}} * \text{Area}_{\text{jacket}} + f_c'_{\text{core}} * \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 28.32$, but $f_c'^{0.5} \leq 8.3$
MPa (22.5.3.1, ACI 318-14)

$M / Vd = 2.00$

$M_u = 2.0433236E-011$

$V_u = 2.5535805E-047$

$d = 0.8 \cdot D = 400.00$
 $Nu = 7389.214$
 $Ag = 196349.541$
 From (11.5.4.8), ACI 318-14: $Vs = Vs1 + Vs2 = 76454.061$
 $Vs1 = 48380.801$ is calculated for jacket, with:
 $Av = \sqrt{2} \cdot A_{stirrup} = 123370.055$
 $fy = 555.56$
 $s = 340.00$
 $Vs1$ is multiplied by $Col1 = 0.60$
 $s/d = 0.85$
 $Vs2 = 28073.261$ is calculated for core, with:
 $Av = \sqrt{2} \cdot A_{stirrup} = 78956.835$
 $fy = 444.44$
 $s = 200.00$
 $Vs2$ is multiplied by $Col2 = 0.66666667$
 $s/d = 0.83333333$
 $Vf ((11-3)-(11.4), ACI 440) = 247653.332$
 $f = 0.95$, for fully-wrapped sections
 $wf/sf = 1$ (FRP strips adjacent to one another).
 In (11.3) $\sin + \cos$ is replaced with $(\cot + \cot a) \sin a$ which is more a generalised expression,
 where a is the angle of the crack direction (see KANEPE).
 This later relation, considered as a function $Vf(\theta, a)$, is implemented for every different fiber orientation a_i ,
 as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.
 orientation 1: $\theta = b1 + 90^\circ = 90.00$
 $Vf = \text{Min}(|Vf(45, \theta)|, |Vf(-45, a1)|)$, with:
 total thickness per orientation, $tf1 = NL \cdot t / NoDir = 1.016$
 $dfv = d$ (figure 11.2, ACI 440) = 470.00
 $ffe ((11-5), ACI 440) = 259.312$
 $Ef = 64828.00$
 $fe = 0.004$, from (11.6a), ACI 440
 with $fu = 0.01$
 From (11-11), ACI 440: $Vs + Vf \leq 444245.712$
 $bw \cdot d = \sqrt{2} \cdot d^2 / 4 = 125663.706$

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

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

Constant Properties

 Knowledge Factor, $\gamma = 1.00$
 Chord Rotation is generally considered as Deformation-Controlled Action according to Table C7-1, ASCE 41-17.
 Mean strengths are used for Deformation-Controlled Actions according to 7.5.1.3, ASCE 41-17
 Consequently:
 Jacket
 New material of Primary Member: Concrete Strength, $fc = f_{cm} = 33.00$
 New material of Primary Member: Steel Strength, $fs = f_{sm} = 555.56$
 Concrete Elasticity, $Ec = 26999.444$
 Steel Elasticity, $Es = 200000.00$
 Existing Column
 Existing material of Primary Member: Concrete Strength, $fc = f_{cm} = 20.00$
 Existing material of Primary Member: Steel Strength, $fs = f_{sm} = 444.44$
 Concrete Elasticity, $Ec = 21019.039$
 Steel Elasticity, $Es = 200000.00$
 External Diameter, $D = 500.00$
 Internal Diameter, $D = 300.00$
 Cover Thickness, $c = 25.00$
 Element Length, $L = 3000.00$
 Primary Member

Ribbed Bars
 Ductile Steel
 Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
 Longitudinal Bars With Ends Lapped Starting at the End Sections
 Lap Length $l_b = 300.00$
 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

Bending Moment, $M = 1.8120144E-009$
 Shear Force, $V_2 = -8960.208$
 Shear Force, $V_3 = -6.3233843E-013$
 Axial Force, $F = -7385.629$
 Longitudinal Reinforcement Area Distribution (in 2 divisions)
 -Tension: $As_t = 1272.345$
 -Compression: $As_c = 1781.283$
 Longitudinal Reinforcement Area Distribution (in 3 divisions)
 -Tension: $As_{,ten} = 1017.876$
 -Compression: $As_{,com} = 1017.876$
 -Middle: $As_{,mid} = 1017.876$
 Mean Diameter of Tension Reinforcement, $Db_L = 18.00$

 Existing component: From table 7-7, ASCE 41_17: Final chord rotation Capacity $u_{,R} = \alpha \cdot u = 0.04710707$
 $u = \alpha \cdot y + \beta = 0.04710707$

 - Calculation of α -

$\alpha = (M_y \cdot L_s / 3) / E_{eff} = 0.00510707$ ((4.29), Biskinis Phd)
 $M_y = 2.4653E+008$
 $L_s = M/V$ (with $L_s > 0.1 \cdot L$ and $L_s < 2 \cdot L$) = 1500.00
 From table 10.5, ASCE 41_17: $E_{eff} = factor \cdot E_c \cdot I_g = 2.4137E+013$
 $factor = 0.30$
 $A_g = 196349.541$
 Mean concrete strength: $f'_c = (f'_{c,jacket} \cdot Area_{jacket} + f'_{c,core} \cdot Area_{core}) / Area_{section} = 28.32$
 $N = 7385.629$
 $E_c \cdot I_g = E_{c,jacket} \cdot I_{g,jacket} + E_{c,core} \cdot I_{g,core} = 8.0455E+013$

 Calculation of Yielding Moment M_y

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

 $M_y = \min(M_{y,ten}, M_{y,com}) = 2.4653E+008$
 $\alpha = 7.1028683E-006$
 $M_{y,ten}$ (8c) = $2.4653E+008$
 $\alpha_{,ten}$ (7c) = 62.22247
 error of function (7c) = 0.00021692
 $M_{y,com}$ (8d) = $8.0674E+008$
 $\alpha_{,com}$ (7d) = 63.84405
 error of function (7d) = -0.00846596
 with ((10.1), ASCE 41-17) $e_y = \min(e_y, 1.25 \cdot e_y \cdot (l_b / l_d)^{2/3}) = 0.0027778$

$\rho_{FRP} = 0.002$
 $a_{pl} = 0.45$ ((9c) in Biskinis and Fardis for FRP Wrap)
 $d_1 = 44.00$
 $R = 250.00$
 $v = 0.00103611$
 $N = 7385.629$
 $A_c = 196349.541$
 $((10.1), ASCE 41-17) = \text{Min}(, 1.25 * (l_b/d)^{2/3}) = 0.23799351$
 with f_c^* ((12.3), ACI 440) = 36.3038
 $f_c = 33.00$
 $f_l = 1.05384$
 $k = 1$
 Effective FRP thickness, $t_f = N L * t * \text{Cos}(b_1) = 1.016$
 e_{fe} ((12.5) and (12.7)) = 0.004
 $f_u = 0.01$
 $E_f = 64828.00$

 Calculation of ratio l_b/d

 Lap Length: $l_d/d, \text{min} = 0.34503556$

$l_b = 300.00$

$l_d = 869.4756$

Calculation of l according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

$= 1$

$d_b = 18.00$

Mean strength value of all re-bars: $f_y = 555.56$

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

$t = 1.00$

$s = 0.80$

$e = 1.00$

$c_b = 25.00$

$K_{tr} = 1.20951$

$A_{tr} = \sqrt{2} * \text{Area of external stirrup} = 123.3701$

$s = s_{\text{external}} = 340.00$

$n = 12.00$

 - Calculation of ρ_p -

 From table 10-9: $\rho_p = 0.042$

with:

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

shear control ratio $V_y E / V_{CoI} O E = 0.29814229$

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

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

$t = s_1 + s_2 + 2 * t_f / b_w * (f_{fe} / f_s) = 0.00519403$

jacket: $s_1 = A_{v1} * (D_{c1} / 2) / (s_1 * A_g) = 0.00081312$

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

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

(shear) direction

$s_1 = 340.00$

core: $s_2 = A_{v2} * (D_{c2} / 2) / (s_2 * A_g) = 0.0005871$

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

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

direction

$s_2 = 200.00$

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

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

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

For the normalisation f_s of jacket is used.

$N_{UD} = 7385.629$

$A_g = 196349.541$

$f_c E = (f_c'_{\text{jacket}} * \text{Area}_{\text{jacket}} + f_c'_{\text{core}} * \text{Area}_{\text{core}}) / \text{section_area} = 28.32$

$f_y E = (f_y_{\text{ext_Long_Reinf}} * \text{Area}_{\text{ext_Long_Reinf}} + f_y_{\text{int_Long_Reinf}} * \text{Area}_{\text{int_Long_Reinf}}) / \text{Area}_{\text{Tot_Long_Rein}} =$

2.1219958E-314

$$f_{tE} = (f_{y_ext_Trans_Reinf} * s_1 + f_{y_int_Trans_Reinf} * s_2) / (s_1 + s_2) = 508.9683$$

$$p_l = \text{Area_Tot_Long_Rein} / (A_g) = 0.015552$$

$$f_{cE} = 28.32$$

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

At local axis: 2

Integration Section: (a)

Calculation No. 11

column C1, Floor 1

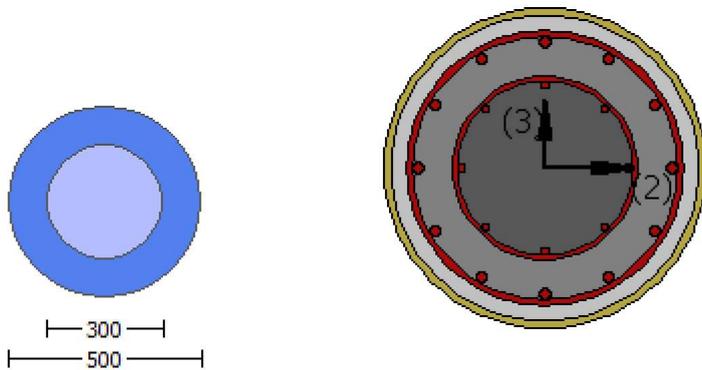
Limit State: Collapse Prevention (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Shear capacity V_{Rd}

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, $f_c = f_{c_lower_bound} = 25.00$

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

Concrete Elasticity, $E_c = 26999.444$

Steel Elasticity, $E_s = 200000.00$

Existing Column

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

Existing material of Primary Member: Steel Strength, $f_s = f_{s_lower_bound} = 400.00$
Concrete Elasticity, $E_c = 21019.039$
Steel Elasticity, $E_s = 200000.00$

Note: Especially for the calculation of γ for displacement ductility demand,
the expected (mean value) strengths are used (7.5.1.3, ASCE 41-17) because bending is considered as
Deformation-Controlled Action (Table C7-1, ASCE 41-17).
Jacket
New material: Concrete Strength, $f_c = f_{cm} = 33.00$
New material: Steel Strength, $f_s = f_{sm} = 555.56$
Existing Column
Existing material: Concrete Strength, $f_c = f_{cm} = 20.00$
Existing material: Steel Strength, $f_s = f_{sm} = 444.44$

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

Stepwise Properties

EDGE -A-
Bending Moment, $M_a = 1.8120144E-009$
Shear Force, $V_a = -6.3233843E-013$
EDGE -B-
Bending Moment, $M_b = 8.5403934E-011$
Shear Force, $V_b = 6.3233843E-013$
BOTH EDGES
Axial Force, $F = -7385.629$
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: $A_{sl,t} = 1272.345$
-Compression: $A_{sl,c} = 1781.283$
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension: $A_{sl,ten} = 1017.876$
-Compression: $A_{sl,com} = 1017.876$
-Middle: $A_{sl,mid} = 1017.876$
Mean Diameter of Tension Reinforcement, $Db_{L,ten} = 18.00$

Existing component: From table 7-7, ASCE 41_17: Final Shear Capacity $V_R = \phi V_n = 488735.20$
 $V_n ((10.3), ASCE 41-17) = k_n \phi V_{CoI} = 488735.20$
 $V_{CoI} = 488735.20$
 $k_n = 1.00$
displacement_ductility_demand = 0.00

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

= 1 (normal-weight concrete)
 Mean concrete strength: $f'_c = (f'_{c_jacket} \cdot Area_jacket + f'_{c_core} \cdot Area_core) / Area_section = 21.76$, but $f'_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $M/Vd = 2.00$
 $\mu_u = 1.8120144E-009$
 $V_u = 6.3233843E-013$
 $d = 0.8 \cdot D = 400.00$
 $N_u = 7385.629$
 $A_g = 196349.541$
 From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 68808.56$
 $V_{s1} = 43542.372$ is calculated for jacket, with:
 $A_v = \sqrt{2} \cdot A_{stirrup} = 123370.055$
 $f_y = 500.00$
 $s = 340.00$
 V_{s1} is multiplied by $Col1 = 0.60$
 $s/d = 0.85$
 $V_{s2} = 25266.187$ is calculated for core, with:
 $A_v = \sqrt{2} \cdot A_{stirrup} = 78956.835$
 $f_y = 400.00$
 $s = 200.00$
 V_{s2} is multiplied by $Col2 = 0.66666667$
 $s/d = 0.83333333$
 $V_f ((11-3)-(11.4), ACI 440) = 247653.332$
 $f = 0.95$, for fully-wrapped sections
 $w_f/s_f = 1$ (FRP strips adjacent to one another).
 In (11.3) $\sin + \cos$ is replaced with $(\cot + \csc) \sin \alpha$ which is more a generalised expression, where α is the angle of the crack direction (see KANEPE).
 This later relation, considered as a function $V_f(\alpha, a_i)$, is implemented for every different fiber orientation a_i , as well as for 2 crack directions, $\alpha = 45^\circ$ and $\alpha = -45^\circ$ to take into consideration the cyclic seismic loading.
 orientation 1: $\alpha = b1 + 90^\circ = 90.00$
 $V_f = \text{Min}(|V_f(45, a1)|, |V_f(-45, a1)|)$, with:
 total thickness per orientation, $t_{f1} = NL \cdot t / NoDir = 1.016$
 $d_{fv} = d$ (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: $V_s + V_f \leq 389409.072$
 $b_w \cdot d = \sqrt{2} \cdot d^2 / 4 = 125663.706$

displacement ductility demand is calculated as δ / y

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

From analysis, chord rotation $\theta = 1.8313396E-020$
 $y = (M_y \cdot L_s / 3) / E_{eff} = 0.00510707$ ((4.29), Biskinis Phd)
 $M_y = 2.4653E+008$
 $L_s = M/V$ (with $L_s > 0.1 \cdot L$ and $L_s < 2 \cdot L$) = 1500.00
 From table 10.5, ASCE 41_17: $E_{eff} = factor \cdot E_c \cdot I_g = 2.4137E+013$
 $factor = 0.30$
 $A_g = 196349.541$
 Mean concrete strength: $f'_c = (f'_{c_jacket} \cdot Area_jacket + f'_{c_core} \cdot Area_core) / Area_section = 28.32$
 $N = 7385.629$
 $E_c \cdot I_g = E_{c_jacket} \cdot I_{g_jacket} + E_{c_core} \cdot I_{g_core} = 8.0455E+013$

Calculation of Yielding Moment M_y

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

$M_y = \text{Min}(M_{y_ten}, M_{y_com}) = 2.4653E+008$
 $\delta / y = 7.1028683E-006$

$M_{y_ten} (8c) = 2.4653E+008$
 $_{ten} (7c) = 62.22247$
error of function (7c) = 0.00021692
 $M_{y_com} (8d) = 8.0674E+008$
 $_{com} (7d) = 63.84405$
error of function (7d) = -0.00846596
with ((10.1), ASCE 41-17) $e_y = \text{Min}(e_y, 1.25 * e_y * (l_b / l_d)^{2/3}) = 0.0027778$
 $e_{co} = 0.002$
 $a_{pl} = 0.45$ ((9c) in Biskinis and Fardis for FRP Wrap)
 $d_1 = 44.00$
 $R = 250.00$
 $v = 0.00103611$
 $N = 7385.629$
 $A_c = 196349.541$
((10.1), ASCE 41-17) $= \text{Min}(, 1.25 * * (l_b / l_d)^{2/3}) = 0.23799351$
with f_c^* ((12.3), ACI 440) = 36.3038
 $f_c = 33.00$
 $f_l = 1.05384$
 $k = 1$
Effective FRP thickness, $t_f = N L * t * \text{Cos}(b_1) = 1.016$
 e_{fe} ((12.5) and (12.7)) = 0.004
 $f_u = 0.01$
 $E_f = 64828.00$

Calculation of ratio l_b / l_d

Lap Length: $l_d / l_d, \text{min} = 0.34503556$

$l_b = 300.00$

$l_d = 869.4756$

Calculation of l according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

$= 1$

$d_b = 18.00$

Mean strength value of all re-bars: $f_y = 555.56$

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

$t = 1.00$

$s = 0.80$

$e = 1.00$

$c_b = 25.00$

$K_{tr} = 1.20951$

$A_{tr} = /2 * \text{Area of external stirrup} = 123.3701$

$s = s_{external} = 340.00$

$n = 12.00$

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

At local axis: 3

Integration Section: (a)

Calculation No. 12

column C1, Floor 1

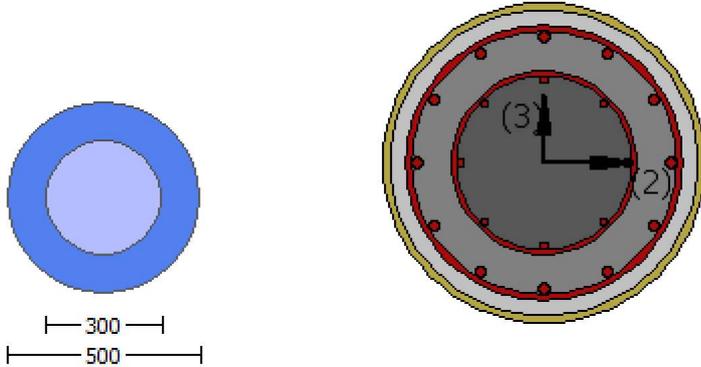
Limit State: Collapse Prevention (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity (θ_r)

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, $f_c = f_{cm} = 33.00$

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

Concrete Elasticity, $E_c = 26999.444$

Steel Elasticity, $E_s = 200000.00$

Existing Column

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

Existing material of Primary Member: Steel Strength, $f_s = f_{sm} = 444.44$

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

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

Jacket

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

Existing Column

Existing material: Steel Strength, $f_s = 1.25 \cdot f_{sm} = 555.55$

#####

External Diameter, $D = 500.00$

Internal Diameter, $D = 300.00$

Cover Thickness, $c = 25.00$

Mean Confinement Factor overall section = 1.46748

Element Length, $L = 3000.00$

Primary Member

Ribbed Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

Lap Length $l_o = 300.00$

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $\epsilon_{fu} = 0.01$

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

Fiber orientations, $b_i = 0.00^\circ$

Number of layers, $N_L = 1$

Radius of rounding corners, $R = 40.00$

Stepwise Properties

At local axis: 3

EDGE -A-

Shear Force, $V_a = 4.1704511E-031$

EDGE -B-

Shear Force, $V_b = -4.1704511E-031$

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, $V_e/V_r = 0.29814229$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 155683.418$

with

$M_{pr1} = \text{Max}(Mu_{1+}, Mu_{1-}) = 2.3353E+008$

$Mu_{1+} = 2.3353E+008$, is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination

$Mu_{1-} = 2.3353E+008$, is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination

$M_{pr2} = \text{Max}(Mu_{2+}, Mu_{2-}) = 2.3353E+008$

$Mu_{2+} = 2.3353E+008$, is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the static loading combination

$Mu_{2-} = 2.3353E+008$, is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the static loading combination

Calculation of Mu_{1+}

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

$Mu = 2.3353E+008$

$\phi = 0.80285146$

$\phi' = 0.71403327$

error of function (3.68), Biskinis Phd = 40102.185

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

conf. factor $c = 1.46748$

$f_c = 33.00$

From 10.3.5, ASCE 41-17, Final value of f_y : $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3}) = 368.0049$

$l_b/l_d = 0.27602844$

$d_1 = 44.00$

$R = 250.00$

$v = 0.00103167$

$$N = 7389.214$$

$$Ac = 196349.541$$

$$= *Min(1,1.25*(lb/ld)^{2/3}) = 0.15689624$$

 Calculation of ratio lb/ld

 Lap Length: lb/ld = 0.27602844

lb = 300.00

ld = 1086.845

Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

= 1

db = 18.00

Mean strength value of all re-bars: fy = 694.45

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

t = 1.00

s = 0.80

e = 1.00

cb = 25.00

Ktr = 1.20951

Atr = /2 * Area of external stirrup = 123.3701

s = s_external = 340.00

n = 12.00

 Calculation of Mu1-

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

Mu = 2.3353E+008

 = 0.80285146

' = 0.71403327

error of function (3.68), Biskinis Phd = 40102.185

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

conf. factor c = 1.46748

fc = 33.00

From 10.3.5, ASCE 41-17, Final value of fy: fy*Min(1,1.25*(lb/ld)^{2/3}) = 368.0049

lb/ld = 0.27602844

d1 = 44.00

R = 250.00

v = 0.00103167

N = 7389.214

Ac = 196349.541

= *Min(1,1.25*(lb/ld)^{2/3}) = 0.15689624

 Calculation of ratio lb/ld

 Lap Length: lb/ld = 0.27602844

lb = 300.00

ld = 1086.845

Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

= 1

db = 18.00

Mean strength value of all re-bars: fy = 694.45

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

t = 1.00

s = 0.80

e = 1.00

cb = 25.00

Ktr = 1.20951

Atr = /2 * Area of external stirrup = 123.3701

s = s_external = 340.00
n = 12.00

Calculation of Mu2+

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), Mu
Mu = 2.3353E+008

= 0.80285146
' = 0.71403327
error of function (3.68), Biskinis Phd = 40102.185
From 5A.2, TBDY: fcc = fc* c = 48.42699
conf. factor c = 1.46748
fc = 33.00
From 10.3.5, ASCE 41-17, Final value of fy: fy*Min(1,1.25*(lb/d)^ 2/3) = 368.0049
lb/d = 0.27602844
d1 = 44.00
R = 250.00
v = 0.00103167
N = 7389.214
Ac = 196349.541
= *Min(1,1.25*(lb/d)^ 2/3) = 0.15689624

Calculation of ratio lb/d

Lap Length: lb/d = 0.27602844
lb = 300.00
ld = 1086.845
Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
= 1
db = 18.00
Mean strength value of all re-bars: fy = 694.45
Mean concrete strength: fc' = (fc'_jacket*Area_jacket + fc'_core*Area_core)/Area_section = 33.00, but fc'^0.5 <= 8.3
MPa (22.5.3.1, ACI 318-14)
t = 1.00
s = 0.80
e = 1.00
cb = 25.00
Ktr = 1.20951
Atr = /2 * Area of external stirrup = 123.3701
s = s_external = 340.00
n = 12.00

Calculation of Mu2-

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), Mu
Mu = 2.3353E+008

= 0.80285146
' = 0.71403327
error of function (3.68), Biskinis Phd = 40102.185
From 5A.2, TBDY: fcc = fc* c = 48.42699
conf. factor c = 1.46748
fc = 33.00
From 10.3.5, ASCE 41-17, Final value of fy: fy*Min(1,1.25*(lb/d)^ 2/3) = 368.0049
lb/d = 0.27602844
d1 = 44.00
R = 250.00

$$v = 0.00103167$$

$$N = 7389.214$$

$$Ac = 196349.541$$

$$= *Min(1, 1.25*(lb/ld)^{2/3}) = 0.15689624$$

Calculation of ratio lb/ld

Lap Length: $lb/ld = 0.27602844$

$lb = 300.00$

$ld = 1086.845$

Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

$= 1$

$db = 18.00$

Mean strength value of all re-bars: $fy = 694.45$

Mean concrete strength: $fc' = (fc'_jacket * Area_jacket + fc'_core * Area_core) / Area_section = 33.00$, but $fc'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$Ktr = 1.20951$

$Atr = \sqrt{2} * \text{Area of external stirrup} = 123.3701$

$s = s_external = 340.00$

$n = 12.00$

Calculation of Shear Strength $Vr = Min(Vr1, Vr2) = 522178.241$

Calculation of Shear Strength at edge 1, $Vr1 = 522178.241$

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

$VColO = 522178.241$

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

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

$= 1$ (normal-weight concrete)

Mean concrete strength: $fc' = (fc'_jacket * Area_jacket + fc'_core * Area_core) / Area_section = 28.32$, but $fc'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/d = 2.00$

$Mu = 2.3891386E-011$

$Vu = 4.1704511E-031$

$d = 0.8 * D = 400.00$

$Nu = 7389.214$

$Ag = 196349.541$

From (11.5.4.8), ACI 318-14: $Vs = Vs1 + Vs2 = 76454.061$

$Vs1 = 48380.801$ is calculated for jacket, with:

$Av = \sqrt{2} * A_stirrup = 123370.055$

$fy = 555.56$

$s = 340.00$

$Vs1$ is multiplied by $Col1 = 0.60$

$s/d = 0.85$

$Vs2 = 28073.261$ is calculated for core, with:

$Av = \sqrt{2} * A_stirrup = 78956.835$

$fy = 444.44$

$s = 200.00$

$Vs2$ is multiplied by $Col2 = 0.66666667$

$s/d = 0.83333333$

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

$f = 0.95$, for fully-wrapped sections

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

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

This later relation, considered as a function $Vf(\alpha)$, 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: $\theta_1 = b_1 + 90^\circ = 90.00$

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

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

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

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

$E_f = 64828.00$

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

with $fu = 0.01$

From (11-11), ACI 440: $V_s + V_f \leq 444245.712$

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

Calculation of Shear Strength at edge 2, $V_{r2} = 522178.241$

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

$V_{Col0} = 522178.241$

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

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

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

Mean concrete strength: $f_c' = (f_c'_{jacket} \cdot \text{Area}_{jacket} + f_c'_{core} \cdot \text{Area}_{core}) / \text{Area}_{section} = 28.32$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M / V d = 2.00$

$\mu_u = 2.3891386E-011$

$\nu_u = 4.1704511E-031$

$d = 0.8 \cdot D = 400.00$

$N_u = 7389.214$

$A_g = 196349.541$

From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 76454.061$

$V_{s1} = 48380.801$ is calculated for jacket, with:

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

$f_y = 555.56$

$s = 340.00$

V_{s1} is multiplied by $\rho_{col1} = 0.60$

$s/d = 0.85$

$V_{s2} = 28073.261$ is calculated for core, with:

$A_v = \rho \cdot A_{stirrup} = 78956.835$

$f_y = 444.44$

$s = 200.00$

V_{s2} is multiplied by $\rho_{col2} = 0.66666667$

$s/d = 0.83333333$

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

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

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

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

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

$E_f = 64828.00$

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

with $fu = 0.01$

From (11-11), ACI 440: $V_s + V_f \leq 444245.712$

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

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

At local axis: 3

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

At Shear local axis: 2

(Bending local axis: 3)

Section Type: rcjcs

Constant Properties

Knowledge Factor, $\gamma = 1.00$

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

Consequently:

Jacket

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

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

Concrete Elasticity, $E_c = 26999.444$

Steel Elasticity, $E_s = 200000.00$

Existing Column

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

Existing material of Primary Member: Steel Strength, $f_s = f_{sm} = 444.44$

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

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

Jacket

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

Existing Column

Existing material: Steel Strength, $f_s = 1.25 \cdot f_{sm} = 555.55$

#####

External Diameter, $D = 500.00$

Internal Diameter, $D = 300.00$

Cover Thickness, $c = 25.00$

Mean Confinement Factor overall section = 1.46748

Element Length, $L = 3000.00$

Primary Member

Ribbed Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

Lap Length $l_o = 300.00$

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, $V_a = -2.5535805E-047$

EDGE -B-

Shear Force, $V_b = 2.5535805E-047$

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, $V_e/V_r = 0.29814229$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 155683.418$

with

$M_{pr1} = \text{Max}(M_{u1+}, M_{u1-}) = 2.3353E+008$

$M_{u1+} = 2.3353E+008$, is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination

$M_{u1-} = 2.3353E+008$, is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination

$M_{pr2} = \text{Max}(M_{u2+}, M_{u2-}) = 2.3353E+008$

$M_{u2+} = 2.3353E+008$, is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the the static loading combination

$M_{u2-} = 2.3353E+008$, is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the the static loading combination

Calculation of M_{u1+}

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

$M_u = 2.3353E+008$

$\phi = 0.80285146$

$\lambda = 0.71403327$

error of function (3.68), Biskinis Phd = 40102.185

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

conf. factor $c = 1.46748$

$f_c = 33.00$

From 10.3.5, ASCE 41-17, Final value of f_y : $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3}) = 368.0049$

$l_b/l_d = 0.27602844$

$d_1 = 44.00$

$R = 250.00$

$v = 0.00103167$

$N = 7389.214$

$A_c = 196349.541$

$= \lambda \cdot \text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3}) = 0.15689624$

Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.27602844$

$l_b = 300.00$

$l_d = 1086.845$

Calculation of l_b, min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

$= 1$

$d_b = 18.00$

Mean strength value of all re-bars: $f_y = 694.45$

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

$t = 1.00$

$s = 0.80$

$e = 1.00$

$c_b = 25.00$

$K_{tr} = 1.20951$

$A_{tr} = \sqrt{2} \cdot \text{Area of external stirrup} = 123.3701$

$s = s_{\text{external}} = 340.00$

$n = 12.00$

Calculation of Mu1-

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

$$\text{Mu} = 2.3353\text{E}+008$$

$$= 0.80285146$$

$$' = 0.71403327$$

error of function (3.68), Biskinis Phd = 40102.185

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

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

$$f_c = 33.00$$

From 10.3.5, ASCE 41-17, Final value of f_y : $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 368.0049$

$$l_b/d = 0.27602844$$

$$d_1 = 44.00$$

$$R = 250.00$$

$$v = 0.00103167$$

$$N = 7389.214$$

$$A_c = 196349.541$$

$$= \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.15689624$$

Calculation of ratio l_b/d

Lap Length: $l_b/d = 0.27602844$

$$l_b = 300.00$$

$$l_d = 1086.845$$

Calculation of l_b , min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

$$= 1$$

$$d_b = 18.00$$

Mean strength value of all re-bars: $f_y = 694.45$

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

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 25.00$$

$$K_{tr} = 1.20951$$

$$A_{tr} = \sqrt{2} \cdot \text{Area of external stirrup} = 123.3701$$

$$s = s_{\text{external}} = 340.00$$

$$n = 12.00$$

Calculation of Mu2+

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

$$\text{Mu} = 2.3353\text{E}+008$$

$$= 0.80285146$$

$$' = 0.71403327$$

error of function (3.68), Biskinis Phd = 40102.185

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

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

$$f_c = 33.00$$

From 10.3.5, ASCE 41-17, Final value of f_y : $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 368.0049$

$$l_b/d = 0.27602844$$

$$d_1 = 44.00$$

$$R = 250.00$$

$$v = 0.00103167$$

$$N = 7389.214$$

$$A_c = 196349.541$$

$$= \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.15689624$$

Calculation of ratio l_b/d

Lap Length: $l_b/d = 0.27602844$

$l_b = 300.00$

$l_d = 1086.845$

Calculation of l_b, \min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

$= 1$

$d_b = 18.00$

Mean strength value of all re-bars: $f_y = 694.45$

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

$t = 1.00$

$s = 0.80$

$e = 1.00$

$c_b = 25.00$

$K_{tr} = 1.20951$

$A_{tr} = \pi/2 \cdot \text{Area of external stirrup} = 123.3701$

$s = s_{\text{external}} = 340.00$

$n = 12.00$

Calculation of μ_2

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

$\mu = 2.3353E+008$

$= 0.80285146$

$' = 0.71403327$

error of function (3.68), Biskinis Phd = 40102.185

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

conf. factor $c = 1.46748$

$f_c = 33.00$

From 10.3.5, ASCE 41-17, Final value of f_y : $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 368.0049$

$l_b/d = 0.27602844$

$d_1 = 44.00$

$R = 250.00$

$v = 0.00103167$

$N = 7389.214$

$A_c = 196349.541$

$= \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.15689624$

Calculation of ratio l_b/d

Lap Length: $l_b/d = 0.27602844$

$l_b = 300.00$

$l_d = 1086.845$

Calculation of l_b, \min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

$= 1$

$d_b = 18.00$

Mean strength value of all re-bars: $f_y = 694.45$

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

$t = 1.00$

$s = 0.80$

$e = 1.00$

$c_b = 25.00$

$K_{tr} = 1.20951$

$A_{tr} = \pi/2 \cdot \text{Area of external stirrup} = 123.3701$

$s = s_{\text{external}} = 340.00$

$n = 12.00$

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 522178.241$

Calculation of Shear Strength at edge 1, $V_{r1} = 522178.241$

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

$V_{CoI0} = 522178.241$

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

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

$k_{nl} = 1$ (normal-weight concrete)

Mean concrete strength: $f_c' = (f_c'_{\text{jacket}} * \text{Area}_{\text{jacket}} + f_c'_{\text{core}} * \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 28.32$, but $f_c'^{0.5} \leq 8.3$
MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$\mu_u = 2.0433236E-011$

$\nu_u = 2.5535805E-047$

$d = 0.8 * D = 400.00$

$N_u = 7389.214$

$A_g = 196349.541$

From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 76454.061$

$V_{s1} = 48380.801$ is calculated for jacket, with:

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

$f_y = 555.56$

$s = 340.00$

V_{s1} is multiplied by $Col1 = 0.60$

$s/d = 0.85$

$V_{s2} = 28073.261$ is calculated for core, with:

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

$f_y = 444.44$

$s = 200.00$

V_{s2} is multiplied by $Col2 = 0.66666667$

$s/d = 0.83333333$

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

$V_f = \text{Min}(|V_f(45, 90)|, |V_f(-45, 90)|)$, 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: $V_s + V_f \leq 444245.712$

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

Calculation of Shear Strength at edge 2, $V_{r2} = 522178.241$

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

$V_{CoI0} = 522178.241$

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

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

$k_{nl} = 1$ (normal-weight concrete)

Mean concrete strength: $f_c' = (f_c'_{\text{jacket}} * \text{Area}_{\text{jacket}} + f_c'_{\text{core}} * \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 28.32$, but $f_c'^{0.5} \leq 8.3$
MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$\mu_u = 2.0433236E-011$

$\nu_u = 2.5535805E-047$

$d = 0.8 \cdot D = 400.00$
 $Nu = 7389.214$
 $Ag = 196349.541$
 From (11.5.4.8), ACI 318-14: $Vs = Vs1 + Vs2 = 76454.061$
 $Vs1 = 48380.801$ is calculated for jacket, with:
 $Av = \sqrt{2} \cdot A_{stirrup} = 123370.055$
 $fy = 555.56$
 $s = 340.00$
 $Vs1$ is multiplied by $Col1 = 0.60$
 $s/d = 0.85$
 $Vs2 = 28073.261$ is calculated for core, with:
 $Av = \sqrt{2} \cdot A_{stirrup} = 78956.835$
 $fy = 444.44$
 $s = 200.00$
 $Vs2$ is multiplied by $Col2 = 0.66666667$
 $s/d = 0.83333333$
 $Vf ((11-3)-(11.4), ACI 440) = 247653.332$
 $f = 0.95$, for fully-wrapped sections
 $wf/sf = 1$ (FRP strips adjacent to one another).
 In (11.3) $\sin + \cos$ is replaced with $(\cot + \cot a) \sin a$ which is more a generalised expression,
 where a is the angle of the crack direction (see KANEPE).
 This later relation, considered as a function $Vf(\theta, a)$, is implemented for every different fiber orientation a_i ,
 as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.
 orientation 1: $\theta = b1 + 90^\circ = 90.00$
 $Vf = \text{Min}(|Vf(45, \theta)|, |Vf(-45, a1)|)$, with:
 total thickness per orientation, $tf1 = NL \cdot t / NoDir = 1.016$
 $dfv = d$ (figure 11.2, ACI 440) = 470.00
 $ffe ((11-5), ACI 440) = 259.312$
 $Ef = 64828.00$
 $fe = 0.004$, from (11.6a), ACI 440
 with $fu = 0.01$
 From (11-11), ACI 440: $Vs + Vf \leq 444245.712$
 $bw \cdot d = \sqrt{2} \cdot d^2 / 4 = 125663.706$

 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, $fc = f_{cm} = 33.00$
 New material of Primary Member: Steel Strength, $fs = f_{sm} = 555.56$
 Concrete Elasticity, $Ec = 26999.444$
 Steel Elasticity, $Es = 200000.00$
 Existing Column
 Existing material of Primary Member: Concrete Strength, $fc = f_{cm} = 20.00$
 Existing material of Primary Member: Steel Strength, $fs = f_{sm} = 444.44$
 Concrete Elasticity, $Ec = 21019.039$
 Steel Elasticity, $Es = 200000.00$
 External Diameter, $D = 500.00$
 Internal Diameter, $D = 300.00$
 Cover Thickness, $c = 25.00$
 Element Length, $L = 3000.00$
 Primary Member

Ribbed Bars
 Ductile Steel
 Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
 Longitudinal Bars With Ends Lapped Starting at the End Sections
 Lap Length $l_b = 300.00$
 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

Bending Moment, $M = -2.6887E+007$
 Shear Force, $V_2 = -8960.208$
 Shear Force, $V_3 = -6.3233843E-013$
 Axial Force, $F = -7385.629$
 Longitudinal Reinforcement Area Distribution (in 2 divisions)
 -Tension: $As_t = 1272.345$
 -Compression: $As_c = 1781.283$
 Longitudinal Reinforcement Area Distribution (in 3 divisions)
 -Tension: $As_{,ten} = 1017.876$
 -Compression: $As_{,com} = 1017.876$
 -Middle: $As_{,mid} = 1017.876$
 Mean Diameter of Tension Reinforcement, $Db_L = 18.00$

 Existing component: From table 7-7, ASCE 41_17: Final chord rotation Capacity $u_{,R} = \gamma + p = 0.05221671$
 $u = \gamma + p = 0.05221671$

 - Calculation of γ -

$\gamma = (M_y * L_s / 3) / E_{eff} = 0.01021671$ ((4.29), Biskinis Phd))
 $M_y = 2.4653E+008$
 $L_s = M/V$ (with $L_s > 0.1 * L$ and $L_s < 2 * L$) = 3000.756
 From table 10.5, ASCE 41_17: $E_{eff} = factor * E_c * I_g = 2.4137E+013$
 $factor = 0.30$
 $A_g = 196349.541$
 Mean concrete strength: $f'_c = (f'_{c,jacket} * Area_{jacket} + f'_{c,core} * Area_{core}) / Area_{section} = 28.32$
 $N = 7385.629$
 $E_c * I_g = E_{c,jacket} * I_{g,jacket} + E_{c,core} * I_{g,core} = 8.0455E+013$

 Calculation of Yielding Moment M_y

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

$M_y = \text{Min}(M_{y,ten}, M_{y,com}) = 2.4653E+008$
 $\gamma = 7.1028683E-006$
 $M_{y,ten}$ (8c) = $2.4653E+008$
 γ_{ten} (7c) = 62.22247
 error of function (7c) = 0.00021692
 $M_{y,com}$ (8d) = $8.0674E+008$
 γ_{com} (7d) = 63.84405
 error of function (7d) = -0.00846596
 with ((10.1), ASCE 41-17) $e_y = \text{Min}(e_y, 1.25 * e_y * (l_b / l_d)^{2/3}) = 0.0027778$

$\rho_{FRP} = 0.002$
 $a_{FRP} = 0.45$ ((9c) in Biskinis and Fardis for FRP Wrap)
 $d_1 = 44.00$
 $R = 250.00$
 $v = 0.00103611$
 $N = 7385.629$
 $A_c = 196349.541$
 $\rho_{FRP} = \text{Min}(0.002, 1.25 \cdot \rho_{FRP} \cdot (l_b/d)^{2/3}) = 0.23799351$
 with $f_c' = 33.00$ ((12.3), ACI 440) = 36.3038
 $f_l = 1.05384$
 $k = 1$
 Effective FRP thickness, $t_f = N \cdot l \cdot \cos(\beta) = 1.016$
 $\rho_{FRP} = 0.004$ ((12.5) and (12.7))
 $f_u = 0.01$
 $E_f = 64828.00$

 Calculation of ratio l_b/d

Lap Length: $l_b/d, \min = 0.34503556$

$l_b = 300.00$

$l_d = 869.4756$

Calculation of l according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

$\rho = 1$

$d_b = 18.00$

Mean strength value of all re-bars: $f_y = 555.56$

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

$t = 1.00$

$s = 0.80$

$e = 1.00$

$c_b = 25.00$

$K_{tr} = 1.20951$

$A_{tr} = \sqrt{2} \cdot \text{Area of external stirrup} = 123.3701$

$s = s_{\text{external}} = 340.00$

$n = 12.00$

 - Calculation of ρ_p -

From table 10-9: $\rho_p = 0.042$

with:

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

shear control ratio $V_y E / V_{CoI} E = 0.29814229$

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

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

$t = s_1 + s_2 + 2 \cdot t_f / b_w \cdot (f_{fe} / f_s) = 0.00519403$

jacket: $s_1 = A_{v1} \cdot (D_{c1} / 2) / (s_1 \cdot A_g) = 0.00081312$

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

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

(shear) direction

$s_1 = 340.00$

core: $s_2 = A_{v2} \cdot (D_{c2} / 2) / (s_2 \cdot A_g) = 0.0005871$

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

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

direction

$s_2 = 200.00$

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.

$N_{UD} = 7385.629$

$A_g = 196349.541$

$f_c E = (f_c'_{\text{jacket}} \cdot \text{Area}_{\text{jacket}} + f_c'_{\text{core}} \cdot \text{Area}_{\text{core}}) / \text{section_area} = 28.32$

$f_y E = (f_y_{\text{ext_Long_Reinf}} \cdot \text{Area}_{\text{ext_Long_Reinf}} + f_y_{\text{int_Long_Reinf}} \cdot \text{Area}_{\text{int_Long_Reinf}}) / \text{Area}_{\text{Tot_Long_Rein}} =$

2.1219958E-314

$$f_{tE} = (f_{y_ext_Trans_Reinf} * s_1 + f_{y_int_Trans_Reinf} * s_2) / (s_1 + s_2) = 508.9683$$

$$p_l = \text{Area_Tot_Long_Rein} / (A_g) = 0.015552$$

$$f_{cE} = 28.32$$

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

At local axis: 3

Integration Section: (a)

Calculation No. 13

column C1, Floor 1

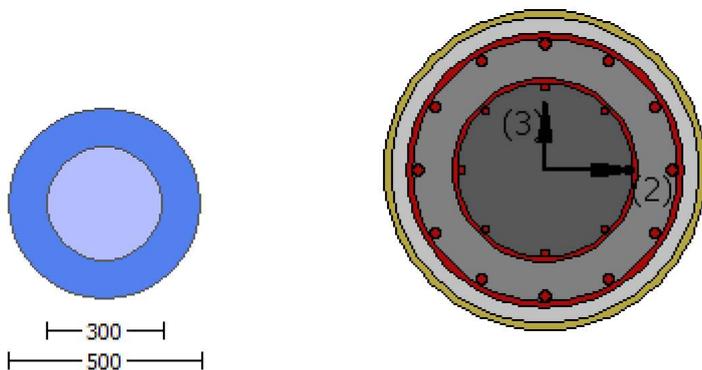
Limit State: Collapse Prevention (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Shear capacity 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, $f_c = f_{c_lower_bound} = 25.00$

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

Concrete Elasticity, $E_c = 26999.444$

Steel Elasticity, $E_s = 200000.00$

Existing Column

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

Existing material of Primary Member: Steel Strength, $f_s = f_{s_lower_bound} = 400.00$
Concrete Elasticity, $E_c = 21019.039$
Steel Elasticity, $E_s = 200000.00$

Note: Especially for the calculation of γ for displacement ductility demand,
the expected (mean value) strengths are used (7.5.1.3, ASCE 41-17) because bending is considered as
Deformation-Controlled Action (Table C7-1, ASCE 41-17).
Jacket
New material: Concrete Strength, $f_c = f_{cm} = 33.00$
New material: Steel Strength, $f_s = f_{sm} = 555.56$
Existing Column
Existing material: Concrete Strength, $f_c = f_{cm} = 20.00$
Existing material: Steel Strength, $f_s = f_{sm} = 444.44$

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

Stepwise Properties

EDGE -A-
Bending Moment, $M_a = -2.6887E+007$
Shear Force, $V_a = -8960.208$
EDGE -B-
Bending Moment, $M_b = 0.1232306$
Shear Force, $V_b = 8960.208$
BOTH EDGES
Axial Force, $F = -7385.629$
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: $A_{sl,t} = 0.00$
-Compression: $A_{sl,c} = 3053.628$
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension: $A_{sl,ten} = 1017.876$
-Compression: $A_{sl,com} = 1017.876$
-Middle: $A_{sl,mid} = 1017.876$
Mean Diameter of Tension Reinforcement, $Db_{L,ten} = 18.00$

Existing component: From table 7-7, ASCE 41_17: Final Shear Capacity $V_R = \phi V_n = 488735.20$
 $V_n ((10.3), ASCE 41-17) = k_n l V_{CoI} = 488735.20$
 $V_{CoI} = 488735.20$
 $k_n l = 1.00$
displacement_ductility_demand = 0.16357538

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: $f_c' = (f_c'_{\text{jacket}} \cdot \text{Area}_{\text{jacket}} + f_c'_{\text{core}} \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 21.76$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $M/Vd = 2.00$
 $\mu_u = 0.1232306$
 $V_u = 8960.208$
 $d = 0.8 \cdot D = 400.00$
 $N_u = 7385.629$
 $A_g = 196349.541$
 From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 68808.56$
 $V_{s1} = 43542.372$ is calculated for jacket, with:
 $A_v = \sqrt{2} \cdot A_{\text{stirrup}} = 123370.055$
 $f_y = 500.00$
 $s = 340.00$
 V_{s1} is multiplied by $\text{Col1} = 0.60$
 $s/d = 0.85$
 $V_{s2} = 25266.187$ is calculated for core, with:
 $A_v = \sqrt{2} \cdot A_{\text{stirrup}} = 78956.835$
 $f_y = 400.00$
 $s = 200.00$
 V_{s2} is multiplied by $\text{Col2} = 0.66666667$
 $s/d = 0.83333333$
 $V_f ((11-3)-(11.4), \text{ACI } 440) = 247653.332$
 $f = 0.95$, for fully-wrapped sections
 $w_f/s_f = 1$ (FRP strips adjacent to one another).
 In (11.3) $\sin + \cos$ is replaced with $(\cot + \csc) \sin \alpha$ which is more a generalised expression, where α is the angle of the crack direction (see KANEPE).
 This later relation, considered as a function $V_f(\alpha, a_i)$, is implemented for every different fiber orientation a_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: $\alpha = b_1 + 90^\circ = 90.00$
 $V_f = \text{Min}(|V_f(45, a_1)|, |V_f(-45, a_1)|)$, with:
 total thickness per orientation, $t_{f1} = N_L \cdot t / N_{\text{Dir}} = 1.016$
 $d_{fv} = d$ (figure 11.2, ACI 440) = 470.00
 $f_{fe} ((11-5), \text{ACI } 440) = 259.312$
 $E_f = 64828.00$
 $f_e = 0.004$, from (11.6a), ACI 440
 with $f_u = 0.01$
 From (11-11), ACI 440: $V_s + V_f \leq 389409.072$
 $b_w \cdot d = \sqrt{2} \cdot d^2 / 4 = 125663.706$

displacement_ductility_demand is calculated as δ / y

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

From analysis, chord rotation $\theta = 0.00016708$
 $y = (M_y \cdot L_s / 3) / E_{\text{eff}} = 0.00102141$ ((4.29), Biskinis Phd)
 $M_y = 2.4653E+008$
 $L_s = M/V$ (with $L_s > 0.1 \cdot L$ and $L_s < 2 \cdot L$) = 300.00
 From table 10.5, ASCE 41_17: $E_{\text{eff}} = \text{factor} \cdot E_c \cdot I_g = 2.4137E+013$
 factor = 0.30
 $A_g = 196349.541$
 Mean concrete strength: $f_c' = (f_c'_{\text{jacket}} \cdot \text{Area}_{\text{jacket}} + f_c'_{\text{core}} \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 28.32$
 $N = 7385.629$
 $E_c \cdot I_g = E_{c_{\text{jacket}}} \cdot I_{g_{\text{jacket}}} + E_{c_{\text{core}}} \cdot I_{g_{\text{core}}} = 8.0455E+013$

Calculation of Yielding Moment M_y

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

$M_y = \text{Min}(M_{y_{\text{ten}}}, M_{y_{\text{com}}}) = 2.4653E+008$
 $\delta / y = 7.1028683E-006$

$M_{y_ten} (8c) = 2.4653E+008$
 $_{ten} (7c) = 62.22247$
error of function (7c) = 0.00021692
 $M_{y_com} (8d) = 8.0674E+008$
 $_{com} (7d) = 63.84405$
error of function (7d) = -0.00846596
with ((10.1), ASCE 41-17) $e_y = \text{Min}(e_y, 1.25 * e_y * (l_b / l_d)^{2/3}) = 0.0027778$
 $e_{co} = 0.002$
 $a_{pl} = 0.45$ ((9c) in Biskinis and Fardis for FRP Wrap)
 $d_1 = 44.00$
 $R = 250.00$
 $v = 0.00103611$
 $N = 7385.629$
 $A_c = 196349.541$
((10.1), ASCE 41-17) $= \text{Min}(, 1.25 * * (l_b / l_d)^{2/3}) = 0.23799351$
with f_c^* ((12.3), ACI 440) = 36.3038
 $f_c = 33.00$
 $f_l = 1.05384$
 $k = 1$
Effective FRP thickness, $t_f = N L * t * \text{Cos}(b_1) = 1.016$
 e_{fe} ((12.5) and (12.7)) = 0.004
 $f_u = 0.01$
 $E_f = 64828.00$

Calculation of ratio l_b / l_d

Lap Length: $l_d / l_d, \text{min} = 0.34503556$

$l_b = 300.00$

$l_d = 869.4756$

Calculation of l according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

$= 1$

$d_b = 18.00$

Mean strength value of all re-bars: $f_y = 555.56$

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

$t = 1.00$

$s = 0.80$

$e = 1.00$

$c_b = 25.00$

$K_{tr} = 1.20951$

$A_{tr} = \sqrt{2} * \text{Area of external stirrup} = 123.3701$

$s = s_{external} = 340.00$

$n = 12.00$

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

At local axis: 2

Integration Section: (b)

Calculation No. 14

column C1, Floor 1

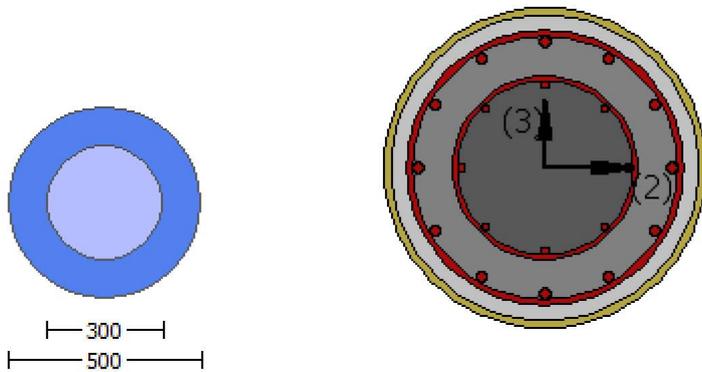
Limit State: Collapse Prevention (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity (θ_r)

Edge: End

Local Axis: (2)



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

At Shear local axis: 3

(Bending local axis: 2)

Section Type: rcjcs

Constant Properties

Knowledge Factor, $\gamma = 1.00$

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

Consequently:

Jacket

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

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

Concrete Elasticity, $E_c = 26999.444$

Steel Elasticity, $E_s = 200000.00$

Existing Column

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

Existing material of Primary Member: Steel Strength, $f_s = f_{sm} = 444.44$

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

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

Jacket

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

Existing Column

Existing material: Steel Strength, $f_s = 1.25 \cdot f_{sm} = 555.55$

#####

External Diameter, $D = 500.00$

Internal Diameter, $D = 300.00$

Cover Thickness, $c = 25.00$

Mean Confinement Factor overall section = 1.46748

Element Length, $L = 3000.00$

Primary Member

Ribbed Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

Lap Length $l_o = 300.00$

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $\epsilon_{fu} = 0.01$

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

Fiber orientations, $b_i = 0.00^\circ$

Number of layers, $N_L = 1$

Radius of rounding corners, $R = 40.00$

Stepwise Properties

At local axis: 3

EDGE -A-

Shear Force, $V_a = 4.1704511E-031$

EDGE -B-

Shear Force, $V_b = -4.1704511E-031$

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, $V_e/V_r = 0.29814229$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 155683.418$

with

$M_{pr1} = \text{Max}(Mu_{1+}, Mu_{1-}) = 2.3353E+008$

$Mu_{1+} = 2.3353E+008$, is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination

$Mu_{1-} = 2.3353E+008$, is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination

$M_{pr2} = \text{Max}(Mu_{2+}, Mu_{2-}) = 2.3353E+008$

$Mu_{2+} = 2.3353E+008$, is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the static loading combination

$Mu_{2-} = 2.3353E+008$, is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the static loading combination

Calculation of Mu_{1+}

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

$Mu = 2.3353E+008$

$\phi = 0.80285146$

$\lambda = 0.71403327$

error of function (3.68), Biskinis Phd = 40102.185

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

conf. factor $c = 1.46748$

$f_c = 33.00$

From 10.3.5, ASCE 41-17, Final value of f_y : $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3}) = 368.0049$

$l_b/l_d = 0.27602844$

$d_1 = 44.00$

$R = 250.00$

$v = 0.00103167$

$$N = 7389.214$$

$$Ac = 196349.541$$

$$= *Min(1,1.25*(lb/d)^{2/3}) = 0.15689624$$

 Calculation of ratio lb/d

 Lap Length: lb/d = 0.27602844

lb = 300.00

ld = 1086.845

Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

= 1

db = 18.00

Mean strength value of all re-bars: fy = 694.45

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

t = 1.00

s = 0.80

e = 1.00

cb = 25.00

Ktr = 1.20951

Atr = /2 * Area of external stirrup = 123.3701

s = s_external = 340.00

n = 12.00

 Calculation of Mu1-

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

Mu = 2.3353E+008

 = 0.80285146

' = 0.71403327

error of function (3.68), Biskinis Phd = 40102.185

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

conf. factor c = 1.46748

fc = 33.00

From 10.3.5, ASCE 41-17, Final value of fy: fy*Min(1,1.25*(lb/d)^{2/3}) = 368.0049

lb/d = 0.27602844

d1 = 44.00

R = 250.00

v = 0.00103167

N = 7389.214

Ac = 196349.541

= *Min(1,1.25*(lb/d)^{2/3}) = 0.15689624

 Calculation of ratio lb/d

 Lap Length: lb/d = 0.27602844

lb = 300.00

ld = 1086.845

Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

= 1

db = 18.00

Mean strength value of all re-bars: fy = 694.45

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

t = 1.00

s = 0.80

e = 1.00

cb = 25.00

Ktr = 1.20951

Atr = /2 * Area of external stirrup = 123.3701

s = s_external = 340.00
n = 12.00

Calculation of Mu2+

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), Mu
Mu = 2.3353E+008

= 0.80285146
' = 0.71403327
error of function (3.68), Biskinis Phd = 40102.185
From 5A.2, TBDY: fcc = fc* c = 48.42699
conf. factor c = 1.46748
fc = 33.00
From 10.3.5, ASCE 41-17, Final value of fy: fy*Min(1,1.25*(lb/d)^ 2/3) = 368.0049
lb/d = 0.27602844
d1 = 44.00
R = 250.00
v = 0.00103167
N = 7389.214
Ac = 196349.541
= *Min(1,1.25*(lb/d)^ 2/3) = 0.15689624

Calculation of ratio lb/d

Lap Length: lb/d = 0.27602844
lb = 300.00
ld = 1086.845
Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
= 1
db = 18.00
Mean strength value of all re-bars: fy = 694.45
Mean concrete strength: fc' = (fc'_jacket*Area_jacket + fc'_core*Area_core)/Area_section = 33.00, but fc'^0.5 <= 8.3 MPa (22.5.3.1, ACI 318-14)
t = 1.00
s = 0.80
e = 1.00
cb = 25.00
Ktr = 1.20951
Atr = /2 * Area of external stirrup = 123.3701
s = s_external = 340.00
n = 12.00

Calculation of Mu2-

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), Mu
Mu = 2.3353E+008

= 0.80285146
' = 0.71403327
error of function (3.68), Biskinis Phd = 40102.185
From 5A.2, TBDY: fcc = fc* c = 48.42699
conf. factor c = 1.46748
fc = 33.00
From 10.3.5, ASCE 41-17, Final value of fy: fy*Min(1,1.25*(lb/d)^ 2/3) = 368.0049
lb/d = 0.27602844
d1 = 44.00
R = 250.00

$$v = 0.00103167$$

$$N = 7389.214$$

$$Ac = 196349.541$$

$$= *Min(1, 1.25*(lb/ld)^{2/3}) = 0.15689624$$

 Calculation of ratio lb/ld

 Lap Length: lb/ld = 0.27602844

lb = 300.00

ld = 1086.845

Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

= 1

db = 18.00

Mean strength value of all re-bars: fy = 694.45

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

t = 1.00

s = 0.80

e = 1.00

cb = 25.00

Ktr = 1.20951

Atr = /2 * Area of external stirrup = 123.3701

s = s_external = 340.00

n = 12.00

 Calculation of Shear Strength Vr = Min(Vr1, Vr2) = 522178.241

 Calculation of Shear Strength at edge 1, Vr1 = 522178.241

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

VCol0 = 522178.241

knl = 1 (zero step-static loading)

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

 = 1 (normal-weight concrete)

Mean concrete strength: fc' = (fc'_jacket*Area_jacket + fc'_core*Area_core)/Area_section = 28.32, but fc'^0.5 <= 8.3 MPa (22.5.3.1, ACI 318-14)

M/Vd = 2.00

Mu = 2.3891386E-011

Vu = 4.1704511E-031

d = 0.8*D = 400.00

Nu = 7389.214

Ag = 196349.541

From (11.5.4.8), ACI 318-14: Vs = Vs1 + Vs2 = 76454.061

Vs1 = 48380.801 is calculated for jacket, with:

Av = /2*A_stirrup = 123370.055

fy = 555.56

s = 340.00

Vs1 is multiplied by Col1 = 0.60

s/d = 0.85

Vs2 = 28073.261 is calculated for core, with:

Av = /2*A_stirrup = 78956.835

fy = 444.44

s = 200.00

Vs2 is multiplied by Col2 = 0.66666667

s/d = 0.83333333

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

f = 0.95, for fully-wrapped sections

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

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

This later relation, considered as a function Vf(,), is implemented for every different fiber orientation ai,

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

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

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

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

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

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

$E_f = 64828.00$

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

with $fu = 0.01$

From (11-11), ACI 440: $V_s + V_f \leq 444245.712$

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

Calculation of Shear Strength at edge 2, $V_{r2} = 522178.241$

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

$V_{Col0} = 522178.241$

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

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

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

Mean concrete strength: $f'_c = (f'_{c_jacket} \cdot \text{Area}_{jacket} + f'_{c_core} \cdot \text{Area}_{core}) / \text{Area}_{section} = 28.32$, but $f'_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$\mu_u = 2.3891386E-011$

$\nu_u = 4.1704511E-031$

$d = 0.8 \cdot D = 400.00$

$N_u = 7389.214$

$A_g = 196349.541$

From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 76454.061$

$V_{s1} = 48380.801$ is calculated for jacket, with:

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

$f_y = 555.56$

$s = 340.00$

V_{s1} is multiplied by $\text{Col1} = 0.60$

$s/d = 0.85$

$V_{s2} = 28073.261$ is calculated for core, with:

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

$f_y = 444.44$

$s = 200.00$

V_{s2} is multiplied by $\text{Col2} = 0.66666667$

$s/d = 0.83333333$

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

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

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

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

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

$E_f = 64828.00$

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

with $fu = 0.01$

From (11-11), ACI 440: $V_s + V_f \leq 444245.712$

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

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

At local axis: 3

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

At Shear local axis: 2

(Bending local axis: 3)

Section Type: rcjcs

Constant Properties

Knowledge Factor, $\gamma = 1.00$

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

Consequently:

Jacket

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

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

Concrete Elasticity, $E_c = 26999.444$

Steel Elasticity, $E_s = 200000.00$

Existing Column

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

Existing material of Primary Member: Steel Strength, $f_s = f_{sm} = 444.44$

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

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

Jacket

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

Existing Column

Existing material: Steel Strength, $f_s = 1.25 \cdot f_{sm} = 555.55$

#####

External Diameter, $D = 500.00$

Internal Diameter, $D = 300.00$

Cover Thickness, $c = 25.00$

Mean Confinement Factor overall section = 1.46748

Element Length, $L = 3000.00$

Primary Member

Ribbed Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

Lap Length $l_o = 300.00$

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, $V_a = -2.5535805E-047$

EDGE -B-

Shear Force, $V_b = 2.5535805E-047$

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: $Asl,com = 1017.876$
-Middle: $Asl,mid = 1017.876$

Calculation of Shear Capacity ratio, $V_e/V_r = 0.29814229$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 155683.418$

with
 $M_{pr1} = \text{Max}(Mu_{1+}, Mu_{1-}) = 2.3353E+008$
 $Mu_{1+} = 2.3353E+008$, is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination
 $Mu_{1-} = 2.3353E+008$, is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination
 $M_{pr2} = \text{Max}(Mu_{2+}, Mu_{2-}) = 2.3353E+008$
 $Mu_{2+} = 2.3353E+008$, 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
 $Mu_{2-} = 2.3353E+008$, 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
 $Mu = 2.3353E+008$

$= 0.80285146$

$' = 0.71403327$

error of function (3.68), Biskinis Phd = 40102.185

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

conf. factor $c = 1.46748$

$f_c = 33.00$

From 10.3.5, ASCE 41-17, Final value of f_y : $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3}) = 368.0049$

$l_b/l_d = 0.27602844$

$d_1 = 44.00$

$R = 250.00$

$v = 0.00103167$

$N = 7389.214$

$A_c = 196349.541$

$= \cdot \text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3}) = 0.15689624$

Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.27602844$

$l_b = 300.00$

$l_d = 1086.845$

Calculation of l_b, \min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

$= 1$

$d_b = 18.00$

Mean strength value of all re-bars: $f_y = 694.45$

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

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 1.20951$

$A_{tr} = \sqrt{2} \cdot \text{Area of external stirrup} = 123.3701$

$s = s_{external} = 340.00$

$n = 12.00$

Calculation of Mu1-

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

$$\text{Mu} = 2.3353\text{E}+008$$

$$= 0.80285146$$

$$' = 0.71403327$$

error of function (3.68), Biskinis Phd = 40102.185

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

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

$$f_c = 33.00$$

From 10.3.5, ASCE 41-17, Final value of f_y : $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 368.0049$

$$l_b/d = 0.27602844$$

$$d_1 = 44.00$$

$$R = 250.00$$

$$v = 0.00103167$$

$$N = 7389.214$$

$$A_c = 196349.541$$

$$= \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.15689624$$

Calculation of ratio l_b/d

Lap Length: $l_b/d = 0.27602844$

$$l_b = 300.00$$

$$l_d = 1086.845$$

Calculation of l_b , min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

$$= 1$$

$$d_b = 18.00$$

Mean strength value of all re-bars: $f_y = 694.45$

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

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 25.00$$

$$K_{tr} = 1.20951$$

$$A_{tr} = \sqrt{2} \cdot \text{Area of external stirrup} = 123.3701$$

$$s = s_{\text{external}} = 340.00$$

$$n = 12.00$$

Calculation of Mu2+

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

$$\text{Mu} = 2.3353\text{E}+008$$

$$= 0.80285146$$

$$' = 0.71403327$$

error of function (3.68), Biskinis Phd = 40102.185

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

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

$$f_c = 33.00$$

From 10.3.5, ASCE 41-17, Final value of f_y : $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 368.0049$

$$l_b/d = 0.27602844$$

$$d_1 = 44.00$$

$$R = 250.00$$

$$v = 0.00103167$$

$$N = 7389.214$$

$$A_c = 196349.541$$

$$= \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.15689624$$

Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.27602844$

$l_b = 300.00$

$l_d = 1086.845$

Calculation of l_b, \min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

$= 1$

$db = 18.00$

Mean strength value of all re-bars: $f_y = 694.45$

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

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 1.20951$

$A_{tr} = \pi/2 \cdot \text{Area of external stirrup} = 123.3701$

$s = s_{\text{external}} = 340.00$

$n = 12.00$

Calculation of μ_2

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

$\mu = 2.3353E+008$

$= 0.80285146$

$' = 0.71403327$

error of function (3.68), Biskinis Phd = 40102.185

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

conf. factor $c = 1.46748$

$f_c = 33.00$

From 10.3.5, ASCE 41-17, Final value of f_y : $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3}) = 368.0049$

$l_b/l_d = 0.27602844$

$d_1 = 44.00$

$R = 250.00$

$v = 0.00103167$

$N = 7389.214$

$A_c = 196349.541$

$= \text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3}) = 0.15689624$

Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.27602844$

$l_b = 300.00$

$l_d = 1086.845$

Calculation of l_b, \min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

$= 1$

$db = 18.00$

Mean strength value of all re-bars: $f_y = 694.45$

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

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 1.20951$

$A_{tr} = \pi/2 \cdot \text{Area of external stirrup} = 123.3701$

$s = s_{\text{external}} = 340.00$

$n = 12.00$

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 522178.241$

Calculation of Shear Strength at edge 1, $V_{r1} = 522178.241$

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

$V_{Co10} = 522178.241$

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

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

$k_{nl} = 1$ (normal-weight concrete)

Mean concrete strength: $f_c' = (f_c'_{\text{jacket}} * \text{Area}_{\text{jacket}} + f_c'_{\text{core}} * \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 28.32$, but $f_c'^{0.5} \leq 8.3$
MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$M_u = 2.0433236E-011$

$V_u = 2.5535805E-047$

$d = 0.8 * D = 400.00$

$N_u = 7389.214$

$A_g = 196349.541$

From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 76454.061$

$V_{s1} = 48380.801$ is calculated for jacket, with:

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

$f_y = 555.56$

$s = 340.00$

V_{s1} is multiplied by $Col1 = 0.60$

$s/d = 0.85$

$V_{s2} = 28073.261$ is calculated for core, with:

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

$f_y = 444.44$

$s = 200.00$

V_{s2} is multiplied by $Col2 = 0.66666667$

$s/d = 0.83333333$

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

$f = 0.95$, for fully-wrapped sections

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

In (11.3) $\sin \theta + \cos \theta$ is replaced with $(\cot \theta + \csc \theta) \sin \alpha$ which is more a generalised expression,
where 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: $\theta = 45^\circ$ and $\alpha = 90^\circ$

$V_f = \text{Min}(|V_f(45, 90)|, |V_f(-45, 90)|)$, with:

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

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

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

$E_f = 64828.00$

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

with $f_u = 0.01$

From (11-11), ACI 440: $V_s + V_f \leq 444245.712$

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

Calculation of Shear Strength at edge 2, $V_{r2} = 522178.241$

$V_{r2} = V_{Co2} \text{ ((10.3), ASCE 41-17)} = k_{nl} * V_{Co10}$

$V_{Co10} = 522178.241$

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

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

$k_{nl} = 1$ (normal-weight concrete)

Mean concrete strength: $f_c' = (f_c'_{\text{jacket}} * \text{Area}_{\text{jacket}} + f_c'_{\text{core}} * \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 28.32$, but $f_c'^{0.5} \leq 8.3$
MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$M_u = 2.0433236E-011$

$V_u = 2.5535805E-047$

$d = 0.8 \cdot D = 400.00$
 $Nu = 7389.214$
 $Ag = 196349.541$
 From (11.5.4.8), ACI 318-14: $Vs = Vs1 + Vs2 = 76454.061$
 $Vs1 = 48380.801$ is calculated for jacket, with:
 $Av = \sqrt{2} \cdot A_{stirrup} = 123370.055$
 $fy = 555.56$
 $s = 340.00$
 $Vs1$ is multiplied by $Col1 = 0.60$
 $s/d = 0.85$
 $Vs2 = 28073.261$ is calculated for core, with:
 $Av = \sqrt{2} \cdot A_{stirrup} = 78956.835$
 $fy = 444.44$
 $s = 200.00$
 $Vs2$ is multiplied by $Col2 = 0.66666667$
 $s/d = 0.83333333$
 $Vf ((11-3)-(11.4), ACI 440) = 247653.332$
 $f = 0.95$, for fully-wrapped sections
 $wf/sf = 1$ (FRP strips adjacent to one another).
 In (11.3) $\sin + \cos$ is replaced with $(\cot + \cot a) \sin a$ which is more a generalised expression,
 where a is the angle of the crack direction (see KANEPE).
 This later relation, considered as a function $Vf(\theta, a)$, is implemented for every different fiber orientation a_i ,
 as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.
 orientation 1: $\theta = b1 + 90^\circ = 90.00$
 $Vf = \text{Min}(|Vf(45, \theta)|, |Vf(-45, a1)|)$, with:
 total thickness per orientation, $tf1 = NL \cdot t / NoDir = 1.016$
 $dfv = d$ (figure 11.2, ACI 440) = 470.00
 $ffe ((11-5), ACI 440) = 259.312$
 $Ef = 64828.00$
 $fe = 0.004$, from (11.6a), ACI 440
 with $fu = 0.01$
 From (11-11), ACI 440: $Vs + Vf \leq 444245.712$
 $bw \cdot d = \sqrt{2} \cdot d \cdot d / 4 = 125663.706$

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

 Start Of Calculation of Chord Rotation Capacity for element: column JCC1 of floor 1
 At local axis: 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, $fc = f_{cm} = 33.00$
 New material of Primary Member: Steel Strength, $fs = f_{sm} = 555.56$
 Concrete Elasticity, $Ec = 26999.444$
 Steel Elasticity, $Es = 200000.00$
 Existing Column
 Existing material of Primary Member: Concrete Strength, $fc = f_{cm} = 20.00$
 Existing material of Primary Member: Steel Strength, $fs = f_{sm} = 444.44$
 Concrete Elasticity, $Ec = 21019.039$
 Steel Elasticity, $Es = 200000.00$
 External Diameter, $D = 500.00$
 Internal Diameter, $D = 300.00$
 Cover Thickness, $c = 25.00$
 Element Length, $L = 3000.00$
 Primary Member

Ribbed Bars
 Ductile Steel
 Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
 Longitudinal Bars With Ends Lapped Starting at the End Sections
 Lap Length $l_b = 300.00$
 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

 Bending Moment, $M = 8.5403934E-011$
 Shear Force, $V_2 = 8960.208$
 Shear Force, $V_3 = 6.3233843E-013$
 Axial Force, $F = -7385.629$
 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: $As_{,ten} = 1017.876$
 -Compression: $As_{,com} = 1017.876$
 -Middle: $As_{,mid} = 1017.876$
 Mean Diameter of Tension Reinforcement, $Db_L = 18.00$

 Existing component: From table 7-7, ASCE 41_17: Final chord rotation Capacity $u_{,R} = \phi \cdot u = 0.04710707$
 $u = y + p = 0.04710707$

 - Calculation of y -

 $y = (M_y \cdot L_s / 3) / E_{eff} = 0.00510707$ ((4.29), Biskinis Phd)
 $M_y = 2.4653E+008$
 $L_s = M/V$ (with $L_s > 0.1 \cdot L$ and $L_s < 2 \cdot L$) = 1500.00
 From table 10.5, ASCE 41_17: $E_{eff} = factor \cdot E_c \cdot I_g = 2.4137E+013$
 $factor = 0.30$
 $A_g = 196349.541$
 Mean concrete strength: $f'_c = (f'_{c_jacket} \cdot Area_{jacket} + f'_{c_core} \cdot Area_{core}) / Area_{section} = 28.32$
 $N = 7385.629$
 $E_c \cdot I_g = E_{c_jacket} \cdot I_{g_jacket} + E_{c_core} \cdot I_{g_core} = 8.0455E+013$

 Calculation of Yielding Moment M_y

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

 $M_y = \min(M_{y_ten}, M_{y_com}) = 2.4653E+008$
 $y = 7.1028683E-006$
 M_{y_ten} (8c) = 2.4653E+008
 y_{ten} (7c) = 62.22247
 error of function (7c) = 0.00021692
 M_{y_com} (8d) = 8.0674E+008
 y_{com} (7d) = 63.84405
 error of function (7d) = -0.00846596
 with ((10.1), ASCE 41-17) $e_y = \min(e_y, 1.25 \cdot e_y \cdot (l_b / l_d)^{2/3}) = 0.0027778$

$\rho_{FRP} = 0.002$
 $\alpha_{FRP} = 0.45$ ((9c) in Biskinis and Fardis for FRP Wrap)
 $d_1 = 44.00$
 $R = 250.00$
 $\nu = 0.00103611$
 $N = 7385.629$
 $A_c = 196349.541$
 $\left(\frac{10.1}{\rho_{FRP}}, ASCE 41-17\right) = \text{Min}\left(1, 1.25 \cdot \left(\frac{l_b}{l_d}\right)^{2/3}\right) = 0.23799351$
 with $f_c^* ((12.3), ACI 440) = 36.3038$
 $f_c = 33.00$
 $\beta_1 = 1.05384$
 $k = 1$
 Effective FRP thickness, $t_f = N L \cdot t \cdot \cos(\beta_1) = 1.016$
 $\rho_{FRP} ((12.5) \text{ and } (12.7)) = 0.004$
 $f_u = 0.01$
 $E_f = 64828.00$

 Calculation of ratio l_b/l_d

Lap Length: $l_d/l_d, \text{min} = 0.34503556$

$l_b = 300.00$

$l_d = 869.4756$

Calculation of l according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

$\beta_1 = 1$

$d_b = 18.00$

Mean strength value of all re-bars: $f_y = 555.56$

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

$t = 1.00$

$s = 0.80$

$e = 1.00$

$c_b = 25.00$

$K_{tr} = 1.20951$

$A_{tr} = \sqrt{2} \cdot \text{Area of external stirrup} = 123.3701$

$s = s_{\text{external}} = 340.00$

$n = 12.00$

 - Calculation of ρ_p -

From table 10-9: $\rho_p = 0.042$

with:

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

shear control ratio $V_y E / V_{CoI} O E = 0.29814229$

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

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

$t = s_1 + s_2 + 2 \cdot t_f / b_w \cdot (f_{fe} / f_s) = 0.00519403$

jacket: $s_1 = A_{v1} \cdot \left(\frac{D_{c1}}{2}\right) / (s_1 \cdot A_g) = 0.00081312$

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

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

(shear) direction

$s_1 = 340.00$

core: $s_2 = A_{v2} \cdot \left(\frac{D_{c2}}{2}\right) / (s_2 \cdot A_g) = 0.0005871$

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

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

direction

$s_2 = 200.00$

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.

$N_{UD} = 7385.629$

$A_g = 196349.541$

$f_c E = (f_c'_{\text{jacket}} \cdot \text{Area}_{\text{jacket}} + f_c'_{\text{core}} \cdot \text{Area}_{\text{core}}) / \text{section_area} = 28.32$

$f_y E = (f_y_{\text{ext_Long_Reinf}} \cdot \text{Area}_{\text{ext_Long_Reinf}} + f_y_{\text{int_Long_Reinf}} \cdot \text{Area}_{\text{int_Long_Reinf}}) / \text{Area}_{\text{Tot_Long_Rein}} =$

2.1219958E-314

$$f_{tE} = (f_{y_ext_Trans_Reinf} * s1 + f_{y_int_Trans_Reinf} * s2) / (s1 + s2) = 508.9683$$

$$p_l = \text{Area_Tot_Long_Rein} / (A_g) = 0.015552$$

$$f_{cE} = 28.32$$

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

At local axis: 2

Integration Section: (b)

Calculation No. 15

column C1, Floor 1

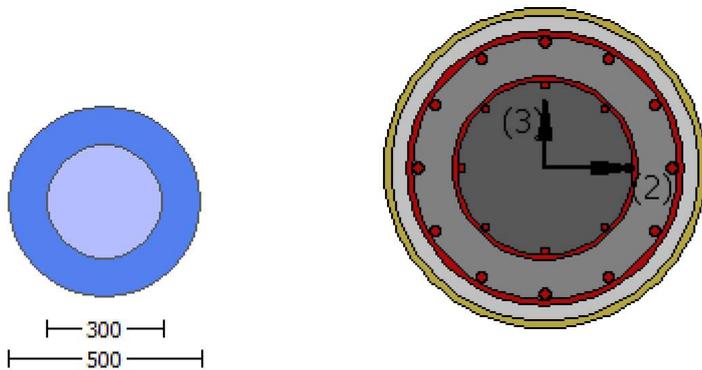
Limit State: Collapse Prevention (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Shear capacity V_{Rd}

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, $f_c = f_{c_lower_bound} = 25.00$

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

Concrete Elasticity, $E_c = 26999.444$

Steel Elasticity, $E_s = 200000.00$

Existing Column

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

Existing material of Primary Member: Steel Strength, $f_s = f_{s_lower_bound} = 400.00$
Concrete Elasticity, $E_c = 21019.039$
Steel Elasticity, $E_s = 200000.00$

Note: Especially for the calculation of γ for displacement ductility demand,
the expected (mean value) strengths are used (7.5.1.3, ASCE 41-17) because bending is considered as
Deformation-Controlled Action (Table C7-1, ASCE 41-17).
Jacket
New material: Concrete Strength, $f_c = f_{cm} = 33.00$
New material: Steel Strength, $f_s = f_{sm} = 555.56$
Existing Column
Existing material: Concrete Strength, $f_c = f_{cm} = 20.00$
Existing material: Steel Strength, $f_s = f_{sm} = 444.44$

External Diameter, $D = 500.00$
Internal Diameter, $D = 300.00$
Cover Thickness, $c = 25.00$
Element Length, $L = 3000.00$
Primary Member
Ribbed Bars
Ductile Steel
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
Lap Length $l_o = l_b = 300.00$
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, $M_a = 1.8120144E-009$
Shear Force, $V_a = -6.3233843E-013$
EDGE -B-
Bending Moment, $M_b = 8.5403934E-011$
Shear Force, $V_b = 6.3233843E-013$
BOTH EDGES
Axial Force, $F = -7385.629$
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: $A_{sl,t} = 0.00$
-Compression: $A_{sl,c} = 3053.628$
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension: $A_{sl,ten} = 1017.876$
-Compression: $A_{sl,com} = 1017.876$
-Middle: $A_{sl,mid} = 1017.876$
Mean Diameter of Tension Reinforcement, $Db_{L,ten} = 18.00$

Existing component: From table 7-7, ASCE 41_17: Final Shear Capacity $V_R = \phi V_n = 488735.20$
 $V_n ((10.3), ASCE 41-17) = k_n l^* V_{CoI} = 488735.20$
 $V_{CoI} = 488735.20$
 $k_n l = 1.00$
displacement_ductility_demand = 0.00

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

= 1 (normal-weight concrete)
 Mean concrete strength: $f'_c = (f'_{c_jacket} \cdot Area_jacket + f'_{c_core} \cdot Area_core) / Area_section = 21.76$, but $f'_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $M/Vd = 2.00$
 $\mu_u = 8.5403934E-011$
 $V_u = 6.3233843E-013$
 $d = 0.8 \cdot D = 400.00$
 $N_u = 7385.629$
 $A_g = 196349.541$
 From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 68808.56$
 $V_{s1} = 43542.372$ is calculated for jacket, with:
 $A_v = \sqrt{2} \cdot A_{stirrup} = 123370.055$
 $f_y = 500.00$
 $s = 340.00$
 V_{s1} is multiplied by $Col1 = 0.60$
 $s/d = 0.85$
 $V_{s2} = 25266.187$ is calculated for core, with:
 $A_v = \sqrt{2} \cdot A_{stirrup} = 78956.835$
 $f_y = 400.00$
 $s = 200.00$
 V_{s2} is multiplied by $Col2 = 0.66666667$
 $s/d = 0.83333333$
 $V_f ((11-3)-(11.4), ACI 440) = 247653.332$
 $f = 0.95$, for fully-wrapped sections
 $w_f/s_f = 1$ (FRP strips adjacent to one another).
 In (11.3) $\sin + \cos$ is replaced with $(\cot + \csc) \sin \alpha$ which is more a generalised expression, where α is the angle of the crack direction (see KANEPE).
 This later relation, considered as a function $V_f(\alpha, a_i)$, is implemented for every different fiber orientation a_i , as well as for 2 crack directions, $\alpha = 45^\circ$ and $\alpha = -45^\circ$ to take into consideration the cyclic seismic loading.
 orientation 1: $\alpha = b1 + 90^\circ = 90.00$
 $V_f = \text{Min}(|V_f(45, a1)|, |V_f(-45, a1)|)$, with:
 total thickness per orientation, $t_{f1} = NL \cdot t / NoDir = 1.016$
 $d_{fv} = d$ (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: $V_s + V_f \leq 389409.072$
 $b_w \cdot d = \sqrt{2} \cdot d^2 / 4 = 125663.706$

displacement_ductility_demand is calculated as δ / y

- Calculation of δ / y for END B -
for rotation axis 2 and integ. section (b)

From analysis, chord rotation $\theta = 9.8988037E-021$
 $y = (M_y \cdot L_s / 3) / E_{eff} = 0.00510707$ ((4.29), Biskinis Phd)
 $M_y = 2.4653E+008$
 $L_s = M/V$ (with $L_s > 0.1 \cdot L$ and $L_s < 2 \cdot L$) = 1500.00
 From table 10.5, ASCE 41_17: $E_{eff} = factor \cdot E_c \cdot I_g = 2.4137E+013$
 $factor = 0.30$
 $A_g = 196349.541$
 Mean concrete strength: $f'_c = (f'_{c_jacket} \cdot Area_jacket + f'_{c_core} \cdot Area_core) / Area_section = 28.32$
 $N = 7385.629$
 $E_c \cdot I_g = E_{c_jacket} \cdot I_{g_jacket} + E_{c_core} \cdot I_{g_core} = 8.0455E+013$

Calculation of Yielding Moment M_y

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

$M_y = \text{Min}(M_{y_ten}, M_{y_com}) = 2.4653E+008$
 $\delta / y = 7.1028683E-006$

$M_{y_ten} (8c) = 2.4653E+008$
 $_{ten} (7c) = 62.22247$
 error of function (7c) = 0.00021692
 $M_{y_com} (8d) = 8.0674E+008$
 $_{com} (7d) = 63.84405$
 error of function (7d) = -0.00846596
 with ((10.1), ASCE 41-17) $e_y = \text{Min}(e_y, 1.25 * e_y * (l_b / l_d)^{2/3}) = 0.0027778$
 $e_{co} = 0.002$
 $a_{pl} = 0.45$ ((9c) in Biskinis and Fardis for FRP Wrap)
 $d_1 = 44.00$
 $R = 250.00$
 $v = 0.00103611$
 $N = 7385.629$
 $A_c = 196349.541$
 ((10.1), ASCE 41-17) $= \text{Min}(, 1.25 * * (l_b / l_d)^{2/3}) = 0.23799351$
 with f_c^* ((12.3), ACI 440) = 36.3038
 $f_c = 33.00$
 $f_l = 1.05384$
 $k = 1$
 Effective FRP thickness, $t_f = N L * t * \text{Cos}(b_1) = 1.016$
 e_{fe} ((12.5) and (12.7)) = 0.004
 $f_u = 0.01$
 $E_f = 64828.00$

 Calculation of ratio l_b / l_d

Lap Length: $l_d / l_d, \text{min} = 0.34503556$

$l_b = 300.00$

$l_d = 869.4756$

Calculation of l according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

$= 1$

$d_b = 18.00$

Mean strength value of all re-bars: $f_y = 555.56$

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

$t = 1.00$

$s = 0.80$

$e = 1.00$

$c_b = 25.00$

$K_{tr} = 1.20951$

$A_{tr} = \sqrt{2} * \text{Area of external stirrup} = 123.3701$

$s = s_{external} = 340.00$

$n = 12.00$

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

At local axis: 3

Integration Section: (b)

Calculation No. 16

column C1, Floor 1

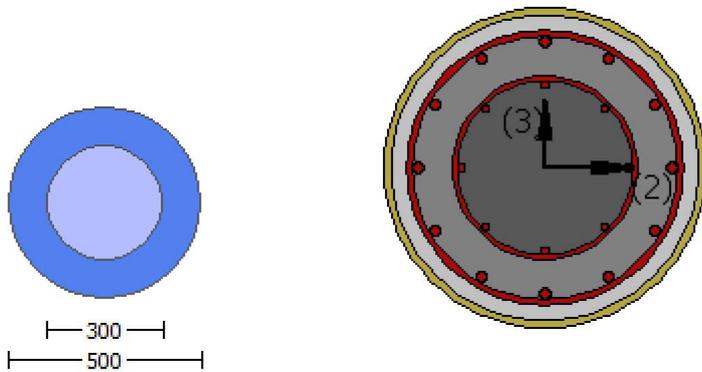
Limit State: Collapse Prevention (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity (θ_r)

Edge: End

Local Axis: (3)



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

At Shear local axis: 3

(Bending local axis: 2)

Section Type: rcjcs

Constant Properties

Knowledge Factor, $\gamma = 1.00$

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

Consequently:

Jacket

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

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

Concrete Elasticity, $E_c = 26999.444$

Steel Elasticity, $E_s = 200000.00$

Existing Column

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

Existing material of Primary Member: Steel Strength, $f_s = f_{sm} = 444.44$

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

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

Jacket

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

Existing Column

Existing material: Steel Strength, $f_s = 1.25 \cdot f_{sm} = 555.55$

#####

External Diameter, $D = 500.00$

Internal Diameter, $D = 300.00$

Cover Thickness, $c = 25.00$

Mean Confinement Factor overall section = 1.46748

Element Length, $L = 3000.00$

Primary Member

Ribbed Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

Lap Length $l_o = 300.00$

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $\epsilon_{fu} = 0.01$

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

Fiber orientations, $b_i = 0.00^\circ$

Number of layers, $N_L = 1$

Radius of rounding corners, $R = 40.00$

Stepwise Properties

At local axis: 3

EDGE -A-

Shear Force, $V_a = 4.1704511E-031$

EDGE -B-

Shear Force, $V_b = -4.1704511E-031$

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, $V_e/V_r = 0.29814229$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 155683.418$

with

$M_{pr1} = \text{Max}(M_{u1+}, M_{u1-}) = 2.3353E+008$

$M_{u1+} = 2.3353E+008$, is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination

$M_{u1-} = 2.3353E+008$, is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination

$M_{pr2} = \text{Max}(M_{u2+}, M_{u2-}) = 2.3353E+008$

$M_{u2+} = 2.3353E+008$, is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the static loading combination

$M_{u2-} = 2.3353E+008$, is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the static loading combination

Calculation of M_{u1+}

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

$M_u = 2.3353E+008$

$\phi = 0.80285146$

$\lambda = 0.71403327$

error of function (3.68), Biskinis Phd = 40102.185

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

conf. factor $c = 1.46748$

$f_c = 33.00$

From 10.3.5, ASCE 41-17, Final value of f_y : $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3}) = 368.0049$

$l_b/l_d = 0.27602844$

$d_1 = 44.00$

$R = 250.00$

$v = 0.00103167$

$$N = 7389.214$$

$$Ac = 196349.541$$

$$= *Min(1,1.25*(lb/d)^{2/3}) = 0.15689624$$

Calculation of ratio lb/d

$$\text{Lap Length: } lb/d = 0.27602844$$

$$lb = 300.00$$

$$ld = 1086.845$$

Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

$$= 1$$

$$db = 18.00$$

$$\text{Mean strength value of all re-bars: } fy = 694.45$$

$$\text{Mean concrete strength: } fc' = (fc'_{\text{jacket}} * Area_{\text{jacket}} + fc'_{\text{core}} * Area_{\text{core}}) / Area_{\text{section}} = 33.00, \text{ but } fc'^{0.5} \leq 8.3$$

MPa (22.5.3.1, ACI 318-14)

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$cb = 25.00$$

$$K_{tr} = 1.20951$$

$$A_{tr} = /2 * \text{Area of external stirrup} = 123.3701$$

$$s = s_{\text{external}} = 340.00$$

$$n = 12.00$$

Calculation of Mu1-

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

$$Mu = 2.3353E+008$$

$$= 0.80285146$$

$$' = 0.71403327$$

error of function (3.68), Biskinis Phd = 40102.185

From 5A.2, TBDY: $f_{cc} = fc' * c = 48.42699$

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

$$fc = 33.00$$

From 10.3.5, ASCE 41-17, Final value of fy: $fy * Min(1,1.25*(lb/d)^{2/3}) = 368.0049$

$$lb/d = 0.27602844$$

$$d1 = 44.00$$

$$R = 250.00$$

$$v = 0.00103167$$

$$N = 7389.214$$

$$Ac = 196349.541$$

$$= *Min(1,1.25*(lb/d)^{2/3}) = 0.15689624$$

Calculation of ratio lb/d

$$\text{Lap Length: } lb/d = 0.27602844$$

$$lb = 300.00$$

$$ld = 1086.845$$

Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

$$= 1$$

$$db = 18.00$$

$$\text{Mean strength value of all re-bars: } fy = 694.45$$

$$\text{Mean concrete strength: } fc' = (fc'_{\text{jacket}} * Area_{\text{jacket}} + fc'_{\text{core}} * Area_{\text{core}}) / Area_{\text{section}} = 33.00, \text{ but } fc'^{0.5} \leq 8.3$$

MPa (22.5.3.1, ACI 318-14)

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$cb = 25.00$$

$$K_{tr} = 1.20951$$

$$A_{tr} = /2 * \text{Area of external stirrup} = 123.3701$$

s = s_external = 340.00
n = 12.00

Calculation of Mu2+

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), Mu
Mu = 2.3353E+008

= 0.80285146
' = 0.71403327
error of function (3.68), Biskinis Phd = 40102.185
From 5A.2, TBDY: fcc = fc* c = 48.42699
conf. factor c = 1.46748
fc = 33.00
From 10.3.5, ASCE 41-17, Final value of fy: fy*Min(1,1.25*(lb/d)^ 2/3) = 368.0049
lb/d = 0.27602844
d1 = 44.00
R = 250.00
v = 0.00103167
N = 7389.214
Ac = 196349.541
= *Min(1,1.25*(lb/d)^ 2/3) = 0.15689624

Calculation of ratio lb/d

Lap Length: lb/d = 0.27602844
lb = 300.00
ld = 1086.845
Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
= 1
db = 18.00
Mean strength value of all re-bars: fy = 694.45
Mean concrete strength: fc' = (fc'_jacket*Area_jacket + fc'_core*Area_core)/Area_section = 33.00, but fc'^0.5 <= 8.3 MPa (22.5.3.1, ACI 318-14)
t = 1.00
s = 0.80
e = 1.00
cb = 25.00
Ktr = 1.20951
Atr = /2 * Area of external stirrup = 123.3701
s = s_external = 340.00
n = 12.00

Calculation of Mu2-

Calculation of ultimate Moment Strength ((3.67), Biskinis Phd), Mu
Mu = 2.3353E+008

= 0.80285146
' = 0.71403327
error of function (3.68), Biskinis Phd = 40102.185
From 5A.2, TBDY: fcc = fc* c = 48.42699
conf. factor c = 1.46748
fc = 33.00
From 10.3.5, ASCE 41-17, Final value of fy: fy*Min(1,1.25*(lb/d)^ 2/3) = 368.0049
lb/d = 0.27602844
d1 = 44.00
R = 250.00

$$v = 0.00103167$$

$$N = 7389.214$$

$$Ac = 196349.541$$

$$= *Min(1, 1.25*(lb/ld)^{2/3}) = 0.15689624$$

 Calculation of ratio lb/ld

 Lap Length: lb/ld = 0.27602844

lb = 300.00

ld = 1086.845

Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

= 1

db = 18.00

Mean strength value of all re-bars: fy = 694.45

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

t = 1.00

s = 0.80

e = 1.00

cb = 25.00

Ktr = 1.20951

Atr = /2 * Area of external stirrup = 123.3701

s = s_external = 340.00

n = 12.00

 Calculation of Shear Strength Vr = Min(Vr1, Vr2) = 522178.241

 Calculation of Shear Strength at edge 1, Vr1 = 522178.241

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

VCol0 = 522178.241

knl = 1 (zero step-static loading)

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

 = 1 (normal-weight concrete)

Mean concrete strength: fc' = (fc'_jacket*Area_jacket + fc'_core*Area_core)/Area_section = 28.32, but fc'^0.5 <= 8.3 MPa (22.5.3.1, ACI 318-14)

M/Vd = 2.00

Mu = 2.3891386E-011

Vu = 4.1704511E-031

d = 0.8*D = 400.00

Nu = 7389.214

Ag = 196349.541

From (11.5.4.8), ACI 318-14: Vs = Vs1 + Vs2 = 76454.061

Vs1 = 48380.801 is calculated for jacket, with:

Av = /2*A_stirrup = 123370.055

fy = 555.56

s = 340.00

Vs1 is multiplied by Col1 = 0.60

s/d = 0.85

Vs2 = 28073.261 is calculated for core, with:

Av = /2*A_stirrup = 78956.835

fy = 444.44

s = 200.00

Vs2 is multiplied by Col2 = 0.66666667

s/d = 0.83333333

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

f = 0.95, for fully-wrapped sections

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

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

This later relation, considered as a function Vf(,), is implemented for every different fiber orientation ai,

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

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

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

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

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

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

$E_f = 64828.00$

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

with $fu = 0.01$

From (11-11), ACI 440: $V_s + V_f \leq 444245.712$

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

Calculation of Shear Strength at edge 2, $V_{r2} = 522178.241$

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

$V_{Col0} = 522178.241$

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

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

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

Mean concrete strength: $f'_c = (f'_{c_jacket} \cdot \text{Area}_{jacket} + f'_{c_core} \cdot \text{Area}_{core}) / \text{Area}_{section} = 28.32$, but $f'_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$\mu_u = 2.3891386E-011$

$\nu_u = 4.1704511E-031$

$d = 0.8 \cdot D = 400.00$

$N_u = 7389.214$

$A_g = 196349.541$

From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 76454.061$

$V_{s1} = 48380.801$ is calculated for jacket, with:

$A_v = \rho \cdot A_{stirup} = 123370.055$

$f_y = 555.56$

$s = 340.00$

V_{s1} is multiplied by $\rho_{col1} = 0.60$

$s/d = 0.85$

$V_{s2} = 28073.261$ is calculated for core, with:

$A_v = \rho \cdot A_{stirup} = 78956.835$

$f_y = 444.44$

$s = 200.00$

V_{s2} is multiplied by $\rho_{col2} = 0.66666667$

$s/d = 0.83333333$

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

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

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

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

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

$E_f = 64828.00$

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

with $fu = 0.01$

From (11-11), ACI 440: $V_s + V_f \leq 444245.712$

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

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

At local axis: 3

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

At Shear local axis: 2

(Bending local axis: 3)

Section Type: rcjcs

Constant Properties

Knowledge Factor, $\gamma = 1.00$

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

Consequently:

Jacket

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

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

Concrete Elasticity, $E_c = 26999.444$

Steel Elasticity, $E_s = 200000.00$

Existing Column

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

Existing material of Primary Member: Steel Strength, $f_s = f_{sm} = 444.44$

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

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

Jacket

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

Existing Column

Existing material: Steel Strength, $f_s = 1.25 \cdot f_{sm} = 555.55$

#####

External Diameter, $D = 500.00$

Internal Diameter, $D = 300.00$

Cover Thickness, $c = 25.00$

Mean Confinement Factor overall section = 1.46748

Element Length, $L = 3000.00$

Primary Member

Ribbed Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

Lap Length $l_o = 300.00$

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, $V_a = -2.5535805E-047$

EDGE -B-

Shear Force, $V_b = 2.5535805E-047$

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: $Asl,com = 1017.876$
-Middle: $Asl,mid = 1017.876$

Calculation of Shear Capacity ratio, $V_e/V_r = 0.29814229$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 155683.418$

with

$M_{pr1} = \text{Max}(Mu_{1+}, Mu_{1-}) = 2.3353E+008$

$Mu_{1+} = 2.3353E+008$, is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination

$Mu_{1-} = 2.3353E+008$, is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination

$M_{pr2} = \text{Max}(Mu_{2+}, Mu_{2-}) = 2.3353E+008$

$Mu_{2+} = 2.3353E+008$, is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the static loading combination

$Mu_{2-} = 2.3353E+008$, is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the static loading combination

Calculation of Mu_{1+}

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

$Mu = 2.3353E+008$

$\phi = 0.80285146$

$\lambda = 0.71403327$

error of function (3.68), Biskinis Phd = 40102.185

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

conf. factor $\lambda = 1.46748$

$f_c = 33.00$

From 10.3.5, ASCE 41-17, Final value of f_y : $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3}) = 368.0049$

$l_b/l_d = 0.27602844$

$d_1 = 44.00$

$R = 250.00$

$v = 0.00103167$

$N = 7389.214$

$A_c = 196349.541$

$\phi \cdot \text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3}) = 0.15689624$

Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.27602844$

$l_b = 300.00$

$l_d = 1086.845$

Calculation of l_b, \min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

$\phi = 1$

$d_b = 18.00$

Mean strength value of all re-bars: $f_y = 694.45$

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

$t = 1.00$

$s = 0.80$

$e = 1.00$

$c_b = 25.00$

$K_{tr} = 1.20951$

$A_{tr} = \sqrt{2} \cdot \text{Area of external stirrup} = 123.3701$

$s = s_{external} = 340.00$

$n = 12.00$

Calculation of Mu1-

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

$$\text{Mu} = 2.3353\text{E}+008$$

$$= 0.80285146$$

$$' = 0.71403327$$

error of function (3.68), Biskinis Phd = 40102.185

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

conf. factor $c = 1.46748$

$$f_c = 33.00$$

From 10.3.5, ASCE 41-17, Final value of f_y : $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 368.0049$

$$l_b/d = 0.27602844$$

$$d_1 = 44.00$$

$$R = 250.00$$

$$v = 0.00103167$$

$$N = 7389.214$$

$$A_c = 196349.541$$

$$= \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.15689624$$

Calculation of ratio lb/d

Lap Length: $l_b/d = 0.27602844$

$$l_b = 300.00$$

$$l_d = 1086.845$$

Calculation of l_b , min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

$$= 1$$

$$d_b = 18.00$$

Mean strength value of all re-bars: $f_y = 694.45$

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

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 25.00$$

$$K_{tr} = 1.20951$$

$$A_{tr} = \sqrt{2} \cdot \text{Area of external stirrup} = 123.3701$$

$$s = s_{\text{external}} = 340.00$$

$$n = 12.00$$

Calculation of Mu2+

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

$$\text{Mu} = 2.3353\text{E}+008$$

$$= 0.80285146$$

$$' = 0.71403327$$

error of function (3.68), Biskinis Phd = 40102.185

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

conf. factor $c = 1.46748$

$$f_c = 33.00$$

From 10.3.5, ASCE 41-17, Final value of f_y : $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 368.0049$

$$l_b/d = 0.27602844$$

$$d_1 = 44.00$$

$$R = 250.00$$

$$v = 0.00103167$$

$$N = 7389.214$$

$$A_c = 196349.541$$

$$= \cdot \text{Min}(1, 1.25 \cdot (l_b/d)^{2/3}) = 0.15689624$$

Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.27602844$

$l_b = 300.00$

$l_d = 1086.845$

Calculation of l_b, \min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

$= 1$

$d_b = 18.00$

Mean strength value of all re-bars: $f_y = 694.45$

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

$t = 1.00$

$s = 0.80$

$e = 1.00$

$c_b = 25.00$

$K_{tr} = 1.20951$

$A_{tr} = \pi/2 \cdot \text{Area of external stirrup} = 123.3701$

$s = s_{\text{external}} = 340.00$

$n = 12.00$

Calculation of μ_2

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

$\mu = 2.3353E+008$

$= 0.80285146$

$' = 0.71403327$

error of function (3.68), Biskinis Phd = 40102.185

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

conf. factor $c = 1.46748$

$f_c = 33.00$

From 10.3.5, ASCE 41-17, Final value of f_y : $f_y \cdot \text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3}) = 368.0049$

$l_b/l_d = 0.27602844$

$d_1 = 44.00$

$R = 250.00$

$v = 0.00103167$

$N = 7389.214$

$A_c = 196349.541$

$= \text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3}) = 0.15689624$

Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.27602844$

$l_b = 300.00$

$l_d = 1086.845$

Calculation of l_b, \min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

$= 1$

$d_b = 18.00$

Mean strength value of all re-bars: $f_y = 694.45$

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

$t = 1.00$

$s = 0.80$

$e = 1.00$

$c_b = 25.00$

$K_{tr} = 1.20951$

$A_{tr} = \pi/2 \cdot \text{Area of external stirrup} = 123.3701$

$s = s_{\text{external}} = 340.00$

$n = 12.00$

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 522178.241$

Calculation of Shear Strength at edge 1, $V_{r1} = 522178.241$

$V_{r1} = V_{Co1} \text{ ((10.3), ASCE 41-17)} = knl * V_{Co10}$

$V_{Co10} = 522178.241$

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

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

$= 1$ (normal-weight concrete)

Mean concrete strength: $f_c' = (f_c'_{\text{jacket}} * \text{Area}_{\text{jacket}} + f_c'_{\text{core}} * \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 28.32$, but $f_c'^{0.5} \leq 8.3$
MPa (22.5.3.1, ACI 318-14)

$M / Vd = 2.00$

$M_u = 2.0433236E-011$

$V_u = 2.5535805E-047$

$d = 0.8 * D = 400.00$

$N_u = 7389.214$

$A_g = 196349.541$

From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 76454.061$

$V_{s1} = 48380.801$ is calculated for jacket, with:

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

$f_y = 555.56$

$s = 340.00$

V_{s1} is multiplied by $Col1 = 0.60$

$s/d = 0.85$

$V_{s2} = 28073.261$ is calculated for core, with:

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

$f_y = 444.44$

$s = 200.00$

V_{s2} is multiplied by $Col2 = 0.66666667$

$s/d = 0.83333333$

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

$f = 0.95$, for fully-wrapped sections

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

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

This later relation, considered as a function $V_f(\alpha, \theta)$, 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: $\theta = 45^\circ + 90^\circ = 135^\circ$

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

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

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

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

$E_f = 64828.00$

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

with $f_u = 0.01$

From (11-11), ACI 440: $V_s + V_f \leq 444245.712$

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

Calculation of Shear Strength at edge 2, $V_{r2} = 522178.241$

$V_{r2} = V_{Co2} \text{ ((10.3), ASCE 41-17)} = knl * V_{Co10}$

$V_{Co10} = 522178.241$

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

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

$= 1$ (normal-weight concrete)

Mean concrete strength: $f_c' = (f_c'_{\text{jacket}} * \text{Area}_{\text{jacket}} + f_c'_{\text{core}} * \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 28.32$, but $f_c'^{0.5} \leq 8.3$
MPa (22.5.3.1, ACI 318-14)

$M / Vd = 2.00$

$M_u = 2.0433236E-011$

$V_u = 2.5535805E-047$

$d = 0.8 \cdot D = 400.00$
 $Nu = 7389.214$
 $Ag = 196349.541$
 From (11.5.4.8), ACI 318-14: $Vs = Vs1 + Vs2 = 76454.061$
 $Vs1 = 48380.801$ is calculated for jacket, with:
 $Av = \sqrt{2} \cdot A_{stirrup} = 123370.055$
 $fy = 555.56$
 $s = 340.00$
 $Vs1$ is multiplied by $Col1 = 0.60$
 $s/d = 0.85$
 $Vs2 = 28073.261$ is calculated for core, with:
 $Av = \sqrt{2} \cdot A_{stirrup} = 78956.835$
 $fy = 444.44$
 $s = 200.00$
 $Vs2$ is multiplied by $Col2 = 0.66666667$
 $s/d = 0.83333333$
 $Vf ((11-3)-(11.4), ACI 440) = 247653.332$
 $f = 0.95$, for fully-wrapped sections
 $wf/sf = 1$ (FRP strips adjacent to one another).
 In (11.3) $\sin + \cos$ is replaced with $(\cot + \cot a) \sin a$ which is more a generalised expression,
 where a is the angle of the crack direction (see KANEPE).
 This later relation, considered as a function $Vf(\theta, a)$, is implemented for every different fiber orientation a_i ,
 as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.
 orientation 1: $\theta = b1 + 90^\circ = 90.00$
 $Vf = \text{Min}(|Vf(45, \theta)|, |Vf(-45, a1)|)$, with:
 total thickness per orientation, $tf1 = NL \cdot t / NoDir = 1.016$
 $dfv = d$ (figure 11.2, ACI 440) = 470.00
 $ffe ((11-5), ACI 440) = 259.312$
 $Ef = 64828.00$
 $fe = 0.004$, from (11.6a), ACI 440
 with $fu = 0.01$
 From (11-11), ACI 440: $Vs + Vf \leq 444245.712$
 $bw \cdot d = \sqrt{2} \cdot d^2 / 4 = 125663.706$

 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, $fc = f_{cm} = 33.00$
 New material of Primary Member: Steel Strength, $fs = f_{sm} = 555.56$
 Concrete Elasticity, $Ec = 26999.444$
 Steel Elasticity, $Es = 200000.00$
 Existing Column
 Existing material of Primary Member: Concrete Strength, $fc = f_{cm} = 20.00$
 Existing material of Primary Member: Steel Strength, $fs = f_{sm} = 444.44$
 Concrete Elasticity, $Ec = 21019.039$
 Steel Elasticity, $Es = 200000.00$
 External Diameter, $D = 500.00$
 Internal Diameter, $D = 300.00$
 Cover Thickness, $c = 25.00$
 Element Length, $L = 3000.00$
 Primary Member

Ribbed Bars
Ductile Steel
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
Lap Length $l_b = 300.00$
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, $M = 0.1232306$
Shear Force, $V_2 = 8960.208$
Shear Force, $V_3 = 6.3233843E-013$
Axial Force, $F = -7385.629$
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: $A_{st} = 0.00$
-Compression: $A_{sc} = 3053.628$
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension: $A_{st,ten} = 1017.876$
-Compression: $A_{st,com} = 1017.876$
-Middle: $A_{st,mid} = 1017.876$
Mean Diameter of Tension Reinforcement, $D_{bL} = 18.00$

Existing component: From table 7-7, ASCE 41_17: Final chord rotation Capacity $u_{R} = u = 0.04302141$
 $u = y + p = 0.04302141$

- Calculation of y -

$y = (M_y * L_s / 3) / E_{eff} = 0.00102141$ ((4.29), Biskinis Phd))
 $M_y = 2.4653E+008$
 $L_s = M/V$ (with $L_s > 0.1 * L$ and $L_s < 2 * L$) = 300.00
From table 10.5, ASCE 41_17: $E_{eff} = factor * E_c * I_g = 2.4137E+013$
factor = 0.30
 $A_g = 196349.541$
Mean concrete strength: $f'_c = (f'_{c,jacket} * Area_{jacket} + f'_{c,core} * Area_{core}) / Area_{section} = 28.32$
 $N = 7385.629$
 $E_c * I_g = E_{c,jacket} * I_{g,jacket} + E_{c,core} * I_{g,core} = 8.0455E+013$

Calculation of Yielding Moment M_y

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

$M_y = \text{Min}(M_{y,ten}, M_{y,com}) = 2.4653E+008$
 $y = 7.1028683E-006$
 $M_{y,ten}$ (8c) = $2.4653E+008$
 $_{ten}$ (7c) = 62.22247
error of function (7c) = 0.00021692
 $M_{y,com}$ (8d) = $8.0674E+008$
 $_{com}$ (7d) = 63.84405
error of function (7d) = -0.00846596
with ((10.1), ASCE 41-17) $e_y = \text{Min}(e_y, 1.25 * e_y * (l_b / l_d)^{2/3}) = 0.0027778$

$\rho_{FRP} = 0.002$
 $\alpha_{FRP} = 0.45$ ((9c) in Biskinis and Fardis for FRP Wrap)
 $d_1 = 44.00$
 $R = 250.00$
 $\nu = 0.00103611$
 $N = 7385.629$
 $A_c = 196349.541$
 $\left(\frac{10.1}{\rho_{FRP}}, ASCE 41-17\right) = \text{Min}\left(1, 1.25 \cdot \left(\frac{l_b}{l_d}\right)^{2/3}\right) = 0.23799351$
 with $f_c^* \left(\frac{12.3}{\rho_{FRP}}, ACI 440\right) = 36.3038$
 $f_c = 33.00$
 $\beta_1 = 1.05384$
 $k = 1$
 Effective FRP thickness, $t_f = N L \cdot t \cdot \cos(\beta_1) = 1.016$
 $\rho_{FRP} \left(\frac{12.5}{\rho_{FRP}} \text{ and } \frac{12.7}{\rho_{FRP}}\right) = 0.004$
 $f_u = 0.01$
 $E_f = 64828.00$

 Calculation of ratio l_b/l_d

Lap Length: $l_d/l_d, \text{min} = 0.34503556$

$l_b = 300.00$

$l_d = 869.4756$

Calculation of l according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

$\beta_1 = 1$

$d_b = 18.00$

Mean strength value of all re-bars: $f_y = 555.56$

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

$t = 1.00$

$s = 0.80$

$e = 1.00$

$c_b = 25.00$

$K_{tr} = 1.20951$

$A_{tr} = \sqrt{2} \cdot \text{Area of external stirrup} = 123.3701$

$s = s_{\text{external}} = 340.00$

$n = 12.00$

 - Calculation of ρ_p -

From table 10-9: $\rho_p = 0.042$

with:

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

shear control ratio $V_y E / V_{CoI} O E = 0.29814229$

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

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

$t = s_1 + s_2 + 2 \cdot t_f / b_w \cdot (f_{fe} / f_s) = 0.00519403$

jacket: $s_1 = A_{v1} \cdot \left(\frac{D_{c1}}{2}\right) / (s_1 \cdot A_g) = 0.00081312$

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

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

(shear) direction

$s_1 = 340.00$

core: $s_2 = A_{v2} \cdot \left(\frac{D_{c2}}{2}\right) / (s_2 \cdot A_g) = 0.0005871$

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

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

direction

$s_2 = 200.00$

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.

$N_{UD} = 7385.629$

$A_g = 196349.541$

$f_c E = (f_c'_{\text{jacket}} \cdot \text{Area}_{\text{jacket}} + f_c'_{\text{core}} \cdot \text{Area}_{\text{core}}) / \text{section_area} = 28.32$

$f_y E = (f_y'_{\text{ext_Long_Reinf}} \cdot \text{Area}_{\text{ext_Long_Reinf}} + f_y'_{\text{int_Long_Reinf}} \cdot \text{Area}_{\text{int_Long_Reinf}}) / \text{Area}_{\text{Tot_Long_Rein}} =$

2.1219958E-314

$$f_{tE} = (f_{y_ext_Trans_Reinf} \cdot s_1 + f_{y_int_Trans_Reinf} \cdot s_2) / (s_1 + s_2) = 508.9683$$

$$p_l = \text{Area_Tot_Long_Rein} / (A_g) = 0.015552$$

$$f_{cE} = 28.32$$

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

At local axis: 3

Integration Section: (b)
