

# Detailed Member Calculations

**Units: N&mm**

**Regulation: ASCE 41-17**

## Calculation No. 1

column C1, Floor 1

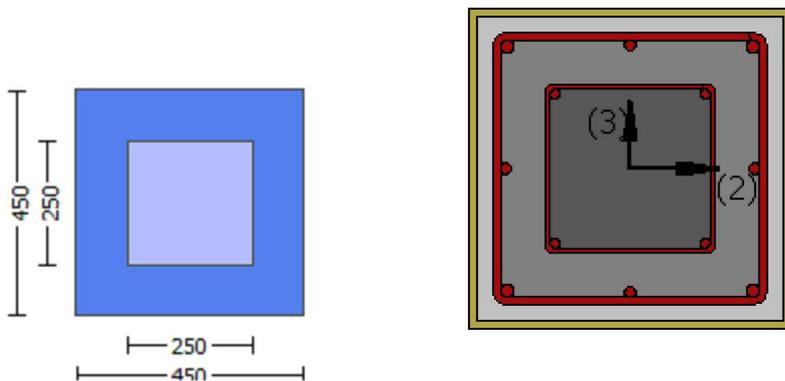
Limit State: Immediate Occupancy (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Shear capacity  $V_{Rd}$

Edge: Start

Local Axis: (2)



Start Of Calculation of Shear Capacity for element: column JC1 of floor 1

At local axis: 2

Integration Section: (a)

Section Type: rcjrs

Constant Properties

Knowledge Factor,  $\gamma = 0.85$

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  $\gamma$  for displacement ductility demand,  
 the expected (mean value) strengths are used (7.5.1.3, ASCE 41-17) because bending is considered as  
 Deformation-Controlled Action (Table C7-1, ASCE 41-17).  
 Jacket  
 New material: Concrete Strength,  $f_c = f_{cm} = 33.00$   
 New material: Steel Strength,  $f_s = f_{sm} = 555.56$   
 Existing Column  
 Existing material: Concrete Strength,  $f_c = f_{cm} = 20.00$   
 Existing material: Steel Strength,  $f_s = f_{sm} = 444.44$   
 #####  
 External Height,  $H = 450.00$   
 External Width,  $W = 450.00$   
 Internal Height,  $H = 250.00$   
 Internal Width,  $W = 250.00$   
 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,  $R = 40.00$

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 Stepwise Properties  
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EDGE -A-  
 Bending Moment,  $M_a = -2.3098E+007$   
 Shear Force,  $V_a = -7697.601$   
 EDGE -B-  
 Bending Moment,  $M_b = 0.06012619$   
 Shear Force,  $V_b = 7697.601$   
 BOTH EDGES  
 Axial Force,  $F = -7503.728$   
 Longitudinal Reinforcement Area Distribution (in 2 divisions)  
 -Tension:  $As_t = 1137.257$   
 -Compression:  $As_c = 1539.38$   
 Longitudinal Reinforcement Area Distribution (in 3 divisions)  
 -Tension:  $As_{l,ten} = 1137.257$   
 -Compression:  $As_{l,com} = 1137.257$   
 -Middle:  $As_{l,mid} = 402.1239$   
 Mean Diameter of Tension Reinforcement,  $Db_{L,ten} = 16.80$   
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Existing component: From table 7-7, ASCE 41\_17: Final Shear Capacity  $V_R = *V_n = 365324.682$   
 $V_n ((10.3), ASCE 41-17) = knl*V_{CoIo} = 429793.743$

VCol = 429793.743

knl = 1.00

displacement\_ductility\_demand = 0.03746071

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:  $f_c' = (f_c'_{\text{jacket}} \cdot \text{Area}_{\text{jacket}} + f_c'_{\text{core}} \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 22.22222$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

M/Vd = 4.00

$\mu_u = 2.3098E+007$

$V_u = 7697.601$

$d = 0.8 \cdot h = 360.00$

$N_u = 7503.728$

$A_g = 202500.00$

From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 129852.496$

where:

$V_{s1} = 62831.853$  is calculated for jacket, with:

$d = 360.00$

$A_v = 157079.633$

$f_y = 500.00$

$s = 300.00$

$V_{s1}$  is multiplied by  $Col1 = 0.66666667$

$s/d = 0.83333333$

$V_{s2} = 67020.643$  is calculated for core, with:

$d = 200.00$

$A_v = 100530.965$

$f_y = 400.00$

$s = 120.00$

$V_{s2}$  is multiplied by  $Col2 = 1.00$

$s/d = 0.60$

$V_f$  ((11-3)-(11.4), ACI 440) = 214457.247

$f = 0.95$ , 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 cyclic fiber orientation  $a_i$ ,  
as well as for 2 crack directions,  $\theta = 45^\circ$  and  $\theta = -45^\circ$  to take into consideration the cyclic seismic loading.

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

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

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

$d_{fv} = d$  (figure 11.2, ACI 440) = 407.00

$f_{fe}$  ((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:  $V_s + V_f \leq 507312.442$

$b_w = 450.00$

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

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

From analysis, chord rotation  $\theta = 0.00024357$

$y = (M_y \cdot L_s / 3) / E_{\text{eff}} = 0.00650201$  ((4.29), Biskinis Phd)

$M_y = 1.7613E+008$

$L_s = M/V$  (with  $L_s > 0.1 \cdot L$  and  $L_s < 2 \cdot L$ ) = 3000.708

From table 10.5, ASCE 41\_17:  $E_{\text{eff}} = \text{factor} \cdot E_c \cdot I_g = 2.7095E+013$

factor = 0.30

$A_g = 202500.00$

Mean concrete strength:  $f_c' = (f_c'_{\text{jacket}} \cdot \text{Area}_{\text{jacket}} + f_c'_{\text{core}} \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 28.98765$

$N = 7503.728$

$E_c \cdot I_g = E_{c_{\text{jacket}}} \cdot I_{g_{\text{jacket}}} + E_{c_{\text{core}}} \cdot I_{g_{\text{core}}} = 9.0315E+013$

Calculation of Yielding Moment  $M_y$

Calculation of  $y$  and  $M_y$  according to Annex 7

$y = \text{Min}(y_{\text{ten}}, y_{\text{com}})$   
 $y_{\text{ten}} = 6.1806747\text{E-}006$   
with ((10.1), ASCE 41-17)  $f_y = \text{Min}(f_y, 1.25 \cdot f_y \cdot (l_b/d)^{2/3}) = 374.3546$   
 $d = 407.00$   
 $y = 0.25591435$   
 $A = 0.0147239$   
 $B = 0.00818869$   
with  $pt = 0.00620943$   
 $pc = 0.00620943$   
 $pv = 0.0021956$   
 $N = 7503.728$   
 $b = 450.00$   
 $" = 0.10565111$   
 $y_{\text{comp}} = 2.2127278\text{E-}005$   
with  $f_c^*$  (12.3, (ACI 440)) = 34.40847  
 $f_c = 33.00$   
 $fl = 0.82797802$   
 $b = 450.00$   
 $h = 450.00$   
 $Ag = 202500.00$   
From (12.9), ACI 440:  $k_a = 0.54261599$   
 $g = pt + pc + pv = 0.01461445$   
 $rc = 40.00$   
 $A_e/A_c = 0.54261599$   
Effective FRP thickness,  $t_f = NL \cdot t \cdot \text{Cos}(b_1) = 1.016$   
effective strain from (12.5) and (12.12),  $\epsilon_{fe} = 0.004$   
 $f_u = 0.01$   
 $E_f = 64828.00$   
 $E_c = 26999.444$   
 $y = 0.25471862$   
 $A = 0.01452515$   
 $B = 0.00807924$   
with  $E_s = 200000.00$

Calculation of ratio  $l_b/d$

Lap Length:  $l_d/l_d, \text{min} = 0.42476573$

$l_b = 300.00$

$l_d = 706.2717$

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

$= 1$

$db = 16.66667$

Mean strength value of all re-bars:  $f_y = 524.4464$

Mean concrete strength:  $f_c' = (f_c'_{\text{jacket}} \cdot \text{Area}_{\text{jacket}} + f_c'_{\text{core}} \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 28.98765$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 2.86234$

$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 257.6106$

where  $A_{tr_x}$ ,  $A_{tr_y}$  are the sum of the area of all stirrup legs along X and Y local axis

$s = \text{Max}(s_{\text{external}}, s_{\text{internal}}) = 300.00$

$n = 12.00$

End Of Calculation of Shear Capacity for element: column JC1 of floor 1

At local axis: 2

Integration Section: (a)

## Calculation No. 2

column C1, Floor 1

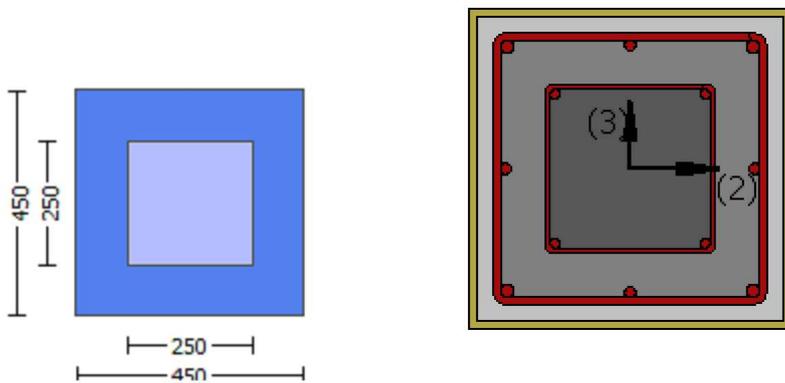
Limit State: Immediate Occupancy (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity (  $\theta$  )

Edge: Start

Local Axis: (2)



Start Of Calculation of Shear Capacity ratio for element: column JC1 of floor 1

At Shear local axis: 3

(Bending local axis: 2)

Section Type: rcjrs

Constant Properties

Knowledge Factor,  $\phi = 0.85$

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 Height, H = 450.00  
External Width, W = 450.00  
Internal Height, H = 250.00  
Internal Width, W = 250.00  
Cover Thickness, c = 25.00  
Mean Confinement Factor overall section = 1.10542  
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, NoDir = 1  
Fiber orientations,  $b_i$ : 0.00°  
Number of layers, NL = 1  
Radius of rounding corners, R = 40.00

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Stepwise Properties  
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At local axis: 3  
EDGE -A-  
Shear Force,  $V_a$  = 2.0531359E-031  
EDGE -B-  
Shear Force,  $V_b$  = -2.0531359E-031  
BOTH EDGES  
Axial Force, F = -7506.808  
Longitudinal Reinforcement Area Distribution (in 2 divisions)  
-Tension:  $A_{sl,t}$  = 0.00  
-Compression:  $A_{sl,c}$  = 2676.637  
Longitudinal Reinforcement Area Distribution (in 3 divisions)  
-Tension:  $A_{sl,ten}$  = 1137.257  
-Compression:  $A_{sl,com}$  = 1137.257  
-Middle:  $A_{sl,mid}$  = 402.1239  
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Calculation of Shear Capacity ratio ,  $V_e/V_r$  = 0.26068017  
Member Controlled by Flexure ( $V_e/V_r < 1$ )  
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 147952.607$   
with  
 $M_{pr1} = \text{Max}(\mu_{u1+}, \mu_{u1-}) = 2.2193E+008$   
 $\mu_{u1+} = 2.2193E+008$ , is the ultimate moment strength at the edge 1 of the member in the actual moment direction  
which is defined for the static loading combination  
 $\mu_{u1-} = 2.2193E+008$ , is the ultimate moment strength at the edge 1 of the member in the opposite moment  
direction which is defined for the static loading combination  
 $M_{pr2} = \text{Max}(\mu_{u2+}, \mu_{u2-}) = 2.2193E+008$   
 $\mu_{u2+} = 2.2193E+008$ , is the ultimate moment strength at the edge 2 of the member in the actual moment direction  
which is defined for the the static loading combination  
 $\mu_{u2-} = 2.2193E+008$ , is the ultimate moment strength at the edge 2 of the member in the opposite moment  
direction which is defined for the the static loading combination

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Calculation of  $\mu_{u1+}$   
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Calculation of ultimate curvature  $\phi_u$  according to 4.1, Biskinis/Fardis 2013:

$$u = 1.9632832E-005$$

$$\mu = 2.2193E+008$$

with full section properties:

$$b = 450.00$$

$$d = 407.00$$

$$d' = 43.00$$

$$v = 0.00124204$$

$$N = 7506.808$$

$$f_c = 33.00$$

$$\omega (5A.5, TBDY) = 0.002$$

$$\text{Final value of } \phi_u: \phi_u^* = \text{shear\_factor} * \text{Max}(\phi_u, \phi_c) = 0.01393923$$

The Shear\_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \phi_u = 0.01393923$$

$$\omega_e ((5.4c), TBDY) = a_{se} * \text{sh}_{, \min} * f_{ywe} / f_{ce} + \text{Min}(\phi_x, \phi_y) = 0.06811101$$

where  $\phi = a_f * p_f * f_{fe} / f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$\phi_x = 0.06628267$$

$$a_f = 0.54930041$$

$$b = 450.00$$

$$h = 450.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.00451556$$

$$b_w = 450.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 881.8461$$

$$\phi_y = 0.06628267$$

$$a_f = 0.54930041$$

$$b = 450.00$$

$$h = 450.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.00451556$$

$$b_w = 450.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 881.8461$$

$$R = 40.00$$

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

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$a_{se} ((5.4d), TBDY) = (a_{se1} * A_{ext} + a_{se2} * A_{int}) / A_{sec} = 0.14546167$$

$$a_{se1} = 0.12623274$$

$$b_{o,1} = 390.00$$

$$h_{o,1} = 390.00$$

$$b_{i2,1} = 608400.00$$

$$a_{se2} = \text{Max}(a_{se1}, a_{se2}) = 0.18853448$$

$$b_{o,2} = 242.00$$

$$h_{o,2} = 242.00$$

$$b_{i2,2} = 234256.00$$

$$p_{sh, \min} * f_{ywe} = \text{Min}(p_{sh,x} * f_{ywe}, p_{sh,y} * f_{ywe}) = 1.38262$$

Expression ((5.4d), TBDY) for  $p_{sh, \min} * f_{ywe}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$$p_{sh,x} * f_{ywe} = p_{sh1} * f_{ywe1} + p_{sh2} * f_{ywe2} = 1.38262$$

$$p_{s1} (\text{external}) = (A_{sh1} * h_1 / s_1) / A_{sec} = 0.00116355$$

$$A_{sh1} = A_{stir,1} * n_{s,1} = 157.0796$$

$$\text{No stirrups, } n_{s,1} = 2.00$$

$$h_1 = 450.00$$

$$p_{s2} (\text{internal}) = (A_{sh2} * h_2 / s_2) / A_{sec} = 0.00103427$$

$$A_{sh2} = A_{stir,2} * n_{s,2} = 100.531$$

$$\text{No stirrups, } n_{s,2} = 2.00$$

$$h_2 = 250.00$$

$$p_{sh,y} * f_{ywe} = p_{sh1} * f_{ywe1} + p_{sh2} * f_{ywe2} = 1.38262$$

$$p_{s1} (\text{external}) = (A_{sh1} * h_1 / s_1) / A_{sec} = 0.00116355$$

$$A_{sh1} = A_{stir,1} * n_{s,1} = 157.0796$$

$$\text{No stirrups, } n_{s,1} = 2.00$$

$$h_1 = 450.00$$

$$ps_2 \text{ (internal)} = (Ash_2 * h_2 / s_2) / A_{sec} = 0.00103427$$

$$Ash_2 = Astir_2 * ns_2 = 100.531$$

$$\text{No stirups, } ns_2 = 2.00$$

$$h_2 = 250.00$$

$$A_{sec} = 202500.00$$

$$s_1 = 300.00$$

$$s_2 = 120.00$$

$$fy_{we1} = 694.45$$

$$fy_{we2} = 555.55$$

$$f_{ce} = 33.00$$

$$\text{From ((5.A.5), TBDY), TBDY: } cc = 0.00305417$$

$$c = \text{confinement factor} = 1.10542$$

$$y_1 = 0.00152175$$

$$sh_1 = 0.0048696$$

$$ft_1 = 479.7871$$

$$fy_1 = 399.8226$$

$$su_1 = 0.0066488$$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

$$lo/lou, \min = lb/ld = 0.33981258$$

$$su_1 = 0.4 * esu_{1\_nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY:  $esu_{1\_nominal} = 0.08$ ,

For calculation of  $esu_{1\_nominal}$  and  $y_1, sh_1, ft_1, fy_1$ , it is considered  
characteristic value  $fsy_1 = fs_1 / 1.2$ , from table 5.1, TBDY.

$y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.

$$\text{with } fs_1 = (fs_{jacket} * Asl, \text{ten, jacket} + fs_{core} * Asl, \text{ten, core}) / Asl, \text{ten} = 399.8226$$

$$\text{with } Es_1 = (Es_{jacket} * Asl, \text{ten, jacket} + Es_{core} * Asl, \text{ten, core}) / Asl, \text{ten} = 200000.00$$

$$y_2 = 0.00152175$$

$$sh_2 = 0.0048696$$

$$ft_2 = 479.7871$$

$$fy_2 = 399.8226$$

$$su_2 = 0.0066488$$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

$$lo/lou, \min = lb/lb, \min = 0.33981258$$

$$su_2 = 0.4 * esu_{2\_nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY:  $esu_{2\_nominal} = 0.08$ ,

For calculation of  $esu_{2\_nominal}$  and  $y_2, sh_2, ft_2, fy_2$ , it is considered  
characteristic value  $fsy_2 = fs_2 / 1.2$ , from table 5.1, TBDY.

$y_2, sh_2, ft_2, fy_2$ , are also multiplied by  $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.

$$\text{with } fs_2 = (fs_{jacket} * Asl, \text{com, jacket} + fs_{core} * Asl, \text{com, core}) / Asl, \text{com} = 399.8226$$

$$\text{with } Es_2 = (Es_{jacket} * Asl, \text{com, jacket} + Es_{core} * Asl, \text{com, core}) / Asl, \text{com} = 200000.00$$

$$y_v = 0.00152175$$

$$sh_v = 0.0048696$$

$$ft_v = 507.2537$$

$$fy_v = 422.7114$$

$$su_v = 0.0066488$$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

$$lo/lou, \min = lb/ld = 0.33981258$$

$$su_v = 0.4 * esuv\_nominal ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY:  $esuv\_nominal = 0.08$ ,

considering characteristic value  $fsy_v = fsv / 1.2$ , from table 5.1, TBDY

For calculation of  $esuv\_nominal$  and  $y_v, sh_v, ft_v, fy_v$ , it is considered  
characteristic value  $fsy_v = fsv / 1.2$ , from table 5.1, TBDY.

$y_v, sh_v, ft_v, fy_v$ , are also multiplied by  $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.

$$\text{with } fsv = (fs_{jacket} * Asl, \text{mid, jacket} + fs_{mid} * Asl, \text{mid, core}) / Asl, \text{mid} = 422.7114$$

$$\text{with } Es_v = (Es_{jacket} * Asl, \text{mid, jacket} + Es_{mid} * Asl, \text{mid, core}) / Asl, \text{mid} = 200000.00$$

$$1 = Asl, \text{ten} / (b * d) * (fs_1 / f_c) = 0.0752324$$

$$2 = Asl, \text{com} / (b * d) * (fs_2 / f_c) = 0.0752324$$

$$v = Asl, \text{mid} / (b * d) * (fsv / f_c) = 0.02812438$$

and confined core properties:

$$b = 390.00$$

$d = 377.00$   
 $d' = 13.00$   
 $f_{cc} (5A.2, TBDY) = 36.47874$   
 $cc (5A.5, TBDY) = 0.00305417$   
 $c = \text{confinement factor} = 1.10542$   
 $1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.09371431$   
 $2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.09371431$   
 $v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.03503353$   
 Case/Assumption: Unconfined full section - Steel rupture  
 ' satisfies Eq. (4.3)

--->  
 $v < v_{s,y2}$  - LHS eq.(4.5) is satisfied  
 --->  
 $su (4.9) = 0.16791801$   
 $Mu = MRc (4.14) = 2.2193E+008$   
 $u = su (4.1) = 1.9632832E-005$

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

-----  
 Lap Length:  $l_b/l_d = 0.33981258$   
 $l_b = 300.00$   
 $l_d = 882.8396$   
 Calculation of  $l_b, \min$  according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.  
 $= 1$   
 $db = 16.66667$   
 Mean strength value of all re-bars:  $f_y = 655.558$   
 Mean concrete strength:  $f_c' = (f_c'_{jacket} * Area_{jacket} + f_c'_{core} * Area_{core}) / Area_{section} = 28.98765$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)  
 $t = 1.00$   
 $s = 0.80$   
 $e = 1.00$   
 $cb = 25.00$   
 $K_{tr} = 2.86234$   
 $A_{tr} = \text{Min}(A_{tr,x}, A_{tr,y}) = 257.6106$   
 where  $A_{tr,x}, A_{tr,y}$  are the sum of the area of all stirrup legs along X and Y local axis  
 $s = \text{Max}(s_{external}, s_{internal}) = 300.00$   
 $n = 12.00$

-----  
 Calculation of  $Mu1$ -

-----  
 Calculation of ultimate curvature  $u$  according to 4.1, Biskinis/Fardis 2013:  
 $u = 1.9632832E-005$   
 $Mu = 2.2193E+008$

-----  
 with full section properties:

$b = 450.00$   
 $d = 407.00$   
 $d' = 43.00$   
 $v = 0.00124204$   
 $N = 7506.808$   
 $f_c = 33.00$   
 $co (5A.5, TBDY) = 0.002$   
 Final value of  $cu$ :  $cu^* = \text{shear\_factor} * \text{Max}(cu, cc) = 0.01393923$   
 The Shear\_factor is considered equal to 1 (pure moment strength)  
 From (5.4b), TBDY:  $cu = 0.01393923$   
 $we ((5.4c), TBDY) = ase * sh_{,min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.06811101$   
 where  $f = af * pf * f_{fe} / f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

-----

$f_x = 0.06628267$   
 $af = 0.54930041$   
 $b = 450.00$   
 $h = 450.00$

From EC8 A.4.4.3(6),  $pf = 2tf/bw = 0.00451556$   
 $bw = 450.00$   
effective stress from (A.35),  $ff,e = 881.8461$

$fy = 0.06628267$   
 $af = 0.54930041$   
 $b = 450.00$   
 $h = 450.00$   
From EC8 A.4.4.3(6),  $pf = 2tf/bw = 0.00451556$   
 $bw = 450.00$   
effective stress from (A.35),  $ff,e = 881.8461$

$R = 40.00$   
Effective FRP thickness,  $tf = NL*t*Cos(b1) = 1.016$   
 $fu,f = 1055.00$   
 $Ef = 64828.00$   
 $u,f = 0.015$   
 $ase ((5.4d), TBDY) = (ase1*Aext+ase2*Aint)/Asec = 0.14546167$   
 $ase1 = 0.12623274$   
 $bo\_1 = 390.00$   
 $ho\_1 = 390.00$   
 $bi2\_1 = 608400.00$   
 $ase2 = Max(ase1,ase2) = 0.18853448$   
 $bo\_2 = 242.00$   
 $ho\_2 = 242.00$   
 $bi2\_2 = 234256.00$

$psh,min*Fywe = Min(psh,x*Fywe, psh,y*Fywe) = 1.38262$   
Expression ((5.4d), TBDY) for  $psh,min*Fywe$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$psh\_x*Fywe = psh1*Fywe1+ps2*Fywe2 = 1.38262$   
 $ps1 (external) = (Ash1*h1/s1)/Asec = 0.00116355$   
 $Ash1 = Astir\_1*ns\_1 = 157.0796$   
No stirrups,  $ns\_1 = 2.00$   
 $h1 = 450.00$   
 $ps2 (internal) = (Ash2*h2/s2)/Asec = 0.00103427$   
 $Ash2 = Astir\_2*ns\_2 = 100.531$   
No stirrups,  $ns\_2 = 2.00$   
 $h2 = 250.00$

$psh\_y*Fywe = psh1*Fywe1+ps2*Fywe2 = 1.38262$   
 $ps1 (external) = (Ash1*h1/s1)/Asec = 0.00116355$   
 $Ash1 = Astir\_1*ns\_1 = 157.0796$   
No stirrups,  $ns\_1 = 2.00$   
 $h1 = 450.00$   
 $ps2 (internal) = (Ash2*h2/s2)/Asec = 0.00103427$   
 $Ash2 = Astir\_2*ns\_2 = 100.531$   
No stirrups,  $ns\_2 = 2.00$   
 $h2 = 250.00$

$Asec = 202500.00$   
 $s1 = 300.00$   
 $s2 = 120.00$   
 $fywe1 = 694.45$   
 $fywe2 = 555.55$   
 $fce = 33.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.00305417$   
 $c = \text{confinement factor} = 1.10542$

$y1 = 0.00152175$   
 $sh1 = 0.0048696$   
 $ft1 = 479.7871$   
 $fy1 = 399.8226$   
 $su1 = 0.0066488$

using (30) in Biskinis/Fardis (2013) multiplied with  $shear\_factor$   
and also multiplied by the  $shear\_factor$  according to 15.7.1.4, with  
 $Shear\_factor = 1.00$   
 $lo/lou,min = lb/d = 0.33981258$

$su_1 = 0.4 * esu_1\_nominal ((5.5), TBDY) = 0.032$   
 From table 5A.1, TBDY:  $esu_1\_nominal = 0.08$ ,  
 For calculation of  $esu_1\_nominal$  and  $y_1, sh_1, ft_1, fy_1$ , it is considered  
 characteristic value  $fsy_1 = fs_1/1.2$ , from table 5.1, TBDY.  
 $y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $Min(1, 1.25 * (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with  $fs_1 = (fs\_jacket * Asl,ten,jacket + fs\_core * Asl,ten,core) / Asl,ten = 399.8226$   
 with  $Es_1 = (Es\_jacket * Asl,ten,jacket + Es\_core * Asl,ten,core) / Asl,ten = 200000.00$   
 $y_2 = 0.00152175$   
 $sh_2 = 0.0048696$   
 $ft_2 = 479.7871$   
 $fy_2 = 399.8226$   
 $su_2 = 0.0066488$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 Shear\_factor = 1.00  
 $lo/lou,min = lb/lb,min = 0.33981258$   
 $su_2 = 0.4 * esu_2\_nominal ((5.5), TBDY) = 0.032$   
 From table 5A.1, TBDY:  $esu_2\_nominal = 0.08$ ,  
 For calculation of  $esu_2\_nominal$  and  $y_2, sh_2, ft_2, fy_2$ , it is considered  
 characteristic value  $fsy_2 = fs_2/1.2$ , from table 5.1, TBDY.  
 $y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $Min(1, 1.25 * (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with  $fs_2 = (fs\_jacket * Asl,com,jacket + fs\_core * Asl,com,core) / Asl,com = 399.8226$   
 with  $Es_2 = (Es\_jacket * Asl,com,jacket + Es\_core * Asl,com,core) / Asl,com = 200000.00$   
 $yv = 0.00152175$   
 $shv = 0.0048696$   
 $ftv = 507.2537$   
 $fyv = 422.7114$   
 $suv = 0.0066488$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 Shear\_factor = 1.00  
 $lo/lou,min = lb/ld = 0.33981258$   
 $suv = 0.4 * esuv\_nominal ((5.5), TBDY) = 0.032$   
 From table 5A.1, TBDY:  $esuv\_nominal = 0.08$ ,  
 considering characteristic value  $fsyv = fsv/1.2$ , from table 5.1, TBDY  
 For calculation of  $esuv\_nominal$  and  $yv, shv, ftv, fyv$ , it is considered  
 characteristic value  $fsyv = fsv/1.2$ , from table 5.1, TBDY.  
 $y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $Min(1, 1.25 * (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with  $fsv = (fs\_jacket * Asl,mid,jacket + fs\_mid * Asl,mid,core) / Asl,mid = 422.7114$   
 with  $Esv = (Es\_jacket * Asl,mid,jacket + Es\_mid * Asl,mid,core) / Asl,mid = 200000.00$   
 $1 = Asl,ten / (b * d) * (fs_1 / fc) = 0.0752324$   
 $2 = Asl,com / (b * d) * (fs_2 / fc) = 0.0752324$   
 $v = Asl,mid / (b * d) * (fsv / fc) = 0.02812438$

and confined core properties:

$b = 390.00$   
 $d = 377.00$   
 $d' = 13.00$   
 $fcc (5A.2, TBDY) = 36.47874$   
 $cc (5A.5, TBDY) = 0.00305417$   
 $c = \text{confinement factor} = 1.10542$   
 $1 = Asl,ten / (b * d) * (fs_1 / fc) = 0.09371431$   
 $2 = Asl,com / (b * d) * (fs_2 / fc) = 0.09371431$   
 $v = Asl,mid / (b * d) * (fsv / fc) = 0.03503353$

Case/Assumption: Unconfined full section - Steel rupture  
 ' satisfies Eq. (4.3)

--->  
 $v < vs,y_2$  - LHS eq.(4.5) is satisfied  
 --->  
 $su (4.9) = 0.16791801$   
 $Mu = MRc (4.14) = 2.2193E+008$   
 $u = su (4.1) = 1.9632832E-005$

-----  
 Calculation of ratio  $lb/ld$

-----  
 Lap Length:  $lb/ld = 0.33981258$   
 $lb = 300.00$

Id = 882.8396

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

= 1

db = 16.66667

Mean strength value of all re-bars:  $f_y = 655.558$

Mean concrete strength:  $f_c' = (f_c'_{jacket} \cdot Area_{jacket} + f_c'_{core} \cdot Area_{core}) / Area_{section} = 28.98765$ , 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

Ktr = 2.86234

Atr =  $\text{Min}(A_{tr_x}, A_{tr_y}) = 257.6106$

where  $A_{tr_x}$ ,  $A_{tr_y}$  are the sum of the area of all stirrup legs along X and Y local axis

s =  $\text{Max}(s_{external}, s_{internal}) = 300.00$

n = 12.00

Calculation of  $Mu_{2+}$

Calculation of ultimate curvature  $\phi_u$  according to 4.1, Biskinis/Fardis 2013:

$u = 1.9632832E-005$

$Mu = 2.2193E+008$

with full section properties:

b = 450.00

d = 407.00

d' = 43.00

v = 0.00124204

N = 7506.808

$f_c = 33.00$

co (5A.5, TBDY) = 0.002

Final value of  $\phi_u$ :  $\phi_u^* = \text{shear\_factor} \cdot \text{Max}(\phi_u, \phi_c) = 0.01393923$

The Shear\_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY:  $\phi_u = 0.01393923$

we ((5.4c), TBDY) =  $ase^* \cdot \text{sh}_{,min} \cdot f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.06811101$

where  $f = af \cdot pf \cdot f_{fe} / f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$f_x = 0.06628267$

af = 0.54930041

b = 450.00

h = 450.00

From EC8 A.4.4.3(6),  $pf = 2t_f / bw = 0.00451556$

bw = 450.00

effective stress from (A.35),  $f_{f,e} = 881.8461$

$f_y = 0.06628267$

af = 0.54930041

b = 450.00

h = 450.00

From EC8 A.4.4.3(6),  $pf = 2t_f / bw = 0.00451556$

bw = 450.00

effective stress from (A.35),  $f_{f,e} = 881.8461$

R = 40.00

Effective FRP thickness,  $t_f = NL \cdot t \cdot \text{Cos}(b1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{,f} = 0.015$

ase ((5.4d), TBDY) =  $(ase1 \cdot A_{ext} + ase2 \cdot A_{int}) / A_{sec} = 0.14546167$

ase1 = 0.12623274

bo\_1 = 390.00

ho\_1 = 390.00

bi2\_1 = 608400.00

$$ase2 = \text{Max}(ase1, ase2) = 0.18853448$$

$$bo\_2 = 242.00$$

$$ho\_2 = 242.00$$

$$bi2\_2 = 234256.00$$

$$psh, \text{min} * Fywe = \text{Min}(psh, x * Fywe, psh, y * Fywe) = 1.38262$$

Expression ((5.4d), TBDY) for psh,min\*Fywe has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$$psh\_x * Fywe = psh1 * Fywe1 + ps2 * Fywe2 = 1.38262$$

$$ps1 \text{ (external)} = (Ash1 * h1 / s1) / Asec = 0.00116355$$

$$Ash1 = Astir\_1 * ns\_1 = 157.0796$$

$$\text{No stirrups, } ns\_1 = 2.00$$

$$h1 = 450.00$$

$$ps2 \text{ (internal)} = (Ash2 * h2 / s2) / Asec = 0.00103427$$

$$Ash2 = Astir\_2 * ns\_2 = 100.531$$

$$\text{No stirrups, } ns\_2 = 2.00$$

$$h2 = 250.00$$

$$psh\_y * Fywe = psh1 * Fywe1 + ps2 * Fywe2 = 1.38262$$

$$ps1 \text{ (external)} = (Ash1 * h1 / s1) / Asec = 0.00116355$$

$$Ash1 = Astir\_1 * ns\_1 = 157.0796$$

$$\text{No stirrups, } ns\_1 = 2.00$$

$$h1 = 450.00$$

$$ps2 \text{ (internal)} = (Ash2 * h2 / s2) / Asec = 0.00103427$$

$$Ash2 = Astir\_2 * ns\_2 = 100.531$$

$$\text{No stirrups, } ns\_2 = 2.00$$

$$h2 = 250.00$$

$$Asec = 202500.00$$

$$s1 = 300.00$$

$$s2 = 120.00$$

$$fywe1 = 694.45$$

$$fywe2 = 555.55$$

$$fce = 33.00$$

From ((5.A5), TBDY), TBDY:  $cc = 0.00305417$

$$c = \text{confinement factor} = 1.10542$$

$$y1 = 0.00152175$$

$$sh1 = 0.0048696$$

$$ft1 = 479.7871$$

$$fy1 = 399.8226$$

$$su1 = 0.0066488$$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00

$$lo/lou, \text{min} = lb/ld = 0.33981258$$

$$su1 = 0.4 * esu1\_nominal \text{ ((5.5), TBDY)} = 0.032$$

From table 5A.1, TBDY:  $esu1\_nominal = 0.08$ ,

For calculation of  $esu1\_nominal$  and  $y1, sh1, ft1, fy1$ , it is considered characteristic value  $fsy1 = fs1/1.2$ , from table 5.1, TBDY.

$y1, sh1, ft1, fy1$ , are also multiplied by  $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.

$$\text{with } fs1 = (fs, \text{jacket} * Asl, \text{ten, jacket} + fs, \text{core} * Asl, \text{ten, core}) / Asl, \text{ten} = 399.8226$$

$$\text{with } Es1 = (Es, \text{jacket} * Asl, \text{ten, jacket} + Es, \text{core} * Asl, \text{ten, core}) / Asl, \text{ten} = 200000.00$$

$$y2 = 0.00152175$$

$$sh2 = 0.0048696$$

$$ft2 = 479.7871$$

$$fy2 = 399.8226$$

$$su2 = 0.0066488$$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00

$$lo/lou, \text{min} = lb/lb, \text{min} = 0.33981258$$

$$su2 = 0.4 * esu2\_nominal \text{ ((5.5), TBDY)} = 0.032$$

From table 5A.1, TBDY:  $esu2\_nominal = 0.08$ ,

For calculation of  $esu2\_nominal$  and  $y2, sh2, ft2, fy2$ , it is considered characteristic value  $fsy2 = fs2/1.2$ , from table 5.1, TBDY.

$y1, sh1, ft1, fy1$ , are also multiplied by  $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.

$$\text{with } fs2 = (fs, \text{jacket} * Asl, \text{com, jacket} + fs, \text{core} * Asl, \text{com, core}) / Asl, \text{com} = 399.8226$$

with  $E_{s2} = (E_{s,jacket} \cdot A_{s,com,jacket} + E_{s,core} \cdot A_{s,com,core}) / A_{s,com} = 200000.00$   
 $y_v = 0.00152175$   
 $sh_v = 0.0048696$   
 $ft_v = 507.2537$   
 $fy_v = 422.7114$   
 $su_v = 0.0066488$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 Shear\_factor = 1.00  
 $l_o/l_{o,min} = l_b/l_d = 0.33981258$   
 $su_v = 0.4 \cdot esuv\_nominal((5.5), TBDY) = 0.032$   
 From table 5A.1, TBDY:  $esuv\_nominal = 0.08$ ,  
 considering characteristic value  $fs_y = f_{sv}/1.2$ , from table 5.1, TBDY  
 For calculation of  $esuv\_nominal$  and  $y_v, sh_v, ft_v, fy_v$ , it is considered  
 characteristic value  $fs_y = f_{sv}/1.2$ , from table 5.1, TBDY.  
 $y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with  $f_{sv} = (f_{s,jacket} \cdot A_{s,mid,jacket} + f_{s,mid} \cdot A_{s,mid,core}) / A_{s,mid} = 422.7114$   
 with  $E_{sv} = (E_{s,jacket} \cdot A_{s,mid,jacket} + E_{s,mid} \cdot A_{s,mid,core}) / A_{s,mid} = 200000.00$   
 $1 = A_{s,ten} / (b \cdot d) \cdot (f_{s1} / f_c) = 0.0752324$   
 $2 = A_{s,com} / (b \cdot d) \cdot (f_{s2} / f_c) = 0.0752324$   
 $v = A_{s,mid} / (b \cdot d) \cdot (f_{sv} / f_c) = 0.02812438$

and confined core properties:

$b = 390.00$   
 $d = 377.00$   
 $d' = 13.00$   
 $f_{cc}(5A.2, TBDY) = 36.47874$   
 $cc(5A.5, TBDY) = 0.00305417$   
 $c = \text{confinement factor} = 1.10542$   
 $1 = A_{s,ten} / (b \cdot d) \cdot (f_{s1} / f_c) = 0.09371431$   
 $2 = A_{s,com} / (b \cdot d) \cdot (f_{s2} / f_c) = 0.09371431$   
 $v = A_{s,mid} / (b \cdot d) \cdot (f_{sv} / f_c) = 0.03503353$

Case/Assumption: Unconfined full section - Steel rupture  
 ' satisfies Eq. (4.3)

--->  
 $v < v_{s,y2}$  - LHS eq.(4.5) is satisfied  
 --->  
 $su(4.9) = 0.16791801$   
 $Mu = MRc(4.14) = 2.2193E+008$   
 $u = su(4.1) = 1.9632832E-005$

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

Lap Length:  $l_b/l_d = 0.33981258$

$l_b = 300.00$   
 $l_d = 882.8396$

Calculation of  $l_b,min$  according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.  
 = 1

$db = 16.66667$   
 Mean strength value of all re-bars:  $f_y = 655.558$   
 Mean concrete strength:  $f_c' = (f_c'_{jacket} \cdot Area_{jacket} + f_c'_{core} \cdot Area_{core}) / Area_{section} = 28.98765$ , but  $f_c'^{0.5} < =$   
 8.3 MPa (22.5.3.1, ACI 318-14)  
 $t = 1.00$   
 $s = 0.80$   
 $e = 1.00$   
 $cb = 25.00$   
 $K_{tr} = 2.86234$   
 $A_{tr} = \text{Min}(A_{tr,x}, A_{tr,y}) = 257.6106$   
 where  $A_{tr,x}, A_{tr,y}$  are the sum of the area of all stirrup legs along X and Y loxal axis  
 $s = \text{Max}(s_{external}, s_{internal}) = 300.00$   
 $n = 12.00$

-----  
 Calculation of  $Mu_2$ -  
 -----

Calculation of ultimate curvature  $\phi_u$  according to 4.1, Biskinis/Fardis 2013:

$$u = 1.9632832E-005$$

$$Mu = 2.2193E+008$$

with full section properties:

$$b = 450.00$$

$$d = 407.00$$

$$d' = 43.00$$

$$v = 0.00124204$$

$$N = 7506.808$$

$$f_c = 33.00$$

$$\alpha_{co} (5A.5, TBDY) = 0.002$$

$$\text{Final value of } \phi_u: \phi_u^* = \text{shear\_factor} * \text{Max}(\phi_{cu}, \phi_{cc}) = 0.01393923$$

The Shear\_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \phi_{cu} = 0.01393923$$

$$\phi_{we} ((5.4c), TBDY) = \alpha_{se} * \text{sh}_{, \text{min}} * f_{ywe} / f_{ce} + \text{Min}(\phi_{fx}, \phi_{fy}) = 0.06811101$$

where  $\phi_f = \alpha_f * \rho_f * f_{fe} / f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$\phi_{fx} = 0.06628267$$

$$\alpha_f = 0.54930041$$

$$b = 450.00$$

$$h = 450.00$$

$$\text{From EC8 A.4.4.3(6), } \rho_f = 2t_f / bw = 0.00451556$$

$$bw = 450.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 881.8461$$

$$\phi_{fy} = 0.06628267$$

$$\alpha_f = 0.54930041$$

$$b = 450.00$$

$$h = 450.00$$

$$\text{From EC8 A.4.4.3(6), } \rho_f = 2t_f / bw = 0.00451556$$

$$bw = 450.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 881.8461$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = NL * t * \text{Cos}(b1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$\alpha_{se} ((5.4d), TBDY) = (\alpha_{se1} * A_{ext} + \alpha_{se2} * A_{int}) / A_{sec} = 0.14546167$$

$$\alpha_{se1} = 0.12623274$$

$$b_{o,1} = 390.00$$

$$h_{o,1} = 390.00$$

$$b_{i2,1} = 608400.00$$

$$\alpha_{se2} = \text{Max}(\alpha_{se1}, \alpha_{se2}) = 0.18853448$$

$$b_{o,2} = 242.00$$

$$h_{o,2} = 242.00$$

$$b_{i2,2} = 234256.00$$

$$\text{psh}_{, \text{min}} * F_{ywe} = \text{Min}(\text{psh}_{,x} * F_{ywe}, \text{psh}_{,y} * F_{ywe}) = 1.38262$$

Expression ((5.4d), TBDY) for  $\text{psh}_{, \text{min}} * F_{ywe}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$$\text{psh}_{,x} * F_{ywe} = \text{psh}_1 * F_{ywe1} + \text{ps}_2 * F_{ywe2} = 1.38262$$

$$\text{ps}_1 \text{ (external)} = (A_{sh1} * h_1 / s_1) / A_{sec} = 0.00116355$$

$$A_{sh1} = A_{\text{stir}_1} * n_{s,1} = 157.0796$$

$$\text{No stirrups, } n_{s,1} = 2.00$$

$$h_1 = 450.00$$

$$\text{ps}_2 \text{ (internal)} = (A_{sh2} * h_2 / s_2) / A_{sec} = 0.00103427$$

$$A_{sh2} = A_{\text{stir}_2} * n_{s,2} = 100.531$$

$$\text{No stirrups, } n_{s,2} = 2.00$$

$$h_2 = 250.00$$

$$\text{psh}_{,y} * F_{ywe} = \text{psh}_1 * F_{ywe1} + \text{ps}_2 * F_{ywe2} = 1.38262$$

$$\text{ps}_1 \text{ (external)} = (A_{sh1} * h_1 / s_1) / A_{sec} = 0.00116355$$

$$A_{sh1} = A_{\text{stir}_1} * n_{s,1} = 157.0796$$

$$\text{No stirrups, } n_{s,1} = 2.00$$

h1 = 450.00  
ps2 (internal) = (Ash2\*h2/s2)/Asec = 0.00103427  
Ash2 = Astir\_2\*ns\_2 = 100.531  
No stirups, ns\_2 = 2.00  
h2 = 250.00

-----  
Asec = 202500.00  
s1 = 300.00  
s2 = 120.00  
fywe1 = 694.45  
fywe2 = 555.55  
fce = 33.00

From ((5.A5), TBDY), TBDY: cc = 0.00305417  
c = confinement factor = 1.10542

y1 = 0.00152175  
sh1 = 0.0048696  
ft1 = 479.7871  
fy1 = 399.8226  
su1 = 0.0066488

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

lo/lou,min = lb/ld = 0.33981258  
su1 = 0.4\*esu1\_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu1\_nominal = 0.08,

For calculation of esu1\_nominal and y1, sh1,ft1,fy1, it is considered  
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.

with fs1 = (fs,jacket\*Asl,ten,jacket + fs,core\*Asl,ten,core)/Asl,ten = 399.8226

with Es1 = (Es,jacket\*Asl,ten,jacket + Es,core\*Asl,ten,core)/Asl,ten = 200000.00

y2 = 0.00152175  
sh2 = 0.0048696  
ft2 = 479.7871  
fy2 = 399.8226  
su2 = 0.0066488

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

lo/lou,min = lb/lb,min = 0.33981258  
su2 = 0.4\*esu2\_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu2\_nominal = 0.08,

For calculation of esu2\_nominal and y2, sh2,ft2,fy2, it is considered  
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.

with fs2 = (fs,jacket\*Asl,com,jacket + fs,core\*Asl,com,core)/Asl,com = 399.8226

with Es2 = (Es,jacket\*Asl,com,jacket + Es,core\*Asl,com,core)/Asl,com = 200000.00

yv = 0.00152175  
shv = 0.0048696  
ftv = 507.2537  
fyv = 422.7114  
suv = 0.0066488

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

lo/lou,min = lb/ld = 0.33981258  
suv = 0.4\*esuv\_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esuv\_nominal = 0.08,

considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY

For calculation of esuv\_nominal and yv, shv,ftv,fyv, it is considered  
characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.

with fsv = (fs,jacket\*Asl,mid,jacket + fs,mid\*Asl,mid,core)/Asl,mid = 422.7114

with Esv = (Es,jacket\*Asl,mid,jacket + Es,mid\*Asl,mid,core)/Asl,mid = 200000.00

1 = Asl,ten/(b\*d)\*(fs1/fc) = 0.0752324

2 = Asl,com/(b\*d)\*(fs2/fc) = 0.0752324

v = Asl,mid/(b\*d)\*(fsv/fc) = 0.02812438

and confined core properties:

$b = 390.00$   
 $d = 377.00$   
 $d' = 13.00$   
 $f_{cc} (5A.2, TBDY) = 36.47874$   
 $cc (5A.5, TBDY) = 0.00305417$   
 $c = \text{confinement factor} = 1.10542$   
 $1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.09371431$   
 $2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.09371431$   
 $v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.03503353$   
 Case/Assumption: Unconfined full section - Steel rupture  
 ' satisfies Eq. (4.3)

--->  
 $v < v_{s,y2}$  - LHS eq.(4.5) is satisfied  
 --->  
 $su (4.9) = 0.16791801$   
 $Mu = MRc (4.14) = 2.2193E+008$   
 $u = su (4.1) = 1.9632832E-005$

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

-----  
 Lap Length:  $l_b/l_d = 0.33981258$

$l_b = 300.00$

$l_d = 882.8396$

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

$= 1$   
 $db = 16.66667$   
 Mean strength value of all re-bars:  $f_y = 655.558$   
 Mean concrete strength:  $f'_c = (f'_{c,jacket} * Area_{jacket} + f'_{c,core} * Area_{core}) / Area_{section} = 28.98765$ , but  $f_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)  
 $t = 1.00$   
 $s = 0.80$   
 $e = 1.00$   
 $cb = 25.00$   
 $K_{tr} = 2.86234$   
 $A_{tr} = \text{Min}(A_{tr,x}, A_{tr,y}) = 257.6106$   
 where  $A_{tr,x}, A_{tr,y}$  are the sum of the area of all stirrup legs along X and Y local axis  
 $s = \text{Max}(s_{external}, s_{internal}) = 300.00$   
 $n = 12.00$

-----  
 Calculation of Shear Strength  $V_r = \text{Min}(V_{r1}, V_{r2}) = 567563.724$

-----  
 Calculation of Shear Strength at edge 1,  $V_{r1} = 567563.724$

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

$V_{Col0} = 567563.724$

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

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

$= 1$  (normal-weight concrete)  
 Mean concrete strength:  $f'_c = (f'_{c,jacket} * Area_{jacket} + f'_{c,core} * Area_{core}) / Area_{section} = 28.98765$ , but  $f_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)  
 $M/Vd = 2.00$   
 $Mu = 1.4404090E-011$   
 $Vu = 2.0531359E-031$   
 $d = 0.8 * h = 360.00$   
 $Nu = 7506.808$   
 $Ag = 202500.00$   
 From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 144280.365$   
 where:  
 $V_{s1} = 69813.729$  is calculated for jacket, with:  
 $d = 360.00$   
 $A_v = 157079.633$

$f_y = 555.56$   
 $s = 300.00$   
 $V_{s1}$  is multiplied by  $Col1 = 0.66666667$   
 $s/d = 0.83333333$   
 $V_{s2} = 74466.637$  is calculated for core, with:  
 $d = 200.00$   
 $A_v = 100530.965$   
 $f_y = 444.44$   
 $s = 120.00$   
 $V_{s2}$  is multiplied by  $Col2 = 1.00$   
 $s/d = 0.60$   
 $V_f$  ((11-3)-(11.4), ACI 440) = 214457.247  
 $f = 0.95$ , for fully-wrapped sections  
 $w_f/s_f = 1$  (FRP strips adjacent to one another).  
 In (11.3)  $\sin + \cos$  is replaced with  $(\cot + \cot a)\sin a$  which is more a generalised expression,  
 where  $a$  is the angle of the crack direction (see KANEPE).  
 This later relation, considered as a function  $V_f(\theta, a)$ , is implemented for every different fiber orientation  $a_i$ ,  
 as well as for 2 crack directions,  $\theta = 45^\circ$  and  $\theta = -45^\circ$  to take into consideration the cyclic seismic loading.  
 orientation 1:  $\theta = b1 + 90^\circ = 90.00$   
 $V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, a1)|)$ , with:  
 total thickness per orientation,  $t_{f1} = NL * t / \text{NoDir} = 1.016$   
 $d_{fv} = d$  (figure 11.2, ACI 440) = 407.00  
 $f_{fe}$  ((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:  $V_s + V_f \leq 579413.096$   
 $b_w = 450.00$

Calculation of Shear Strength at edge 2,  $V_{r2} = 567563.724$   
 $V_{r2} = V_{Col}$  ((10.3), ASCE 41-17) =  $k_{nl} * V_{Col0}$   
 $V_{Col0} = 567563.724$   
 $k_{nl} = 1$  (zero step-static loading)

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

$\rho = 1$  (normal-weight concrete)  
 Mean concrete strength:  $f'_c = (f'_{c,jacket} * Area_{jacket} + f'_{c,core} * Area_{core}) / Area_{section} = 28.98765$ , but  $f_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)  
 $M/Vd = 2.00$   
 $M_u = 1.4404090E-011$   
 $V_u = 2.0531359E-031$   
 $d = 0.8 * h = 360.00$   
 $N_u = 7506.808$   
 $A_g = 202500.00$   
 From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 144280.365$   
 where:  
 $V_{s1} = 69813.729$  is calculated for jacket, with:  
 $d = 360.00$   
 $A_v = 157079.633$   
 $f_y = 555.56$   
 $s = 300.00$   
 $V_{s1}$  is multiplied by  $Col1 = 0.66666667$   
 $s/d = 0.83333333$   
 $V_{s2} = 74466.637$  is calculated for core, with:  
 $d = 200.00$   
 $A_v = 100530.965$   
 $f_y = 444.44$   
 $s = 120.00$   
 $V_{s2}$  is multiplied by  $Col2 = 1.00$   
 $s/d = 0.60$   
 $V_f$  ((11-3)-(11.4), ACI 440) = 214457.247  
 $f = 0.95$ , for fully-wrapped sections  
 $w_f/s_f = 1$  (FRP strips adjacent to one another).  
 In (11.3)  $\sin + \cos$  is replaced with  $(\cot + \cot a)\sin a$  which is more a generalised expression,

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

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

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

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

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

$d_{fv} = d$  (figure 11.2, ACI 440) = 407.00

$f_{fe}$  ((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:  $V_s + V_f \leq 579413.096$

$b_w = 450.00$

-----  
End Of Calculation of Shear Capacity ratio for element: column JC1 of floor 1  
At local axis: 3

-----  
Start Of Calculation of Shear Capacity ratio for element: column JC1 of floor 1  
At Shear local axis: 2  
(Bending local axis: 3)  
Section Type: rcjrs

Constant Properties

-----  
Knowledge Factor,  $\gamma = 0.85$

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 Height,  $H = 450.00$

External Width,  $W = 450.00$

Internal Height,  $H = 250.00$

Internal Width,  $W = 250.00$

Cover Thickness,  $c = 25.00$

Mean Confinement Factor overall section = 1.10542

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,  $NoDir = 1$   
Fiber orientations,  $bi = 0.00^\circ$   
Number of layers,  $NL = 1$   
Radius of rounding corners,  $R = 40.00$

#### Stepwise Properties

At local axis: 2  
EDGE -A-  
Shear Force,  $V_a = -2.7162834E-031$   
EDGE -B-  
Shear Force,  $V_b = 2.7162834E-031$   
BOTH EDGES  
Axial Force,  $F = -7506.808$   
Longitudinal Reinforcement Area Distribution (in 2 divisions)  
-Tension:  $As_t = 0.00$   
-Compression:  $As_c = 2676.637$   
Longitudinal Reinforcement Area Distribution (in 3 divisions)  
-Tension:  $As_{t,ten} = 1137.257$   
-Compression:  $As_{l,com} = 1137.257$   
-Middle:  $As_{l,mid} = 402.1239$

Calculation of Shear Capacity ratio,  $V_e/V_r = 0.26068017$   
Member Controlled by Flexure ( $V_e/V_r < 1$ )  
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 147952.607$   
with

$M_{pr1} = \text{Max}(\mu_{1+}, \mu_{1-}) = 2.2193E+008$

$\mu_{1+} = 2.2193E+008$ , 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

$\mu_{1-} = 2.2193E+008$ , 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

$M_{pr2} = \text{Max}(\mu_{2+}, \mu_{2-}) = 2.2193E+008$

$\mu_{2+} = 2.2193E+008$ , 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

$\mu_{2-} = 2.2193E+008$ , 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 curvature  $\mu$  according to 4.1, Biskinis/Fardis 2013:

$\mu = 1.9632832E-005$

$\mu_u = 2.2193E+008$

with full section properties:

$b = 450.00$

$d = 407.00$

$d' = 43.00$

$v = 0.00124204$

$N = 7506.808$

$f_c = 33.00$

$\alpha_1 = 0.85$  (5A.5, TBDY) = 0.002

Final value of  $\mu_u$ :  $\mu_u^* = \text{shear\_factor} * \text{Max}(\mu_u, \mu_c) = 0.01393923$

The Shear\_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY:  $\mu_u = 0.01393923$

where  $\mu_u = \alpha_1 * \rho_f * f_{fe} / f_{ce} + \text{Min}(\mu_{fx}, \mu_{fy}) = 0.06811101$

where  $\mu_f = \alpha_1 * \rho_f * f_{fe} / f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$\mu_{fx} = 0.06628267$

af = 0.54930041  
b = 450.00  
h = 450.00  
From EC8 A.4.4.3(6),  $pf = 2tf/bw = 0.00451556$   
bw = 450.00  
effective stress from (A.35),  $ff,e = 881.8461$

fy = 0.06628267  
af = 0.54930041  
b = 450.00  
h = 450.00  
From EC8 A.4.4.3(6),  $pf = 2tf/bw = 0.00451556$   
bw = 450.00  
effective stress from (A.35),  $ff,e = 881.8461$

R = 40.00  
Effective FRP thickness,  $tf = NL*t*Cos(b1) = 1.016$   
fu,f = 1055.00  
Ef = 64828.00  
u,f = 0.015  
ase ((5.4d), TBDY) =  $(ase1*Aext+ase2*Aint)/Asec = 0.14546167$   
ase1 = 0.12623274  
bo\_1 = 390.00  
ho\_1 = 390.00  
bi2\_1 = 608400.00  
ase2 =  $Max(ase1,ase2) = 0.18853448$   
bo\_2 = 242.00  
ho\_2 = 242.00  
bi2\_2 = 234256.00

psh,min\*Fywe =  $Min(psh,x*Fywe, psh,y*Fywe) = 1.38262$   
Expression ((5.4d), TBDY) for psh,min\*Fywe has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

psh\_x\*Fywe =  $psh1*Fywe1+ps2*Fywe2 = 1.38262$   
ps1 (external) =  $(Ash1*h1/s1)/Asec = 0.00116355$   
Ash1 =  $Astir_1*ns_1 = 157.0796$   
No stirrups, ns\_1 = 2.00  
h1 = 450.00  
ps2 (internal) =  $(Ash2*h2/s2)/Asec = 0.00103427$   
Ash2 =  $Astir_2*ns_2 = 100.531$   
No stirrups, ns\_2 = 2.00  
h2 = 250.00

psh\_y\*Fywe =  $psh1*Fywe1+ps2*Fywe2 = 1.38262$   
ps1 (external) =  $(Ash1*h1/s1)/Asec = 0.00116355$   
Ash1 =  $Astir_1*ns_1 = 157.0796$   
No stirrups, ns\_1 = 2.00  
h1 = 450.00  
ps2 (internal) =  $(Ash2*h2/s2)/Asec = 0.00103427$   
Ash2 =  $Astir_2*ns_2 = 100.531$   
No stirrups, ns\_2 = 2.00  
h2 = 250.00

Asec = 202500.00  
s1 = 300.00  
s2 = 120.00  
fywe1 = 694.45  
fywe2 = 555.55  
fce = 33.00

From ((5.A5), TBDY), TBDY:  $cc = 0.00305417$   
c = confinement factor = 1.10542

y1 = 0.00152175  
sh1 = 0.0048696  
ft1 = 479.7871  
fy1 = 399.8226  
su1 = 0.0066488

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor

and also multiplied by the shear\_factor according to 15.7.1.4, with

Shear\_factor = 1.00

$l_o/l_{ou,min} = l_b/l_d = 0.33981258$

$su_1 = 0.4 * esu_{1,nominal} ((5.5), TBDY) = 0.032$

From table 5A.1, TBDY:  $esu_{1,nominal} = 0.08$ ,

For calculation of  $esu_{1,nominal}$  and  $y_1, sh_1, ft_1, fy_1$ , it is considered characteristic value  $fsy_1 = fs_1/1.2$ , from table 5.1, TBDY.

$y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.

with  $fs_1 = (f_s,jacket * A_{s,ten,jacket} + f_s,core * A_{s,ten,core}) / A_{s,ten} = 399.8226$

with  $Es_1 = (E_s,jacket * A_{s,ten,jacket} + E_s,core * A_{s,ten,core}) / A_{s,ten} = 200000.00$

$y_2 = 0.00152175$

$sh_2 = 0.0048696$

$ft_2 = 479.7871$

$fy_2 = 399.8226$

$su_2 = 0.0066488$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor

and also multiplied by the shear\_factor according to 15.7.1.4, with

Shear\_factor = 1.00

$l_o/l_{ou,min} = l_b/l_{b,min} = 0.33981258$

$su_2 = 0.4 * esu_{2,nominal} ((5.5), TBDY) = 0.032$

From table 5A.1, TBDY:  $esu_{2,nominal} = 0.08$ ,

For calculation of  $esu_{2,nominal}$  and  $y_2, sh_2, ft_2, fy_2$ , it is considered characteristic value  $fsy_2 = fs_2/1.2$ , from table 5.1, TBDY.

$y_2, sh_2, ft_2, fy_2$ , are also multiplied by  $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.

with  $fs_2 = (f_s,jacket * A_{s,com,jacket} + f_s,core * A_{s,com,core}) / A_{s,com} = 399.8226$

with  $Es_2 = (E_s,jacket * A_{s,com,jacket} + E_s,core * A_{s,com,core}) / A_{s,com} = 200000.00$

$y_v = 0.00152175$

$sh_v = 0.0048696$

$ft_v = 507.2537$

$fy_v = 422.7114$

$suv = 0.0066488$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor

and also multiplied by the shear\_factor according to 15.7.1.4, with

Shear\_factor = 1.00

$l_o/l_{ou,min} = l_b/l_d = 0.33981258$

$suv = 0.4 * esuv_{nominal} ((5.5), TBDY) = 0.032$

From table 5A.1, TBDY:  $esuv_{nominal} = 0.08$ ,

considering characteristic value  $fsyv = fsv/1.2$ , from table 5.1, TBDY

For calculation of  $esuv_{nominal}$  and  $y_v, sh_v, ft_v, fy_v$ , it is considered characteristic value  $fsyv = fsv/1.2$ , from table 5.1, TBDY.

$y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.

with  $fsv = (f_s,jacket * A_{s,mid,jacket} + f_s,mid * A_{s,mid,core}) / A_{s,mid} = 422.7114$

with  $Esv = (E_s,jacket * A_{s,mid,jacket} + E_s,mid * A_{s,mid,core}) / A_{s,mid} = 200000.00$

$1 = A_{s,ten} / (b * d) * (f_s1 / f_c) = 0.0752324$

$2 = A_{s,com} / (b * d) * (f_s2 / f_c) = 0.0752324$

$v = A_{s,mid} / (b * d) * (fsv / f_c) = 0.02812438$

and confined core properties:

$b = 390.00$

$d = 377.00$

$d' = 13.00$

$f_{cc} (5A.2, TBDY) = 36.47874$

$cc (5A.5, TBDY) = 0.00305417$

$c = \text{confinement factor} = 1.10542$

$1 = A_{s,ten} / (b * d) * (f_s1 / f_c) = 0.09371431$

$2 = A_{s,com} / (b * d) * (f_s2 / f_c) = 0.09371431$

$v = A_{s,mid} / (b * d) * (fsv / f_c) = 0.03503353$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < v_{s,y2}$  - LHS eq.(4.5) is satisfied

--->

$su (4.9) = 0.16791801$

$Mu = MRc (4.14) = 2.2193E+008$

$u = su (4.1) = 1.9632832E-005$

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

Lap Length:  $l_b/l_d = 0.33981258$

$l_b = 300.00$

$l_d = 882.8396$

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

$= 1$

$db = 16.66667$

Mean strength value of all re-bars:  $f_y = 655.558$

Mean concrete strength:  $f_c' = (f_c'_{jacket} \cdot Area_{jacket} + f_c'_{core} \cdot Area_{core}) / Area_{section} = 28.98765$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 2.86234$

$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 257.6106$

where  $A_{tr_x}$ ,  $A_{tr_y}$  are the sum of the area of all stirrup legs along X and Y local axis

$s = \text{Max}(s_{external}, s_{internal}) = 300.00$

$n = 12.00$

Calculation of  $\mu_{u1}$ -

Calculation of ultimate curvature  $\mu_u$  according to 4.1, Biskinis/Fardis 2013:

$\mu_u = 1.9632832E-005$

$\mu_u = 2.2193E+008$

with full section properties:

$b = 450.00$

$d = 407.00$

$d' = 43.00$

$v = 0.00124204$

$N = 7506.808$

$f_c = 33.00$

$\alpha_1 = 0.85$  (5A.5, TBDY) = 0.002

Final value of  $\mu_u$ :  $\mu_u^* = \text{shear\_factor} \cdot \text{Max}(\mu_u, \mu_{cc}) = 0.01393923$

The Shear\_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY:  $\mu_u = 0.01393923$

where  $\mu_u = \alpha_1 \cdot \text{Min}(f_{ywe}/f_{ce} + \text{Min}(f_x, f_y)) = 0.06811101$

where  $f = \alpha_1 \cdot \text{Min}(f_{ywe}/f_{ce} + \text{Min}(f_x, f_y))$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$f_x = 0.06628267$

$\alpha_1 = 0.54930041$

$b = 450.00$

$h = 450.00$

From EC8 A.4.4.3(6),  $\alpha_1 = 2t_f/bw = 0.00451556$

$bw = 450.00$

effective stress from (A.35),  $f_{ywe} = 881.8461$

$f_y = 0.06628267$

$\alpha_1 = 0.54930041$

$b = 450.00$

$h = 450.00$

From EC8 A.4.4.3(6),  $\alpha_1 = 2t_f/bw = 0.00451556$

$bw = 450.00$

effective stress from (A.35),  $f_{ywe} = 881.8461$

$R = 40.00$

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

$f_u = 1055.00$

$E_f = 64828.00$

$u_f = 0.015$

$\alpha_{se} = ((5.4d), TBDY) = (\alpha_{se1} \cdot A_{ext} + \alpha_{se2} \cdot A_{int}) / A_{sec} = 0.14546167$

$\alpha_{se1} = 0.12623274$

bo\_1 = 390.00  
ho\_1 = 390.00  
bi2\_1 = 608400.00  
ase2 = Max(ase1,ase2) = 0.18853448  
bo\_2 = 242.00  
ho\_2 = 242.00  
bi2\_2 = 234256.00

psh,min\*Fywe = Min(psh,x\*Fywe , psh,y\*Fywe) = 1.38262

Expression ((5.4d), TBDY) for psh,min\*Fywe has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

psh\_x\*Fywe = psh1\*Fywe1+ps2\*Fywe2 = 1.38262  
ps1 (external) = (Ash1\*h1/s1)/Asec = 0.00116355  
Ash1 = Astir\_1\*ns\_1 = 157.0796  
No stirrups, ns\_1 = 2.00  
h1 = 450.00  
ps2 (internal) = (Ash2\*h2/s2)/Asec = 0.00103427  
Ash2 = Astir\_2\*ns\_2 = 100.531  
No stirrups, ns\_2 = 2.00  
h2 = 250.00

psh\_y\*Fywe = psh1\*Fywe1+ps2\*Fywe2 = 1.38262  
ps1 (external) = (Ash1\*h1/s1)/Asec = 0.00116355  
Ash1 = Astir\_1\*ns\_1 = 157.0796  
No stirrups, ns\_1 = 2.00  
h1 = 450.00  
ps2 (internal) = (Ash2\*h2/s2)/Asec = 0.00103427  
Ash2 = Astir\_2\*ns\_2 = 100.531  
No stirrups, ns\_2 = 2.00  
h2 = 250.00

Asec = 202500.00

s1 = 300.00

s2 = 120.00

fywe1 = 694.45

fywe2 = 555.55

fce = 33.00

From ((5.A5), TBDY), TBDY: cc = 0.00305417

c = confinement factor = 1.10542

y1 = 0.00152175

sh1 = 0.0048696

ft1 = 479.7871

fy1 = 399.8226

su1 = 0.0066488

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

lo/lou,min = lb/lb = 0.33981258

su1 = 0.4\*esu1\_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu1\_nominal = 0.08,

For calculation of esu1\_nominal and y1, sh1,ft1,fy1, it is considered  
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25\*(lb/lb)^ 2/3), from 10.3.5, ASCE 41-17.

with fs1 = (fs,jacket\*Asl,ten,jacket + fs,core\*Asl,ten,core)/Asl,ten = 399.8226

with Es1 = (Es,jacket\*Asl,ten,jacket + Es,core\*Asl,ten,core)/Asl,ten = 200000.00

y2 = 0.00152175

sh2 = 0.0048696

ft2 = 479.7871

fy2 = 399.8226

su2 = 0.0066488

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

lo/lou,min = lb/lb,min = 0.33981258

su2 = 0.4\*esu2\_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu2\_nominal = 0.08,

For calculation of esu2\_nominal and y2, sh2,ft2,fy2, it is considered

characteristic value  $f_{s2} = f_{s2}/1.2$ , from table 5.1, TBDY.

$y_1, sh_1, ft_1, f_{y1}$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.

with  $f_{s2} = (f_{s,jacket} \cdot A_{s1,com,jacket} + f_{s,core} \cdot A_{s1,com,core})/A_{s1,com} = 399.8226$

with  $E_{s2} = (E_{s,jacket} \cdot A_{s1,com,jacket} + E_{s,core} \cdot A_{s1,com,core})/A_{s1,com} = 200000.00$

$y_v = 0.00152175$

$sh_v = 0.0048696$

$ft_v = 507.2537$

$f_{y_v} = 422.7114$

$s_{u_v} = 0.0066488$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor

and also multiplied by the shear\_factor according to 15.7.1.4, with

Shear\_factor = 1.00

$l_o/l_{o,min} = l_b/l_d = 0.33981258$

$s_{u_v} = 0.4 \cdot e_{s_{u_v,nominal}} ((5.5), TBDY) = 0.032$

From table 5A.1, TBDY:  $e_{s_{u_v,nominal}} = 0.08$ ,

considering characteristic value  $f_{s_{y_v}} = f_{s_{y_v}}/1.2$ , from table 5.1, TBDY

For calculation of  $e_{s_{u_v,nominal}}$  and  $y_v, sh_v, ft_v, f_{y_v}$ , it is considered

characteristic value  $f_{s_{y_v}} = f_{s_{y_v}}/1.2$ , from table 5.1, TBDY.

$y_1, sh_1, ft_1, f_{y1}$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.

with  $f_{s_{y_v}} = (f_{s,jacket} \cdot A_{s1,mid,jacket} + f_{s,mid} \cdot A_{s1,mid,core})/A_{s1,mid} = 422.7114$

with  $E_{s_{y_v}} = (E_{s,jacket} \cdot A_{s1,mid,jacket} + E_{s,mid} \cdot A_{s1,mid,core})/A_{s1,mid} = 200000.00$

$1 = A_{s1,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.0752324$

$2 = A_{s1,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.0752324$

$v = A_{s1,mid}/(b \cdot d) \cdot (f_{s_{y_v}}/f_c) = 0.02812438$

and confined core properties:

$b = 390.00$

$d = 377.00$

$d' = 13.00$

$f_{cc} (5A.2, TBDY) = 36.47874$

$cc (5A.5, TBDY) = 0.00305417$

$c = \text{confinement factor} = 1.10542$

$1 = A_{s1,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.09371431$

$2 = A_{s1,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.09371431$

$v = A_{s1,mid}/(b \cdot d) \cdot (f_{s_{y_v}}/f_c) = 0.03503353$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < v_{s,y2}$  - LHS eq.(4.5) is satisfied

--->

$s_u (4.9) = 0.16791801$

$\mu_u = MR_c (4.14) = 2.2193E+008$

$u = s_u (4.1) = 1.9632832E-005$

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

Lap Length:  $l_b/l_d = 0.33981258$

$l_b = 300.00$

$l_d = 882.8396$

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

= 1

$d_b = 16.66667$

Mean strength value of all re-bars:  $f_y = 655.558$

Mean concrete strength:  $f'_c = (f'_{c,jacket} \cdot Area_{jacket} + f'_{c,core} \cdot Area_{core})/Area_{section} = 28.98765$ , but  $f_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 2.86234$

$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 257.6106$

where  $A_{tr_x}, A_{tr_y}$  are the sum of the area of all stirrup legs along X and Y local axis

$s = \text{Max}(s_{external}, s_{internal}) = 300.00$

$n = 12.00$

Calculation of  $\mu_{2+}$

Calculation of ultimate curvature  $\mu$  according to 4.1, Biskinis/Fardis 2013:

$$u = 1.9632832E-005$$

$$\mu = 2.2193E+008$$

with full section properties:

$$b = 450.00$$

$$d = 407.00$$

$$d' = 43.00$$

$$v = 0.00124204$$

$$N = 7506.808$$

$$f_c = 33.00$$

$$c_o (5A.5, TBDY) = 0.002$$

$$\text{Final value of } c_u: c_u^* = \text{shear\_factor} * \text{Max}(c_u, c_c) = 0.01393923$$

The Shear\_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } c_u = 0.01393923$$

$$w_e ((5.4c), TBDY) = a_s e^* s_{h,\min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.06811101$$

where  $f = a_f * p_f * f_{fe} / f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.06628267$$

$$a_f = 0.54930041$$

$$b = 450.00$$

$$h = 450.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.00451556$$

$$b_w = 450.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 881.8461$$

$$f_y = 0.06628267$$

$$a_f = 0.54930041$$

$$b = 450.00$$

$$h = 450.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.00451556$$

$$b_w = 450.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 881.8461$$

$$R = 40.00$$

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

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$a_s e ((5.4d), TBDY) = (a_{s1} * A_{ext} + a_{s2} * A_{int}) / A_{sec} = 0.14546167$$

$$a_{s1} = 0.12623274$$

$$b_{o,1} = 390.00$$

$$h_{o,1} = 390.00$$

$$b_{i,2,1} = 608400.00$$

$$a_{s2} = \text{Max}(a_{s1}, a_{s2}) = 0.18853448$$

$$b_{o,2} = 242.00$$

$$h_{o,2} = 242.00$$

$$b_{i,2,2} = 234256.00$$

$$p_{sh,\min} * F_{ywe} = \text{Min}(p_{sh,x} * F_{ywe}, p_{sh,y} * F_{ywe}) = 1.38262$$

Expression ((5.4d), TBDY) for  $p_{sh,\min} * F_{ywe}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$$p_{sh,x} * F_{ywe} = p_{s1} * F_{ywe1} + p_{s2} * F_{ywe2} = 1.38262$$

$$p_{s1} (\text{external}) = (A_{sh1} * h_1 / s_1) / A_{sec} = 0.00116355$$

$$A_{sh1} = A_{stir,1} * n_{s,1} = 157.0796$$

$$\text{No stirrups, } n_{s,1} = 2.00$$

$$h_1 = 450.00$$

$$p_{s2} (\text{internal}) = (A_{sh2} * h_2 / s_2) / A_{sec} = 0.00103427$$

$$A_{sh2} = A_{stir,2} * n_{s,2} = 100.531$$

$$\text{No stirrups, } n_{s,2} = 2.00$$

$$h_2 = 250.00$$

$$p_{sh,y} * F_{ywe} = p_{s1} * F_{ywe1} + p_{s2} * F_{ywe2} = 1.38262$$

$$ps1 \text{ (external)} = (Ash1 \cdot h1 / s1) / Asec = 0.00116355$$

$$Ash1 = Astir_1 \cdot ns_1 = 157.0796$$

$$\text{No stirups, } ns_1 = 2.00$$

$$h1 = 450.00$$

$$ps2 \text{ (internal)} = (Ash2 \cdot h2 / s2) / Asec = 0.00103427$$

$$Ash2 = Astir_2 \cdot ns_2 = 100.531$$

$$\text{No stirups, } ns_2 = 2.00$$

$$h2 = 250.00$$

---

$$Asec = 202500.00$$

$$s1 = 300.00$$

$$s2 = 120.00$$

$$fywe1 = 694.45$$

$$fywe2 = 555.55$$

$$fce = 33.00$$

$$\text{From } ((5.A5), \text{ TBDY}), \text{ TBDY: } cc = 0.00305417$$

$$c = \text{confinement factor} = 1.10542$$

$$y1 = 0.00152175$$

$$sh1 = 0.0048696$$

$$ft1 = 479.7871$$

$$fy1 = 399.8226$$

$$su1 = 0.0066488$$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

$$lo/lou, \text{min} = lb/d = 0.33981258$$

$$su1 = 0.4 \cdot esu1_{\text{nominal}} ((5.5), \text{ TBDY}) = 0.032$$

$$\text{From table 5A.1, TBDY: } esu1_{\text{nominal}} = 0.08,$$

For calculation of  $esu1_{\text{nominal}}$  and  $y1, sh1, ft1, fy1$ , it is considered  
characteristic value  $fsy1 = fs1/1.2$ , from table 5.1, TBDY.

$$y1, sh1, ft1, fy1, \text{ are also multiplied by } \text{Min}(1, 1.25 \cdot (lb/d)^{2/3}), \text{ from 10.3.5, ASCE 41-17.}$$

$$\text{with } fs1 = (fs_{\text{jacket}} \cdot Asl, \text{ten, jacket} + fs_{\text{core}} \cdot Asl, \text{ten, core}) / Asl, \text{ten} = 399.8226$$

$$\text{with } Es1 = (Es_{\text{jacket}} \cdot Asl, \text{ten, jacket} + Es_{\text{core}} \cdot Asl, \text{ten, core}) / Asl, \text{ten} = 200000.00$$

$$y2 = 0.00152175$$

$$sh2 = 0.0048696$$

$$ft2 = 479.7871$$

$$fy2 = 399.8226$$

$$su2 = 0.0066488$$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

$$lo/lou, \text{min} = lb/lb, \text{min} = 0.33981258$$

$$su2 = 0.4 \cdot esu2_{\text{nominal}} ((5.5), \text{ TBDY}) = 0.032$$

$$\text{From table 5A.1, TBDY: } esu2_{\text{nominal}} = 0.08,$$

For calculation of  $esu2_{\text{nominal}}$  and  $y2, sh2, ft2, fy2$ , it is considered  
characteristic value  $fsy2 = fs2/1.2$ , from table 5.1, TBDY.

$$y1, sh1, ft1, fy1, \text{ are also multiplied by } \text{Min}(1, 1.25 \cdot (lb/d)^{2/3}), \text{ from 10.3.5, ASCE 41-17.}$$

$$\text{with } fs2 = (fs_{\text{jacket}} \cdot Asl, \text{com, jacket} + fs_{\text{core}} \cdot Asl, \text{com, core}) / Asl, \text{com} = 399.8226$$

$$\text{with } Es2 = (Es_{\text{jacket}} \cdot Asl, \text{com, jacket} + Es_{\text{core}} \cdot Asl, \text{com, core}) / Asl, \text{com} = 200000.00$$

$$yv = 0.00152175$$

$$shv = 0.0048696$$

$$ftv = 507.2537$$

$$fyv = 422.7114$$

$$suv = 0.0066488$$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

$$lo/lou, \text{min} = lb/d = 0.33981258$$

$$suv = 0.4 \cdot esuv_{\text{nominal}} ((5.5), \text{ TBDY}) = 0.032$$

$$\text{From table 5A.1, TBDY: } esuv_{\text{nominal}} = 0.08,$$

considering characteristic value  $fsyv = fsv/1.2$ , from table 5.1, TBDY  
For calculation of  $esuv_{\text{nominal}}$  and  $yv, shv, ftv, fyv$ , it is considered  
characteristic value  $fsyv = fsv/1.2$ , from table 5.1, TBDY.

$$y1, sh1, ft1, fy1, \text{ are also multiplied by } \text{Min}(1, 1.25 \cdot (lb/d)^{2/3}), \text{ from 10.3.5, ASCE 41-17.}$$

$$\text{with } fsv = (fs_{\text{jacket}} \cdot Asl, \text{mid, jacket} + fs_{\text{mid}} \cdot Asl, \text{mid, core}) / Asl, \text{mid} = 422.7114$$

$$\text{with } Esv = (Es_{\text{jacket}} \cdot Asl, \text{mid, jacket} + Es_{\text{mid}} \cdot Asl, \text{mid, core}) / Asl, \text{mid} = 200000.00$$

$$1 = Asl, \text{ten} / (b \cdot d) \cdot (fs1 / fce) = 0.0752324$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.0752324$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.02812438$$

and confined core properties:

$$b = 390.00$$

$$d = 377.00$$

$$d' = 13.00$$

$$f_{cc} (5A.2, TBDY) = 36.47874$$

$$c_c (5A.5, TBDY) = 0.00305417$$

$$c = \text{confinement factor} = 1.10542$$

$$1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.09371431$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.09371431$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.03503353$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < v_{s,y2}$  - LHS eq.(4.5) is satisfied

--->

$$s_u (4.9) = 0.16791801$$

$$M_u = M_{Rc} (4.14) = 2.2193E+008$$

$$u = s_u (4.1) = 1.9632832E-005$$

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

Lap Length:  $l_b/d = 0.33981258$

$$l_b = 300.00$$

$$d = 882.8396$$

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

$$= 1$$

$$d_b = 16.66667$$

$$\text{Mean strength value of all re-bars: } f_y = 655.558$$

Mean concrete strength:  $f_c' = (f_c'_{jacket} * \text{Area}_{jacket} + f_c'_{core} * \text{Area}_{core}) / \text{Area}_{section} = 28.98765$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 25.00$$

$$K_{tr} = 2.86234$$

$$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 257.6106$$

where  $A_{tr_x}$ ,  $A_{tr_y}$  are the sum of the area of all stirrup legs along X and Y local axis

$$s = \text{Max}(s_{external}, s_{internal}) = 300.00$$

$$n = 12.00$$

-----  
Calculation of  $M_u$

-----  
Calculation of ultimate curvature  $u$  according to 4.1, Biskinis/Fardis 2013:

$$u = 1.9632832E-005$$

$$M_u = 2.2193E+008$$

-----  
with full section properties:

$$b = 450.00$$

$$d = 407.00$$

$$d' = 43.00$$

$$v = 0.00124204$$

$$N = 7506.808$$

$$f_c = 33.00$$

$$c_o (5A.5, TBDY) = 0.002$$

$$\text{Final value of } c_u: c_u^* = \text{shear\_factor} * \text{Max}(c_u, c_c) = 0.01393923$$

The Shear\_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } c_u = 0.01393923$$

$$w_e ((5.4c), TBDY) = a_{se} * s_{h,min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.06811101$$

where  $f = a_f * p_f * f_{fe}/f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

fx = 0.06628267  
af = 0.54930041  
b = 450.00  
h = 450.00  
From EC8 A 4.4.3(6), pf = 2tf/bw = 0.00451556  
bw = 450.00  
effective stress from (A.35), ff,e = 881.8461

fy = 0.06628267  
af = 0.54930041  
b = 450.00  
h = 450.00  
From EC8 A 4.4.3(6), pf = 2tf/bw = 0.00451556  
bw = 450.00  
effective stress from (A.35), ff,e = 881.8461

R = 40.00  
Effective FRP thickness, tf = NL\*t\*Cos(b1) = 1.016  
fu,f = 1055.00  
Ef = 64828.00  
u,f = 0.015  
ase ((5.4d), TBDY) = (ase1\*Aext+ase2\*Aint)/Asec = 0.14546167  
ase1 = 0.12623274  
bo\_1 = 390.00  
ho\_1 = 390.00  
bi2\_1 = 608400.00  
ase2 = Max(ase1,ase2) = 0.18853448  
bo\_2 = 242.00  
ho\_2 = 242.00  
bi2\_2 = 234256.00

psh,min\*Fywe = Min(psh,x\*Fywe , psh,y\*Fywe) = 1.38262  
Expression ((5.4d), TBDY) for psh,min\*Fywe has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

psh\_x\*Fywe = psh1\*Fywe1+ps2\*Fywe2 = 1.38262  
ps1 (external) = (Ash1\*h1/s1)/Asec = 0.00116355  
Ash1 = Astir\_1\*ns\_1 = 157.0796  
No stirrups, ns\_1 = 2.00  
h1 = 450.00  
ps2 (internal) = (Ash2\*h2/s2)/Asec = 0.00103427  
Ash2 = Astir\_2\*ns\_2 = 100.531  
No stirrups, ns\_2 = 2.00  
h2 = 250.00

psh\_y\*Fywe = psh1\*Fywe1+ps2\*Fywe2 = 1.38262  
ps1 (external) = (Ash1\*h1/s1)/Asec = 0.00116355  
Ash1 = Astir\_1\*ns\_1 = 157.0796  
No stirrups, ns\_1 = 2.00  
h1 = 450.00  
ps2 (internal) = (Ash2\*h2/s2)/Asec = 0.00103427  
Ash2 = Astir\_2\*ns\_2 = 100.531  
No stirrups, ns\_2 = 2.00  
h2 = 250.00

Asec = 202500.00  
s1 = 300.00  
s2 = 120.00  
fywe1 = 694.45  
fywe2 = 555.55  
fce = 33.00

From ((5.A5), TBDY), TBDY: cc = 0.00305417  
c = confinement factor = 1.10542

y1 = 0.00152175  
sh1 = 0.0048696  
ft1 = 479.7871  
fy1 = 399.8226  
su1 = 0.0066488

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

$$l_0/l_{ou,min} = l_b/l_d = 0.33981258$$

$$s_u1 = 0.4 * e_{su1,nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY:  $e_{su1,nominal} = 0.08$ ,

For calculation of  $e_{su1,nominal}$  and  $y_1, sh_1, ft_1, fy_1$ , it is considered  
characteristic value  $f_{sy1} = f_{s1}/1.2$ , from table 5.1, TBDY.

$y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.

$$\text{with } f_{s1} = (f_{s,jacket} * A_{s,ten,jacket} + f_{s,core} * A_{s,ten,core}) / A_{s,ten} = 399.8226$$

$$\text{with } E_{s1} = (E_{s,jacket} * A_{s,ten,jacket} + E_{s,core} * A_{s,ten,core}) / A_{s,ten} = 200000.00$$

$$y_2 = 0.00152175$$

$$sh_2 = 0.0048696$$

$$ft_2 = 479.7871$$

$$fy_2 = 399.8226$$

$$s_u2 = 0.0066488$$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

$$l_0/l_{ou,min} = l_b/l_{b,min} = 0.33981258$$

$$s_u2 = 0.4 * e_{su2,nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY:  $e_{su2,nominal} = 0.08$ ,

For calculation of  $e_{su2,nominal}$  and  $y_2, sh_2, ft_2, fy_2$ , it is considered  
characteristic value  $f_{sy2} = f_{s2}/1.2$ , from table 5.1, TBDY.

$y_2, sh_2, ft_2, fy_2$ , are also multiplied by  $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.

$$\text{with } f_{s2} = (f_{s,jacket} * A_{s,com,jacket} + f_{s,core} * A_{s,com,core}) / A_{s,com} = 399.8226$$

$$\text{with } E_{s2} = (E_{s,jacket} * A_{s,com,jacket} + E_{s,core} * A_{s,com,core}) / A_{s,com} = 200000.00$$

$$y_v = 0.00152175$$

$$sh_v = 0.0048696$$

$$ft_v = 507.2537$$

$$fy_v = 422.7114$$

$$s_{uv} = 0.0066488$$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

$$l_0/l_{ou,min} = l_b/l_d = 0.33981258$$

$$s_{uv} = 0.4 * e_{suv,nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY:  $e_{suv,nominal} = 0.08$ ,

considering characteristic value  $f_{syv} = f_{sv}/1.2$ , from table 5.1, TBDY

For calculation of  $e_{suv,nominal}$  and  $y_v, sh_v, ft_v, fy_v$ , it is considered  
characteristic value  $f_{syv} = f_{sv}/1.2$ , from table 5.1, TBDY.

$y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.

$$\text{with } f_{sv} = (f_{s,jacket} * A_{s,mid,jacket} + f_{s,mid} * A_{s,mid,core}) / A_{s,mid} = 422.7114$$

$$\text{with } E_{sv} = (E_{s,jacket} * A_{s,mid,jacket} + E_{s,mid} * A_{s,mid,core}) / A_{s,mid} = 200000.00$$

$$1 = A_{s,ten} / (b * d) * (f_{s1} / f_c) = 0.0752324$$

$$2 = A_{s,com} / (b * d) * (f_{s2} / f_c) = 0.0752324$$

$$v = A_{s,mid} / (b * d) * (f_{sv} / f_c) = 0.02812438$$

and confined core properties:

$$b = 390.00$$

$$d = 377.00$$

$$d' = 13.00$$

$$f_{cc} (5A.2, TBDY) = 36.47874$$

$$c_c (5A.5, TBDY) = 0.00305417$$

$$c = \text{confinement factor} = 1.10542$$

$$1 = A_{s,ten} / (b * d) * (f_{s1} / f_c) = 0.09371431$$

$$2 = A_{s,com} / (b * d) * (f_{s2} / f_c) = 0.09371431$$

$$v = A_{s,mid} / (b * d) * (f_{sv} / f_c) = 0.03503353$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < v_{s,y2}$  - LHS eq.(4.5) is satisfied

--->

$$s_u (4.9) = 0.16791801$$

$$\mu_u = M_{Rc} (4.14) = 2.2193E+008$$

$$u = s_u (4.1) = 1.9632832E-005$$

Calculation of ratio  $l_b/d$

Lap Length:  $l_b/d = 0.33981258$

$l_b = 300.00$

$d = 882.8396$

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

$\lambda = 1$

$d_b = 16.66667$

Mean strength value of all re-bars:  $f_y = 655.558$

Mean concrete strength:  $f'_c = (f'_{c\_jacket} \cdot Area\_jacket + f'_{c\_core} \cdot Area\_core) / Area\_section = 28.98765$ , but  $f'_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$c_b = 25.00$

$K_{tr} = 2.86234$

$A_{tr} = \min(A_{tr\_x}, A_{tr\_y}) = 257.6106$

where  $A_{tr\_x}$ ,  $A_{tr\_y}$  are the sum of the area of all stirrup legs along X and Y local axis

$s = \max(s_{external}, s_{internal}) = 300.00$

$n = 12.00$

Calculation of Shear Strength  $V_r = \min(V_{r1}, V_{r2}) = 567563.724$

Calculation of Shear Strength at edge 1,  $V_{r1} = 567563.724$

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

$V_{Col0} = 567563.724$

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

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

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

Mean concrete strength:  $f'_c = (f'_{c\_jacket} \cdot Area\_jacket + f'_{c\_core} \cdot Area\_core) / Area\_section = 28.98765$ , but  $f'_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M/d = 2.00$

$M_u = 1.0463738E-012$

$V_u = 2.7162834E-031$

$d = 0.8 \cdot h = 360.00$

$N_u = 7506.808$

$A_g = 202500.00$

From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 144280.365$

where:

$V_{s1} = 69813.729$  is calculated for jacket, with:

$d = 360.00$

$A_v = 157079.633$

$f_y = 555.56$

$s = 300.00$

$V_{s1}$  is multiplied by  $Col1 = 0.66666667$

$s/d = 0.83333333$

$V_{s2} = 74466.637$  is calculated for core, with:

$d = 200.00$

$A_v = 100530.965$

$f_y = 444.44$

$s = 120.00$

$V_{s2}$  is multiplied by  $Col2 = 1.00$

$s/d = 0.60$

$V_f ((11-3)-(11.4), ACI 440) = 214457.247$

$f = 0.95$ , for fully-wrapped sections

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

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

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

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

$V_f = \text{Min}(|V_f(45, 1)|, |V_f(-45, a1)|)$ , with:  
 total thickness per orientation,  $tf1 = NL*t/NoDir = 1.016$   
 $dfv = d$  (figure 11.2, ACI 440) = 407.00  
 $ffe$  ((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:  $V_s + V_f \leq 579413.096$   
 $bw = 450.00$

Calculation of Shear Strength at edge 2,  $Vr2 = 567563.724$   
 $Vr2 = V_{Col}$  ((10.3), ASCE 41-17) =  $knl * V_{Col0}$   
 $V_{Col0} = 567563.724$   
 $knl = 1$  (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:  $fc' = (fc'_{jacket} * Area_{jacket} + fc'_{core} * Area_{core}) / Area_{section} = 28.98765$ , but  $fc'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$   
 $Mu = 1.0463738E-012$   
 $Vu = 2.7162834E-031$   
 $d = 0.8 * h = 360.00$   
 $Nu = 7506.808$   
 $Ag = 202500.00$   
 From (11.5.4.8), ACI 318-14:  $V_s = Vs1 + Vs2 = 144280.365$

where:

$Vs1 = 69813.729$  is calculated for jacket, with:

$d = 360.00$   
 $A_v = 157079.633$   
 $f_y = 555.56$   
 $s = 300.00$

$Vs1$  is multiplied by  $Col1 = 0.66666667$

$s/d = 0.83333333$

$Vs2 = 74466.637$  is calculated for core, with:

$d = 200.00$   
 $A_v = 100530.965$   
 $f_y = 444.44$   
 $s = 120.00$

$Vs2$  is multiplied by  $Col2 = 1.00$

$s/d = 0.60$

$V_f$  ((11-3)-(11.4), ACI 440) = 214457.247

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

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

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

$dfv = d$  (figure 11.2, ACI 440) = 407.00

$ffe$  ((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:  $V_s + V_f \leq 579413.096$

$bw = 450.00$

End Of Calculation of Shear Capacity ratio for element: column JC1 of floor 1  
 At local axis: 2

Start Of Calculation of Chord Rotation Capacity for element: column JC1 of floor 1

At local axis: 2

Integration Section: (a)

Section Type: rcjrs

#### Constant Properties

Knowledge Factor,  $\gamma = 0.85$

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

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

Consequently:

Jacket

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

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,  $E_s = 200000.00$

External Height,  $H = 450.00$

External Width,  $W = 450.00$

Internal Height,  $H = 250.00$

Internal Width,  $W = 250.00$

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,  $ε_{fu} = 0.01$

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

Fiber orientations,  $b_i = 0.00^\circ$

Number of layers,  $N_L = 1$

Radius of rounding corners,  $R = 40.00$

#### Stepwise Properties

Bending Moment,  $M = -3.5391295E-010$

Shear Force,  $V_2 = -7697.601$

Shear Force,  $V_3 = 1.7235006E-013$

Axial Force,  $F = -7503.728$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension:  $As_{t} = 1137.257$

-Compression:  $As_{c} = 1539.38$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension:  $As_{t,ten} = 1137.257$

-Compression:  $As_{c,com} = 1137.257$

-Middle:  $As_{c,mid} = 402.1239$

Longitudinal External Reinforcement Area Distribution (in 3 divisions)

-Tension:  $As_{t,ten,jacket} = 829.3805$

-Compression:  $As_{c,com,jacket} = 829.3805$

-Middle:  $As_{c,mid,jacket} = 402.1239$

Longitudinal Internal Reinforcement Area Distribution (in 3 divisions)

-Tension:  $As_{t,ten,core} = 307.8761$

-Compression:  $A_{sl,com,core} = 307.8761$

-Middle:  $A_{sl,mid,core} = 0.00$

Mean Diameter of Tension Reinforcement,  $DbL = 16.80$

Existing component: From table 7-7, ASCE 41\_17: Final chord rotation Capacity  $u_{,R} = u = 0.0027627$

$u = y + p = 0.00325024$

- Calculation of  $y$  -

$y = (My * L_s / 3) / E_{eff} = 0.00325024$  ((4.29), Biskinis Phd))

$My = 1.7613E+008$

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

From table 10.5, ASCE 41\_17:  $E_{eff} = factor * E_c * I_g = 2.7095E+013$

factor = 0.30

$A_g = 202500.00$

Mean concrete strength:  $fc' = (fc'_{jacket} * Area_{jacket} + fc'_{core} * Area_{core}) / Area_{section} = 28.98765$

$N = 7503.728$

$E_c * I_g = E_c * I_{g,jacket} + E_c * I_{g,core} = 9.0315E+013$

Calculation of Yielding Moment  $My$

Calculation of  $y$  and  $My$  according to Annex 7 -

$y = \text{Min}(y_{ten}, y_{com})$

$y_{ten} = 6.1806747E-006$

with ((10.1), ASCE 41-17)  $f_y = \text{Min}(f_y, 1.25 * f_y * (l_b / d)^{2/3}) = 374.3546$

$d = 407.00$

$y = 0.25591435$

$A = 0.0147239$

$B = 0.00818869$

with  $pt = 0.00430549$

$pc = 0.00620943$

$pv = 0.0021956$

$N = 7503.728$

$b = 450.00$

" = 0.10565111

$y_{comp} = 2.2127278E-005$

with  $fc' (12.3, (ACI 440)) = 34.40847$

$fc = 33.00$

$fl = 0.82797802$

$b = 450.00$

$h = 450.00$

$A_g = 202500.00$

From (12.9), ACI 440:  $k_a = 0.54261599$

$g = pt + pc + pv = 0.01461445$

$rc = 40.00$

$A_e / A_c = 0.54261599$

Effective FRP thickness,  $t_f = NL * t * \text{Cos}(b1) = 1.016$

effective strain from (12.5) and (12.12),  $\epsilon_{fe} = 0.004$

$f_u = 0.01$

$E_f = 64828.00$

$E_c = 26999.444$

$y = 0.25471862$

$A = 0.01452515$

$B = 0.00807924$

with  $E_s = 200000.00$

Calculation of ratio  $l_b / d$

Lap Length:  $l_d/l_{d,min} = 0.42476573$

$l_b = 300.00$

$l_d = 706.2717$

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

$= 1$

$d_b = 16.66667$

Mean strength value of all re-bars:  $f_y = 524.4464$

Mean concrete strength:  $f'_c = (f'_{c,jacket} \cdot Area_{jacket} + f'_{c,core} \cdot Area_{core}) / Area_{section} = 28.98765$ , but  $f_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 2.86234$

$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 257.6106$

where  $A_{tr_x}, A_{tr_y}$  are the sum of the area of all stirrup legs along X and Y local axis

$s = \text{Max}(s_{external}, s_{internal}) = 300.00$

$n = 12.00$

-----  
- Calculation of  $\rho$  -  
-----

From table 10-8:  $\rho = 0.00$

with:

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

shear control ratio  $V_y E / V_{col} E = 0.26068017$

$d = d_{external} = 407.00$

$s = s_{external} = 0.00$

$t = s_1 + s_2 + 2 \cdot t_f / b_w \cdot (f_{fe} / f_s) = 0.00430549$

jacket:  $s_1 = A_{v1} \cdot h_1 / (s_1 \cdot A_g) = 0.00116355$

$A_{v1} = 157.0796$ , is the total area of all stirrups parallel to loading (shear) direction

$h_1 = 450.00$

$s_1 = 300.00$

core:  $s_2 = A_{v2} \cdot h_2 / (s_2 \cdot A_g) = 0.00103427$

$A_{v2} = 100.531$ , is the total area of all stirrups parallel to loading (shear) direction

$h_2 = 250.00$

$s_2 = 120.00$

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.

$N_{UD} = 7503.728$

$A_g = 202500.00$

$f_{cE} = (f_{c,jacket} \cdot Area_{jacket} + f_{c,core} \cdot Area_{core}) / section\_area = 28.98765$

$f_{yE} = (f_{y,ext\_Long\_Reinf} \cdot Area_{ext\_Long\_Reinf} + f_{y,int\_Long\_Reinf} \cdot Area_{int\_Long\_Reinf}) / Area_{Tot\_Long\_Rein} = 529.9972$

$f_{yE} = (f_{y,ext\_Trans\_Reinf} \cdot s_1 + f_{y,int\_Trans\_Reinf} \cdot s_2) / (s_1 + s_2) = 503.2682$

$\rho_l = Area_{Tot\_Long\_Rein} / (b \cdot d) = 0.01461445$

$b = 450.00$

$d = 407.00$

$f_{cE} = 28.98765$

-----  
End Of Calculation of Chord Rotation Capacity for element: column JC1 of floor 1

At local axis: 2

Integration Section: (a)

## Calculation No. 3

column C1, Floor 1

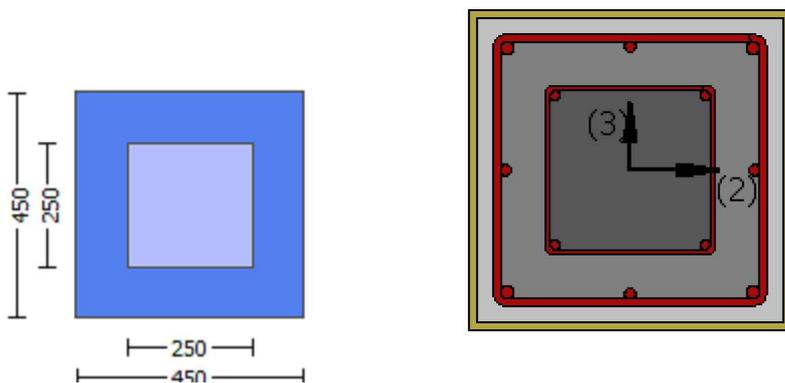
Limit State: Immediate Occupancy (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Shear capacity VRd

Edge: Start

Local Axis: (3)



Start Of Calculation of Shear Capacity for element: column JC1 of floor 1

At local axis: 3

Integration Section: (a)

Section Type: rcjrs

Constant Properties

Knowledge Factor,  $\gamma = 0.85$

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  $\gamma$  for displacement ductility demand, the expected (mean value) strengths are used (7.5.1.3, ASCE 41-17) because bending is considered as Deformation-Controlled Action (Table C7-1, ASCE 41-17).

Jacket

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

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

Existing Column

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

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

#####

External Height, H = 450.00  
 External Width, W = 450.00  
 Internal Height, H = 250.00  
 Internal Width, W = 250.00  
 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,  $M_a = -3.5391295E-010$   
 Shear Force,  $V_a = 1.7235006E-013$   
 EDGE -B-  
 Bending Moment,  $M_b = -1.6313530E-010$   
 Shear Force,  $V_b = -1.7235006E-013$   
 BOTH EDGES  
 Axial Force, F = -7503.728  
 Longitudinal Reinforcement Area Distribution (in 2 divisions)  
 -Tension:  $As_t = 1137.257$   
 -Compression:  $As_c = 1539.38$   
 Longitudinal Reinforcement Area Distribution (in 3 divisions)  
 -Tension:  $As_{t,ten} = 1137.257$   
 -Compression:  $As_{c,com} = 1137.257$   
 -Middle:  $As_{mid} = 402.1239$   
 Mean Diameter of Tension Reinforcement,  $Db_{L,ten} = 16.80$

Existing component: From table 7-7, ASCE 41\_17: Final Shear Capacity  $V_R = \phi V_n = 447100.515$   
 $V_n ((10.3), ASCE 41-17) = k_n l V_{CoI} = 526000.605$   
 $V_{CoI} = 526000.605$   
 $k_n l = 1.00$   
 displacement\_ductility\_demand = 0.00

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

= 1 (normal-weight concrete)  
 Mean concrete strength:  $f'_c = (f'_{c,jacket} \text{Area}_{jacket} + f'_{c,core} \text{Area}_{core}) / \text{Area}_{section} = 22.22222$ , but  $f_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)  
 $M/Vd = 2.00$   
 $M_u = 3.5391295E-010$   
 $V_u = 1.7235006E-013$   
 $d = 0.8 \cdot h = 360.00$   
 $N_u = 7503.728$   
 $A_g = 202500.00$   
 From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 129852.496$   
 where:

Vs1 = 62831.853 is calculated for jacket, with:

$$d = 360.00$$

$$A_v = 157079.633$$

$$f_y = 500.00$$

$$s = 300.00$$

Vs1 is multiplied by Col1 = 0.66666667

$$s/d = 0.83333333$$

Vs2 = 67020.643 is calculated for core, with:

$$d = 200.00$$

$$A_v = 100530.965$$

$$f_y = 400.00$$

$$s = 120.00$$

Vs2 is multiplied by Col2 = 1.00

$$s/d = 0.60$$

Vf ((11-3)-(11.4), ACI 440) = 214457.247

f = 0.95, for fully-wrapped sections

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

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

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

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

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

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

$d_{fv} = d$  (figure 11.2, ACI 440) = 407.00

$f_{fe}$  ((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:  $V_s + V_f \leq 507312.442$

$$b_w = 450.00$$

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

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

for rotation axis 2 and integ. section (a)

From analysis, chord rotation  $\theta = 5.1751012E-023$

$$y = (M_y * L_s / 3) / E_{eff} = 0.00325024 \text{ ((4.29), Biskinis Phd)}$$

$$M_y = 1.7613E+008$$

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

From table 10.5, ASCE 41\_17:  $E_{eff} = \text{factor} * E_c * I_g = 2.7095E+013$

$$\text{factor} = 0.30$$

$$A_g = 202500.00$$

$$\text{Mean concrete strength: } f_c' = (f_c'_{\text{jacket}} * \text{Area}_{\text{jacket}} + f_c'_{\text{core}} * \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 28.98765$$

$$N = 7503.728$$

$$E_c * I_g = E_{c_{\text{jacket}}} * I_{g_{\text{jacket}}} + E_{c_{\text{core}}} * I_{g_{\text{core}}} = 9.0315E+013$$

Calculation of Yielding Moment  $M_y$

Calculation of  $\delta / y$  and  $M_y$  according to Annex 7 -

$$y = \text{Min}(y_{\text{ten}}, y_{\text{com}})$$

$$y_{\text{ten}} = 6.1806747E-006$$

with ((10.1), ASCE 41-17)  $f_y = \text{Min}(f_y, 1.25 * f_y * (I_b / I_d)^{2/3}) = 374.3546$

$$d = 407.00$$

$$y = 0.25591435$$

$$A = 0.0147239$$

$$B = 0.00818869$$

with  $p_t = 0.00620943$

$$p_c = 0.00620943$$

$$p_v = 0.0021956$$

$$N = 7503.728$$

$b = 450.00$   
 $\mu = 0.10565111$   
 $y_{comp} = 2.2127278E-005$   
 with  $fc^*$  (12.3, (ACI 440)) = 34.40847  
 $fc = 33.00$   
 $fl = 0.82797802$   
 $b = 450.00$   
 $h = 450.00$   
 $Ag = 202500.00$   
 From (12.9), ACI 440:  $ka = 0.54261599$   
 $g = pt + pc + pv = 0.01461445$   
 $rc = 40.00$   
 $Ae/Ac = 0.54261599$   
 Effective FRP thickness,  $tf = NL*t*\cos(b1) = 1.016$   
 effective strain from (12.5) and (12.12),  $efe = 0.004$   
 $fu = 0.01$   
 $Ef = 64828.00$   
 $Ec = 26999.444$   
 $y = 0.25471862$   
 $A = 0.01452515$   
 $B = 0.00807924$   
 with  $Es = 200000.00$

-----  
 Calculation of ratio  $lb/ld$

-----  
 Lap Length:  $ld/ld,min = 0.42476573$

$lb = 300.00$

$ld = 706.2717$

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

$= 1$

$db = 16.66667$

Mean strength value of all re-bars:  $fy = 524.4464$

Mean concrete strength:  $fc' = (fc'_{jacket}*Area_{jacket} + fc'_{core}*Area_{core})/Area_{section} = 28.98765$ , but  $fc'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$Ktr = 2.86234$

$Atr = \min(Atr_x, Atr_y) = 257.6106$

where  $Atr_x$ ,  $Atr_y$  are the sum of the area of all stirrup legs along X and Y local axis

$s = \max(s_{external}, s_{internal}) = 300.00$

$n = 12.00$

-----  
 End Of Calculation of Shear Capacity for element: column JC1 of floor 1

At local axis: 3

Integration Section: (a)

-----  
**Calculation No. 4**

column C1, Floor 1

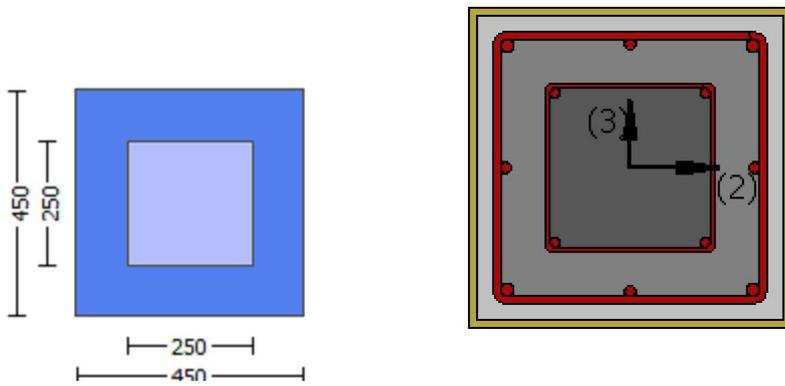
Limit State: Immediate Occupancy (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity ( $\theta_u$ )

Edge: Start

Local Axis: (3)



Start Of Calculation of Shear Capacity ratio for element: column JC1 of floor 1

At Shear local axis: 3

(Bending local axis: 2)

Section Type: rcjrs

Constant Properties

Knowledge Factor,  $\gamma = 0.85$

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 Height,  $H = 450.00$

External Width,  $W = 450.00$

Internal Height,  $H = 250.00$

Internal Width,  $W = 250.00$

Cover Thickness,  $c = 25.00$

Mean Confinement Factor overall section = 1.10542

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,  $V_a = 2.0531359E-031$

EDGE -B-

Shear Force,  $V_b = -2.0531359E-031$

BOTH EDGES

Axial Force,  $F = -7506.808$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension:  $A_{sl,t} = 0.00$

-Compression:  $A_{sl,c} = 2676.637$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension:  $A_{sl,ten} = 1137.257$

-Compression:  $A_{sl,com} = 1137.257$

-Middle:  $A_{sl,mid} = 402.1239$

Calculation of Shear Capacity ratio,  $V_e/V_r = 0.26068017$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 147952.607$

with

$M_{pr1} = \text{Max}(M_{u1+}, M_{u1-}) = 2.2193E+008$

$M_{u1+} = 2.2193E+008$ , 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

$M_{u1-} = 2.2193E+008$ , 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

$M_{pr2} = \text{Max}(M_{u2+}, M_{u2-}) = 2.2193E+008$

$M_{u2+} = 2.2193E+008$ , 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

$M_{u2-} = 2.2193E+008$ , 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 curvature  $\phi_u$  according to 4.1, Biskinis/Fardis 2013:

$\phi_u = 1.9632832E-005$

$M_u = 2.2193E+008$

with full section properties:

$b = 450.00$

$d = 407.00$

$d' = 43.00$

$v = 0.00124204$

$N = 7506.808$

$f_c = 33.00$

$\alpha_{co} (5A.5, TBDY) = 0.002$

Final value of  $c_u$ :  $c_u^* = \text{shear\_factor} * \text{Max}(c_u, c_c) = 0.01393923$

The Shear\_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY:  $c_u = 0.01393923$

$w_e$  ((5.4c), TBDY) =  $ase * sh_{min} * fy_{we} / f_{ce} + \text{Min}(f_x, f_y) = 0.06811101$

where  $f = af * pf * f_{fe} / f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

-----  
 $f_x = 0.06628267$

$af = 0.54930041$

$b = 450.00$

$h = 450.00$

From EC8 A.4.4.3(6),  $pf = 2tf/bw = 0.00451556$

$bw = 450.00$

effective stress from (A.35),  $f_{f,e} = 881.8461$

-----  
 $f_y = 0.06628267$

$af = 0.54930041$

$b = 450.00$

$h = 450.00$

From EC8 A.4.4.3(6),  $pf = 2tf/bw = 0.00451556$

$bw = 450.00$

effective stress from (A.35),  $f_{f,e} = 881.8461$

-----  
 $R = 40.00$

Effective FRP thickness,  $tf = NL * t * \text{Cos}(b1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{,f} = 0.015$

$ase$  ((5.4d), TBDY) =  $(ase1 * A_{ext} + ase2 * A_{int}) / A_{sec} = 0.14546167$

$ase1 = 0.12623274$

$bo_{,1} = 390.00$

$ho_{,1} = 390.00$

$bi_{2,1} = 608400.00$

$ase2 = \text{Max}(ase1, ase2) = 0.18853448$

$bo_{,2} = 242.00$

$ho_{,2} = 242.00$

$bi_{2,2} = 234256.00$

$psh_{min} * fy_{we} = \text{Min}(psh_x * fy_{we}, psh_y * fy_{we}) = 1.38262$

Expression ((5.4d), TBDY) for  $psh_{min} * fy_{we}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

-----  
 $psh_x * fy_{we} = psh1 * fy_{we1} + ps2 * fy_{we2} = 1.38262$

$ps1$  (external) =  $(Ash1 * h1 / s1) / A_{sec} = 0.00116355$

$Ash1 = Astir_{,1} * ns_{,1} = 157.0796$

No stirrups,  $ns_{,1} = 2.00$

$h1 = 450.00$

$ps2$  (internal) =  $(Ash2 * h2 / s2) / A_{sec} = 0.00103427$

$Ash2 = Astir_{,2} * ns_{,2} = 100.531$

No stirrups,  $ns_{,2} = 2.00$

$h2 = 250.00$

-----  
 $psh_y * fy_{we} = psh1 * fy_{we1} + ps2 * fy_{we2} = 1.38262$

$ps1$  (external) =  $(Ash1 * h1 / s1) / A_{sec} = 0.00116355$

$Ash1 = Astir_{,1} * ns_{,1} = 157.0796$

No stirrups,  $ns_{,1} = 2.00$

$h1 = 450.00$

$ps2$  (internal) =  $(Ash2 * h2 / s2) / A_{sec} = 0.00103427$

$Ash2 = Astir_{,2} * ns_{,2} = 100.531$

No stirrups,  $ns_{,2} = 2.00$

$h2 = 250.00$

-----  
 $A_{sec} = 202500.00$

$s1 = 300.00$

$s2 = 120.00$

$fy_{we1} = 694.45$

$fy_{we2} = 555.55$

$f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY:  $c_c = 0.00305417$

$c = \text{confinement factor} = 1.10542$   
 $y1 = 0.00152175$   
 $sh1 = 0.0048696$   
 $ft1 = 479.7871$   
 $fy1 = 399.8226$   
 $su1 = 0.0066488$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 $\text{Shear\_factor} = 1.00$   
 $lo/lou,min = lb/ld = 0.33981258$   
 $su1 = 0.4 * esu1\_nominal ((5.5), \text{TBDY}) = 0.032$   
 From table 5A.1, TBDY:  $esu1\_nominal = 0.08$ ,  
 For calculation of  $esu1\_nominal$  and  $y1, sh1, ft1, fy1$ , it is considered  
 characteristic value  $fsy1 = fs1/1.2$ , from table 5.1, TBDY.  
 $y1, sh1, ft1, fy1$ , are also multiplied by  $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with  $fs1 = (fs,jacket * Asl,ten,jacket + fs,core * Asl,ten,core) / Asl,ten = 399.8226$   
 with  $Es1 = (Es,jacket * Asl,ten,jacket + Es,core * Asl,ten,core) / Asl,ten = 200000.00$   
 $y2 = 0.00152175$   
 $sh2 = 0.0048696$   
 $ft2 = 479.7871$   
 $fy2 = 399.8226$   
 $su2 = 0.0066488$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 $\text{Shear\_factor} = 1.00$   
 $lo/lou,min = lb/lb,min = 0.33981258$   
 $su2 = 0.4 * esu2\_nominal ((5.5), \text{TBDY}) = 0.032$   
 From table 5A.1, TBDY:  $esu2\_nominal = 0.08$ ,  
 For calculation of  $esu2\_nominal$  and  $y2, sh2, ft2, fy2$ , it is considered  
 characteristic value  $fsy2 = fs2/1.2$ , from table 5.1, TBDY.  
 $y1, sh1, ft1, fy1$ , are also multiplied by  $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with  $fs2 = (fs,jacket * Asl,com,jacket + fs,core * Asl,com,core) / Asl,com = 399.8226$   
 with  $Es2 = (Es,jacket * Asl,com,jacket + Es,core * Asl,com,core) / Asl,com = 200000.00$   
 $yv = 0.00152175$   
 $shv = 0.0048696$   
 $ftv = 507.2537$   
 $fyv = 422.7114$   
 $suv = 0.0066488$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 $\text{Shear\_factor} = 1.00$   
 $lo/lou,min = lb/ld = 0.33981258$   
 $suv = 0.4 * esuv\_nominal ((5.5), \text{TBDY}) = 0.032$   
 From table 5A.1, TBDY:  $esuv\_nominal = 0.08$ ,  
 considering characteristic value  $fsyv = fsv/1.2$ , from table 5.1, TBDY  
 For calculation of  $esuv\_nominal$  and  $yv, shv, ftv, fyv$ , it is considered  
 characteristic value  $fsyv = fsv/1.2$ , from table 5.1, TBDY.  
 $y1, sh1, ft1, fy1$ , are also multiplied by  $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with  $fsv = (fs,jacket * Asl,mid,jacket + fs,mid * Asl,mid,core) / Asl,mid = 422.7114$   
 with  $Es_v = (Es,jacket * Asl,mid,jacket + Es,mid * Asl,mid,core) / Asl,mid = 200000.00$   
 $1 = Asl,ten / (b * d) * (fs1 / fc) = 0.0752324$   
 $2 = Asl,com / (b * d) * (fs2 / fc) = 0.0752324$   
 $v = Asl,mid / (b * d) * (fsv / fc) = 0.02812438$   
 and confined core properties:  
 $b = 390.00$   
 $d = 377.00$   
 $d' = 13.00$   
 $fcc (5A.2, \text{TBDY}) = 36.47874$   
 $cc (5A.5, \text{TBDY}) = 0.00305417$   
 $c = \text{confinement factor} = 1.10542$   
 $1 = Asl,ten / (b * d) * (fs1 / fc) = 0.09371431$   
 $2 = Asl,com / (b * d) * (fs2 / fc) = 0.09371431$   
 $v = Asl,mid / (b * d) * (fsv / fc) = 0.03503353$   
 Case/Assumption: Unconfined full section - Steel rupture  
 ' satisfies Eq. (4.3)  
 --->  
 $v < vs,y2$  - LHS eq.(4.5) is satisfied

--->

su (4.9) = 0.16791801  
Mu = MRc (4.14) = 2.2193E+008  
u = su (4.1) = 1.9632832E-005

-----  
Calculation of ratio lb/l<sub>d</sub>

-----  
Lap Length: lb/l<sub>d</sub> = 0.33981258

lb = 300.00

l<sub>d</sub> = 882.8396

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

= 1

db = 16.66667

Mean strength value of all re-bars: fy = 655.558

Mean concrete strength: fc' = (fc'\_jacket\*Area\_jacket + fc'\_core\*Area\_core)/Area\_section = 28.98765, 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 = 2.86234

Atr = Min(Atr\_x,Atr\_y) = 257.6106

where Atr\_x, Atr\_y are the sum of the area of all stirrup legs along X and Y loxal axis

s = Max(s\_external,s\_internal) = 300.00

n = 12.00

-----  
Calculation of Mu1-

-----  
Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

u = 1.9632832E-005

Mu = 2.2193E+008

-----  
with full section properties:

b = 450.00

d = 407.00

d' = 43.00

v = 0.00124204

N = 7506.808

fc = 33.00

co (5A.5, TBDY) = 0.002

Final value of cu: cu\* = shear\_factor \* Max( cu, cc) = 0.01393923

The Shear\_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: cu = 0.01393923

we ((5.4c), TBDY) = ase\* sh,min\*fywe/fce+Min( fx, fy) = 0.06811101

where f = af\*pf\*ffe/fce is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

-----  
fx = 0.06628267

af = 0.54930041

b = 450.00

h = 450.00

From EC8 A.4.4.3(6), pf = 2tf/bw = 0.00451556

bw = 450.00

effective stress from (A.35), ff,e = 881.8461

-----  
fy = 0.06628267

af = 0.54930041

b = 450.00

h = 450.00

From EC8 A.4.4.3(6), pf = 2tf/bw = 0.00451556

bw = 450.00

effective stress from (A.35), ff,e = 881.8461

$R = 40.00$   
 Effective FRP thickness,  $t_f = NL * t * \cos(b_1) = 1.016$   
 $f_{u,f} = 1055.00$   
 $E_f = 64828.00$   
 $u_{,f} = 0.015$   
 $ase((5.4d), TBDY) = (ase_1 * A_{ext} + ase_2 * A_{int}) / A_{sec} = 0.14546167$   
 $ase_1 = 0.12623274$   
 $bo_1 = 390.00$   
 $ho_1 = 390.00$   
 $bi_2_1 = 608400.00$   
 $ase_2 = \text{Max}(ase_1, ase_2) = 0.18853448$   
 $bo_2 = 242.00$   
 $ho_2 = 242.00$   
 $bi_2_2 = 234256.00$

$psh_{,min} * F_{ywe} = \text{Min}(psh_{,x} * F_{ywe}, psh_{,y} * F_{ywe}) = 1.38262$   
 Expression ((5.4d), TBDY) for  $psh_{,min} * F_{ywe}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$psh_{,x} * F_{ywe} = psh_1 * F_{ywe1} + ps_2 * F_{ywe2} = 1.38262$   
 $ps_1 \text{ (external)} = (Ash_1 * h_1 / s_1) / A_{sec} = 0.00116355$   
 $Ash_1 = Astir_1 * ns_1 = 157.0796$   
 No stirrups,  $ns_1 = 2.00$   
 $h_1 = 450.00$   
 $ps_2 \text{ (internal)} = (Ash_2 * h_2 / s_2) / A_{sec} = 0.00103427$   
 $Ash_2 = Astir_2 * ns_2 = 100.531$   
 No stirrups,  $ns_2 = 2.00$   
 $h_2 = 250.00$

$psh_{,y} * F_{ywe} = psh_1 * F_{ywe1} + ps_2 * F_{ywe2} = 1.38262$   
 $ps_1 \text{ (external)} = (Ash_1 * h_1 / s_1) / A_{sec} = 0.00116355$   
 $Ash_1 = Astir_1 * ns_1 = 157.0796$   
 No stirrups,  $ns_1 = 2.00$   
 $h_1 = 450.00$   
 $ps_2 \text{ (internal)} = (Ash_2 * h_2 / s_2) / A_{sec} = 0.00103427$   
 $Ash_2 = Astir_2 * ns_2 = 100.531$   
 No stirrups,  $ns_2 = 2.00$   
 $h_2 = 250.00$

$A_{sec} = 202500.00$   
 $s_1 = 300.00$   
 $s_2 = 120.00$   
 $f_{ywe1} = 694.45$   
 $f_{ywe2} = 555.55$   
 $f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.00305417$   
 $c = \text{confinement factor} = 1.10542$

$y_1 = 0.00152175$   
 $sh_1 = 0.0048696$   
 $ft_1 = 479.7871$   
 $fy_1 = 399.8226$   
 $su_1 = 0.0066488$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 $\text{Shear\_factor} = 1.00$

$lo/lo_{,min} = lb/ld = 0.33981258$   
 $su_1 = 0.4 * esu_1_{nominal}((5.5), TBDY) = 0.032$

From table 5A.1, TBDY:  $esu_1_{nominal} = 0.08$ ,

For calculation of  $esu_1_{nominal}$  and  $y_1, sh_1, ft_1, fy_1$ , it is considered  
 characteristic value  $fsy_1 = fs_1 / 1.2$ , from table 5.1, TBDY.

$y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.

with  $fs_1 = (fs_{jacket} * A_{sl,ten,jacket} + fs_{core} * A_{sl,ten,core}) / A_{sl,ten} = 399.8226$

with  $Es_1 = (Es_{jacket} * A_{sl,ten,jacket} + Es_{core} * A_{sl,ten,core}) / A_{sl,ten} = 200000.00$

$y_2 = 0.00152175$   
 $sh_2 = 0.0048696$   
 $ft_2 = 479.7871$   
 $fy_2 = 399.8226$   
 $su_2 = 0.0066488$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

$$l_o/l_{o,min} = l_b/l_{b,min} = 0.33981258$$

$$s_u2 = 0.4 * e_{s_u2,nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY:  $e_{s_u2,nominal} = 0.08$ ,

For calculation of  $e_{s_u2,nominal}$  and  $y_2, sh_2, ft_2, fy_2$ , it is considered  
characteristic value  $f_{s_y2} = f_{s_2}/1.2$ , from table 5.1, TBDY.

$y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.

$$\text{with } f_{s_2} = (f_{s,jacket} * A_{s_l,com,jacket} + f_{s,core} * A_{s_l,com,core}) / A_{s_l,com} = 399.8226$$

$$\text{with } E_{s_2} = (E_{s,jacket} * A_{s_l,com,jacket} + E_{s,core} * A_{s_l,com,core}) / A_{s_l,com} = 200000.00$$

$$y_v = 0.00152175$$

$$sh_v = 0.0048696$$

$$ft_v = 507.2537$$

$$fy_v = 422.7114$$

$$s_{u_v} = 0.0066488$$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

$$l_o/l_{o,min} = l_b/l_d = 0.33981258$$

$$s_{u_v} = 0.4 * e_{s_{u_v},nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY:  $e_{s_{u_v},nominal} = 0.08$ ,

considering characteristic value  $f_{s_{y_v}} = f_{s_v}/1.2$ , from table 5.1, TBDY  
For calculation of  $e_{s_{u_v},nominal}$  and  $y_v, sh_v, ft_v, fy_v$ , it is considered  
characteristic value  $f_{s_{y_v}} = f_{s_v}/1.2$ , from table 5.1, TBDY.

$y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.

$$\text{with } f_{s_v} = (f_{s,jacket} * A_{s_l,mid,jacket} + f_{s,mid} * A_{s_l,mid,core}) / A_{s_l,mid} = 422.7114$$

$$\text{with } E_{s_v} = (E_{s,jacket} * A_{s_l,mid,jacket} + E_{s,mid} * A_{s_l,mid,core}) / A_{s_l,mid} = 200000.00$$

$$1 = A_{s_l,ten} / (b * d) * (f_{s_1} / f_c) = 0.0752324$$

$$2 = A_{s_l,com} / (b * d) * (f_{s_2} / f_c) = 0.0752324$$

$$v = A_{s_l,mid} / (b * d) * (f_{s_v} / f_c) = 0.02812438$$

and confined core properties:

$$b = 390.00$$

$$d = 377.00$$

$$d' = 13.00$$

$$f_{cc} (5A.2, TBDY) = 36.47874$$

$$cc (5A.5, TBDY) = 0.00305417$$

$$c = \text{confinement factor} = 1.10542$$

$$1 = A_{s_l,ten} / (b * d) * (f_{s_1} / f_c) = 0.09371431$$

$$2 = A_{s_l,com} / (b * d) * (f_{s_2} / f_c) = 0.09371431$$

$$v = A_{s_l,mid} / (b * d) * (f_{s_v} / f_c) = 0.03503353$$

Case/Assumption: Unconfined full section - Steel rupture  
' satisfies Eq. (4.3)

--->

$v < v_{s,y_2}$  - LHS eq.(4.5) is satisfied

--->

$$s_u (4.9) = 0.16791801$$

$$\mu = MR_c (4.14) = 2.2193E+008$$

$$u = s_u (4.1) = 1.9632832E-005$$

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

Lap Length:  $l_b/l_d = 0.33981258$

$$l_b = 300.00$$

$$l_d = 882.8396$$

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

$$= 1$$

$$d_b = 16.66667$$

Mean strength value of all re-bars:  $f_y = 655.558$

Mean concrete strength:  $f'_c = (f'_{c,jacket} * Area_{jacket} + f'_{c,core} * Area_{core}) / Area_{section} = 28.98765$ , but  $f_c^{0.5} < =$   
8.3 MPa (22.5.3.1, ACI 318-14)

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 25.00$$

$$K_{tr} = 2.86234$$

$$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 257.6106$$

where  $A_{tr_x}$ ,  $A_{tr_y}$  are the sum of the area of all stirrup legs along X and Y local axis

$$s = \text{Max}(s_{\text{external}}, s_{\text{internal}}) = 300.00$$

$$n = 12.00$$

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

-----  
-----  
-----  
Calculation of ultimate curvature  $\mu$  according to 4.1, Biskinis/Fardis 2013:

$$u = 1.9632832E-005$$

$$\mu = 2.2193E+008$$

-----  
-----  
-----  
with full section properties:

$$b = 450.00$$

$$d = 407.00$$

$$d' = 43.00$$

$$v = 0.00124204$$

$$N = 7506.808$$

$$f_c = 33.00$$

$$c_o \text{ (5A.5, TBDY)} = 0.002$$

$$\text{Final value of } c_u: c_u^* = \text{shear\_factor} * \text{Max}(c_u, c_c) = 0.01393923$$

The Shear\_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } c_u = 0.01393923$$

$$w_e \text{ ((5.4c), TBDY)} = a_{se} * s_{h,\text{min}} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.06811101$$

where  $f = a_f * p_f * f_{fe} / f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.06628267$$

$$a_f = 0.54930041$$

$$b = 450.00$$

$$h = 450.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.00451556$$

$$b_w = 450.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 881.8461$$

$$f_y = 0.06628267$$

$$a_f = 0.54930041$$

$$b = 450.00$$

$$h = 450.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.00451556$$

$$b_w = 450.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 881.8461$$

$$R = 40.00$$

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

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{f} = 0.015$$

$$a_{se} \text{ ((5.4d), TBDY)} = (a_{se1} * A_{ext} + a_{se2} * A_{int}) / A_{sec} = 0.14546167$$

$$a_{se1} = 0.12623274$$

$$b_{o_1} = 390.00$$

$$h_{o_1} = 390.00$$

$$b_{i2_1} = 608400.00$$

$$a_{se2} = \text{Max}(a_{se1}, a_{se2}) = 0.18853448$$

$$b_{o_2} = 242.00$$

$$h_{o_2} = 242.00$$

$$b_{i2_2} = 234256.00$$

$$p_{sh,\text{min}} * f_{ywe} = \text{Min}(p_{sh,x} * f_{ywe}, p_{sh,y} * f_{ywe}) = 1.38262$$

Expression ((5.4d), TBDY) for  $p_{sh,\text{min}} * f_{ywe}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$$p_{sh_x} * f_{ywe} = p_{sh1} * f_{ywe1} + p_{sh2} * f_{ywe2} = 1.38262$$

$$p_{s1} \text{ (external)} = (A_{sh1} * h_1 / s_1) / A_{sec} = 0.00116355$$

$$A_{sh1} = A_{stir_1} * n_{s_1} = 157.0796$$

$$\text{No stirrups, } n_{s_1} = 2.00$$

h1 = 450.00  
ps2 (internal) = (Ash2\*h2/s2)/Asec = 0.00103427  
Ash2 = Astir\_2\*ns\_2 = 100.531  
No stirups, ns\_2 = 2.00  
h2 = 250.00

-----  
psh\_y\*Fywe = psh1\*Fywe1+ps2\*Fywe2 = 1.38262  
ps1 (external) = (Ash1\*h1/s1)/Asec = 0.00116355  
Ash1 = Astir\_1\*ns\_1 = 157.0796  
No stirups, ns\_1 = 2.00  
h1 = 450.00  
ps2 (internal) = (Ash2\*h2/s2)/Asec = 0.00103427  
Ash2 = Astir\_2\*ns\_2 = 100.531  
No stirups, ns\_2 = 2.00  
h2 = 250.00

-----  
Asec = 202500.00  
s1 = 300.00  
s2 = 120.00  
fywe1 = 694.45  
fywe2 = 555.55  
fce = 33.00

From ((5.A5), TBDY), TBDY: cc = 0.00305417  
c = confinement factor = 1.10542

y1 = 0.00152175  
sh1 = 0.0048696  
ft1 = 479.7871  
fy1 = 399.8226  
su1 = 0.0066488

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

lo/lou,min = lb/d = 0.33981258

su1 = 0.4\*esu1\_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu1\_nominal = 0.08,

For calculation of esu1\_nominal and y1, sh1,ft1,fy1, it is considered  
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25\*(lb/d)^ 2/3), from 10.3.5, ASCE 41-17.

with fs1 = (fs,jacket\*Asl,ten,jacket + fs,core\*Asl,ten,core)/Asl,ten = 399.8226

with Es1 = (Es,jacket\*Asl,ten,jacket + Es,core\*Asl,ten,core)/Asl,ten = 200000.00

y2 = 0.00152175  
sh2 = 0.0048696  
ft2 = 479.7871  
fy2 = 399.8226  
su2 = 0.0066488

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

lo/lou,min = lb/lb,min = 0.33981258

su2 = 0.4\*esu2\_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu2\_nominal = 0.08,

For calculation of esu2\_nominal and y2, sh2,ft2,fy2, it is considered  
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25\*(lb/d)^ 2/3), from 10.3.5, ASCE 41-17.

with fs2 = (fs,jacket\*Asl,com,jacket + fs,core\*Asl,com,core)/Asl,com = 399.8226

with Es2 = (Es,jacket\*Asl,com,jacket + Es,core\*Asl,com,core)/Asl,com = 200000.00

yv = 0.00152175  
shv = 0.0048696  
ftv = 507.2537  
fyv = 422.7114  
suv = 0.0066488

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

lo/lou,min = lb/d = 0.33981258

suv = 0.4\*esuv\_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esuv\_nominal = 0.08,

considering characteristic value  $f_{sv} = f_{sv}/1.2$ , from table 5.1, TBDY

For calculation of  $e_{suv\_nominal}$  and  $y_v$ ,  $sh_v$ ,  $ft_v$ ,  $fy_v$ , it is considered characteristic value  $f_{sv} = f_{sv}/1.2$ , from table 5.1, TBDY.

$y_1$ ,  $sh_1$ ,  $ft_1$ ,  $fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.

with  $f_{sv} = (f_{s,jacket} \cdot A_{s,mid,jacket} + f_{s,mid} \cdot A_{s,mid,core}) / A_{s,mid} = 422.7114$

with  $E_{sv} = (E_{s,jacket} \cdot A_{s,mid,jacket} + E_{s,mid} \cdot A_{s,mid,core}) / A_{s,mid} = 200000.00$

$1 = A_{s,ten} / (b \cdot d) \cdot (f_{s1} / f_c) = 0.0752324$

$2 = A_{s,com} / (b \cdot d) \cdot (f_{s2} / f_c) = 0.0752324$

$v = A_{s,mid} / (b \cdot d) \cdot (f_{sv} / f_c) = 0.02812438$

and confined core properties:

$b = 390.00$

$d = 377.00$

$d' = 13.00$

$f_{cc}$  (5A.2, TBDY) = 36.47874

$cc$  (5A.5, TBDY) = 0.00305417

$c$  = confinement factor = 1.10542

$1 = A_{s,ten} / (b \cdot d) \cdot (f_{s1} / f_c) = 0.09371431$

$2 = A_{s,com} / (b \cdot d) \cdot (f_{s2} / f_c) = 0.09371431$

$v = A_{s,mid} / (b \cdot d) \cdot (f_{sv} / f_c) = 0.03503353$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < v_{s,y2}$  - LHS eq.(4.5) is satisfied

--->

$su$  (4.9) = 0.16791801

$Mu = MRc$  (4.14) = 2.2193E+008

$u = su$  (4.1) = 1.9632832E-005

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

Lap Length:  $l_b/l_d = 0.33981258$

$l_b = 300.00$

$l_d = 882.8396$

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

= 1

$db = 16.66667$

Mean strength value of all re-bars:  $f_y = 655.558$

Mean concrete strength:  $f'_c = (f'_{c,jacket} \cdot Area_{jacket} + f'_{c,core} \cdot Area_{core}) / Area_{section} = 28.98765$ , but  $f_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 2.86234$

$A_{tr} = \text{Min}(A_{tr,x}, A_{tr,y}) = 257.6106$

where  $A_{tr,x}$ ,  $A_{tr,y}$  are the sum of the area of all stirrup legs along X and Y local axis

$s = \text{Max}(s_{external}, s_{internal}) = 300.00$

$n = 12.00$

-----  
Calculation of  $Mu_2$ -

-----  
Calculation of ultimate curvature  $u$  according to 4.1, Biskinis/Fardis 2013:

$u = 1.9632832E-005$

$Mu = 2.2193E+008$

-----  
with full section properties:

$b = 450.00$

$d = 407.00$

$d' = 43.00$

$v = 0.00124204$

$N = 7506.808$

$f_c = 33.00$

co (5A.5, TBDY) = 0.002

Final value of cu:  $cu^* = \text{shear\_factor} * \text{Max}(cu, cc) = 0.01393923$

The Shear\_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY:  $cu = 0.01393923$

we ((5.4c), TBDY) =  $ase * sh_{,min} * fy_{we} / f_{ce} + \text{Min}(fx, fy) = 0.06811101$

where  $f = af * pf * f_{fe} / f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

-----  
 $fx = 0.06628267$

$af = 0.54930041$

$b = 450.00$

$h = 450.00$

From EC8 A.4.4.3(6),  $pf = 2tf/bw = 0.00451556$

$bw = 450.00$

effective stress from (A.35),  $ff_{,e} = 881.8461$

-----  
 $fy = 0.06628267$

$af = 0.54930041$

$b = 450.00$

$h = 450.00$

From EC8 A.4.4.3(6),  $pf = 2tf/bw = 0.00451556$

$bw = 450.00$

effective stress from (A.35),  $ff_{,e} = 881.8461$

-----  
 $R = 40.00$

Effective FRP thickness,  $tf = NL * t * \text{Cos}(b1) = 1.016$

$fu_{,f} = 1055.00$

$Ef = 64828.00$

$u_{,f} = 0.015$

$ase$  ((5.4d), TBDY) =  $(ase1 * A_{ext} + ase2 * A_{int}) / A_{sec} = 0.14546167$

$ase1 = 0.12623274$

$bo_{,1} = 390.00$

$ho_{,1} = 390.00$

$bi2_{,1} = 608400.00$

$ase2 = \text{Max}(ase1, ase2) = 0.18853448$

$bo_{,2} = 242.00$

$ho_{,2} = 242.00$

$bi2_{,2} = 234256.00$

$psh_{,min} * fy_{we} = \text{Min}(psh_{,x} * fy_{we}, psh_{,y} * fy_{we}) = 1.38262$

Expression ((5.4d), TBDY) for  $psh_{,min} * fy_{we}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

-----  
 $psh_{,x} * fy_{we} = psh1 * fy_{we1} + ps2 * fy_{we2} = 1.38262$

$ps1$  (external) =  $(Ash1 * h1 / s1) / A_{sec} = 0.00116355$

$Ash1 = Astir_{,1} * ns_{,1} = 157.0796$

No stirrups,  $ns_{,1} = 2.00$

$h1 = 450.00$

$ps2$  (internal) =  $(Ash2 * h2 / s2) / A_{sec} = 0.00103427$

$Ash2 = Astir_{,2} * ns_{,2} = 100.531$

No stirrups,  $ns_{,2} = 2.00$

$h2 = 250.00$

-----  
 $psh_{,y} * fy_{we} = psh1 * fy_{we1} + ps2 * fy_{we2} = 1.38262$

$ps1$  (external) =  $(Ash1 * h1 / s1) / A_{sec} = 0.00116355$

$Ash1 = Astir_{,1} * ns_{,1} = 157.0796$

No stirrups,  $ns_{,1} = 2.00$

$h1 = 450.00$

$ps2$  (internal) =  $(Ash2 * h2 / s2) / A_{sec} = 0.00103427$

$Ash2 = Astir_{,2} * ns_{,2} = 100.531$

No stirrups,  $ns_{,2} = 2.00$

$h2 = 250.00$

-----  
 $A_{sec} = 202500.00$

$s1 = 300.00$

$s2 = 120.00$

$fy_{we1} = 694.45$

$fy_{we2} = 555.55$

$f_{ce} = 33.00$

From ((5.A.5), TBDY), TBDY:  $cc = 0.00305417$   
 $c = \text{confinement factor} = 1.10542$

$y1 = 0.00152175$

$sh1 = 0.0048696$

$ft1 = 479.7871$

$fy1 = 399.8226$

$su1 = 0.0066488$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

$lo/lou,min = lb/ld = 0.33981258$

$su1 = 0.4 * esu1\_nominal ((5.5), TBDY) = 0.032$

From table 5A.1, TBDY:  $esu1\_nominal = 0.08$ ,

For calculation of  $esu1\_nominal$  and  $y1, sh1, ft1, fy1$ , it is considered  
characteristic value  $fsy1 = fs1/1.2$ , from table 5.1, TBDY.

$y1, sh1, ft1, fy1$ , are also multiplied by  $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.

with  $fs1 = (fs\_jacket * Asl,ten,jacket + fs\_core * Asl,ten,core) / Asl,ten = 399.8226$

with  $Es1 = (Es\_jacket * Asl,ten,jacket + Es\_core * Asl,ten,core) / Asl,ten = 200000.00$

$y2 = 0.00152175$

$sh2 = 0.0048696$

$ft2 = 479.7871$

$fy2 = 399.8226$

$su2 = 0.0066488$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

$lo/lou,min = lb/lb,min = 0.33981258$

$su2 = 0.4 * esu2\_nominal ((5.5), TBDY) = 0.032$

From table 5A.1, TBDY:  $esu2\_nominal = 0.08$ ,

For calculation of  $esu2\_nominal$  and  $y2, sh2, ft2, fy2$ , it is considered  
characteristic value  $fsy2 = fs2/1.2$ , from table 5.1, TBDY.

$y1, sh1, ft1, fy1$ , are also multiplied by  $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.

with  $fs2 = (fs\_jacket * Asl,com,jacket + fs\_core * Asl,com,core) / Asl,com = 399.8226$

with  $Es2 = (Es\_jacket * Asl,com,jacket + Es\_core * Asl,com,core) / Asl,com = 200000.00$

$yv = 0.00152175$

$shv = 0.0048696$

$ftv = 507.2537$

$fyv = 422.7114$

$su1 = 0.0066488$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

$lo/lou,min = lb/ld = 0.33981258$

$su1 = 0.4 * esuv\_nominal ((5.5), TBDY) = 0.032$

From table 5A.1, TBDY:  $esuv\_nominal = 0.08$ ,

considering characteristic value  $fsyv = fsv/1.2$ , from table 5.1, TBDY

For calculation of  $esuv\_nominal$  and  $yv, shv, ftv, fyv$ , it is considered  
characteristic value  $fsyv = fsv/1.2$ , from table 5.1, TBDY.

$y1, sh1, ft1, fy1$ , are also multiplied by  $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.

with  $fsv = (fs\_jacket * Asl,mid,jacket + fs\_mid * Asl,mid,core) / Asl,mid = 422.7114$

with  $Es1 = (Es\_jacket * Asl,mid,jacket + Es\_mid * Asl,mid,core) / Asl,mid = 200000.00$

$1 = Asl,ten / (b * d) * (fs1 / fc) = 0.0752324$

$2 = Asl,com / (b * d) * (fs2 / fc) = 0.0752324$

$v = Asl,mid / (b * d) * (fsv / fc) = 0.02812438$

and confined core properties:

$b = 390.00$

$d = 377.00$

$d' = 13.00$

$fcc (5A.2, TBDY) = 36.47874$

$cc (5A.5, TBDY) = 0.00305417$

$c = \text{confinement factor} = 1.10542$

$1 = Asl,ten / (b * d) * (fs1 / fc) = 0.09371431$

$2 = Asl,com / (b * d) * (fs2 / fc) = 0.09371431$

$v = Asl,mid / (b * d) * (fsv / fc) = 0.03503353$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < v_s, y_2$  - LHS eq.(4.5) is satisfied

--->

$$s_u(4.9) = 0.16791801$$

$$M_u = MR_c(4.14) = 2.2193E+008$$

$$u = s_u(4.1) = 1.9632832E-005$$

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

Lap Length:  $l_b/l_d = 0.33981258$

$$l_b = 300.00$$

$$l_d = 882.8396$$

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

$$= 1$$

$$d_b = 16.66667$$

Mean strength value of all re-bars:  $f_y = 655.558$

Mean concrete strength:  $f_c' = (f_c'_{jacket} \cdot Area_{jacket} + f_c'_{core} \cdot Area_{core}) / Area_{section} = 28.98765$ , but  $f_c'^{0.5} < =$

8.3 MPa (22.5.3.1, ACI 318-14)

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 25.00$$

$$K_{tr} = 2.86234$$

$$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 257.6106$$

where  $A_{tr_x}, A_{tr_y}$  are the sum of the area of all stirrup legs along X and Y local axis

$$s = \text{Max}(s_{external}, s_{internal}) = 300.00$$

$$n = 12.00$$

-----  
Calculation of Shear Strength  $V_r = \text{Min}(V_{r1}, V_{r2}) = 567563.724$

-----  
Calculation of Shear Strength at edge 1,  $V_{r1} = 567563.724$

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

$$V_{Col0} = 567563.724$$

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

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

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

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

Mean concrete strength:  $f_c' = (f_c'_{jacket} \cdot Area_{jacket} + f_c'_{core} \cdot Area_{core}) / Area_{section} = 28.98765$ , but  $f_c'^{0.5} < =$

8.3 MPa (22.5.3.1, ACI 318-14)

$$M/Vd = 2.00$$

$$M_u = 1.4404090E-011$$

$$V_u = 2.0531359E-031$$

$$d = 0.8 \cdot h = 360.00$$

$$N_u = 7506.808$$

$$A_g = 202500.00$$

$$\text{From (11.5.4.8), ACI 318-14: } V_s = V_{s1} + V_{s2} = 144280.365$$

where:

$V_{s1} = 69813.729$  is calculated for jacket, with:

$$d = 360.00$$

$$A_v = 157079.633$$

$$f_y = 555.56$$

$$s = 300.00$$

$V_{s1}$  is multiplied by  $Col1 = 0.66666667$

$$s/d = 0.83333333$$

$V_{s2} = 74466.637$  is calculated for core, with:

$$d = 200.00$$

$$A_v = 100530.965$$

$$f_y = 444.44$$

$$s = 120.00$$

$V_{s2}$  is multiplied by  $Col2 = 1.00$

$$s/d = 0.60$$

$$V_f \text{ ((11-3)-(11.4), ACI 440) } = 214457.247$$

$f = 0.95$ , for fully-wrapped sections  
 $wf/sf = 1$  (FRP strips adjacent to one another).  
 In (11.3)  $\sin + \cos$  is replaced with  $(\cot + \cot a)\sin a$  which is more a generalised expression,  
 where  $a$  is the angle of the crack direction (see KANEPE).  
 This later relation, considered as a function  $V_f(\theta)$ , is implemented for every different fiber orientation  $a_i$ ,  
 as well as for 2 crack directions,  $\theta = 45^\circ$  and  $\theta = -45^\circ$  to take into consideration the cyclic seismic loading.  
 orientation 1:  $\theta = b1 + 90^\circ = 90.00$   
 $V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, a1)|)$ , with:  
 total thickness per orientation,  $tf1 = NL * t / \text{NoDir} = 1.016$   
 $dfv = d$  (figure 11.2, ACI 440) = 407.00  
 $ffe$  ((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:  $V_s + V_f \leq 579413.096$   
 $bw = 450.00$

Calculation of Shear Strength at edge 2,  $V_{r2} = 567563.724$   
 $V_{r2} = V_{Col}$  ((10.3), ASCE 41-17) =  $knl * V_{Col0}$   
 $V_{Col0} = 567563.724$   
 $knl = 1$  (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).

$\gamma = 1$  (normal-weight concrete)  
 Mean concrete strength:  $f_c' = (f_c'_{jacket} * Area_{jacket} + f_c'_{core} * Area_{core}) / Area_{section} = 28.98765$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M/d = 2.00$   
 $\mu_u = 1.4404090E-011$   
 $\nu_u = 2.0531359E-031$   
 $d = 0.8 * h = 360.00$   
 $N_u = 7506.808$   
 $A_g = 202500.00$   
 From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 144280.365$   
 where:

$V_{s1} = 69813.729$  is calculated for jacket, with:  
 $d = 360.00$   
 $A_v = 157079.633$   
 $f_y = 555.56$   
 $s = 300.00$

$V_{s1}$  is multiplied by  $Col1 = 0.66666667$   
 $s/d = 0.83333333$

$V_{s2} = 74466.637$  is calculated for core, with:  
 $d = 200.00$   
 $A_v = 100530.965$   
 $f_y = 444.44$   
 $s = 120.00$

$V_{s2}$  is multiplied by  $Col2 = 1.00$   
 $s/d = 0.60$

$V_f$  ((11-3)-(11.4), ACI 440) = 214457.247  
 $f = 0.95$ , for fully-wrapped sections

$wf/sf = 1$  (FRP strips adjacent to one another).  
 In (11.3)  $\sin + \cos$  is replaced with  $(\cot + \cot a)\sin a$  which is more a generalised expression,  
 where  $a$  is the angle of the crack direction (see KANEPE).  
 This later relation, considered as a function  $V_f(\theta)$ , is implemented for every different fiber orientation  $a_i$ ,  
 as well as for 2 crack directions,  $\theta = 45^\circ$  and  $\theta = -45^\circ$  to take into consideration the cyclic seismic loading.

orientation 1:  $\theta = b1 + 90^\circ = 90.00$   
 $V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, a1)|)$ , with:  
 total thickness per orientation,  $tf1 = NL * t / \text{NoDir} = 1.016$   
 $dfv = d$  (figure 11.2, ACI 440) = 407.00  
 $ffe$  ((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:  $V_s + V_f \leq 579413.096$

bw = 450.00

End Of Calculation of Shear Capacity ratio for element: column JC1 of floor 1  
At local axis: 3

Start Of Calculation of Shear Capacity ratio for element: column JC1 of floor 1  
At Shear local axis: 2  
(Bending local axis: 3)  
Section Type: rcjrs

#### Constant Properties

Knowledge Factor,  $\gamma = 0.85$

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 Height,  $H = 450.00$

External Width,  $W = 450.00$

Internal Height,  $H = 250.00$

Internal Width,  $W = 250.00$

Cover Thickness,  $c = 25.00$

Mean Confinement Factor overall section = 1.10542

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,  $NoDir = 1$

Fiber orientations,  $bi: 0.00^\circ$

Number of layers,  $NL = 1$

Radius of rounding corners,  $R = 40.00$

#### Stepwise Properties

At local axis: 2

EDGE -A-

Shear Force,  $V_a = -2.7162834E-031$

EDGE -B-

Shear Force,  $V_b = 2.7162834E-031$

BOTH EDGES

Axial Force,  $F = -7506.808$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension:  $As_{lt} = 0.00$

-Compression:  $As_{lc} = 2676.637$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension:  $As_{l,ten} = 1137.257$

-Compression:  $As_{l,com} = 1137.257$

-Middle:  $As_{l,mid} = 402.1239$

Calculation of Shear Capacity ratio,  $V_e/V_r = 0.26068017$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 147952.607$

with

$M_{pr1} = \text{Max}(Mu_{1+}, Mu_{1-}) = 2.2193E+008$

$Mu_{1+} = 2.2193E+008$ , 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

$Mu_{1-} = 2.2193E+008$ , 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

$M_{pr2} = \text{Max}(Mu_{2+}, Mu_{2-}) = 2.2193E+008$

$Mu_{2+} = 2.2193E+008$ , 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

$Mu_{2-} = 2.2193E+008$ , 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 curvature  $\phi_u$  according to 4.1, Biskinis/Fardis 2013:

$\phi_u = 1.9632832E-005$

$M_u = 2.2193E+008$

with full section properties:

$b = 450.00$

$d = 407.00$

$d' = 43.00$

$v = 0.00124204$

$N = 7506.808$

$f_c = 33.00$

$\alpha_{co}$  (5A.5, TBDY) = 0.002

Final value of  $\phi_u$ :  $\phi_u^* = \text{shear\_factor} * \text{Max}(\phi_u, \phi_c) = 0.01393923$

The Shear\_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY:  $\phi_u = 0.01393923$

$\phi_{we}$  ((5.4c), TBDY) =  $\alpha_{se} * \phi_{sh,min} * f_{ywe}/f_{ce} + \text{Min}(\phi_x, \phi_y) = 0.06811101$

where  $\phi = \alpha_{se} * \phi_{sh,min} * f_{ywe}/f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$\phi_x = 0.06628267$

$\alpha_{se} = 0.54930041$

$b = 450.00$

$h = 450.00$

From EC8 A.4.4.3(6),  $\phi_{sh} = 2t_f/b_w = 0.00451556$

$b_w = 450.00$

effective stress from (A.35),  $f_{f,e} = 881.8461$

$\phi_y = 0.06628267$

$\alpha_{se} = 0.54930041$

$b = 450.00$

$h = 450.00$

From EC8 A.4.4.3(6),  $\phi_{sh} = 2t_f/b_w = 0.00451556$

bw = 450.00  
effective stress from (A.35),  $f_{f,e} = 881.8461$

R = 40.00  
Effective FRP thickness,  $t_f = NL * t * \cos(b_1) = 1.016$   
 $f_{u,f} = 1055.00$   
 $E_f = 64828.00$   
 $u_{,f} = 0.015$   
 $ase((5.4d), TBDY) = (ase_1 * A_{ext} + ase_2 * A_{int}) / A_{sec} = 0.14546167$   
 $ase_1 = 0.12623274$   
 $bo_1 = 390.00$   
 $ho_1 = 390.00$   
 $bi_2_1 = 608400.00$   
 $ase_2 = \max(ase_1, ase_2) = 0.18853448$   
 $bo_2 = 242.00$   
 $ho_2 = 242.00$   
 $bi_2_2 = 234256.00$

$p_{sh,min} * F_{ywe} = \min(p_{sh,x} * F_{ywe}, p_{sh,y} * F_{ywe}) = 1.38262$   
Expression ((5.4d), TBDY) for  $p_{sh,min} * F_{ywe}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$p_{sh,x} * F_{ywe} = p_{sh1} * F_{ywe1} + ps_2 * F_{ywe2} = 1.38262$   
 $ps_1$  (external) =  $(A_{sh1} * h_1 / s_1) / A_{sec} = 0.00116355$   
 $A_{sh1} = A_{stir_1} * ns_1 = 157.0796$   
No stirrups,  $ns_1 = 2.00$   
 $h_1 = 450.00$   
 $ps_2$  (internal) =  $(A_{sh2} * h_2 / s_2) / A_{sec} = 0.00103427$   
 $A_{sh2} = A_{stir_2} * ns_2 = 100.531$   
No stirrups,  $ns_2 = 2.00$   
 $h_2 = 250.00$

$p_{sh,y} * F_{ywe} = p_{sh1} * F_{ywe1} + ps_2 * F_{ywe2} = 1.38262$   
 $ps_1$  (external) =  $(A_{sh1} * h_1 / s_1) / A_{sec} = 0.00116355$   
 $A_{sh1} = A_{stir_1} * ns_1 = 157.0796$   
No stirrups,  $ns_1 = 2.00$   
 $h_1 = 450.00$   
 $ps_2$  (internal) =  $(A_{sh2} * h_2 / s_2) / A_{sec} = 0.00103427$   
 $A_{sh2} = A_{stir_2} * ns_2 = 100.531$   
No stirrups,  $ns_2 = 2.00$   
 $h_2 = 250.00$

$A_{sec} = 202500.00$   
 $s_1 = 300.00$   
 $s_2 = 120.00$   
 $f_{ywe1} = 694.45$   
 $f_{ywe2} = 555.55$   
 $f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.00305417$   
 $c =$  confinement factor = 1.10542

$y_1 = 0.00152175$   
 $sh_1 = 0.0048696$   
 $ft_1 = 479.7871$   
 $fy_1 = 399.8226$   
 $su_1 = 0.0066488$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

$lo/lo_{u,min} = lb/ld = 0.33981258$   
 $su_1 = 0.4 * esu_{1,nominal}((5.5), TBDY) = 0.032$

From table 5A.1, TBDY:  $esu_{1,nominal} = 0.08$ ,

For calculation of  $esu_{1,nominal}$  and  $y_1, sh_1, ft_1, fy_1$ , it is considered  
characteristic value  $fsy_1 = fs_1 / 1.2$ , from table 5.1, TBDY.

$y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\min(1, 1.25 * (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.

with  $fs_1 = (f_{s,jacket} * A_{s,ten,jacket} + f_{s,core} * A_{s,ten,core}) / A_{s,ten} = 399.8226$

with  $Es_1 = (E_{s,jacket} * A_{s,ten,jacket} + E_{s,core} * A_{s,ten,core}) / A_{s,ten} = 200000.00$

$y_2 = 0.00152175$   
 $sh_2 = 0.0048696$

$$ft2 = 479.7871$$

$$fy2 = 399.8226$$

$$su2 = 0.0066488$$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

$$lo/lou,min = lb/lb,min = 0.33981258$$

$$su2 = 0.4*esu2\_nominal ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: esu2\_nominal = 0.08,

For calculation of esu2\_nominal and y2, sh2,ft2,fy2, it is considered  
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by  $\text{Min}(1, 1.25*(lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.

$$\text{with } fs2 = (fs\_jacket*Asl,com,jacket + fs\_core*Asl,com,core)/Asl,com = 399.8226$$

$$\text{with } Es2 = (Es\_jacket*Asl,com,jacket + Es\_core*Asl,com,core)/Asl,com = 200000.00$$

$$yv = 0.00152175$$

$$shv = 0.0048696$$

$$ftv = 507.2537$$

$$fyv = 422.7114$$

$$suv = 0.0066488$$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

$$lo/lou,min = lb/ld = 0.33981258$$

$$suv = 0.4*esuv\_nominal ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: esuv\_nominal = 0.08,

considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY

For calculation of esuv\_nominal and yv, shv,ftv,fyv, it is considered  
characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by  $\text{Min}(1, 1.25*(lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.

$$\text{with } fsv = (fs\_jacket*Asl,mid,jacket + fs\_mid*Asl,mid,core)/Asl,mid = 422.7114$$

$$\text{with } Esv = (Es\_jacket*Asl,mid,jacket + Es\_mid*Asl,mid,core)/Asl,mid = 200000.00$$

$$1 = Asl,ten/(b*d)*(fs1/fc) = 0.0752324$$

$$2 = Asl,com/(b*d)*(fs2/fc) = 0.0752324$$

$$v = Asl,mid/(b*d)*(fsv/fc) = 0.02812438$$

and confined core properties:

$$b = 390.00$$

$$d = 377.00$$

$$d' = 13.00$$

$$fcc (5A.2, TBDY) = 36.47874$$

$$cc (5A.5, TBDY) = 0.00305417$$

$$c = \text{confinement factor} = 1.10542$$

$$1 = Asl,ten/(b*d)*(fs1/fc) = 0.09371431$$

$$2 = Asl,com/(b*d)*(fs2/fc) = 0.09371431$$

$$v = Asl,mid/(b*d)*(fsv/fc) = 0.03503353$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

---->

$v < vs,y2$  - LHS eq.(4.5) is satisfied

---->

$$su (4.9) = 0.16791801$$

$$Mu = MRc (4.14) = 2.2193E+008$$

$$u = su (4.1) = 1.9632832E-005$$

-----  
Calculation of ratio lb/ld

-----  
Lap Length: lb/ld = 0.33981258

$$lb = 300.00$$

$$ld = 882.8396$$

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

$$= 1$$

$$db = 16.66667$$

Mean strength value of all re-bars: fy = 655.558

Mean concrete strength: fc' = (fc'\_jacket\*Area\_jacket + fc'\_core\*Area\_core)/Area\_section = 28.98765, 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 = 2.86234  
Atr = Min(Atr\_x,Atr\_y) = 257.6106  
where Atr\_x, Atr\_y are the sum of the area of all stirrup legs along X and Y loxal axis  
s = Max(s\_external,s\_internal) = 300.00  
n = 12.00

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

-----  
-----  
Calculation of ultimate curvature  $\phi_u$  according to 4.1, Biskinis/Fardis 2013:  
u = 1.9632832E-005  
Mu = 2.2193E+008

-----  
with full section properties:

b = 450.00  
d = 407.00  
d' = 43.00  
v = 0.00124204  
N = 7506.808  
fc = 33.00  
co (5A.5, TBDY) = 0.002  
Final value of  $\phi_u$ :  $\phi_u^* = \text{shear\_factor} * \text{Max}(\phi_u, \phi_c) = 0.01393923$   
The Shear\_factor is considered equal to 1 (pure moment strength)  
From (5.4b), TBDY:  $\phi_u = 0.01393923$   
 $\phi_{we}$  ((5.4c), TBDY) =  $\text{ase} * \text{sh}_{\min} * \text{fy}_{we} / \text{f}_{ce} + \text{Min}(\phi_x, \phi_y) = 0.06811101$   
where  $\phi = \text{af} * \text{pf} * \text{ffe} / \text{f}_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

-----  
 $\phi_x = 0.06628267$   
 $\text{af} = 0.54930041$   
b = 450.00  
h = 450.00  
From EC8 A.4.4.3(6),  $\text{pf} = 2\text{tf}/\text{bw} = 0.00451556$   
bw = 450.00  
effective stress from (A.35),  $\text{ff}_{e} = 881.8461$

-----  
 $\phi_y = 0.06628267$   
 $\text{af} = 0.54930041$   
b = 450.00  
h = 450.00  
From EC8 A.4.4.3(6),  $\text{pf} = 2\text{tf}/\text{bw} = 0.00451556$   
bw = 450.00  
effective stress from (A.35),  $\text{ff}_{e} = 881.8461$

-----  
R = 40.00  
Effective FRP thickness,  $\text{tf} = \text{NL} * \text{t} * \text{Cos}(b1) = 1.016$   
 $\text{fu}_f = 1055.00$   
 $E_f = 64828.00$   
 $u_{f} = 0.015$   
 $\text{ase}$  ((5.4d), TBDY) =  $(\text{ase1} * \text{A}_{\text{ext}} + \text{ase2} * \text{A}_{\text{int}}) / \text{A}_{\text{sec}} = 0.14546167$   
 $\text{ase1} = 0.12623274$   
 $\text{bo}_1 = 390.00$   
 $\text{ho}_1 = 390.00$   
 $\text{bi2}_1 = 608400.00$   
 $\text{ase2} = \text{Max}(\text{ase1}, \text{ase2}) = 0.18853448$   
 $\text{bo}_2 = 242.00$   
 $\text{ho}_2 = 242.00$   
 $\text{bi2}_2 = 234256.00$

$\text{psh}_{\min} * \text{Fy}_{we} = \text{Min}(\text{psh}_x * \text{Fy}_{we}, \text{psh}_y * \text{Fy}_{we}) = 1.38262$   
Expression ((5.4d), TBDY) for  $\text{psh}_{\min} * \text{Fy}_{we}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

-----  
 $\text{psh}_x * \text{Fy}_{we} = \text{psh1} * \text{Fy}_{we1} + \text{ps2} * \text{Fy}_{we2} = 1.38262$

ps1 (external) =  $(Ash1 \cdot h1 / s1) / Asec = 0.00116355$   
Ash1 = Astir\_1 \* ns\_1 = 157.0796  
No stirups, ns\_1 = 2.00  
h1 = 450.00  
ps2 (internal) =  $(Ash2 \cdot h2 / s2) / Asec = 0.00103427$   
Ash2 = Astir\_2 \* ns\_2 = 100.531  
No stirups, ns\_2 = 2.00  
h2 = 250.00

psh\_y \* Fywe = psh1 \* Fywe1 + ps2 \* Fywe2 = 1.38262  
ps1 (external) =  $(Ash1 \cdot h1 / s1) / Asec = 0.00116355$   
Ash1 = Astir\_1 \* ns\_1 = 157.0796  
No stirups, ns\_1 = 2.00  
h1 = 450.00  
ps2 (internal) =  $(Ash2 \cdot h2 / s2) / Asec = 0.00103427$   
Ash2 = Astir\_2 \* ns\_2 = 100.531  
No stirups, ns\_2 = 2.00  
h2 = 250.00

Asec = 202500.00  
s1 = 300.00  
s2 = 120.00  
fywe1 = 694.45  
fywe2 = 555.55  
fce = 33.00

From ((5.A5), TBDY), TBDY: cc = 0.00305417  
c = confinement factor = 1.10542

y1 = 0.00152175  
sh1 = 0.0048696  
ft1 = 479.7871  
fy1 = 399.8226  
su1 = 0.0066488

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

lo/lou,min = lb/lb = 0.33981258  
su1 =  $0.4 \cdot esu1\_nominal$  ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu1\_nominal = 0.08,  
For calculation of esu1\_nominal and y1, sh1, ft1, fy1, it is considered  
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1, ft1, fy1, are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/lb)^{2/3})$ , from 10.3.5, ASCE 41-17.

with fs1 =  $(fs\_jacket \cdot Asl,ten,jacket + fs\_core \cdot Asl,ten,core) / Asl,ten = 399.8226$

with Es1 =  $(Es\_jacket \cdot Asl,ten,jacket + Es\_core \cdot Asl,ten,core) / Asl,ten = 200000.00$

y2 = 0.00152175  
sh2 = 0.0048696  
ft2 = 479.7871  
fy2 = 399.8226  
su2 = 0.0066488

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

lo/lou,min = lb/lb,min = 0.33981258  
su2 =  $0.4 \cdot esu2\_nominal$  ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu2\_nominal = 0.08,  
For calculation of esu2\_nominal and y2, sh2, ft2, fy2, it is considered  
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

y1, sh1, ft1, fy1, are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/lb)^{2/3})$ , from 10.3.5, ASCE 41-17.

with fs2 =  $(fs\_jacket \cdot Asl,com,jacket + fs\_core \cdot Asl,com,core) / Asl,com = 399.8226$

with Es2 =  $(Es\_jacket \cdot Asl,com,jacket + Es\_core \cdot Asl,com,core) / Asl,com = 200000.00$

yv = 0.00152175  
shv = 0.0048696  
ftv = 507.2537  
fyv = 422.7114  
suv = 0.0066488

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

$$l_0/l_{ou,min} = l_b/l_d = 0.33981258$$

$$s_{uv} = 0.4 * e_{suv\_nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY:  $e_{suv\_nominal} = 0.08$ ,

considering characteristic value  $f_{sv} = f_{sv}/1.2$ , from table 5.1, TBDY

For calculation of  $e_{suv\_nominal}$  and  $\gamma_v$ ,  $sh_v, ft_v, fy_v$ , it is considered

characteristic value  $f_{sv} = f_{sv}/1.2$ , from table 5.1, TBDY.

$$\gamma_1, sh_1, ft_1, fy_1, \text{ are also multiplied by } \text{Min}(1, 1.25 * (l_b/l_d)^{2/3}), \text{ from 10.3.5, ASCE 41-17.}$$

$$\text{with } f_{sv} = (f_{s,jacket} * A_{s,mid,jacket} + f_{s,mid} * A_{s,mid,core}) / A_{s,mid} = 422.7114$$

$$\text{with } E_{sv} = (E_{s,jacket} * A_{s,mid,jacket} + E_{s,mid} * A_{s,mid,core}) / A_{s,mid} = 200000.00$$

$$1 = A_{s,ten} / (b * d) * (f_{s1} / f_c) = 0.0752324$$

$$2 = A_{s,com} / (b * d) * (f_{s2} / f_c) = 0.0752324$$

$$v = A_{s,mid} / (b * d) * (f_{sv} / f_c) = 0.02812438$$

and confined core properties:

$$b = 390.00$$

$$d = 377.00$$

$$d' = 13.00$$

$$f_{cc} (5A.2, TBDY) = 36.47874$$

$$c_c (5A.5, TBDY) = 0.00305417$$

$$c = \text{confinement factor} = 1.10542$$

$$1 = A_{s,ten} / (b * d) * (f_{s1} / f_c) = 0.09371431$$

$$2 = A_{s,com} / (b * d) * (f_{s2} / f_c) = 0.09371431$$

$$v = A_{s,mid} / (b * d) * (f_{sv} / f_c) = 0.03503353$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < v_{s,y2}$  - LHS eq.(4.5) is satisfied

--->

$$s_u (4.9) = 0.16791801$$

$$M_u = M_{Rc} (4.14) = 2.2193E+008$$

$$u = s_u (4.1) = 1.9632832E-005$$

Calculation of ratio  $l_b/l_d$

Lap Length:  $l_b/l_d = 0.33981258$

$$l_b = 300.00$$

$$l_d = 882.8396$$

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

$$= 1$$

$$d_b = 16.66667$$

Mean strength value of all re-bars:  $f_y = 655.558$

Mean concrete strength:  $f'_c = (f'_{c,jacket} * Area_{jacket} + f'_{c,core} * Area_{core}) / Area_{section} = 28.98765$ , but  $f_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 25.00$$

$$K_{tr} = 2.86234$$

$$A_{tr} = \text{Min}(A_{tr,x}, A_{tr,y}) = 257.6106$$

where  $A_{tr,x}$ ,  $A_{tr,y}$  are the sum of the area of all stirrup legs along X and Y local axis

$$s = \text{Max}(s_{external}, s_{internal}) = 300.00$$

$$n = 12.00$$

Calculation of  $M_u2+$

Calculation of ultimate curvature  $u$  according to 4.1, Biskinis/Fardis 2013:

$$u = 1.9632832E-005$$

$$M_u = 2.2193E+008$$

with full section properties:

$$b = 450.00$$

$$d = 407.00$$

$$d' = 43.00$$

$$v = 0.00124204$$

$$N = 7506.808$$

$$fc = 33.00$$

$$co \text{ (5A.5, TBDY)} = 0.002$$

$$\text{Final value of } cu: cu^* = \text{shear\_factor} * \text{Max}(cu, cc) = 0.01393923$$

The Shear\_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } cu = 0.01393923$$

$$\text{we ((5.4c), TBDY)} = ase * sh_{min} * fy_{we} / f_{ce} + \text{Min}(fx, fy) = 0.06811101$$

where  $f = af * pf * f_{fe} / f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$fx = 0.06628267$$

$$af = 0.54930041$$

$$b = 450.00$$

$$h = 450.00$$

$$\text{From EC8 A.4.4.3(6), } pf = 2tf/bw = 0.00451556$$

$$bw = 450.00$$

$$\text{effective stress from (A.35), } ff,e = 881.8461$$

$$fy = 0.06628267$$

$$af = 0.54930041$$

$$b = 450.00$$

$$h = 450.00$$

$$\text{From EC8 A.4.4.3(6), } pf = 2tf/bw = 0.00451556$$

$$bw = 450.00$$

$$\text{effective stress from (A.35), } ff,e = 881.8461$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } tf = NL * t * \text{Cos}(b1) = 1.016$$

$$fu,f = 1055.00$$

$$Ef = 64828.00$$

$$u,f = 0.015$$

$$ase \text{ ((5.4d), TBDY)} = (ase1 * A_{ext} + ase2 * A_{int}) / A_{sec} = 0.14546167$$

$$ase1 = 0.12623274$$

$$bo\_1 = 390.00$$

$$ho\_1 = 390.00$$

$$bi2\_1 = 608400.00$$

$$ase2 = \text{Max}(ase1, ase2) = 0.18853448$$

$$bo\_2 = 242.00$$

$$ho\_2 = 242.00$$

$$bi2\_2 = 234256.00$$

$$psh_{min} * Fy_{we} = \text{Min}(psh_x * Fy_{we}, psh_y * Fy_{we}) = 1.38262$$

Expression ((5.4d), TBDY) for  $psh_{min} * Fy_{we}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$$psh_x * Fy_{we} = psh1 * Fy_{we1} + ps2 * Fy_{we2} = 1.38262$$

$$ps1 \text{ (external)} = (Ash1 * h1 / s1) / A_{sec} = 0.00116355$$

$$Ash1 = Astir\_1 * ns\_1 = 157.0796$$

$$\text{No stirrups, } ns\_1 = 2.00$$

$$h1 = 450.00$$

$$ps2 \text{ (internal)} = (Ash2 * h2 / s2) / A_{sec} = 0.00103427$$

$$Ash2 = Astir\_2 * ns\_2 = 100.531$$

$$\text{No stirrups, } ns\_2 = 2.00$$

$$h2 = 250.00$$

$$psh_y * Fy_{we} = psh1 * Fy_{we1} + ps2 * Fy_{we2} = 1.38262$$

$$ps1 \text{ (external)} = (Ash1 * h1 / s1) / A_{sec} = 0.00116355$$

$$Ash1 = Astir\_1 * ns\_1 = 157.0796$$

$$\text{No stirrups, } ns\_1 = 2.00$$

$$h1 = 450.00$$

$$ps2 \text{ (internal)} = (Ash2 * h2 / s2) / A_{sec} = 0.00103427$$

$$Ash2 = Astir\_2 * ns\_2 = 100.531$$

$$\text{No stirrups, } ns\_2 = 2.00$$

$$h2 = 250.00$$

$$A_{sec} = 202500.00$$

$$s1 = 300.00$$

$$s2 = 120.00$$

fywe1 = 694.45  
fywe2 = 555.55  
fce = 33.00

From ((5.A.5), TBDY), TBDY: cc = 0.00305417  
c = confinement factor = 1.10542

y1 = 0.00152175  
sh1 = 0.0048696  
ft1 = 479.7871  
fy1 = 399.8226  
su1 = 0.0066488

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

lo/lou,min = lb/ld = 0.33981258

su1 = 0.4\*esu1\_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu1\_nominal = 0.08,

For calculation of esu1\_nominal and y1, sh1,ft1,fy1, it is considered  
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by  $\text{Min}(1, 1.25 \cdot (\text{lb}/\text{ld})^{2/3})$ , from 10.3.5, ASCE 41-17.

with fs1 = (fs,jacket\*Asl,ten,jacket + fs,core\*Asl,ten,core)/Asl,ten = 399.8226

with Es1 = (Es,jacket\*Asl,ten,jacket + Es,core\*Asl,ten,core)/Asl,ten = 200000.00

y2 = 0.00152175  
sh2 = 0.0048696  
ft2 = 479.7871  
fy2 = 399.8226  
su2 = 0.0066488

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

lo/lou,min = lb/lb,min = 0.33981258

su2 = 0.4\*esu2\_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu2\_nominal = 0.08,

For calculation of esu2\_nominal and y2, sh2,ft2,fy2, it is considered  
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by  $\text{Min}(1, 1.25 \cdot (\text{lb}/\text{ld})^{2/3})$ , from 10.3.5, ASCE 41-17.

with fs2 = (fs,jacket\*Asl,com,jacket + fs,core\*Asl,com,core)/Asl,com = 399.8226

with Es2 = (Es,jacket\*Asl,com,jacket + Es,core\*Asl,com,core)/Asl,com = 200000.00

yv = 0.00152175  
shv = 0.0048696  
ftv = 507.2537  
fyv = 422.7114  
suv = 0.0066488

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

lo/lou,min = lb/ld = 0.33981258

suv = 0.4\*esuv\_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esuv\_nominal = 0.08,

considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY

For calculation of esuv\_nominal and yv, shv,ftv,fyv, it is considered  
characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by  $\text{Min}(1, 1.25 \cdot (\text{lb}/\text{ld})^{2/3})$ , from 10.3.5, ASCE 41-17.

with fsv = (fs,jacket\*Asl,mid,jacket + fs,mid\*Asl,mid,core)/Asl,mid = 422.7114

with Esv = (Es,jacket\*Asl,mid,jacket + Es,mid\*Asl,mid,core)/Asl,mid = 200000.00

1 = Asl,ten/(b\*d)\*(fs1/fc) = 0.0752324

2 = Asl,com/(b\*d)\*(fs2/fc) = 0.0752324

v = Asl,mid/(b\*d)\*(fsv/fc) = 0.02812438

and confined core properties:

b = 390.00  
d = 377.00  
d' = 13.00

fcc (5A.2, TBDY) = 36.47874

cc (5A.5, TBDY) = 0.00305417

c = confinement factor = 1.10542

1 = Asl,ten/(b\*d)\*(fs1/fc) = 0.09371431

2 = Asl,com/(b\*d)\*(fs2/fc) = 0.09371431

v = Asl,mid/(b\*d)\*(fsv/fc) = 0.03503353

Case/Assumption: Unconfined full section - Steel rupture  
' satisfies Eq. (4.3)

--->  
v < vs,y2 - LHS eq.(4.5) is satisfied

--->  
su (4.9) = 0.16791801  
Mu = MRc (4.14) = 2.2193E+008  
u = su (4.1) = 1.9632832E-005

-----  
Calculation of ratio lb/l<sub>d</sub>

-----  
Lap Length: lb/l<sub>d</sub> = 0.33981258

lb = 300.00

l<sub>d</sub> = 882.8396

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

= 1

db = 16.66667

Mean strength value of all re-bars: fy = 655.558

Mean concrete strength: fc' = (fc'\_jacket\*Area\_jacket + fc'\_core\*Area\_core)/Area\_section = 28.98765, 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 = 2.86234

Atr = Min(Atr\_x,Atr\_y) = 257.6106

where Atr\_x, Atr\_y are the sum of the area of all stirrup legs along X and Y local axis

s = Max(s\_external,s\_internal) = 300.00

n = 12.00

-----  
Calculation of Mu2-

-----  
Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

u = 1.9632832E-005

Mu = 2.2193E+008

-----  
with full section properties:

b = 450.00

d = 407.00

d' = 43.00

v = 0.00124204

N = 7506.808

fc = 33.00

co (5A.5, TBDY) = 0.002

Final value of cu: cu\* = shear\_factor \* Max( cu, cc) = 0.01393923

The Shear\_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: cu = 0.01393923

we ((5.4c), TBDY) = ase\* sh,min\*fywe/fce+ Min( fx, fy) = 0.06811101

where f = af\*pf\*ffe/fce is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

-----  
fx = 0.06628267

af = 0.54930041

b = 450.00

h = 450.00

From EC8 A.4.4.3(6), pf = 2tf/bw = 0.00451556

bw = 450.00

effective stress from (A.35), ff,e = 881.8461

-----  
fy = 0.06628267

af = 0.54930041

b = 450.00

h = 450.00

From EC8 A.4.4.3(6),  $pf = 2tf/bw = 0.00451556$   
 $bw = 450.00$   
effective stress from (A.35),  $ff,e = 881.8461$

R = 40.00  
Effective FRP thickness,  $tf = NL*t*\text{Cos}(b1) = 1.016$   
 $f_{u,f} = 1055.00$   
 $E_f = 64828.00$   
 $u_{,f} = 0.015$   
 $ase((5.4d), \text{TBDY}) = (ase1*A_{ext} + ase2*A_{int})/A_{sec} = 0.14546167$   
 $ase1 = 0.12623274$   
 $bo_1 = 390.00$   
 $ho_1 = 390.00$   
 $bi2_1 = 608400.00$   
 $ase2 = \text{Max}(ase1, ase2) = 0.18853448$   
 $bo_2 = 242.00$   
 $ho_2 = 242.00$   
 $bi2_2 = 234256.00$

$psh_{,min}*F_{ywe} = \text{Min}(psh_{,x}*F_{ywe}, psh_{,y}*F_{ywe}) = 1.38262$   
Expression ((5.4d), TBDY) for  $psh_{,min}*F_{ywe}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$psh_{,x}*F_{ywe} = psh1*F_{ywe1} + ps2*F_{ywe2} = 1.38262$   
 $ps1(\text{external}) = (Ash1*h1/s1)/A_{sec} = 0.00116355$   
 $Ash1 = Astir_1*ns_1 = 157.0796$   
No stirrups,  $ns_1 = 2.00$   
 $h1 = 450.00$   
 $ps2(\text{internal}) = (Ash2*h2/s2)/A_{sec} = 0.00103427$   
 $Ash2 = Astir_2*ns_2 = 100.531$   
No stirrups,  $ns_2 = 2.00$   
 $h2 = 250.00$

$psh_{,y}*F_{ywe} = psh1*F_{ywe1} + ps2*F_{ywe2} = 1.38262$   
 $ps1(\text{external}) = (Ash1*h1/s1)/A_{sec} = 0.00116355$   
 $Ash1 = Astir_1*ns_1 = 157.0796$   
No stirrups,  $ns_1 = 2.00$   
 $h1 = 450.00$   
 $ps2(\text{internal}) = (Ash2*h2/s2)/A_{sec} = 0.00103427$   
 $Ash2 = Astir_2*ns_2 = 100.531$   
No stirrups,  $ns_2 = 2.00$   
 $h2 = 250.00$

$A_{sec} = 202500.00$   
 $s1 = 300.00$   
 $s2 = 120.00$   
 $f_{ywe1} = 694.45$   
 $f_{ywe2} = 555.55$   
 $f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.00305417$   
 $c = \text{confinement factor} = 1.10542$

$y1 = 0.00152175$   
 $sh1 = 0.0048696$   
 $ft1 = 479.7871$   
 $fy1 = 399.8226$   
 $su1 = 0.0066488$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
 $\text{Shear\_factor} = 1.00$

$lo/lo_{u,min} = lb/d = 0.33981258$   
 $su1 = 0.4*esu1_{nominal}((5.5), \text{TBDY}) = 0.032$

From table 5A.1, TBDY:  $esu1_{nominal} = 0.08$ ,

For calculation of  $esu1_{nominal}$  and  $y1, sh1, ft1, fy1$ , it is considered  
characteristic value  $fsy1 = fs1/1.2$ , from table 5.1, TBDY.

$y1, sh1, ft1, fy1$ , are also multiplied by  $\text{Min}(1, 1.25*(lb/d)^{2/3})$ , from 10.3.5, ASCE 41-17.

with  $fs1 = (fs_{jacket}*A_{sl,ten,jacket} + fs_{core}*A_{sl,ten,core})/A_{sl,ten} = 399.8226$

with  $Es1 = (Es_{jacket}*A_{sl,ten,jacket} + Es_{core}*A_{sl,ten,core})/A_{sl,ten} = 200000.00$

$y2 = 0.00152175$

$sh_2 = 0.0048696$   
 $ft_2 = 479.7871$   
 $fy_2 = 399.8226$   
 $su_2 = 0.0066488$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 Shear\_factor = 1.00  
 $lo/lo_{min} = lb/lb_{min} = 0.33981258$   
 $su_2 = 0.4 * esu_{2,nominal} ((5.5), TBDY) = 0.032$   
 From table 5A.1, TBDY:  $esu_{2,nominal} = 0.08$ ,  
 For calculation of  $esu_{2,nominal}$  and  $y_2, sh_2, ft_2, fy_2$ , it is considered  
 characteristic value  $fsy_2 = fs_2/1.2$ , from table 5.1, TBDY.  
 $y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $Min(1, 1.25 * (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with  $fs_2 = (fs_{jacket} * Asl_{com,jacket} + fs_{core} * Asl_{com,core}) / Asl_{com} = 399.8226$   
 with  $Es_2 = (Es_{jacket} * Asl_{com,jacket} + Es_{core} * Asl_{com,core}) / Asl_{com} = 200000.00$   
 $yv = 0.00152175$   
 $shv = 0.0048696$   
 $ftv = 507.2537$   
 $fyv = 422.7114$   
 $suv = 0.0066488$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 Shear\_factor = 1.00  
 $lo/lo_{min} = lb/ld = 0.33981258$   
 $suv = 0.4 * esuv_{nominal} ((5.5), TBDY) = 0.032$   
 From table 5A.1, TBDY:  $esuv_{nominal} = 0.08$ ,  
 considering characteristic value  $fsyv = fsv/1.2$ , from table 5.1, TBDY  
 For calculation of  $esuv_{nominal}$  and  $yv, shv, ftv, fyv$ , it is considered  
 characteristic value  $fsyv = fsv/1.2$ , from table 5.1, TBDY.  
 $y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $Min(1, 1.25 * (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with  $fsv = (fs_{jacket} * Asl_{mid,jacket} + fs_{mid} * Asl_{mid,core}) / Asl_{mid} = 422.7114$   
 with  $Es_v = (Es_{jacket} * Asl_{mid,jacket} + Es_{mid} * Asl_{mid,core}) / Asl_{mid} = 200000.00$   
 $1 = Asl_{ten} / (b * d) * (fs_1 / fc) = 0.0752324$   
 $2 = Asl_{com} / (b * d) * (fs_2 / fc) = 0.0752324$   
 $v = Asl_{mid} / (b * d) * (fsv / fc) = 0.02812438$

and confined core properties:

$b = 390.00$   
 $d = 377.00$   
 $d' = 13.00$   
 $fcc (5A.2, TBDY) = 36.47874$   
 $cc (5A.5, TBDY) = 0.00305417$   
 $c = \text{confinement factor} = 1.10542$   
 $1 = Asl_{ten} / (b * d) * (fs_1 / fc) = 0.09371431$   
 $2 = Asl_{com} / (b * d) * (fs_2 / fc) = 0.09371431$   
 $v = Asl_{mid} / (b * d) * (fsv / fc) = 0.03503353$

Case/Assumption: Unconfined full section - Steel rupture  
 ' satisfies Eq. (4.3)

--->  
 $v < v_{s,y_2}$  - LHS eq.(4.5) is satisfied  
 --->  
 $su (4.9) = 0.16791801$   
 $Mu = MRc (4.14) = 2.2193E+008$   
 $u = su (4.1) = 1.9632832E-005$

-----  
 Calculation of ratio  $lb/ld$

-----  
 Lap Length:  $lb/ld = 0.33981258$   
 $lb = 300.00$   
 $ld = 882.8396$   
 Calculation of  $lb_{min}$  according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.  
 $= 1$   
 $db = 16.66667$   
 Mean strength value of all re-bars:  $fy = 655.558$   
 Mean concrete strength:  $fc' = (fc'_{jacket} * Area_{jacket} + fc'_{core} * Area_{core}) / Area_{section} = 28.98765$ , but  $fc'^{0.5} < =$   
 $8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$   
 $t = 1.00$

$s = 0.80$   
 $e = 1.00$   
 $cb = 25.00$   
 $Ktr = 2.86234$   
 $Atr = \text{Min}(Atr_x, Atr_y) = 257.6106$   
 where  $Atr_x, Atr_y$  are the sum of the area of all stirrup legs along X and Y loxal axis  
 $s = \text{Max}(s_{\text{external}}, s_{\text{internal}}) = 300.00$   
 $n = 12.00$

-----  
 Calculation of Shear Strength  $Vr = \text{Min}(Vr1, Vr2) = 567563.724$   
 -----

Calculation of Shear Strength at edge 1,  $Vr1 = 567563.724$

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

$VCol0 = 567563.724$

$knl = 1$  (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:  $fc' = (fc'_{\text{jacket}} * Area_{\text{jacket}} + fc'_{\text{core}} * Area_{\text{core}}) / Area_{\text{section}} = 28.98765$ , but  $fc'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$Mu = 1.0463738E-012$

$Vu = 2.7162834E-031$

$d = 0.8 * h = 360.00$

$Nu = 7506.808$

$Ag = 202500.00$

From (11.5.4.8), ACI 318-14:  $Vs = Vs1 + Vs2 = 144280.365$

where:

$Vs1 = 69813.729$  is calculated for jacket, with:

$d = 360.00$

$Av = 157079.633$

$fy = 555.56$

$s = 300.00$

$Vs1$  is multiplied by  $Col1 = 0.66666667$

$s/d = 0.83333333$

$Vs2 = 74466.637$  is calculated for core, with:

$d = 200.00$

$Av = 100530.965$

$fy = 444.44$

$s = 120.00$

$Vs2$  is multiplied by  $Col2 = 1.00$

$s/d = 0.60$

$Vf$  ((11-3)-(11.4), ACI 440) =  $214457.247$

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

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

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

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

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

$dfv = d$  (figure 11.2, ACI 440) =  $407.00$

$ffe$  ((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:  $Vs + Vf \leq 579413.096$

$bw = 450.00$

-----  
 Calculation of Shear Strength at edge 2,  $Vr2 = 567563.724$   
 -----

Vr2 = VCol ((10.3), ASCE 41-17) = knl\*VCol0

VCol0 = 567563.724

kn1 = 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 = 28.98765, but fc'^0.5 <= 8.3 MPa (22.5.3.1, ACI 318-14)

M/Vd = 2.00

Mu = 1.0463738E-012

Vu = 2.7162834E-031

d = 0.8\*h = 360.00

Nu = 7506.808

Ag = 202500.00

From (11.5.4.8), ACI 318-14: Vs = Vs1 + Vs2 = 144280.365

where:

Vs1 = 69813.729 is calculated for jacket, with:

d = 360.00

Av = 157079.633

fy = 555.56

s = 300.00

Vs1 is multiplied by Col1 = 0.66666667

s/d = 0.83333333

Vs2 = 74466.637 is calculated for core, with:

d = 200.00

Av = 100530.965

fy = 444.44

s = 120.00

Vs2 is multiplied by Col2 = 1.00

s/d = 0.60

Vf ((11-3)-(11.4), ACI 440) = 214457.247

f = 0.95, for fully-wrapped sections

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

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

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

orientation 1: 1 = b1 + 90° = 90.00

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

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

dfv = d (figure 11.2, ACI 440) = 407.00

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 <= 579413.096

bw = 450.00

End Of Calculation of Shear Capacity ratio for element: column JC1 of floor 1

At local axis: 2

Start Of Calculation of Chord Rotation Capacity for element: column JC1 of floor 1

At local axis: 3

Integration Section: (a)

Section Type: rcjrs

Constant Properties

Knowledge Factor, = 0.85

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

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

Consequently:

Jacket

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

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,  $E_s = 200000.00$

External Height,  $H = 450.00$

External Width,  $W = 450.00$

Internal Height,  $H = 250.00$

Internal Width,  $W = 250.00$

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,  $M = -2.3098E+007$

Shear Force,  $V_2 = -7697.601$

Shear Force,  $V_3 = 1.7235006E-013$

Axial Force,  $F = -7503.728$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension:  $As_{t} = 1137.257$

-Compression:  $As_{c} = 1539.38$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension:  $As_{l,ten} = 1137.257$

-Compression:  $As_{l,com} = 1137.257$

-Middle:  $As_{l,mid} = 402.1239$

Longitudinal External Reinforcement Area Distribution (in 3 divisions)

-Tension:  $As_{l,ten,jacket} = 829.3805$

-Compression:  $As_{l,com,jacket} = 829.3805$

-Middle:  $As_{l,mid,jacket} = 402.1239$

Longitudinal Internal Reinforcement Area Distribution (in 3 divisions)

-Tension:  $As_{l,ten,core} = 307.8761$

-Compression:  $As_{l,com,core} = 307.8761$

-Middle:  $As_{l,mid,core} = 0.00$

Mean Diameter of Tension Reinforcement,  $Db_L = 16.80$

-----  
Existing component: From table 7-7, ASCE 41\_17: Final chord rotation Capacity  $u_{,R} = \alpha \cdot u = 0.00552671$

$u = \gamma + \rho = 0.00650201$

-----  
- Calculation of  $\gamma$  -

$y = (M_y * L_s / 3) / E_{eff} = 0.00650201$  ((4.29), Biskinis Phd)  
 $M_y = 1.7613E+008$   
 $L_s = M/V$  (with  $L_s > 0.1 * L$  and  $L_s < 2 * L$ ) = 3000.708  
 From table 10.5, ASCE 41\_17:  $E_{eff} = factor * E_c * I_g = 2.7095E+013$   
 $factor = 0.30$   
 $A_g = 202500.00$   
 Mean concrete strength:  $f_c' = (f_c'_{jacket} * Area_{jacket} + f_c'_{core} * Area_{core}) / Area_{section} = 28.98765$   
 $N = 7503.728$   
 $E_c * I_g = E_c_{jacket} * I_{g,jacket} + E_c_{core} * I_{g,core} = 9.0315E+013$

Calculation of Yielding Moment  $M_y$

Calculation of  $y$  and  $M_y$  according to Annex 7 -

$y = \text{Min}(y_{ten}, y_{com})$   
 $y_{ten} = 6.1806747E-006$   
 with ((10.1), ASCE 41-17)  $f_y = \text{Min}(f_y, 1.25 * f_y * (I_b / I_d)^{2/3}) = 374.3546$   
 $d = 407.00$   
 $y = 0.25591435$   
 $A = 0.0147239$   
 $B = 0.00818869$   
 with  $pt = 0.00430549$   
 $pc = 0.00620943$   
 $pv = 0.0021956$   
 $N = 7503.728$   
 $b = 450.00$   
 $" = 0.10565111$   
 $y_{comp} = 2.2127278E-005$   
 with  $f_c' (12.3, (ACI 440)) = 34.40847$   
 $f_c = 33.00$   
 $f_l = 0.82797802$   
 $b = 450.00$   
 $h = 450.00$   
 $A_g = 202500.00$   
 From (12.9), ACI 440:  $k_a = 0.54261599$   
 $g = pt + pc + pv = 0.01461445$   
 $rc = 40.00$   
 $A_e / A_c = 0.54261599$   
 Effective FRP thickness,  $t_f = N L * t * \text{Cos}(b_1) = 1.016$   
 effective strain from (12.5) and (12.12),  $e_{fe} = 0.004$   
 $f_u = 0.01$   
 $E_f = 64828.00$   
 $E_c = 26999.444$   
 $y = 0.25471862$   
 $A = 0.01452515$   
 $B = 0.00807924$   
 with  $E_s = 200000.00$

Calculation of ratio  $I_b / I_d$

Lap Length:  $I_d / I_{d,min} = 0.42476573$

$I_b = 300.00$

$I_d = 706.2717$

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

= 1

$db = 16.66667$

Mean strength value of all re-bars:  $f_y = 524.4464$

Mean concrete strength:  $f_c' = (f_c'_{jacket} * Area_{jacket} + f_c'_{core} * Area_{core}) / Area_{section} = 28.98765$ , 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  
Ktr = 2.86234  
Atr = Min(Atr\_x,Atr\_y) = 257.6106  
where Atr\_x, Atr\_y are the sum of the area of all stirrup legs along X and Y local axis  
s = Max(s\_external,s\_internal) = 300.00  
n = 12.00

-----  
- Calculation of p -  
-----

From table 10-8: p = 0.00

with:

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

shear control ratio  $V_y E / V_{CoI} E = 0.26068017$

d = d\_external = 407.00

s = s\_external = 0.00

t =  $s_1 + s_2 + 2 * t_f / b_w * (f_{fe} / f_s) = 0.00430549$

jacket:  $s_1 = A_{v1} * h_1 / (s_1 * A_g) = 0.00116355$

Av1 = 157.0796, is the total area of all stirrups parallel to loading (shear) direction

h1 = 450.00

s1 = 300.00

core:  $s_2 = A_{v2} * h_2 / (s_2 * A_g) = 0.00103427$

Av2 = 100.531, is the total area of all stirrups parallel to loading (shear) direction

h2 = 250.00

s2 = 120.00

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

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

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

For the normalisation  $f_s$  of jacket is used.

NUD = 7503.728

Ag = 202500.00

f<sub>cE</sub> =  $(f_{c\_jacket} * Area\_jacket + f_{c\_core} * Area\_core) / section\_area = 28.98765$

f<sub>yE</sub> =  $(f_{y\_ext\_Long\_Reinf} * Area\_ext\_Long\_Reinf + f_{y\_int\_Long\_Reinf} * Area\_int\_Long\_Reinf) / Area\_Tot\_Long\_Rein = 529.9972$

f<sub>ytE</sub> =  $(f_{y\_ext\_Trans\_Reinf} * s_1 + f_{y\_int\_Trans\_Reinf} * s_2) / (s_1 + s_2) = 503.2682$

pl =  $Area\_Tot\_Long\_Rein / (b * d) = 0.01461445$

b = 450.00

d = 407.00

f<sub>cE</sub> = 28.98765

-----  
End Of Calculation of Chord Rotation Capacity for element: column JC1 of floor 1

At local axis: 3

Integration Section: (a)  
-----

**Calculation No. 5**

column C1, Floor 1

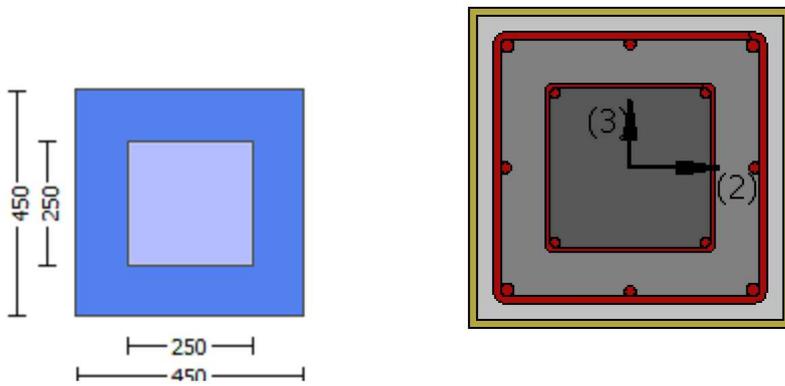
Limit State: Immediate Occupancy (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Shear capacity VRd

Edge: End

Local Axis: (2)



Start Of Calculation of Shear Capacity for element: column JC1 of floor 1

At local axis: 2

Integration Section: (b)

Section Type: rcjrs

Constant Properties

Knowledge Factor,  $\gamma = 0.85$

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  $\gamma$  for displacement ductility demand, the expected (mean value) strengths are used (7.5.1.3, ASCE 41-17) because bending is considered as Deformation-Controlled Action (Table C7-1, ASCE 41-17).

Jacket

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

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

Existing Column

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

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

#####

External Height,  $H = 450.00$

External Width,  $W = 450.00$

Internal Height,  $H = 250.00$

Internal Width,  $W = 250.00$

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,  $M_a = -2.3098E+007$   
Shear Force,  $V_a = -7697.601$   
EDGE -B-  
Bending Moment,  $M_b = 0.06012619$   
Shear Force,  $V_b = 7697.601$   
BOTH EDGES  
Axial Force,  $F = -7503.728$   
Longitudinal Reinforcement Area Distribution (in 2 divisions)  
-Tension:  $A_{sl,t} = 0.00$   
-Compression:  $A_{sl,c} = 2676.637$   
Longitudinal Reinforcement Area Distribution (in 3 divisions)  
-Tension:  $A_{sl,ten} = 1137.257$   
-Compression:  $A_{sl,com} = 1137.257$   
-Middle:  $A_{sl,mid} = 402.1239$   
Mean Diameter of Tension Reinforcement,  $Db_{L,ten} = 16.80$

Existing component: From table 7-7, ASCE 41\_17: Final Shear Capacity  $V_R = \phi V_n = 447100.515$   
 $V_n$  ((10.3), ASCE 41-17) =  $k_n \phi V_{CoI0} = 526000.605$   
 $V_{CoI} = 526000.605$   
 $k_n = 1.00$   
displacement\_ductility\_demand = 0.19669705

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:  $f_c' = (f_c'_{jacket} \cdot Area_{jacket} + f_c'_{core} \cdot Area_{core}) / Area_{section} = 22.22222$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)  
 $M/Vd = 2.00$   
 $M_u = 0.06012619$   
 $V_u = 7697.601$   
 $d = 0.8 \cdot h = 360.00$   
 $N_u = 7503.728$   
 $A_g = 202500.00$   
From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 129852.496$   
where:  
 $V_{s1} = 62831.853$  is calculated for jacket, with:  
 $d = 360.00$   
 $A_v = 157079.633$   
 $f_y = 500.00$   
 $s = 300.00$   
 $V_{s1}$  is multiplied by  $Col1 = 0.66666667$   
 $s/d = 0.83333333$

Vs2 = 67020.643 is calculated for core, with:

$$d = 200.00$$

$$A_v = 100530.965$$

$$f_y = 400.00$$

$$s = 120.00$$

Vs2 is multiplied by Col2 = 1.00

$$s/d = 0.60$$

Vf ((11-3)-(11.4), ACI 440) = 214457.247

f = 0.95, for fully-wrapped sections

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

orientation 1:  $\alpha_1 = b1 + 90^\circ = 90.00$

Vf = Min(|Vf(45,  $\alpha_1$ )|, |Vf(-45,  $\alpha_1$ )|), with:

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

dfv = d (figure 11.2, ACI 440) = 407.00

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: Vs + Vf <= 507312.442

$$b_w = 450.00$$

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

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

for rotation axis 3 and integ. section (b)

-----  
From analysis, chord rotation  $\theta = 0.00012786$

$y = (M_y * L_s / 3) / E_{eff} = 0.00065005$  ((4.29), Biskinis Phd)

$$M_y = 1.7613E+008$$

Ls = M/V (with Ls > 0.1\*L and Ls < 2\*L) = 300.00

From table 10.5, ASCE 41\_17:  $E_{eff} = factor * E_c * I_g = 2.7095E+013$

$$factor = 0.30$$

$$A_g = 202500.00$$

$$\text{Mean concrete strength: } f'_c = (f'_{c\_jacket} * Area_{jacket} + f'_{c\_core} * Area_{core}) / Area_{section} = 28.98765$$

$$N = 7503.728$$

$$E_c * I_g = E_{c\_jacket} * I_{g\_jacket} + E_{c\_core} * I_{g\_core} = 9.0315E+013$$

-----  
Calculation of Yielding Moment My

-----  
Calculation of  $\delta / y$  and My according to Annex 7 -

$$y = \text{Min}(y_{ten}, y_{com})$$

$$y_{ten} = 6.1806747E-006$$

with ((10.1), ASCE 41-17)  $f_y = \text{Min}(f_y, 1.25 * f_y * (I_b / I_d)^{2/3}) = 374.3546$

$$d = 407.00$$

$$y = 0.25591435$$

$$A = 0.0147239$$

$$B = 0.00818869$$

with pt = 0.00620943

$$p_c = 0.00620943$$

$$p_v = 0.0021956$$

$$N = 7503.728$$

$$b = 450.00$$

$$\alpha = 0.10565111$$

$$y_{comp} = 2.2127278E-005$$

with  $f'_c$  (12.3, (ACI 440)) = 34.40847

$$f_c = 33.00$$

$$f_l = 0.82797802$$

$$b = 450.00$$

h = 450.00  
Ag = 202500.00  
From (12.9), ACI 440: ka = 0.54261599  
g = pt + pc + pv = 0.01461445  
rc = 40.00  
Ae/Ac = 0.54261599  
Effective FRP thickness, tf = NL\*t\*Cos(b1) = 1.016  
effective strain from (12.5) and (12.12), efe = 0.004  
fu = 0.01  
Ef = 64828.00  
Ec = 26999.444  
y = 0.25471862  
A = 0.01452515  
B = 0.00807924  
with Es = 200000.00

-----  
-----  
Calculation of ratio lb/ld

Lap Length: ld/ld,min = 0.42476573

lb = 300.00

ld = 706.2717

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

= 1

db = 16.66667

Mean strength value of all re-bars: fy = 524.4464

Mean concrete strength: fc' = (fc'\_jacket\*Area\_jacket + fc'\_core\*Area\_core)/Area\_section = 28.98765, 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 = 2.86234

Atr = Min(Atr\_x,Atr\_y) = 257.6106

where Atr\_x, Atr\_y are the sum of the area of all stirrup legs along X and Y local axis

s = Max(s\_external,s\_internal) = 300.00

n = 12.00

-----  
End Of Calculation of Shear Capacity for element: column JC1 of floor 1

At local axis: 2

Integration Section: (b)

## Calculation No. 6

column C1, Floor 1

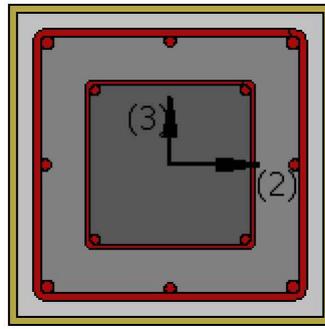
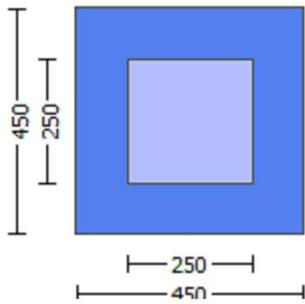
Limit State: Immediate Occupancy (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity ( u)

Edge: End

Local Axis: (2)



Start Of Calculation of Shear Capacity ratio for element: column JC1 of floor 1

At Shear local axis: 3

(Bending local axis: 2)

Section Type: rcjrs

Constant Properties

Knowledge Factor,  $\gamma = 0.85$

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 Height,  $H = 450.00$

External Width,  $W = 450.00$

Internal Height,  $H = 250.00$

Internal Width,  $W = 250.00$

Cover Thickness,  $c = 25.00$

Mean Confinement Factor overall section = 1.10542

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,  $V_a = 2.0531359E-031$

EDGE -B-

Shear Force,  $V_b = -2.0531359E-031$

BOTH EDGES

Axial Force,  $F = -7506.808$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension:  $As_t = 0.00$

-Compression:  $As_c = 2676.637$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension:  $As_{t,ten} = 1137.257$

-Compression:  $As_{l,com} = 1137.257$

-Middle:  $As_{l,mid} = 402.1239$

Calculation of Shear Capacity ratio,  $V_e/V_r = 0.26068017$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 147952.607$

with

$M_{pr1} = \text{Max}(M_{u1+}, M_{u1-}) = 2.2193E+008$

$M_{u1+} = 2.2193E+008$ , 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

$M_{u1-} = 2.2193E+008$ , 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

$M_{pr2} = \text{Max}(M_{u2+}, M_{u2-}) = 2.2193E+008$

$M_{u2+} = 2.2193E+008$ , 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

$M_{u2-} = 2.2193E+008$ , 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 curvature  $\phi_u$  according to 4.1, Biskinis/Fardis 2013:

$\phi_u = 1.9632832E-005$

$M_u = 2.2193E+008$

with full section properties:

$b = 450.00$

$d = 407.00$

$d' = 43.00$

$v = 0.00124204$

$N = 7506.808$

$f_c = 33.00$

$\alpha$  (5A.5, TBDY) = 0.002

Final value of  $\phi_u$ :  $\phi_u^* = \text{shear\_factor} * \text{Max}(\phi_u, \phi_c) = 0.01393923$

The Shear\_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY:  $\phi_u = 0.01393923$

where  $\phi_u$  ((5.4c), TBDY) =  $\alpha s_e * \text{sh}_{\min} * f_{ywe} / f_{ce} + \text{Min}(\phi_x, \phi_y) = 0.06811101$

where  $\phi = \alpha f * p_f * f_{fe} / f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$\phi_x = 0.06628267$

$\alpha f = 0.54930041$

$b = 450.00$

$h = 450.00$

From EC8 A.4.4.3(6),  $p_f = 2t_f/bw = 0.00451556$

$bw = 450.00$

effective stress from (A.35),  $f_{fe} = 881.8461$

fy = 0.06628267  
af = 0.54930041  
b = 450.00  
h = 450.00  
From EC8 A.4.4.3(6), pf = 2tf/bw = 0.00451556  
bw = 450.00  
effective stress from (A.35), ff,e = 881.8461

R = 40.00  
Effective FRP thickness, tf = NL\*t\*Cos(b1) = 1.016  
fu,f = 1055.00  
Ef = 64828.00  
u,f = 0.015  
ase ((5.4d), TBDY) = (ase1\*Aext+ase2\*Aint)/Asec = 0.14546167  
ase1 = 0.12623274  
bo\_1 = 390.00  
ho\_1 = 390.00  
bi2\_1 = 608400.00  
ase2 = Max(ase1,ase2) = 0.18853448  
bo\_2 = 242.00  
ho\_2 = 242.00  
bi2\_2 = 234256.00  
psh,min\*Fywe = Min(psh,x\*Fywe , psh,y\*Fywe) = 1.38262

Expression ((5.4d), TBDY) for psh,min\*Fywe has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

psh\_x\*Fywe = psh1\*Fywe1+ps2\*Fywe2 = 1.38262  
ps1 (external) = (Ash1\*h1/s1)/Asec = 0.00116355  
Ash1 = Astir\_1\*ns\_1 = 157.0796  
No stirrups, ns\_1 = 2.00  
h1 = 450.00  
ps2 (internal) = (Ash2\*h2/s2)/Asec = 0.00103427  
Ash2 = Astir\_2\*ns\_2 = 100.531  
No stirrups, ns\_2 = 2.00  
h2 = 250.00

psh\_y\*Fywe = psh1\*Fywe1+ps2\*Fywe2 = 1.38262  
ps1 (external) = (Ash1\*h1/s1)/Asec = 0.00116355  
Ash1 = Astir\_1\*ns\_1 = 157.0796  
No stirrups, ns\_1 = 2.00  
h1 = 450.00  
ps2 (internal) = (Ash2\*h2/s2)/Asec = 0.00103427  
Ash2 = Astir\_2\*ns\_2 = 100.531  
No stirrups, ns\_2 = 2.00  
h2 = 250.00

Asec = 202500.00  
s1 = 300.00  
s2 = 120.00  
fywe1 = 694.45  
fywe2 = 555.55  
fce = 33.00

From ((5.A5), TBDY), TBDY: cc = 0.00305417  
c = confinement factor = 1.10542

y1 = 0.00152175  
sh1 = 0.0048696  
ft1 = 479.7871  
fy1 = 399.8226  
su1 = 0.0066488

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

lo/lou,min = lb/d = 0.33981258

su1 = 0.4\*esu1\_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu1\_nominal = 0.08,

For calculation of esu1\_nominal and y1, sh1,ft1,fy1, it is considered

characteristic value  $f_{sy1} = f_{s1}/1.2$ , from table 5.1, TBDY.

$y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.

with  $f_{s1} = (f_{s,jacket} \cdot A_{s,ten,jacket} + f_{s,core} \cdot A_{s,ten,core})/A_{s,ten} = 399.8226$

with  $E_{s1} = (E_{s,jacket} \cdot A_{s,ten,jacket} + E_{s,core} \cdot A_{s,ten,core})/A_{s,ten} = 200000.00$

$y_2 = 0.00152175$

$sh_2 = 0.0048696$

$ft_2 = 479.7871$

$fy_2 = 399.8226$

$su_2 = 0.0066488$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor

and also multiplied by the shear\_factor according to 15.7.1.4, with

Shear\_factor = 1.00

$l_o/l_{o,min} = l_b/l_{b,min} = 0.33981258$

$su_2 = 0.4 \cdot esu_{2,nominal} ((5.5), TBDY) = 0.032$

From table 5A.1, TBDY:  $esu_{2,nominal} = 0.08$ ,

For calculation of  $esu_{2,nominal}$  and  $y_2, sh_2, ft_2, fy_2$ , it is considered

characteristic value  $f_{sy2} = f_{s2}/1.2$ , from table 5.1, TBDY.

$y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.

with  $f_{s2} = (f_{s,jacket} \cdot A_{s,com,jacket} + f_{s,core} \cdot A_{s,com,core})/A_{s,com} = 399.8226$

with  $E_{s2} = (E_{s,jacket} \cdot A_{s,com,jacket} + E_{s,core} \cdot A_{s,com,core})/A_{s,com} = 200000.00$

$y_v = 0.00152175$

$sh_v = 0.0048696$

$ft_v = 507.2537$

$fy_v = 422.7114$

$su_v = 0.0066488$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor

and also multiplied by the shear\_factor according to 15.7.1.4, with

Shear\_factor = 1.00

$l_o/l_{o,min} = l_b/l_d = 0.33981258$

$su_v = 0.4 \cdot esu_{v,nominal} ((5.5), TBDY) = 0.032$

From table 5A.1, TBDY:  $esu_{v,nominal} = 0.08$ ,

considering characteristic value  $f_{syv} = f_{sv}/1.2$ , from table 5.1, TBDY

For calculation of  $esu_{v,nominal}$  and  $y_v, sh_v, ft_v, fy_v$ , it is considered

characteristic value  $f_{syv} = f_{sv}/1.2$ , from table 5.1, TBDY.

$y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.

with  $f_{sv} = (f_{s,jacket} \cdot A_{s,mid,jacket} + f_{s,mid} \cdot A_{s,mid,core})/A_{s,mid} = 422.7114$

with  $E_{sv} = (E_{s,jacket} \cdot A_{s,mid,jacket} + E_{s,mid} \cdot A_{s,mid,core})/A_{s,mid} = 200000.00$

$1 = A_{s,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.0752324$

$2 = A_{s,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.0752324$

$v = A_{s,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.02812438$

and confined core properties:

$b = 390.00$

$d = 377.00$

$d' = 13.00$

$f_{cc} (5A.2, TBDY) = 36.47874$

$cc (5A.5, TBDY) = 0.00305417$

$c = \text{confinement factor} = 1.10542$

$1 = A_{s,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.09371431$

$2 = A_{s,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.09371431$

$v = A_{s,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.03503353$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

---->

$v < v_{s,y2}$  - LHS eq.(4.5) is satisfied

---->

$su (4.9) = 0.16791801$

$Mu = MRc (4.14) = 2.2193E+008$

$u = su (4.1) = 1.9632832E-005$

Calculation of ratio  $l_b/l_d$

Lap Length:  $l_b/l_d = 0.33981258$

$l_b = 300.00$

$l_d = 882.8396$

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

= 1

$db = 16.66667$   
 Mean strength value of all re-bars:  $f_y = 655.558$   
 Mean concrete strength:  $f_c' = (f_c'_{jacket} \cdot Area_{jacket} + f_c'_{core} \cdot Area_{core}) / Area_{section} = 28.98765$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)  
 $t = 1.00$   
 $s = 0.80$   
 $e = 1.00$   
 $cb = 25.00$   
 $K_{tr} = 2.86234$   
 $A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 257.6106$   
 where  $A_{tr_x}$ ,  $A_{tr_y}$  are the sum of the area of all stirrup legs along X and Y local axis  
 $s = \text{Max}(s_{external}, s_{internal}) = 300.00$   
 $n = 12.00$

-----  
 -----  
 -----  
 Calculation of  $\mu_1$ -  
 -----

Calculation of ultimate curvature  $\mu$  according to 4.1, Biskinis/Fardis 2013:  
 $\mu = 1.9632832E-005$   
 $\mu_u = 2.2193E+008$

-----  
 with full section properties:

$b = 450.00$   
 $d = 407.00$   
 $d' = 43.00$   
 $v = 0.00124204$   
 $N = 7506.808$   
 $f_c = 33.00$   
 $\alpha_1$  (5A.5, TBDY) = 0.002  
 Final value of  $\mu_c$ :  $\mu_c^* = \text{shear\_factor} \cdot \text{Max}(\mu_c, \mu_{cc}) = 0.01393923$   
 The Shear\_factor is considered equal to 1 (pure moment strength)  
 From (5.4b), TBDY:  $\mu_c = 0.01393923$   
 $\mu_{ve}$  ((5.4c), TBDY) =  $\alpha_{se} \cdot \text{sh}_{\min} \cdot f_{yve} / f_{ce} + \text{Min}(f_x, f_y) = 0.06811101$   
 where  $f = \alpha_f \cdot \rho_f \cdot f_{fe} / f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

-----  
 $f_x = 0.06628267$   
 $\alpha_f = 0.54930041$   
 $b = 450.00$   
 $h = 450.00$   
 From EC8 A.4.4.3(6),  $\rho_f = 2t_f/bw = 0.00451556$   
 $bw = 450.00$   
 effective stress from (A.35),  $f_{fe} = 881.8461$

-----  
 $f_y = 0.06628267$   
 $\alpha_f = 0.54930041$   
 $b = 450.00$   
 $h = 450.00$   
 From EC8 A.4.4.3(6),  $\rho_f = 2t_f/bw = 0.00451556$   
 $bw = 450.00$   
 effective stress from (A.35),  $f_{fe} = 881.8461$

-----  
 $R = 40.00$   
 Effective FRP thickness,  $t_f = NL \cdot t \cdot \text{Cos}(\beta_1) = 1.016$   
 $f_{u,f} = 1055.00$   
 $E_f = 64828.00$   
 $u_f = 0.015$   
 $\alpha_{se}$  ((5.4d), TBDY) =  $(\alpha_{se1} \cdot A_{ext} + \alpha_{se2} \cdot A_{int}) / A_{sec} = 0.14546167$   
 $\alpha_{se1} = 0.12623274$   
 $bo_1 = 390.00$   
 $ho_1 = 390.00$   
 $bi_2 = 608400.00$   
 $\alpha_{se2} = \text{Max}(\alpha_{se1}, \alpha_{se2}) = 0.18853448$   
 $bo_2 = 242.00$   
 $ho_2 = 242.00$

$$bi_{2,2} = 234256.00$$

$$psh_{min} * Fy_{we} = \text{Min}(psh_x * Fy_{we}, psh_y * Fy_{we}) = 1.38262$$

Expression ((5.4d), TBDY) for  $psh_{min} * Fy_{we}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$$psh_x * Fy_{we} = psh_1 * Fy_{we1} + ps_2 * Fy_{we2} = 1.38262$$

$$ps_1 \text{ (external)} = (Ash_1 * h_1 / s_1) / A_{sec} = 0.00116355$$

$$Ash_1 = Astir_1 * ns_1 = 157.0796$$

$$\text{No stirrups, } ns_1 = 2.00$$

$$h_1 = 450.00$$

$$ps_2 \text{ (internal)} = (Ash_2 * h_2 / s_2) / A_{sec} = 0.00103427$$

$$Ash_2 = Astir_2 * ns_2 = 100.531$$

$$\text{No stirrups, } ns_2 = 2.00$$

$$h_2 = 250.00$$

$$psh_y * Fy_{we} = psh_1 * Fy_{we1} + ps_2 * Fy_{we2} = 1.38262$$

$$ps_1 \text{ (external)} = (Ash_1 * h_1 / s_1) / A_{sec} = 0.00116355$$

$$Ash_1 = Astir_1 * ns_1 = 157.0796$$

$$\text{No stirrups, } ns_1 = 2.00$$

$$h_1 = 450.00$$

$$ps_2 \text{ (internal)} = (Ash_2 * h_2 / s_2) / A_{sec} = 0.00103427$$

$$Ash_2 = Astir_2 * ns_2 = 100.531$$

$$\text{No stirrups, } ns_2 = 2.00$$

$$h_2 = 250.00$$

$$A_{sec} = 202500.00$$

$$s_1 = 300.00$$

$$s_2 = 120.00$$

$$fy_{we1} = 694.45$$

$$fy_{we2} = 555.55$$

$$f_{ce} = 33.00$$

$$\text{From ((5.A5), TBDY), TBDY: } cc = 0.00305417$$

$$c = \text{confinement factor} = 1.10542$$

$$y_1 = 0.00152175$$

$$sh_1 = 0.0048696$$

$$ft_1 = 479.7871$$

$$fy_1 = 399.8226$$

$$su_1 = 0.0066488$$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00

$$lo/lou_{min} = lb/l_d = 0.33981258$$

$$su_1 = 0.4 * esu_{1\_nominal} \text{ ((5.5), TBDY)} = 0.032$$

$$\text{From table 5A.1, TBDY: } esu_{1\_nominal} = 0.08,$$

For calculation of  $esu_{1\_nominal}$  and  $y_1, sh_1, ft_1, fy_1$ , it is considered characteristic value  $fsy_1 = fs_1 / 1.2$ , from table 5.1, TBDY.

$y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 * (lb/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.

$$\text{with } fs_1 = (fs_{jacket} * A_{sl,ten,jacket} + fs_{core} * A_{sl,ten,core}) / A_{sl,ten} = 399.8226$$

$$\text{with } Es_1 = (Es_{jacket} * A_{sl,ten,jacket} + Es_{core} * A_{sl,ten,core}) / A_{sl,ten} = 200000.00$$

$$y_2 = 0.00152175$$

$$sh_2 = 0.0048696$$

$$ft_2 = 479.7871$$

$$fy_2 = 399.8226$$

$$su_2 = 0.0066488$$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00

$$lo/lou_{min} = lb/l_{b,min} = 0.33981258$$

$$su_2 = 0.4 * esu_{2\_nominal} \text{ ((5.5), TBDY)} = 0.032$$

$$\text{From table 5A.1, TBDY: } esu_{2\_nominal} = 0.08,$$

For calculation of  $esu_{2\_nominal}$  and  $y_2, sh_2, ft_2, fy_2$ , it is considered characteristic value  $fsy_2 = fs_2 / 1.2$ , from table 5.1, TBDY.

$y_2, sh_2, ft_2, fy_2$ , are also multiplied by  $\text{Min}(1, 1.25 * (lb/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.

$$\text{with } fs_2 = (fs_{jacket} * A_{sl,com,jacket} + fs_{core} * A_{sl,com,core}) / A_{sl,com} = 399.8226$$

$$\text{with } Es_2 = (Es_{jacket} * A_{sl,com,jacket} + Es_{core} * A_{sl,com,core}) / A_{sl,com} = 200000.00$$

$$y_v = 0.00152175$$

$$sh_v = 0.0048696$$

$$ftv = 507.2537$$

$$fyv = 422.7114$$

$$suv = 0.0066488$$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

$$lo/lo_{u,min} = lb/ld = 0.33981258$$

$$suv = 0.4 * esuv_{nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY:  $esuv_{nominal} = 0.08$ ,

considering characteristic value  $fsyv = fsv/1.2$ , from table 5.1, TBDY

For calculation of  $esuv_{nominal}$  and  $yv$ ,  $shv$ ,  $ftv$ ,  $fyv$ , it is considered  
characteristic value  $fsyv = fsv/1.2$ , from table 5.1, TBDY.

$y1$ ,  $sh1$ ,  $ft1$ ,  $fy1$ , are also multiplied by  $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.

$$\text{with } fsv = (fs_{jacket} * Asl_{mid,jacket} + fs_{mid} * Asl_{mid,core}) / Asl_{mid} = 422.7114$$

$$\text{with } Es_v = (Es_{jacket} * Asl_{mid,jacket} + Es_{mid} * Asl_{mid,core}) / Asl_{mid} = 200000.00$$

$$1 = Asl_{ten} / (b * d) * (fs1 / fc) = 0.0752324$$

$$2 = Asl_{com} / (b * d) * (fs2 / fc) = 0.0752324$$

$$v = Asl_{mid} / (b * d) * (fsv / fc) = 0.02812438$$

and confined core properties:

$$b = 390.00$$

$$d = 377.00$$

$$d' = 13.00$$

$$fcc (5A.2, TBDY) = 36.47874$$

$$cc (5A.5, TBDY) = 0.00305417$$

$$c = \text{confinement factor} = 1.10542$$

$$1 = Asl_{ten} / (b * d) * (fs1 / fc) = 0.09371431$$

$$2 = Asl_{com} / (b * d) * (fs2 / fc) = 0.09371431$$

$$v = Asl_{mid} / (b * d) * (fsv / fc) = 0.03503353$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < vs_{y2}$  - LHS eq.(4.5) is satisfied

--->

$$su (4.9) = 0.16791801$$

$$Mu = MRc (4.14) = 2.2193E+008$$

$$u = su (4.1) = 1.9632832E-005$$

-----  
Calculation of ratio  $lb/ld$

-----  
Lap Length:  $lb/ld = 0.33981258$

$$lb = 300.00$$

$$ld = 882.8396$$

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

$$= 1$$

$$db = 16.66667$$

Mean strength value of all re-bars:  $fy = 655.558$

Mean concrete strength:  $fc' = (fc'_{jacket} * Area_{jacket} + fc'_{core} * Area_{core}) / Area_{section} = 28.98765$ , but  $fc'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$cb = 25.00$$

$$Ktr = 2.86234$$

$$Atr = \text{Min}(Atr_x, Atr_y) = 257.6106$$

where  $Atr_x$ ,  $Atr_y$  are the sum of the area of all stirrup legs along X and Y local axis

$$s = \text{Max}(s_{external}, s_{internal}) = 300.00$$

$$n = 12.00$$

-----  
Calculation of  $Mu_{2+}$

-----  
Calculation of ultimate curvature  $u$  according to 4.1, Biskinis/Fardis 2013:

$$u = 1.9632832E-005$$

Mu = 2.2193E+008

with full section properties:

b = 450.00

d = 407.00

d' = 43.00

v = 0.00124204

N = 7506.808

fc = 33.00

co (5A.5, TBDY) = 0.002

Final value of cu: cu\* = shear\_factor \* Max( cu, cc) = 0.01393923

The Shear\_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: cu = 0.01393923

we ((5.4c), TBDY) = ase\* sh,min\*fywe/fce+ Min( fx, fy) = 0.06811101

where f = af\*pf\*ffe/fce is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

fx = 0.06628267

af = 0.54930041

b = 450.00

h = 450.00

From EC8 A.4.4.3(6), pf = 2tf/bw = 0.00451556

bw = 450.00

effective stress from (A.35), ff,e = 881.8461

fy = 0.06628267

af = 0.54930041

b = 450.00

h = 450.00

From EC8 A.4.4.3(6), pf = 2tf/bw = 0.00451556

bw = 450.00

effective stress from (A.35), ff,e = 881.8461

R = 40.00

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

fu,f = 1055.00

Ef = 64828.00

u,f = 0.015

ase ((5.4d), TBDY) = (ase1\*Aext+ase2\*Aint)/Asec = 0.14546167

ase1 = 0.12623274

bo\_1 = 390.00

ho\_1 = 390.00

bi2\_1 = 608400.00

ase2 = Max(ase1,ase2) = 0.18853448

bo\_2 = 242.00

ho\_2 = 242.00

bi2\_2 = 234256.00

psh,min\*Fywe = Min(psh,x\*Fywe , psh,y\*Fywe) = 1.38262

Expression ((5.4d), TBDY) for psh,min\*Fywe has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

psh\_x\*Fywe = psh1\*Fywe1+ps2\*Fywe2 = 1.38262

ps1 (external) = (Ash1\*h1/s1)/Asec = 0.00116355

Ash1 = Astir\_1\*ns\_1 = 157.0796

No stirrups, ns\_1 = 2.00

h1 = 450.00

ps2 (internal) = (Ash2\*h2/s2)/Asec = 0.00103427

Ash2 = Astir\_2\*ns\_2 = 100.531

No stirrups, ns\_2 = 2.00

h2 = 250.00

psh\_y\*Fywe = psh1\*Fywe1+ps2\*Fywe2 = 1.38262

ps1 (external) = (Ash1\*h1/s1)/Asec = 0.00116355

Ash1 = Astir\_1\*ns\_1 = 157.0796

No stirrups, ns\_1 = 2.00

h1 = 450.00

ps2 (internal) = (Ash2\*h2/s2)/Asec = 0.00103427

Ash2 = Astir\_2\*ns\_2 = 100.531

No stirrups, ns\_2 = 2.00  
h2 = 250.00

Asec = 202500.00

s1 = 300.00

s2 = 120.00

fywe1 = 694.45

fywe2 = 555.55

fce = 33.00

From ((5.A.5), TBDY), TBDY: cc = 0.00305417

c = confinement factor = 1.10542

y1 = 0.00152175

sh1 = 0.0048696

ft1 = 479.7871

fy1 = 399.8226

su1 = 0.0066488

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

lo/lou,min = lb/lc = 0.33981258

su1 = 0.4\*esu1\_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu1\_nominal = 0.08,

For calculation of esu1\_nominal and y1, sh1,ft1,fy1, it is considered  
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/lc)^{2/3})$ , from 10.3.5, ASCE 41-17.

with fs1 = (fs,jacket\*Asl,ten,jacket + fs,core\*Asl,ten,core)/Asl,ten = 399.8226

with Es1 = (Es,jacket\*Asl,ten,jacket + Es,core\*Asl,ten,core)/Asl,ten = 200000.00

y2 = 0.00152175

sh2 = 0.0048696

ft2 = 479.7871

fy2 = 399.8226

su2 = 0.0066488

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

lo/lou,min = lb/lb,min = 0.33981258

su2 = 0.4\*esu2\_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu2\_nominal = 0.08,

For calculation of esu2\_nominal and y2, sh2,ft2,fy2, it is considered  
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/lc)^{2/3})$ , from 10.3.5, ASCE 41-17.

with fs2 = (fs,jacket\*Asl,com,jacket + fs,core\*Asl,com,core)/Asl,com = 399.8226

with Es2 = (Es,jacket\*Asl,com,jacket + Es,core\*Asl,com,core)/Asl,com = 200000.00

yv = 0.00152175

shv = 0.0048696

ftv = 507.2537

fyv = 422.7114

suv = 0.0066488

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

lo/lou,min = lb/lc = 0.33981258

suv = 0.4\*esuv\_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esuv\_nominal = 0.08,

considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY  
For calculation of esuv\_nominal and yv, shv,ftv,fyv, it is considered

characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/lc)^{2/3})$ , from 10.3.5, ASCE 41-17.

with fsv = (fs,jacket\*Asl,mid,jacket + fs,mid\*Asl,mid,core)/Asl,mid = 422.7114

with Esv = (Es,jacket\*Asl,mid,jacket + Es,mid\*Asl,mid,core)/Asl,mid = 200000.00

1 = Asl,ten/(b\*d)\*(fs1/fc) = 0.0752324

2 = Asl,com/(b\*d)\*(fs2/fc) = 0.0752324

v = Asl,mid/(b\*d)\*(fsv/fc) = 0.02812438

and confined core properties:

b = 390.00

d = 377.00

d' = 13.00

$f_{cc}$  (5A.2, TBDY) = 36.47874  
 $c_c$  (5A.5, TBDY) = 0.00305417  
 $c$  = confinement factor = 1.10542  
 $1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.09371431$   
 $2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.09371431$   
 $v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.03503353$   
 Case/Assumption: Unconfined full section - Steel rupture  
 ' satisfies Eq. (4.3)

--->  
 $v < v_{s,y2}$  - LHS eq.(4.5) is satisfied

--->  
 $\mu_u$  (4.9) = 0.16791801  
 $M_u = M_{Rc}$  (4.14) = 2.2193E+008  
 $u = \mu_u$  (4.1) = 1.9632832E-005

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

-----  
 Lap Length:  $l_b/l_d = 0.33981258$

$l_b = 300.00$

$l_d = 882.8396$

Calculation of  $l_b, min$  according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.  
 $= 1$

$d_b = 16.66667$

Mean strength value of all re-bars:  $f_y = 655.558$

Mean concrete strength:  $f'_c = (f'_{c,jacket} * Area_{jacket} + f'_{c,core} * Area_{core}) / Area_{section} = 28.98765$ , but  $f_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$c_b = 25.00$

$K_{tr} = 2.86234$

$A_{tr} = \text{Min}(A_{tr,x}, A_{tr,y}) = 257.6106$

where  $A_{tr,x}$ ,  $A_{tr,y}$  are the sum of the area of all stirrup legs along X and Y local axis

$s = \text{Max}(s_{external}, s_{internal}) = 300.00$

$n = 12.00$

-----  
 Calculation of  $\mu_u$

-----  
 Calculation of ultimate curvature  $\mu_u$  according to 4.1, Biskinis/Fardis 2013:

$u = 1.9632832E-005$

$M_u = 2.2193E+008$

-----  
 with full section properties:

$b = 450.00$

$d = 407.00$

$d' = 43.00$

$v = 0.00124204$

$N = 7506.808$

$f_c = 33.00$

$c_c$  (5A.5, TBDY) = 0.002

Final value of  $\mu_u$ :  $\mu_u = \text{shear\_factor} * \text{Max}(\mu_u, c_c) = 0.01393923$

The Shear\_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY:  $\mu_u = 0.01393923$

we ((5.4c), TBDY) =  $a_s * \text{sh}_{,min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.06811101$

where  $f = a_f * p_f * f_{fe} / f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

-----  
 $f_x = 0.06628267$

$a_f = 0.54930041$

$b = 450.00$

$h = 450.00$

From EC8 A.4.4.3(6),  $p_f = 2t_f/b_w = 0.00451556$

$b_w = 450.00$

effective stress from (A.35),  $f_{f,e} = 881.8461$

$f_y = 0.06628267$

$a_f = 0.54930041$

$b = 450.00$

$h = 450.00$

From EC8 A.4.4.3(6),  $p_f = 2t_f/b_w = 0.00451556$

$b_w = 450.00$

effective stress from (A.35),  $f_{f,e} = 881.8461$

$R = 40.00$

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

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{,f} = 0.015$

$a_{se} ((5.4d), TBDY) = (a_{se1}*A_{ext} + a_{se2}*A_{int})/A_{sec} = 0.14546167$

$a_{se1} = 0.12623274$

$b_{o,1} = 390.00$

$h_{o,1} = 390.00$

$b_{i2,1} = 608400.00$

$a_{se2} = \text{Max}(a_{se1}, a_{se2}) = 0.18853448$

$b_{o,2} = 242.00$

$h_{o,2} = 242.00$

$b_{i2,2} = 234256.00$

$p_{sh,min}*F_{ywe} = \text{Min}(p_{sh,x}*F_{ywe}, p_{sh,y}*F_{ywe}) = 1.38262$

Expression ((5.4d), TBDY) for  $p_{sh,min}*F_{ywe}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$p_{sh,x}*F_{ywe} = p_{sh1}*F_{ywe1} + p_{s2}*F_{ywe2} = 1.38262$

$p_{s1} \text{ (external)} = (A_{sh1}*h_1/s_1)/A_{sec} = 0.00116355$

$A_{sh1} = A_{stir,1}*n_{s,1} = 157.0796$

No stirrups,  $n_{s,1} = 2.00$

$h_1 = 450.00$

$p_{s2} \text{ (internal)} = (A_{sh2}*h_2/s_2)/A_{sec} = 0.00103427$

$A_{sh2} = A_{stir,2}*n_{s,2} = 100.531$

No stirrups,  $n_{s,2} = 2.00$

$h_2 = 250.00$

$p_{sh,y}*F_{ywe} = p_{sh1}*F_{ywe1} + p_{s2}*F_{ywe2} = 1.38262$

$p_{s1} \text{ (external)} = (A_{sh1}*h_1/s_1)/A_{sec} = 0.00116355$

$A_{sh1} = A_{stir,1}*n_{s,1} = 157.0796$

No stirrups,  $n_{s,1} = 2.00$

$h_1 = 450.00$

$p_{s2} \text{ (internal)} = (A_{sh2}*h_2/s_2)/A_{sec} = 0.00103427$

$A_{sh2} = A_{stir,2}*n_{s,2} = 100.531$

No stirrups,  $n_{s,2} = 2.00$

$h_2 = 250.00$

$A_{sec} = 202500.00$

$s_1 = 300.00$

$s_2 = 120.00$

$f_{ywe1} = 694.45$

$f_{ywe2} = 555.55$

$f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY:  $c_c = 0.00305417$

$c = \text{confinement factor} = 1.10542$

$y_1 = 0.00152175$

$sh_1 = 0.0048696$

$ft_1 = 479.7871$

$fy_1 = 399.8226$

$su_1 = 0.0066488$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00

$l_o/l_{o,min} = l_b/d = 0.33981258$

$su_1 = 0.4*es_{u1,nominal} ((5.5), TBDY) = 0.032$

From table 5A.1, TBDY:  $es_{u1,nominal} = 0.08$ ,

For calculation of  $es_{u1\_nominal}$  and  $y_1, sh_1, ft_1, fy_1$ , it is considered characteristic value  $fs_{y1} = fs_1/1.2$ , from table 5.1, TBDY.

$y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.

with  $fs_1 = (fs_{jacket} \cdot A_{s,ten,jacket} + fs_{core} \cdot A_{s,ten,core}) / A_{s,ten} = 399.8226$

with  $Es_1 = (Es_{jacket} \cdot A_{s,ten,jacket} + Es_{core} \cdot A_{s,ten,core}) / A_{s,ten} = 200000.00$

$y_2 = 0.00152175$

$sh_2 = 0.0048696$

$ft_2 = 479.7871$

$fy_2 = 399.8226$

$su_2 = 0.0066488$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00

$lo/lo_{ou,min} = lb/lb_{,min} = 0.33981258$

$su_2 = 0.4 \cdot es_{u2\_nominal} ((5.5), TBDY) = 0.032$

From table 5A.1, TBDY:  $es_{u2\_nominal} = 0.08$ ,

For calculation of  $es_{u2\_nominal}$  and  $y_2, sh_2, ft_2, fy_2$ , it is considered characteristic value  $fs_{y2} = fs_2/1.2$ , from table 5.1, TBDY.

$y_2, sh_2, ft_2, fy_2$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.

with  $fs_2 = (fs_{jacket} \cdot A_{s,com,jacket} + fs_{core} \cdot A_{s,com,core}) / A_{s,com} = 399.8226$

with  $Es_2 = (Es_{jacket} \cdot A_{s,com,jacket} + Es_{core} \cdot A_{s,com,core}) / A_{s,com} = 200000.00$

$y_v = 0.00152175$

$sh_v = 0.0048696$

$ft_v = 507.2537$

$fy_v = 422.7114$

$suv = 0.0066488$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00

$lo/lo_{ou,min} = lb/ld = 0.33981258$

$suv = 0.4 \cdot es_{uv\_nominal} ((5.5), TBDY) = 0.032$

From table 5A.1, TBDY:  $es_{uv\_nominal} = 0.08$ ,

considering characteristic value  $fs_{yv} = f_{sv}/1.2$ , from table 5.1, TBDY

For calculation of  $es_{uv\_nominal}$  and  $y_v, sh_v, ft_v, fy_v$ , it is considered characteristic value  $fs_{yv} = f_{sv}/1.2$ , from table 5.1, TBDY.

$y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.

with  $f_{sv} = (f_{s,jacket} \cdot A_{s,mid,jacket} + f_{s,mid} \cdot A_{s,mid,core}) / A_{s,mid} = 422.7114$

with  $Es_v = (Es_{jacket} \cdot A_{s,mid,jacket} + Es_{mid} \cdot A_{s,mid,core}) / A_{s,mid} = 200000.00$

$1 = A_{s,ten} / (b \cdot d) \cdot (fs_1 / fc) = 0.0752324$

$2 = A_{s,com} / (b \cdot d) \cdot (fs_2 / fc) = 0.0752324$

$v = A_{s,mid} / (b \cdot d) \cdot (f_{sv} / fc) = 0.02812438$

and confined core properties:

$b = 390.00$

$d = 377.00$

$d' = 13.00$

$f_{cc} (5A.2, TBDY) = 36.47874$

$cc (5A.5, TBDY) = 0.00305417$

$c = \text{confinement factor} = 1.10542$

$1 = A_{s,ten} / (b \cdot d) \cdot (fs_1 / fc) = 0.09371431$

$2 = A_{s,com} / (b \cdot d) \cdot (fs_2 / fc) = 0.09371431$

$v = A_{s,mid} / (b \cdot d) \cdot (f_{sv} / fc) = 0.03503353$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < v_{s,y2}$  - LHS eq.(4.5) is satisfied

--->

$su (4.9) = 0.16791801$

$\mu = MR_c (4.14) = 2.2193E+008$

$u = su (4.1) = 1.9632832E-005$

Calculation of ratio  $lb/ld$

Lap Length:  $lb/ld = 0.33981258$

$lb = 300.00$

$ld = 882.8396$

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

$$= 1$$

$$db = 16.66667$$

Mean strength value of all re-bars:  $f_y = 655.558$

Mean concrete strength:  $f_c' = (f_c'_{\text{jacket}} \cdot \text{Area}_{\text{jacket}} + f_c'_{\text{core}} \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 28.98765$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$cb = 25.00$$

$$K_{tr} = 2.86234$$

$$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 257.6106$$

where  $A_{tr_x}$ ,  $A_{tr_y}$  are the sum of the area of all stirrup legs along X and Y local axis

$$s = \text{Max}(s_{\text{external}}, s_{\text{internal}}) = 300.00$$

$$n = 12.00$$

-----  
Calculation of Shear Strength  $V_r = \text{Min}(V_{r1}, V_{r2}) = 567563.724$

-----  
Calculation of Shear Strength at edge 1,  $V_{r1} = 567563.724$

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

$$V_{\text{Col}0} = 567563.724$$

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

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

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

Mean concrete strength:  $f_c' = (f_c'_{\text{jacket}} \cdot \text{Area}_{\text{jacket}} + f_c'_{\text{core}} \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 28.98765$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$$M/Vd = 2.00$$

$$M_u = 1.4404090E-011$$

$$V_u = 2.0531359E-031$$

$$d = 0.8 \cdot h = 360.00$$

$$N_u = 7506.808$$

$$A_g = 202500.00$$

From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 144280.365$

where:

$V_{s1} = 69813.729$  is calculated for jacket, with:

$$d = 360.00$$

$$A_v = 157079.633$$

$$f_y = 555.56$$

$$s = 300.00$$

$V_{s1}$  is multiplied by  $Col1 = 0.66666667$

$$s/d = 0.83333333$$

$V_{s2} = 74466.637$  is calculated for core, with:

$$d = 200.00$$

$$A_v = 100530.965$$

$$f_y = 444.44$$

$$s = 120.00$$

$V_{s2}$  is multiplied by  $Col2 = 1.00$

$$s/d = 0.60$$

$V_f$  ((11-3)-(11.4), ACI 440) = 214457.247

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

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

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

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

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

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

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

$d_{fv} = d$  (figure 11.2, ACI 440) = 407.00

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

$$E_f = 64828.00$$

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

with  $f_u = 0.01$

From (11-11), ACI 440:  $V_s + V_f \leq 579413.096$   
 $bw = 450.00$

Calculation of Shear Strength at edge 2,  $V_{r2} = 567563.724$   
 $V_{r2} = V_{Col} ((10.3), ASCE 41-17) = knl * V_{Col0}$   
 $V_{Col0} = 567563.724$   
 $knl = 1$  (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:  $f_c' = (f_c'_{jacket} * Area_{jacket} + f_c'_{core} * Area_{core}) / Area_{section} = 28.98765$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M / Vd = 2.00$

$\mu_u = 1.4404090E-011$

$V_u = 2.0531359E-031$

$d = 0.8 * h = 360.00$

$N_u = 7506.808$

$A_g = 202500.00$

From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 144280.365$

where:

$V_{s1} = 69813.729$  is calculated for jacket, with:

$d = 360.00$

$A_v = 157079.633$

$f_y = 555.56$

$s = 300.00$

$V_{s1}$  is multiplied by  $Col1 = 0.66666667$

$s/d = 0.83333333$

$V_{s2} = 74466.637$  is calculated for core, with:

$d = 200.00$

$A_v = 100530.965$

$f_y = 444.44$

$s = 120.00$

$V_{s2}$  is multiplied by  $Col2 = 1.00$

$s/d = 0.60$

$V_f ((11-3)-(11.4), ACI 440) = 214457.247$

$f = 0.95$ , for fully-wrapped sections

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

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

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

orientation 1:  $a_1 = b_1 + 90^\circ = 90.00$

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

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

$d_{fv} = d$  (figure 11.2, ACI 440) = 407.00

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

$E_f = 64828.00$

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

with  $f_u = 0.01$

From (11-11), ACI 440:  $V_s + V_f \leq 579413.096$   
 $bw = 450.00$

End Of Calculation of Shear Capacity ratio for element: column JC1 of floor 1  
At local axis: 3

Start Of Calculation of Shear Capacity ratio for element: column JC1 of floor 1  
At Shear local axis: 2  
(Bending local axis: 3)  
Section Type: rcjrs

Constant Properties

Knowledge Factor,  $\gamma = 0.85$

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 Height,  $H = 450.00$

External Width,  $W = 450.00$

Internal Height,  $H = 250.00$

Internal Width,  $W = 250.00$

Cover Thickness,  $c = 25.00$

Mean Confinement Factor overall section = 1.10542

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: 2

EDGE -A-

Shear Force,  $V_a = -2.7162834E-031$

EDGE -B-

Shear Force,  $V_b = 2.7162834E-031$

BOTH EDGES

Axial Force,  $F = -7506.808$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension:  $A_{sl,t} = 0.00$

-Compression:  $A_{sl,c} = 2676.637$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension:  $A_{sl,ten} = 1137.257$

-Compression:  $A_{sl,com} = 1137.257$

-Middle:  $A_{sl,mid} = 402.1239$

Calculation of Shear Capacity ratio ,  $V_e/V_r = 0.26068017$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 147952.607$

with  
 $M_{pr1} = \text{Max}(M_{u1+}, M_{u1-}) = 2.2193E+008$   
 $M_{u1+} = 2.2193E+008$ , 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  
 $M_{u1-} = 2.2193E+008$ , 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  
 $M_{pr2} = \text{Max}(M_{u2+}, M_{u2-}) = 2.2193E+008$   
 $M_{u2+} = 2.2193E+008$ , 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  
 $M_{u2-} = 2.2193E+008$ , 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 curvature  $\phi_u$  according to 4.1, Biskinis/Fardis 2013:

$\phi_u = 1.9632832E-005$

$M_u = 2.2193E+008$

with full section properties:

$b = 450.00$

$d = 407.00$

$d' = 43.00$

$v = 0.00124204$

$N = 7506.808$

$f_c = 33.00$

$\alpha_1$  (5A.5, TBDY) = 0.002

Final value of  $\phi_u$ :  $\phi_u^* = \text{shear\_factor} * \text{Max}(\phi_u, \phi_c) = 0.01393923$

The Shear\_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY:  $\phi_u = 0.01393923$

$\omega_e$  ((5.4c), TBDY) =  $\alpha_1 * \rho_{s,\min} * f_{ywe} / f_{ce} + \text{Min}(\phi_x, \phi_y) = 0.06811101$

where  $\phi = \alpha_1 * \rho_f * f_{fe} / f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$\phi_x = 0.06628267$

$\alpha_f = 0.54930041$

$b = 450.00$

$h = 450.00$

From EC8 A.4.4.3(6),  $\rho_f = 2t_f/bw = 0.00451556$

$bw = 450.00$

effective stress from (A.35),  $f_{f,e} = 881.8461$

$\phi_y = 0.06628267$

$\alpha_f = 0.54930041$

$b = 450.00$

$h = 450.00$

From EC8 A.4.4.3(6),  $\rho_f = 2t_f/bw = 0.00451556$

$bw = 450.00$

effective stress from (A.35),  $f_{f,e} = 881.8461$

$R = 40.00$

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

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{,f} = 0.015$

$\alpha_{se}$  ((5.4d), TBDY) =  $(\alpha_{se1} * A_{ext} + \alpha_{se2} * A_{int}) / A_{sec} = 0.14546167$

$\alpha_{se1} = 0.12623274$

$b_{o,1} = 390.00$

$h_{o,1} = 390.00$

$b_{i,1} = 608400.00$

$$ase2 = \text{Max}(ase1, ase2) = 0.18853448$$

$$bo\_2 = 242.00$$

$$ho\_2 = 242.00$$

$$bi2\_2 = 234256.00$$

$$psh, \text{min} * Fywe = \text{Min}(psh, x * Fywe, psh, y * Fywe) = 1.38262$$

Expression ((5.4d), TBDY) for psh,min\*Fywe has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$$psh\_x * Fywe = psh1 * Fywe1 + ps2 * Fywe2 = 1.38262$$

$$ps1 \text{ (external)} = (Ash1 * h1 / s1) / Asec = 0.00116355$$

$$Ash1 = Astir\_1 * ns\_1 = 157.0796$$

No stirrups, ns<sub>1</sub> = 2.00

$$h1 = 450.00$$

$$ps2 \text{ (internal)} = (Ash2 * h2 / s2) / Asec = 0.00103427$$

$$Ash2 = Astir\_2 * ns\_2 = 100.531$$

No stirrups, ns<sub>2</sub> = 2.00

$$h2 = 250.00$$

$$psh\_y * Fywe = psh1 * Fywe1 + ps2 * Fywe2 = 1.38262$$

$$ps1 \text{ (external)} = (Ash1 * h1 / s1) / Asec = 0.00116355$$

$$Ash1 = Astir\_1 * ns\_1 = 157.0796$$

No stirrups, ns<sub>1</sub> = 2.00

$$h1 = 450.00$$

$$ps2 \text{ (internal)} = (Ash2 * h2 / s2) / Asec = 0.00103427$$

$$Ash2 = Astir\_2 * ns\_2 = 100.531$$

No stirrups, ns<sub>2</sub> = 2.00

$$h2 = 250.00$$

$$Asec = 202500.00$$

$$s1 = 300.00$$

$$s2 = 120.00$$

$$fywe1 = 694.45$$

$$fywe2 = 555.55$$

$$fce = 33.00$$

From ((5.A5), TBDY), TBDY: cc = 0.00305417

c = confinement factor = 1.10542

$$y1 = 0.00152175$$

$$sh1 = 0.0048696$$

$$ft1 = 479.7871$$

$$fy1 = 399.8226$$

$$su1 = 0.0066488$$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00

$$lo/lou, \text{min} = lb/ld = 0.33981258$$

$$su1 = 0.4 * esu1\_nominal \text{ ((5.5), TBDY)} = 0.032$$

From table 5A.1, TBDY: esu1\_nominal = 0.08,

For calculation of esu1\_nominal and y1, sh1, ft1, fy1, it is considered characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1, ft1, fy1, are also multiplied by Min(1, 1.25 \* (lb/ld)<sup>2/3</sup>), from 10.3.5, ASCE 41-17.

$$\text{with } fs1 = (fs, \text{jacket} * Asl, \text{ten, jacket} + fs, \text{core} * Asl, \text{ten, core}) / Asl, \text{ten} = 399.8226$$

$$\text{with } Es1 = (Es, \text{jacket} * Asl, \text{ten, jacket} + Es, \text{core} * Asl, \text{ten, core}) / Asl, \text{ten} = 200000.00$$

$$y2 = 0.00152175$$

$$sh2 = 0.0048696$$

$$ft2 = 479.7871$$

$$fy2 = 399.8226$$

$$su2 = 0.0066488$$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00

$$lo/lou, \text{min} = lb/lb, \text{min} = 0.33981258$$

$$su2 = 0.4 * esu2\_nominal \text{ ((5.5), TBDY)} = 0.032$$

From table 5A.1, TBDY: esu2\_nominal = 0.08,

For calculation of esu2\_nominal and y2, sh2, ft2, fy2, it is considered characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

y1, sh1, ft1, fy1, are also multiplied by Min(1, 1.25 \* (lb/ld)<sup>2/3</sup>), from 10.3.5, ASCE 41-17.

$$\text{with } fs2 = (fs, \text{jacket} * Asl, \text{com, jacket} + fs, \text{core} * Asl, \text{com, core}) / Asl, \text{com} = 399.8226$$

with  $E_s2 = (E_{s,jacket} \cdot A_{s,com,jacket} + E_{s,core} \cdot A_{s,com,core}) / A_{s,com} = 200000.00$   
 $y_v = 0.00152175$   
 $sh_v = 0.0048696$   
 $ft_v = 507.2537$   
 $fy_v = 422.7114$   
 $su_v = 0.0066488$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 Shear\_factor = 1.00  
 $l_o/l_{o,min} = l_b/l_d = 0.33981258$   
 $su_v = 0.4 \cdot esuv\_nominal((5.5), TBDY) = 0.032$   
 From table 5A.1, TBDY:  $esuv\_nominal = 0.08$ ,  
 considering characteristic value  $fs_yv = f_{sv}/1.2$ , from table 5.1, TBDY  
 For calculation of  $esuv\_nominal$  and  $y_v, sh_v, ft_v, fy_v$ , it is considered  
 characteristic value  $fs_yv = f_{sv}/1.2$ , from table 5.1, TBDY.  
 $y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with  $f_{sv} = (f_{s,jacket} \cdot A_{s,mid,jacket} + f_{s,mid} \cdot A_{s,mid,core}) / A_{s,mid} = 422.7114$   
 with  $E_{sv} = (E_{s,jacket} \cdot A_{s,mid,jacket} + E_{s,mid} \cdot A_{s,mid,core}) / A_{s,mid} = 200000.00$   
 $1 = A_{s,ten} / (b \cdot d) \cdot (f_{s1} / f_c) = 0.0752324$   
 $2 = A_{s,com} / (b \cdot d) \cdot (f_{s2} / f_c) = 0.0752324$   
 $v = A_{s,mid} / (b \cdot d) \cdot (f_{sv} / f_c) = 0.02812438$   
 and confined core properties:  
 $b = 390.00$   
 $d = 377.00$   
 $d' = 13.00$   
 $f_{cc}(5A.2, TBDY) = 36.47874$   
 $cc(5A.5, TBDY) = 0.00305417$   
 $c = \text{confinement factor} = 1.10542$   
 $1 = A_{s,ten} / (b \cdot d) \cdot (f_{s1} / f_c) = 0.09371431$   
 $2 = A_{s,com} / (b \cdot d) \cdot (f_{s2} / f_c) = 0.09371431$   
 $v = A_{s,mid} / (b \cdot d) \cdot (f_{sv} / f_c) = 0.03503353$   
 Case/Assumption: Unconfined full section - Steel rupture  
 ' satisfies Eq. (4.3)  
 --->  
 $v < v_{s,y2}$  - LHS eq.(4.5) is satisfied  
 --->  
 $su(4.9) = 0.16791801$   
 $Mu = MRc(4.14) = 2.2193E+008$   
 $u = su(4.1) = 1.9632832E-005$

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Calculation of ratio  $l_b/l_d$

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Lap Length:  $l_b/l_d = 0.33981258$   
 $l_b = 300.00$   
 $l_d = 882.8396$   
 Calculation of  $l_b,min$  according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.  
 $= 1$   
 $db = 16.66667$   
 Mean strength value of all re-bars:  $fy = 655.558$   
 Mean concrete strength:  $fc' = (fc'_jacket \cdot Area\_jacket + fc'_core \cdot Area\_core) / Area\_section = 28.98765$ , but  $fc'^{0.5} < =$   
 8.3 MPa (22.5.3.1, ACI 318-14)  
 $t = 1.00$   
 $s = 0.80$   
 $e = 1.00$   
 $cb = 25.00$   
 $Ktr = 2.86234$   
 $Atr = \text{Min}(Atr\_x, Atr\_y) = 257.6106$   
 where  $Atr\_x, Atr\_y$  are the sum of the area of all stirrup legs along X and Y loxal axis  
 $s = \text{Max}(s\_external, s\_internal) = 300.00$   
 $n = 12.00$

---



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Calculation of  $Mu1-$

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Calculation of ultimate curvature  $\phi_u$  according to 4.1, Biskinis/Fardis 2013:

$$u = 1.9632832E-005$$

$$Mu = 2.2193E+008$$

with full section properties:

$$b = 450.00$$

$$d = 407.00$$

$$d' = 43.00$$

$$v = 0.00124204$$

$$N = 7506.808$$

$$f_c = 33.00$$

$$c_o(5A.5, TBDY) = 0.002$$

$$\text{Final value of } \phi_u: \phi_u^* = \text{shear\_factor} * \text{Max}(\phi_{cu}, \phi_{cc}) = 0.01393923$$

The Shear\_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \phi_{cu} = 0.01393923$$

$$\phi_{we}((5.4c), TBDY) = a_{se} * \phi_{sh, \min} * f_{ywe} / f_{ce} + \text{Min}(\phi_{fx}, \phi_{fy}) = 0.06811101$$

where  $\phi_f = a_f * \phi_{f'} * f_{fe} / f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$\phi_{fx} = 0.06628267$$

$$a_f = 0.54930041$$

$$b = 450.00$$

$$h = 450.00$$

$$\text{From EC8 A.4.4.3(6), } \phi_f = 2t_f / b_w = 0.00451556$$

$$b_w = 450.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 881.8461$$

$$\phi_{fy} = 0.06628267$$

$$a_f = 0.54930041$$

$$b = 450.00$$

$$h = 450.00$$

$$\text{From EC8 A.4.4.3(6), } \phi_f = 2t_f / b_w = 0.00451556$$

$$b_w = 450.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 881.8461$$

$$R = 40.00$$

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

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$a_{se}((5.4d), TBDY) = (a_{se1} * A_{ext} + a_{se2} * A_{int}) / A_{sec} = 0.14546167$$

$$a_{se1} = 0.12623274$$

$$b_{o,1} = 390.00$$

$$h_{o,1} = 390.00$$

$$b_{i2,1} = 608400.00$$

$$a_{se2} = \text{Max}(a_{se1}, a_{se2}) = 0.18853448$$

$$b_{o,2} = 242.00$$

$$h_{o,2} = 242.00$$

$$b_{i2,2} = 234256.00$$

$$\phi_{psh, \min} * f_{ywe} = \text{Min}(\phi_{psh,x} * f_{ywe}, \phi_{psh,y} * f_{ywe}) = 1.38262$$

Expression ((5.4d), TBDY) for  $\phi_{psh, \min} * f_{ywe}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$$\phi_{psh,x} * f_{ywe} = \phi_{psh1} * f_{ywe1} + \phi_{psh2} * f_{ywe2} = 1.38262$$

$$\phi_{psh1} \text{ (external)} = (A_{sh1} * h_1 / s_1) / A_{sec} = 0.00116355$$

$$A_{sh1} = A_{stir,1} * n_{s,1} = 157.0796$$

$$\text{No stirrups, } n_{s,1} = 2.00$$

$$h_1 = 450.00$$

$$\phi_{psh2} \text{ (internal)} = (A_{sh2} * h_2 / s_2) / A_{sec} = 0.00103427$$

$$A_{sh2} = A_{stir,2} * n_{s,2} = 100.531$$

$$\text{No stirrups, } n_{s,2} = 2.00$$

$$h_2 = 250.00$$

$$\phi_{psh,y} * f_{ywe} = \phi_{psh1} * f_{ywe1} + \phi_{psh2} * f_{ywe2} = 1.38262$$

$$\phi_{psh1} \text{ (external)} = (A_{sh1} * h_1 / s_1) / A_{sec} = 0.00116355$$

$$A_{sh1} = A_{stir,1} * n_{s,1} = 157.0796$$

$$\text{No stirrups, } n_{s,1} = 2.00$$

h1 = 450.00  
ps2 (internal) = (Ash2\*h2/s2)/Asec = 0.00103427  
Ash2 = Astir\_2\*ns\_2 = 100.531  
No stirups, ns\_2 = 2.00  
h2 = 250.00

-----  
Asec = 202500.00  
s1 = 300.00  
s2 = 120.00  
fywe1 = 694.45  
fywe2 = 555.55  
fce = 33.00

From ((5.A5), TBDY), TBDY: cc = 0.00305417  
c = confinement factor = 1.10542

y1 = 0.00152175  
sh1 = 0.0048696  
ft1 = 479.7871  
fy1 = 399.8226  
su1 = 0.0066488

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

lo/lou,min = lb/ld = 0.33981258

su1 = 0.4\*esu1\_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu1\_nominal = 0.08,

For calculation of esu1\_nominal and y1, sh1,ft1,fy1, it is considered  
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by  $\text{Min}(1, 1.25 \cdot (\text{lb}/\text{ld})^{2/3})$ , from 10.3.5, ASCE 41-17.

with fs1 = (fs,jacket\*Asl,ten,jacket + fs,core\*Asl,ten,core)/Asl,ten = 399.8226

with Es1 = (Es,jacket\*Asl,ten,jacket + Es,core\*Asl,ten,core)/Asl,ten = 200000.00

y2 = 0.00152175  
sh2 = 0.0048696  
ft2 = 479.7871  
fy2 = 399.8226  
su2 = 0.0066488

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

lo/lou,min = lb/lb,min = 0.33981258

su2 = 0.4\*esu2\_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu2\_nominal = 0.08,

For calculation of esu2\_nominal and y2, sh2,ft2,fy2, it is considered  
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by  $\text{Min}(1, 1.25 \cdot (\text{lb}/\text{ld})^{2/3})$ , from 10.3.5, ASCE 41-17.

with fs2 = (fs,jacket\*Asl,com,jacket + fs,core\*Asl,com,core)/Asl,com = 399.8226

with Es2 = (Es,jacket\*Asl,com,jacket + Es,core\*Asl,com,core)/Asl,com = 200000.00

yv = 0.00152175  
shv = 0.0048696  
ftv = 507.2537  
fyv = 422.7114  
suv = 0.0066488

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

lo/lou,min = lb/ld = 0.33981258

suv = 0.4\*esuv\_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esuv\_nominal = 0.08,

considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY

For calculation of esuv\_nominal and yv, shv,ftv,fyv, it is considered  
characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by  $\text{Min}(1, 1.25 \cdot (\text{lb}/\text{ld})^{2/3})$ , from 10.3.5, ASCE 41-17.

with fsv = (fs,jacket\*Asl,mid,jacket + fs,mid\*Asl,mid,core)/Asl,mid = 422.7114

with Esv = (Es,jacket\*Asl,mid,jacket + Es,mid\*Asl,mid,core)/Asl,mid = 200000.00

1 = Asl,ten/(b\*d)\*(fs1/fc) = 0.0752324

2 = Asl,com/(b\*d)\*(fs2/fc) = 0.0752324

v = Asl,mid/(b\*d)\*(fsv/fc) = 0.02812438

and confined core properties:

$b = 390.00$   
 $d = 377.00$   
 $d' = 13.00$   
 $f_{cc} (5A.2, TBDY) = 36.47874$   
 $cc (5A.5, TBDY) = 0.00305417$   
 $c = \text{confinement factor} = 1.10542$   
 $1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.09371431$   
 $2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.09371431$   
 $v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.03503353$   
 Case/Assumption: Unconfined full section - Steel rupture  
 ' satisfies Eq. (4.3)

--->  
 $v < v_{s,y2}$  - LHS eq.(4.5) is satisfied  
 --->  
 $su (4.9) = 0.16791801$   
 $Mu = MRc (4.14) = 2.2193E+008$   
 $u = su (4.1) = 1.9632832E-005$

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

Lap Length:  $l_b/l_d = 0.33981258$

$l_b = 300.00$

$l_d = 882.8396$

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

= 1

$db = 16.66667$

Mean strength value of all re-bars:  $f_y = 655.558$

Mean concrete strength:  $f_c' = (f_c'_{jacket} * Area_{jacket} + f_c'_{core} * Area_{core}) / Area_{section} = 28.98765$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 2.86234$

$A_{tr} = \text{Min}(A_{tr,x}, A_{tr,y}) = 257.6106$

where  $A_{tr,x}$ ,  $A_{tr,y}$  are the sum of the area of all stirrup legs along X and Y loxal axis

$s = \text{Max}(s_{external}, s_{internal}) = 300.00$

$n = 12.00$

-----  
 Calculation of  $Mu_{2+}$   
 -----

-----  
 Calculation of ultimate curvature  $u$  according to 4.1, Biskinis/Fardis 2013:

$u = 1.9632832E-005$

$Mu = 2.2193E+008$

-----  
 with full section properties:

$b = 450.00$

$d = 407.00$

$d' = 43.00$

$v = 0.00124204$

$N = 7506.808$

$f_c = 33.00$

$co (5A.5, TBDY) = 0.002$

Final value of  $cu$ :  $cu^* = \text{shear\_factor} * \text{Max}(cu, cc) = 0.01393923$

The Shear\_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY:  $cu = 0.01393923$

we ((5.4c), TBDY) =  $ase * sh, \min * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.06811101$

where  $f = af * pf * f_{fe} / f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

-----  
 $f_x = 0.06628267$

$af = 0.54930041$

$b = 450.00$

h = 450.00  
From EC8 A.4.4.3(6),  $pf = 2tf/bw = 0.00451556$   
bw = 450.00  
effective stress from (A.35),  $ff,e = 881.8461$

fy = 0.06628267  
af = 0.54930041  
b = 450.00  
h = 450.00  
From EC8 A.4.4.3(6),  $pf = 2tf/bw = 0.00451556$   
bw = 450.00  
effective stress from (A.35),  $ff,e = 881.8461$

R = 40.00  
Effective FRP thickness,  $tf = NL*t*Cos(b1) = 1.016$   
fu,f = 1055.00  
Ef = 64828.00  
u,f = 0.015  
 $ase ((5.4d), TBDY) = (ase1*Aext+ase2*Aint)/Asec = 0.14546167$   
ase1 = 0.12623274  
bo\_1 = 390.00  
ho\_1 = 390.00  
bi2\_1 = 608400.00  
ase2 = Max(ase1,ase2) = 0.18853448  
bo\_2 = 242.00  
ho\_2 = 242.00  
bi2\_2 = 234256.00

$psh,min*Fywe = Min(psh,x*Fywe, psh,y*Fywe) = 1.38262$   
Expression ((5.4d), TBDY) for  $psh,min*Fywe$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$psh_x*Fywe = psh1*Fywe1+ps2*Fywe2 = 1.38262$   
ps1 (external) =  $(Ash1*h1/s1)/Asec = 0.00116355$   
Ash1 = Astir\_1\*ns\_1 = 157.0796  
No stirrups, ns\_1 = 2.00  
h1 = 450.00  
ps2 (internal) =  $(Ash2*h2/s2)/Asec = 0.00103427$   
Ash2 = Astir\_2\*ns\_2 = 100.531  
No stirrups, ns\_2 = 2.00  
h2 = 250.00

$psh_y*Fywe = psh1*Fywe1+ps2*Fywe2 = 1.38262$   
ps1 (external) =  $(Ash1*h1/s1)/Asec = 0.00116355$   
Ash1 = Astir\_1\*ns\_1 = 157.0796  
No stirrups, ns\_1 = 2.00  
h1 = 450.00  
ps2 (internal) =  $(Ash2*h2/s2)/Asec = 0.00103427$   
Ash2 = Astir\_2\*ns\_2 = 100.531  
No stirrups, ns\_2 = 2.00  
h2 = 250.00

Asec = 202500.00  
s1 = 300.00  
s2 = 120.00  
fywe1 = 694.45  
fywe2 = 555.55  
fce = 33.00

From ((5.A5), TBDY), TBDY:  $cc = 0.00305417$   
c = confinement factor = 1.10542

y1 = 0.00152175  
sh1 = 0.0048696  
ft1 = 479.7871  
fy1 = 399.8226  
su1 = 0.0066488

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

$$l_0/l_{ou,min} = l_b/l_d = 0.33981258$$

$$s_u = 0.4 * e_{su1\_nominal} ((5.5), TBDY) = 0.032$$

$$\text{From table 5A.1, TBDY: } e_{su1\_nominal} = 0.08,$$

For calculation of  $e_{su1\_nominal}$  and  $y_1, sh_1, ft_1, fy_1$ , it is considered characteristic value  $f_{sy1} = f_{s1}/1.2$ , from table 5.1, TBDY.

$$y_1, sh_1, ft_1, fy_1, \text{ are also multiplied by } \text{Min}(1, 1.25 * (l_b/l_d)^{2/3}), \text{ from 10.3.5, ASCE 41-17.}$$

$$\text{with } f_{s1} = (f_{s,jacket} * A_{sl,ten,jacket} + f_{s,core} * A_{sl,ten,core}) / A_{sl,ten} = 399.8226$$

$$\text{with } E_{s1} = (E_{s,jacket} * A_{sl,ten,jacket} + E_{s,core} * A_{sl,ten,core}) / A_{sl,ten} = 200000.00$$

$$y_2 = 0.00152175$$

$$sh_2 = 0.0048696$$

$$ft_2 = 479.7871$$

$$fy_2 = 399.8226$$

$$s_u = 0.0066488$$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00

$$l_0/l_{ou,min} = l_b/l_{b,min} = 0.33981258$$

$$s_u = 0.4 * e_{su2\_nominal} ((5.5), TBDY) = 0.032$$

$$\text{From table 5A.1, TBDY: } e_{su2\_nominal} = 0.08,$$

For calculation of  $e_{su2\_nominal}$  and  $y_2, sh_2, ft_2, fy_2$ , it is considered characteristic value  $f_{sy2} = f_{s2}/1.2$ , from table 5.1, TBDY.

$$y_1, sh_1, ft_1, fy_1, \text{ are also multiplied by } \text{Min}(1, 1.25 * (l_b/l_d)^{2/3}), \text{ from 10.3.5, ASCE 41-17.}$$

$$\text{with } f_{s2} = (f_{s,jacket} * A_{sl,com,jacket} + f_{s,core} * A_{sl,com,core}) / A_{sl,com} = 399.8226$$

$$\text{with } E_{s2} = (E_{s,jacket} * A_{sl,com,jacket} + E_{s,core} * A_{sl,com,core}) / A_{sl,com} = 200000.00$$

$$y_v = 0.00152175$$

$$sh_v = 0.0048696$$

$$ft_v = 507.2537$$

$$fy_v = 422.7114$$

$$s_u = 0.0066488$$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00

$$l_0/l_{ou,min} = l_b/l_d = 0.33981258$$

$$s_u = 0.4 * e_{suv\_nominal} ((5.5), TBDY) = 0.032$$

$$\text{From table 5A.1, TBDY: } e_{suv\_nominal} = 0.08,$$

considering characteristic value  $f_{syv} = f_{sv}/1.2$ , from table 5.1, TBDY  
For calculation of  $e_{suv\_nominal}$  and  $y_v, sh_v, ft_v, fy_v$ , it is considered characteristic value  $f_{syv} = f_{sv}/1.2$ , from table 5.1, TBDY.

$$y_1, sh_1, ft_1, fy_1, \text{ are also multiplied by } \text{Min}(1, 1.25 * (l_b/l_d)^{2/3}), \text{ from 10.3.5, ASCE 41-17.}$$

$$\text{with } f_{sv} = (f_{s,jacket} * A_{sl,mid,jacket} + f_{s,mid} * A_{sl,mid,core}) / A_{sl,mid} = 422.7114$$

$$\text{with } E_{sv} = (E_{s,jacket} * A_{sl,mid,jacket} + E_{s,mid} * A_{sl,mid,core}) / A_{sl,mid} = 200000.00$$

$$1 = A_{sl,ten} / (b * d) * (f_{s1} / f_c) = 0.0752324$$

$$2 = A_{sl,com} / (b * d) * (f_{s2} / f_c) = 0.0752324$$

$$v = A_{sl,mid} / (b * d) * (f_{sv} / f_c) = 0.02812438$$

and confined core properties:

$$b = 390.00$$

$$d = 377.00$$

$$d' = 13.00$$

$$f_{cc} (5A.2, TBDY) = 36.47874$$

$$c_c (5A.5, TBDY) = 0.00305417$$

$$c = \text{confinement factor} = 1.10542$$

$$1 = A_{sl,ten} / (b * d) * (f_{s1} / f_c) = 0.09371431$$

$$2 = A_{sl,com} / (b * d) * (f_{s2} / f_c) = 0.09371431$$

$$v = A_{sl,mid} / (b * d) * (f_{sv} / f_c) = 0.03503353$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < v_{s,y2}$  - LHS eq.(4.5) is satisfied

--->

$$s_u (4.9) = 0.16791801$$

$$\mu = M R_c (4.14) = 2.2193E+008$$

$$u = s_u (4.1) = 1.9632832E-005$$

Calculation of ratio  $l_b/l_d$

$$\text{Lap Length: } l_b/l_d = 0.33981258$$

lb = 300.00

ld = 882.8396

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

= 1

db = 16.66667

Mean strength value of all re-bars: fy = 655.558

Mean concrete strength: fc' = (fc'\_jacket\*Area\_jacket + fc'\_core\*Area\_core)/Area\_section = 28.98765, 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 = 2.86234

Atr = Min(Atr\_x,Atr\_y) = 257.6106

where Atr\_x, Atr\_y are the sum of the area of all stirrup legs along X and Y loxal axis

s = Max(s\_external,s\_internal) = 300.00

n = 12.00

Calculation of Mu2-

Calculation of ultimate curvature  $\phi_u$  according to 4.1, Biskinis/Fardis 2013:

u = 1.9632832E-005

Mu = 2.2193E+008

with full section properties:

b = 450.00

d = 407.00

d' = 43.00

v = 0.00124204

N = 7506.808

fc = 33.00

co (5A.5, TBDY) = 0.002

Final value of  $\phi_u$ :  $\phi_u^* = \text{shear\_factor} * \text{Max}(\phi_u, \phi_c) = 0.01393923$

The Shear\_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY:  $\phi_u = 0.01393923$

we ((5.4c), TBDY) =  $\text{ase}^* \text{sh}_{\min} * \text{fy}_{we} / \text{f}_{ce} + \text{Min}(\phi_x, \phi_y) = 0.06811101$

where  $\phi = \text{af} * \text{pf} * \text{ffe} / \text{f}_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

fx = 0.06628267

af = 0.54930041

b = 450.00

h = 450.00

From EC8 A.4.4.3(6), pf =  $2\text{tf}/\text{bw} = 0.00451556$

bw = 450.00

effective stress from (A.35),  $\text{ff}_{e} = 881.8461$

fy = 0.06628267

af = 0.54930041

b = 450.00

h = 450.00

From EC8 A.4.4.3(6), pf =  $2\text{tf}/\text{bw} = 0.00451556$

bw = 450.00

effective stress from (A.35),  $\text{ff}_{e} = 881.8461$

R = 40.00

Effective FRP thickness,  $\text{tf} = \text{NL} * \text{t} * \text{Cos}(b1) = 1.016$

fu,f = 1055.00

Ef = 64828.00

u,f = 0.015

ase ((5.4d), TBDY) =  $(\text{ase1} * \text{A}_{\text{ext}} + \text{ase2} * \text{A}_{\text{int}}) / \text{A}_{\text{sec}} = 0.14546167$

ase1 = 0.12623274

bo\_1 = 390.00

ho\_1 = 390.00

bi2\_1 = 608400.00  
ase2 = Max(ase1,ase2) = 0.18853448  
bo\_2 = 242.00  
ho\_2 = 242.00  
bi2\_2 = 234256.00

psh,min\*Fywe = Min(psh,x\*Fywe , psh,y\*Fywe) = 1.38262

Expression ((5.4d), TBDY) for psh,min\*Fywe has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

psh\_x\*Fywe = psh1\*Fywe1+ps2\*Fywe2 = 1.38262  
ps1 (external) = (Ash1\*h1/s1)/Asec = 0.00116355  
Ash1 = Astir\_1\*ns\_1 = 157.0796  
No stirrups, ns\_1 = 2.00  
h1 = 450.00  
ps2 (internal) = (Ash2\*h2/s2)/Asec = 0.00103427  
Ash2 = Astir\_2\*ns\_2 = 100.531  
No stirrups, ns\_2 = 2.00  
h2 = 250.00

psh\_y\*Fywe = psh1\*Fywe1+ps2\*Fywe2 = 1.38262  
ps1 (external) = (Ash1\*h1/s1)/Asec = 0.00116355  
Ash1 = Astir\_1\*ns\_1 = 157.0796  
No stirrups, ns\_1 = 2.00  
h1 = 450.00  
ps2 (internal) = (Ash2\*h2/s2)/Asec = 0.00103427  
Ash2 = Astir\_2\*ns\_2 = 100.531  
No stirrups, ns\_2 = 2.00  
h2 = 250.00

Asec = 202500.00  
s1 = 300.00  
s2 = 120.00  
fywe1 = 694.45  
fywe2 = 555.55  
fce = 33.00

From ((5.A5), TBDY), TBDY: cc = 0.00305417  
c = confinement factor = 1.10542

y1 = 0.00152175  
sh1 = 0.0048696  
ft1 = 479.7871  
fy1 = 399.8226  
su1 = 0.0066488

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

lo/lou,min = lb/lb,min = 0.33981258

su1 = 0.4\*esu1\_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu1\_nominal = 0.08,

For calculation of esu1\_nominal and y1, sh1,ft1,fy1, it is considered  
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25\*(lb/lb,min)^ 2/3), from 10.3.5, ASCE 41-17.

with fs1 = (fs,jacket\*Asl,ten,jacket + fs,core\*Asl,ten,core)/Asl,ten = 399.8226

with Es1 = (Es,jacket\*Asl,ten,jacket + Es,core\*Asl,ten,core)/Asl,ten = 200000.00

y2 = 0.00152175  
sh2 = 0.0048696  
ft2 = 479.7871  
fy2 = 399.8226  
su2 = 0.0066488

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

lo/lou,min = lb/lb,min = 0.33981258

su2 = 0.4\*esu2\_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu2\_nominal = 0.08,

For calculation of esu2\_nominal and y2, sh2,ft2,fy2, it is considered  
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25\*(lb/lb,min)^ 2/3), from 10.3.5, ASCE 41-17.

$with fs2 = (fs_{jacket} \cdot Asl_{com,jacket} + fs_{core} \cdot Asl_{com,core}) / Asl_{com} = 399.8226$   
 $with Es2 = (Es_{jacket} \cdot Asl_{com,jacket} + Es_{core} \cdot Asl_{com,core}) / Asl_{com} = 200000.00$   
 $yv = 0.00152175$   
 $shv = 0.0048696$   
 $ftv = 507.2537$   
 $fyv = 422.7114$   
 $suv = 0.0066488$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 $Shear\_factor = 1.00$   
 $lo/lou,min = lb/ld = 0.33981258$   
 $suv = 0.4 \cdot esuv\_nominal ((5.5), TBDY) = 0.032$   
 From table 5A.1, TBDY:  $esuv\_nominal = 0.08$ ,  
 considering characteristic value  $fsyv = fsv/1.2$ , from table 5.1, TBDY  
 For calculation of  $esuv\_nominal$  and  $yv, shv,ftv,fyv$ , it is considered  
 characteristic value  $fsyv = fsv/1.2$ , from table 5.1, TBDY.  
 $y1, sh1,ft1,fy1$ , are also multiplied by  $Min(1,1.25 \cdot (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.  
 $with fsv = (fs_{jacket} \cdot Asl_{mid,jacket} + fs_{mid} \cdot Asl_{mid,core}) / Asl_{mid} = 422.7114$   
 $with Esv = (Es_{jacket} \cdot Asl_{mid,jacket} + Es_{mid} \cdot Asl_{mid,core}) / Asl_{mid} = 200000.00$   
 $1 = Asl_{ten} / (b \cdot d) \cdot (fs1 / fc) = 0.0752324$   
 $2 = Asl_{com} / (b \cdot d) \cdot (fs2 / fc) = 0.0752324$   
 $v = Asl_{mid} / (b \cdot d) \cdot (fsv / fc) = 0.02812438$

and confined core properties:

$b = 390.00$   
 $d = 377.00$   
 $d' = 13.00$   
 $fcc (5A.2, TBDY) = 36.47874$   
 $cc (5A.5, TBDY) = 0.00305417$   
 $c = \text{confinement factor} = 1.10542$   
 $1 = Asl_{ten} / (b \cdot d) \cdot (fs1 / fc) = 0.09371431$   
 $2 = Asl_{com} / (b \cdot d) \cdot (fs2 / fc) = 0.09371431$   
 $v = Asl_{mid} / (b \cdot d) \cdot (fsv / fc) = 0.03503353$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

---

$v < vs,y2$  - LHS eq.(4.5) is satisfied

---

$su (4.9) = 0.16791801$

$Mu = MRc (4.14) = 2.2193E+008$

$u = su (4.1) = 1.9632832E-005$

-----  
 Calculation of ratio  $lb/ld$

Lap Length:  $lb/ld = 0.33981258$

$lb = 300.00$

$ld = 882.8396$

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

= 1

$db = 16.66667$

Mean strength value of all re-bars:  $fy = 655.558$

Mean concrete strength:  $fc' = (fc'_{jacket} \cdot Area_{jacket} + fc'_{core} \cdot Area_{core}) / Area_{section} = 28.98765$ , but  $fc'^{0.5} \leq$

8.3 MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$Ktr = 2.86234$

$Atr = Min(Atr_x, Atr_y) = 257.6106$

where  $Atr_x, Atr_y$  are the sum of the area of all stirrup legs along X and Y loxal axis

$s = Max(s_{external}, s_{internal}) = 300.00$

$n = 12.00$

-----  
 -----  
 -----  
 -----  
 Calculation of Shear Strength  $Vr = Min(Vr1, Vr2) = 567563.724$

-----  
Calculation of Shear Strength at edge 1,  $V_{r1} = 567563.724$

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

$V_{ColO} = 567563.724$

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

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

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

Mean concrete strength:  $f_c' = (f_c'_{jacket} * Area_{jacket} + f_c'_{core} * Area_{core}) / Area_{section} = 28.98765$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M / Vd = 2.00$

$\mu_u = 1.0463738E-012$

$\nu_u = 2.7162834E-031$

$d = 0.8 * h = 360.00$

$N_u = 7506.808$

$A_g = 202500.00$

From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 144280.365$

where:

$V_{s1} = 69813.729$  is calculated for jacket, with:

$d = 360.00$

$A_v = 157079.633$

$f_y = 555.56$

$s = 300.00$

$V_{s1}$  is multiplied by  $Col1 = 0.66666667$

$s/d = 0.83333333$

$V_{s2} = 74466.637$  is calculated for core, with:

$d = 200.00$

$A_v = 100530.965$

$f_y = 444.44$

$s = 120.00$

$V_{s2}$  is multiplied by  $Col2 = 1.00$

$s/d = 0.60$

$V_f$  ((11-3)-(11.4), ACI 440) = 214457.247

$f = 0.95$ , for fully-wrapped sections

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

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

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

$d_{fv} = d$  (figure 11.2, ACI 440) = 407.00

$f_{fe}$  ((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:  $V_s + V_f \leq 579413.096$

$b_w = 450.00$

-----  
Calculation of Shear Strength at edge 2,  $V_{r2} = 567563.724$

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

$V_{ColO} = 567563.724$

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

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

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

Mean concrete strength:  $f_c' = (f_c'_{jacket} * Area_{jacket} + f_c'_{core} * Area_{core}) / Area_{section} = 28.98765$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M / Vd = 2.00$

$\mu_u = 1.0463738E-012$

$\nu_u = 2.7162834E-031$

$d = 0.8 \cdot h = 360.00$   
 $Nu = 7506.808$   
 $Ag = 202500.00$   
 From (11.5.4.8), ACI 318-14:  $Vs = Vs1 + Vs2 = 144280.365$   
 where:  
 $Vs1 = 69813.729$  is calculated for jacket, with:  
 $d = 360.00$   
 $Av = 157079.633$   
 $fy = 555.56$   
 $s = 300.00$   
 $Vs1$  is multiplied by  $Col1 = 0.66666667$   
 $s/d = 0.833333333$   
 $Vs2 = 74466.637$  is calculated for core, with:  
 $d = 200.00$   
 $Av = 100530.965$   
 $fy = 444.44$   
 $s = 120.00$   
 $Vs2$  is multiplied by  $Col2 = 1.00$   
 $s/d = 0.60$   
 $Vf$  ((11-3)-(11.4), ACI 440) = 214457.247  
 $f = 0.95$ , 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  $Vf( , )$ , is implemented for every different fiber orientation  $a_i$ ,  
 as well as for 2 crack directions,  $a = 45^\circ$  and  $a = -45^\circ$  to take into consideration the cyclic seismic loading.  
 orientation 1:  $a = b1 + 90^\circ = 90.00$   
 $Vf = \text{Min}(|Vf(45, 1)|, |Vf(-45, a1)|)$ , with:  
 total thickness per orientation,  $tf1 = NL \cdot t / \text{NoDir} = 1.016$   
 $dfv = d$  (figure 11.2, ACI 440) = 407.00  
 $ffe$  ((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:  $Vs + Vf \leq 579413.096$   
 $bw = 450.00$

-----  
 End Of Calculation of Shear Capacity ratio for element: column JC1 of floor 1  
 At local axis: 2

-----  
 Start Of Calculation of Chord Rotation Capacity for element: column JC1 of floor 1  
 At local axis: 2  
 Integration Section: (b)  
 Section Type: rcjrs

Constant Properties

-----  
 Knowledge Factor,  $\phi = 0.85$   
 Chord Rotation is generally considered as Deformation-Controlled Action according to Table C7-1, ASCE 41-17.  
 Mean strengths are used for Deformation-Controlled Actions according to 7.5.1.3, ASCE 41-17  
 Consequently:  
 Jacket  
 New material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 33.00$   
 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,  $E_s = 200000.00$   
 External Height,  $H = 450.00$   
 External Width,  $W = 450.00$

Internal Height, H = 250.00  
 Internal Width, W = 250.00  
 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,  $M = -1.6313530E-010$   
 Shear Force,  $V_2 = 7697.601$   
 Shear Force,  $V_3 = -1.7235006E-013$   
 Axial Force,  $F = -7503.728$   
 Longitudinal Reinforcement Area Distribution (in 2 divisions)  
   -Tension:  $As_t = 0.00$   
   -Compression:  $As_c = 2676.637$   
 Longitudinal Reinforcement Area Distribution (in 3 divisions)  
   -Tension:  $As_{t,ten} = 1137.257$   
   -Compression:  $As_{c,com} = 1137.257$   
   -Middle:  $As_{mid} = 402.1239$   
 Longitudinal External Reinforcement Area Distribution (in 3 divisions)  
   -Tension:  $As_{t,ten,jacket} = 829.3805$   
   -Compression:  $As_{c,com,jacket} = 829.3805$   
   -Middle:  $As_{mid,jacket} = 402.1239$   
 Longitudinal Internal Reinforcement Area Distribution (in 3 divisions)  
   -Tension:  $As_{t,ten,core} = 307.8761$   
   -Compression:  $As_{c,com,core} = 307.8761$   
   -Middle:  $As_{mid,core} = 0.00$   
 Mean Diameter of Tension Reinforcement,  $Db_L = 16.80$

-----  
 Existing component: From table 7-7, ASCE 41\_17: Final chord rotation Capacity  $u_{,R} = * u = 0.0027627$   
 $u = y + p = 0.00325024$

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

$y = (My * L_s / 3) / E_{eff} = 0.00325024$  ((4.29), Biskinis Phd))  
 $My = 1.7613E+008$   
 $L_s = M/V$  (with  $L_s > 0.1 * L$  and  $L_s < 2 * L$ ) = 1500.00  
 From table 10.5, ASCE 41\_17:  $E_{eff} = factor * E_c * I_g = 2.7095E+013$   
 $factor = 0.30$   
 $Ag = 202500.00$   
 Mean concrete strength:  $fc' = (fc'_{jacket} * Area_{jacket} + fc'_{core} * Area_{core}) / Area_{section} = 28.98765$   
 $N = 7503.728$   
 $Ec * I_g = Ec_{jacket} * I_{g,jacket} + Ec_{core} * I_{g,core} = 9.0315E+013$

Calculation of Yielding Moment  $M_y$

Calculation of  $\rho_y$  and  $M_y$  according to Annex 7 -

$$y = \text{Min}(y_{\text{ten}}, y_{\text{com}})$$

$$y_{\text{ten}} = 6.1806747\text{E-}006$$

$$\text{with } ((10.1), \text{ASCE 41-17}) f_y = \text{Min}(f_y, 1.25 \cdot f_y \cdot (l_b/d)^{2/3}) = 374.3546$$

$$d = 407.00$$

$$y = 0.25591435$$

$$A = 0.0147239$$

$$B = 0.00818869$$

$$\text{with } p_t = 0.00430549$$

$$p_c = 0.00620943$$

$$p_v = 0.0021956$$

$$N = 7503.728$$

$$b = 450.00$$

$$\rho = 0.10565111$$

$$y_{\text{comp}} = 2.2127278\text{E-}005$$

$$\text{with } f_c^* (12.3, \text{ACI 440}) = 34.40847$$

$$f_c = 33.00$$

$$f_l = 0.82797802$$

$$b = 450.00$$

$$h = 450.00$$

$$A_g = 202500.00$$

$$\text{From } (12.9), \text{ACI 440: } k_a = 0.54261599$$

$$g = p_t + p_c + p_v = 0.01461445$$

$$r_c = 40.00$$

$$A_e/A_c = 0.54261599$$

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

$$\text{effective strain from } (12.5) \text{ and } (12.12), \epsilon_{fe} = 0.004$$

$$f_u = 0.01$$

$$E_f = 64828.00$$

$$E_c = 26999.444$$

$$y = 0.25471862$$

$$A = 0.01452515$$

$$B = 0.00807924$$

$$\text{with } E_s = 200000.00$$

Calculation of ratio  $l_b/d$

$$\text{Lap Length: } l_b/d_{\text{min}} = 0.42476573$$

$$l_b = 300.00$$

$$d = 706.2717$$

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

$$= 1$$

$$d_b = 16.66667$$

$$\text{Mean strength value of all re-bars: } f_y = 524.4464$$

$$\text{Mean concrete strength: } f_c' = (f_c'_{\text{jacket}} \cdot \text{Area}_{\text{jacket}} + f_c'_{\text{core}} \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 28.98765, \text{ but } f_c'^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 25.00$$

$$K_{tr} = 2.86234$$

$$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 257.6106$$

where  $A_{tr_x}$ ,  $A_{tr_y}$  are the sum of the area of all stirrup legs along X and Y local axis

$$s = \text{Max}(s_{\text{external}}, s_{\text{internal}}) = 300.00$$

$$n = 12.00$$

- Calculation of  $\rho_p$  -

From table 10-8:  $\rho_p = 0.00$

with:

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

shear control ratio  $V_y E / V_{Col} I_{OE} = 0.26068017$

$d = d_{external} = 407.00$

$s = s_{external} = 0.00$

$t = s_1 + s_2 + 2 * t_f / b_w * (f_{fe} / f_s) = 0.00430549$

jacket:  $s_1 = A_{v1} * h_1 / (s_1 * A_g) = 0.00116355$

$A_{v1} = 157.0796$ , is the total area of all stirrups parallel to loading (shear) direction

$h_1 = 450.00$

$s_1 = 300.00$

core:  $s_2 = A_{v2} * h_2 / (s_2 * A_g) = 0.00103427$

$A_{v2} = 100.531$ , is the total area of all stirrups parallel to loading (shear) direction

$h_2 = 250.00$

$s_2 = 120.00$

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

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

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

For the normalisation  $f_s$  of jacket is used.

$NUD = 7503.728$

$A_g = 202500.00$

$f_{cE} = (f_{c,jacket} * Area_{jacket} + f_{c,core} * Area_{core}) / section\_area = 28.98765$

$f_{yIE} = (f_{y,ext\_Long\_Reinf} * Area_{ext\_Long\_Reinf} + f_{y,int\_Long\_Reinf} * Area_{int\_Long\_Reinf}) / Area_{Tot\_Long\_Rein} = 529.9972$

$f_{ytE} = (f_{y,ext\_Trans\_Reinf} * s_1 + f_{y,int\_Trans\_Reinf} * s_2) / (s_1 + s_2) = 503.2682$

$\rho_l = Area_{Tot\_Long\_Rein} / (b * d) = 0.01461445$

$b = 450.00$

$d = 407.00$

$f_{cE} = 28.98765$

-----  
End Of Calculation of Chord Rotation Capacity for element: column JC1 of floor 1

At local axis: 2

Integration Section: (b)

-----

## Calculation No. 7

column C1, Floor 1

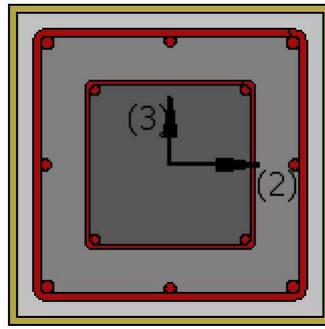
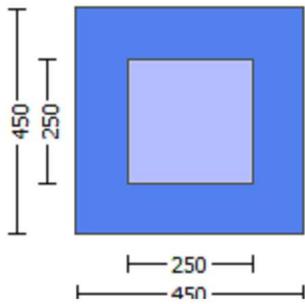
Limit State: Immediate Occupancy (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Shear capacity VRd

Edge: End

Local Axis: (3)



Start Of Calculation of Shear Capacity for element: column JC1 of floor 1

At local axis: 3

Integration Section: (b)

Section Type: rcjrs

Constant Properties

Knowledge Factor,  $\gamma = 0.85$

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  $\gamma$  for displacement ductility demand, the expected (mean value) strengths are used (7.5.1.3, ASCE 41-17) because bending is considered as Deformation-Controlled Action (Table C7-1, ASCE 41-17).

Jacket

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

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

Existing Column

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

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

#####

External Height,  $H = 450.00$

External Width,  $W = 450.00$

Internal Height,  $H = 250.00$

Internal Width,  $W = 250.00$

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,  $\theta_i$ : 0.00°  
Number of layers, NL = 1  
Radius of rounding corners, R = 40.00

-----  
Stepwise Properties

-----  
EDGE -A-  
Bending Moment,  $M_a$  = -3.5391295E-010  
Shear Force,  $V_a$  = 1.7235006E-013  
EDGE -B-  
Bending Moment,  $M_b$  = -1.6313530E-010  
Shear Force,  $V_b$  = -1.7235006E-013  
BOTH EDGES  
Axial Force, F = -7503.728  
Longitudinal Reinforcement Area Distribution (in 2 divisions)  
-Tension:  $A_{st}$  = 0.00  
-Compression:  $A_{sc}$  = 2676.637  
Longitudinal Reinforcement Area Distribution (in 3 divisions)  
-Tension:  $A_{st,ten}$  = 1137.257  
-Compression:  $A_{sc,com}$  = 1137.257  
-Middle:  $A_{st,mid}$  = 402.1239  
Mean Diameter of Tension Reinforcement,  $D_{bL,ten}$  = 16.80

-----  
Existing component: From table 7-7, ASCE 41\_17: Final Shear Capacity  $V_R = \phi V_n = 447100.515$   
 $V_n$  ((10.3), ASCE 41-17) =  $k_n \phi V_{Co10} = 526000.605$   
 $V_{Co10} = 526000.605$   
 $k_n = 1.00$   
displacement\_ductility\_demand = 0.00

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

-----  
= 1 (normal-weight concrete)  
Mean concrete strength:  $f_c' = (f_c'_{jacket} \cdot Area_{jacket} + f_c'_{core} \cdot Area_{core}) / Area_{section} = 22.22222$ , but  $f_c'^{0.5} < =$   
8.3 MPa (22.5.3.1, ACI 318-14)  
 $M / Vd = 2.00$   
 $M_u = 1.6313530E-010$   
 $V_u = 1.7235006E-013$   
 $d = 0.8 \cdot h = 360.00$   
 $N_u = 7503.728$   
 $A_g = 202500.00$   
From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 129852.496$   
where:  
 $V_{s1} = 62831.853$  is calculated for jacket, with:  
 $d = 360.00$   
 $A_v = 157079.633$   
 $f_y = 500.00$   
 $s = 300.00$   
 $V_{s1}$  is multiplied by  $Col1 = 0.66666667$   
 $s/d = 0.83333333$   
 $V_{s2} = 67020.643$  is calculated for core, with:  
 $d = 200.00$   
 $A_v = 100530.965$   
 $f_y = 400.00$   
 $s = 120.00$   
 $V_{s2}$  is multiplied by  $Col2 = 1.00$   
 $s/d = 0.60$   
 $V_f$  ((11-3)-(11.4), ACI 440) = 214457.247  
 $\phi = 0.95$ , 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  $\alpha$  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  $\theta_i$ ,

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

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

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

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

$d_{fv} = d$  (figure 11.2, ACI 440) = 407.00

$f_{fe}$  ((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:  $V_s + V_f \leq 507312.442$

$b_w = 450.00$

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

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

for rotation axis 2 and integ. section (b)

From analysis, chord rotation  $\theta = 9.3519433E-023$

$y = (M_y \cdot L_s / 3) / E_{\text{eff}} = 0.00325024$  ((4.29), Biskinis Phd)

$M_y = 1.7613E+008$

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

From table 10.5, ASCE 41\_17:  $E_{\text{eff}} = \text{factor} \cdot E_c \cdot I_g = 2.7095E+013$

factor = 0.30

$A_g = 202500.00$

Mean concrete strength:  $f_c' = (f_c'_{\text{jacket}} \cdot \text{Area}_{\text{jacket}} + f_c'_{\text{core}} \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 28.98765$

$N = 7503.728$

$E_c \cdot I_g = E_{c_{\text{jacket}}} \cdot I_{g_{\text{jacket}}} + E_{c_{\text{core}}} \cdot I_{g_{\text{core}}} = 9.0315E+013$

Calculation of Yielding Moment  $M_y$

Calculation of  $\delta / y$  and  $M_y$  according to Annex 7 -

$y = \text{Min}(y_{\text{ten}}, y_{\text{com}})$

$y_{\text{ten}} = 6.1806747E-006$

with ((10.1), ASCE 41-17)  $f_y = \text{Min}(f_y, 1.25 \cdot f_y \cdot (I_b / I_d)^{2/3}) = 374.3546$

$d = 407.00$

$y = 0.25591435$

$A = 0.0147239$

$B = 0.00818869$

with  $p_t = 0.00620943$

$p_c = 0.00620943$

$p_v = 0.0021956$

$N = 7503.728$

$b = 450.00$

$\theta = 0.10565111$

$y_{\text{comp}} = 2.2127278E-005$

with  $f_c^*$  (12.3, (ACI 440)) = 34.40847

$f_c = 33.00$

$f_l = 0.82797802$

$b = 450.00$

$h = 450.00$

$A_g = 202500.00$

From (12.9), ACI 440:  $k_a = 0.54261599$

$g = p_t + p_c + p_v = 0.01461445$

$r_c = 40.00$

$A_e / A_c = 0.54261599$

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

effective strain from (12.5) and (12.12),  $e_{fe} = 0.004$

$f_u = 0.01$

$E_f = 64828.00$

$E_c = 26999.444$

$y = 0.25471862$

$A = 0.01452515$

$B = 0.00807924$   
with  $E_s = 200000.00$

Calculation of ratio  $l_b/d$

Lap Length:  $l_d/d, \min = 0.42476573$

$l_b = 300.00$

$l_d = 706.2717$

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

$= 1$

$d_b = 16.66667$

Mean strength value of all re-bars:  $f_y = 524.4464$

Mean concrete strength:  $f_c' = (f_c'_{\text{jacket}} \cdot \text{Area}_{\text{jacket}} + f_c'_{\text{core}} \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 28.98765$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$c_b = 25.00$

$K_{tr} = 2.86234$

$A_{tr} = \min(A_{tr_x}, A_{tr_y}) = 257.6106$

where  $A_{tr_x}$ ,  $A_{tr_y}$  are the sum of the area of all stirrup legs along X and Y local axis

$s = \max(s_{\text{external}}, s_{\text{internal}}) = 300.00$

$n = 12.00$

End Of Calculation of Shear Capacity for element: column JC1 of floor 1

At local axis: 3

Integration Section: (b)

## Calculation No. 8

column C1, Floor 1

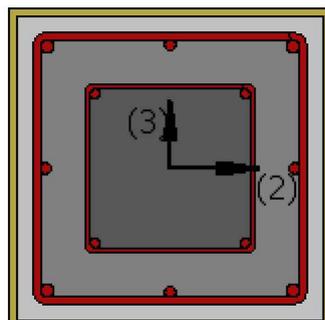
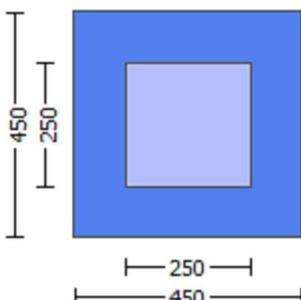
Limit State: Immediate Occupancy (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity ( $\theta_u$ )

Edge: End

Local Axis: (3)



Start Of Calculation of Shear Capacity ratio for element: column JC1 of floor 1

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

Constant Properties

Knowledge Factor,  $\gamma = 0.85$   
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 Height,  $H = 450.00$

External Width,  $W = 450.00$

Internal Height,  $H = 250.00$

Internal Width,  $W = 250.00$

Cover Thickness,  $c = 25.00$

Mean Confinement Factor overall section = 1.10542

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,  $V_a = 2.0531359E-031$

EDGE -B-

Shear Force,  $V_b = -2.0531359E-031$

BOTH EDGES

Axial Force,  $F = -7506.808$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension:  $A_{st} = 0.00$

-Compression:  $As_c = 2676.637$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension:  $As_{ten} = 1137.257$

-Compression:  $As_{com} = 1137.257$

-Middle:  $As_{mid} = 402.1239$

Calculation of Shear Capacity ratio,  $V_e/V_r = 0.26068017$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 147952.607$

with

$M_{pr1} = \text{Max}(Mu_{1+}, Mu_{1-}) = 2.2193E+008$

$Mu_{1+} = 2.2193E+008$ , 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

$Mu_{1-} = 2.2193E+008$ , 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

$M_{pr2} = \text{Max}(Mu_{2+}, Mu_{2-}) = 2.2193E+008$

$Mu_{2+} = 2.2193E+008$ , 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

$Mu_{2-} = 2.2193E+008$ , 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 curvature  $\phi_u$  according to 4.1, Biskinis/Fardis 2013:

$\phi_u = 1.9632832E-005$

$M_u = 2.2193E+008$

with full section properties:

$b = 450.00$

$d = 407.00$

$d' = 43.00$

$v = 0.00124204$

$N = 7506.808$

$f_c = 33.00$

$\phi_c$  (5A.5, TBDY) = 0.002

Final value of  $\phi_u$ :  $\phi_u^* = \text{shear\_factor} * \text{Max}(\phi_u, \phi_c) = 0.01393923$

The Shear\_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY:  $\phi_u = 0.01393923$

$\phi_{we}$  ((5.4c), TBDY) =  $\phi_u * \text{sh}_{min} * f_{ywe}/f_{ce} + \text{Min}(\phi_x, \phi_y) = 0.06811101$

where  $\phi = \phi_u * p_f * f_{fe}/f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$\phi_x = 0.06628267$

$\phi_f = 0.54930041$

$b = 450.00$

$h = 450.00$

From EC8 A.4.4.3(6),  $p_f = 2t_f/b_w = 0.00451556$

$b_w = 450.00$

effective stress from (A.35),  $f_{fe} = 881.8461$

$\phi_y = 0.06628267$

$\phi_f = 0.54930041$

$b = 450.00$

$h = 450.00$

From EC8 A.4.4.3(6),  $p_f = 2t_f/b_w = 0.00451556$

$b_w = 450.00$

effective stress from (A.35),  $f_{fe} = 881.8461$

$R = 40.00$

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

$f_{u,f} = 1055.00$

$E_f = 64828.00$

u,f = 0.015

ase ((5.4d), TBDY) = (ase1\*Aext+ase2\*Aint)/Asec = 0.14546167

ase1 = 0.12623274

bo\_1 = 390.00

ho\_1 = 390.00

bi2\_1 = 608400.00

ase2 = Max(ase1,ase2) = 0.18853448

bo\_2 = 242.00

ho\_2 = 242.00

bi2\_2 = 234256.00

psh,min\*Fywe = Min(psh,x\*Fywe , psh,y\*Fywe) = 1.38262

Expression ((5.4d), TBDY) for psh,min\*Fywe has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

psh\_x\*Fywe = psh1\*Fywe1+ps2\*Fywe2 = 1.38262

ps1 (external) = (Ash1\*h1/s1)/Asec = 0.00116355

Ash1 = Astir\_1\*ns\_1 = 157.0796

No stirrups, ns\_1 = 2.00

h1 = 450.00

ps2 (internal) = (Ash2\*h2/s2)/Asec = 0.00103427

Ash2 = Astir\_2\*ns\_2 = 100.531

No stirrups, ns\_2 = 2.00

h2 = 250.00

psh\_y\*Fywe = psh1\*Fywe1+ps2\*Fywe2 = 1.38262

ps1 (external) = (Ash1\*h1/s1)/Asec = 0.00116355

Ash1 = Astir\_1\*ns\_1 = 157.0796

No stirrups, ns\_1 = 2.00

h1 = 450.00

ps2 (internal) = (Ash2\*h2/s2)/Asec = 0.00103427

Ash2 = Astir\_2\*ns\_2 = 100.531

No stirrups, ns\_2 = 2.00

h2 = 250.00

Asec = 202500.00

s1 = 300.00

s2 = 120.00

fywe1 = 694.45

fywe2 = 555.55

fce = 33.00

From ((5.A5), TBDY), TBDY: cc = 0.00305417

c = confinement factor = 1.10542

y1 = 0.00152175

sh1 = 0.0048696

ft1 = 479.7871

fy1 = 399.8226

su1 = 0.0066488

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00

lo/lou,min = lb/d = 0.33981258

su1 = 0.4\*esu1\_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu1\_nominal = 0.08,

For calculation of esu1\_nominal and y1, sh1,ft1,fy1, it is considered characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25\*(lb/d)^2/3), from 10.3.5, ASCE 41-17.

with fs1 = (fs,jacket\*Asl,ten,jacket + fs,core\*Asl,ten,core)/Asl,ten = 399.8226

with Es1 = (Es,jacket\*Asl,ten,jacket + Es,core\*Asl,ten,core)/Asl,ten = 200000.00

y2 = 0.00152175

sh2 = 0.0048696

ft2 = 479.7871

fy2 = 399.8226

su2 = 0.0066488

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00

lo/lou,min = lb/lb,min = 0.33981258

$su_2 = 0.4 \cdot esu_2\_nominal ((5.5), TBDY) = 0.032$   
 From table 5A.1, TBDY:  $esu_2\_nominal = 0.08$ ,  
 For calculation of  $esu_2\_nominal$  and  $y_2, sh_2, ft_2, fy_2$ , it is considered  
 characteristic value  $fsy_2 = fs_2/1.2$ , from table 5.1, TBDY.  
 $y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with  $fs_2 = (fs\_jacket \cdot Asl\_com\_jacket + fs\_core \cdot Asl\_com\_core) / Asl\_com = 399.8226$   
 with  $Es_2 = (Es\_jacket \cdot Asl\_com\_jacket + Es\_core \cdot Asl\_com\_core) / Asl\_com = 200000.00$   
 $yv = 0.00152175$   
 $shv = 0.0048696$   
 $ftv = 507.2537$   
 $fyv = 422.7114$   
 $suv = 0.0066488$   
 using (30) in Biskinis/Fardis (2013) multiplied with  $shear\_factor$   
 and also multiplied by the  $shear\_factor$  according to 15.7.1.4, with  
 $Shear\_factor = 1.00$   
 $lo/lo_{u,min} = lb/ld = 0.33981258$   
 $suv = 0.4 \cdot esuv\_nominal ((5.5), TBDY) = 0.032$   
 From table 5A.1, TBDY:  $esuv\_nominal = 0.08$ ,  
 considering characteristic value  $fsyv = fsv/1.2$ , from table 5.1, TBDY  
 For calculation of  $esuv\_nominal$  and  $yv, shv, ftv, fyv$ , it is considered  
 characteristic value  $fsyv = fsv/1.2$ , from table 5.1, TBDY.  
 $y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with  $fsv = (fs\_jacket \cdot Asl\_mid\_jacket + fs\_mid \cdot Asl\_mid\_core) / Asl\_mid = 422.7114$   
 with  $Es_v = (Es\_jacket \cdot Asl\_mid\_jacket + Es\_mid \cdot Asl\_mid\_core) / Asl\_mid = 200000.00$   
 $1 = Asl\_ten / (b \cdot d) \cdot (fs_1 / fc) = 0.0752324$   
 $2 = Asl\_com / (b \cdot d) \cdot (fs_2 / fc) = 0.0752324$   
 $v = Asl\_mid / (b \cdot d) \cdot (fsv / fc) = 0.02812438$   
 and confined core properties:  
 $b = 390.00$   
 $d = 377.00$   
 $d' = 13.00$   
 $fcc (5A.2, TBDY) = 36.47874$   
 $cc (5A.5, TBDY) = 0.00305417$   
 $c = \text{confinement factor} = 1.10542$   
 $1 = Asl\_ten / (b \cdot d) \cdot (fs_1 / fc) = 0.09371431$   
 $2 = Asl\_com / (b \cdot d) \cdot (fs_2 / fc) = 0.09371431$   
 $v = Asl\_mid / (b \cdot d) \cdot (fsv / fc) = 0.03503353$   
 Case/Assumption: Unconfined full section - Steel rupture  
 ' satisfies Eq. (4.3)  
 --->  
 $v < v_{s,y2}$  - LHS eq.(4.5) is satisfied  
 --->  
 $su (4.9) = 0.16791801$   
 $Mu = MRc (4.14) = 2.2193E+008$   
 $u = su (4.1) = 1.9632832E-005$   
 -----  
 Calculation of ratio  $lb/ld$   
 -----  
 Lap Length:  $lb/ld = 0.33981258$   
 $lb = 300.00$   
 $ld = 882.8396$   
 Calculation of  $lb_{min}$  according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.  
 $= 1$   
 $db = 16.66667$   
 Mean strength value of all re-bars:  $fy = 655.558$   
 Mean concrete strength:  $fc' = (fc'_jacket \cdot Area\_jacket + fc'_core \cdot Area\_core) / Area\_section = 28.98765$ , but  $fc'^{0.5} < =$   
 $8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$   
 $t = 1.00$   
 $s = 0.80$   
 $e = 1.00$   
 $cb = 25.00$   
 $Ktr = 2.86234$   
 $Atr = \text{Min}(Atr\_x, Atr\_y) = 257.6106$   
 where  $Atr\_x, Atr\_y$  are the sum of the area of all stirrup legs along X and Y loxal axis  
 $s = \text{Max}(s\_external, s\_internal) = 300.00$   
 $n = 12.00$

Calculation of Mu1-

Calculation of ultimate curvature  $\mu$  according to 4.1, Biskinis/Fardis 2013:

$$\mu = 1.9632832E-005$$

$$Mu = 2.2193E+008$$

with full section properties:

$$b = 450.00$$

$$d = 407.00$$

$$d' = 43.00$$

$$v = 0.00124204$$

$$N = 7506.808$$

$$f_c = 33.00$$

$$c_o \text{ (5A.5, TBDY)} = 0.002$$

$$\text{Final value of } c_u: c_u^* = \text{shear\_factor} * \text{Max}(c_u, c_c) = 0.01393923$$

The Shear\_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } c_u = 0.01393923$$

$$w_e \text{ ((5.4c), TBDY)} = a_{se} * s_{h,min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.06811101$$

where  $f = a_f * p_f * f_{fe} / f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.06628267$$

$$a_f = 0.54930041$$

$$b = 450.00$$

$$h = 450.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.00451556$$

$$b_w = 450.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 881.8461$$

$$f_y = 0.06628267$$

$$a_f = 0.54930041$$

$$b = 450.00$$

$$h = 450.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.00451556$$

$$b_w = 450.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 881.8461$$

$$R = 40.00$$

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

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$a_{se} \text{ ((5.4d), TBDY)} = (a_{se1} * A_{ext} + a_{se2} * A_{int}) / A_{sec} = 0.14546167$$

$$a_{se1} = 0.12623274$$

$$b_{o,1} = 390.00$$

$$h_{o,1} = 390.00$$

$$b_{i2,1} = 608400.00$$

$$a_{se2} = \text{Max}(a_{se1}, a_{se2}) = 0.18853448$$

$$b_{o,2} = 242.00$$

$$h_{o,2} = 242.00$$

$$b_{i2,2} = 234256.00$$

$$p_{sh,min} * F_{ywe} = \text{Min}(p_{sh,x} * F_{ywe}, p_{sh,y} * F_{ywe}) = 1.38262$$

Expression ((5.4d), TBDY) for  $p_{sh,min} * F_{ywe}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$$p_{sh,x} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{sh2} * F_{ywe2} = 1.38262$$

$$p_{s1} \text{ (external)} = (A_{sh1} * h_1 / s_1) / A_{sec} = 0.00116355$$

$$A_{sh1} = A_{stir,1} * n_{s,1} = 157.0796$$

$$\text{No stirrups, } n_{s,1} = 2.00$$

$$h_1 = 450.00$$

$$p_{s2} \text{ (internal)} = (A_{sh2} * h_2 / s_2) / A_{sec} = 0.00103427$$

$$A_{sh2} = A_{stir,2} * n_{s,2} = 100.531$$

$$\text{No stirrups, } n_{s,2} = 2.00$$

$$h2 = 250.00$$

$$\begin{aligned} psh\_y * Fywe &= psh1 * Fywe1 + ps2 * Fywe2 = 1.38262 \\ ps1 \text{ (external)} &= (Ash1 * h1 / s1) / Asec = 0.00116355 \\ Ash1 &= Astir\_1 * ns\_1 = 157.0796 \\ \text{No stirups, } ns\_1 &= 2.00 \\ h1 &= 450.00 \\ ps2 \text{ (internal)} &= (Ash2 * h2 / s2) / Asec = 0.00103427 \\ Ash2 &= Astir\_2 * ns\_2 = 100.531 \\ \text{No stirups, } ns\_2 &= 2.00 \\ h2 &= 250.00 \end{aligned}$$

$$Asec = 202500.00$$

$$s1 = 300.00$$

$$s2 = 120.00$$

$$fywe1 = 694.45$$

$$fywe2 = 555.55$$

$$fce = 33.00$$

$$\text{From } ((5.A.5), \text{ TBDY}), \text{ TBDY: } cc = 0.00305417$$

$$c = \text{confinement factor} = 1.10542$$

$$y1 = 0.00152175$$

$$sh1 = 0.0048696$$

$$ft1 = 479.7871$$

$$fy1 = 399.8226$$

$$su1 = 0.0066488$$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

$$lo/lou, \text{min} = lb/ld = 0.33981258$$

$$su1 = 0.4 * esu1\_nominal \text{ ((5.5), TBDY)} = 0.032$$

From table 5A.1, TBDY: esu1\_nominal = 0.08,

For calculation of esu1\_nominal and y1, sh1, ft1, fy1, it is considered  
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1, ft1, fy1, are also multiplied by  $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.

$$\text{with } fs1 = (fs\_jacket * Asl, \text{ten, jacket} + fs\_core * Asl, \text{ten, core}) / Asl, \text{ten} = 399.8226$$

$$\text{with } Es1 = (Es\_jacket * Asl, \text{ten, jacket} + Es\_core * Asl, \text{ten, core}) / Asl, \text{ten} = 200000.00$$

$$y2 = 0.00152175$$

$$sh2 = 0.0048696$$

$$ft2 = 479.7871$$

$$fy2 = 399.8226$$

$$su2 = 0.0066488$$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

$$lo/lou, \text{min} = lb/lb, \text{min} = 0.33981258$$

$$su2 = 0.4 * esu2\_nominal \text{ ((5.5), TBDY)} = 0.032$$

From table 5A.1, TBDY: esu2\_nominal = 0.08,

For calculation of esu2\_nominal and y2, sh2, ft2, fy2, it is considered  
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

y1, sh1, ft1, fy1, are also multiplied by  $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.

$$\text{with } fs2 = (fs\_jacket * Asl, \text{com, jacket} + fs\_core * Asl, \text{com, core}) / Asl, \text{com} = 399.8226$$

$$\text{with } Es2 = (Es\_jacket * Asl, \text{com, jacket} + Es\_core * Asl, \text{com, core}) / Asl, \text{com} = 200000.00$$

$$yv = 0.00152175$$

$$shv = 0.0048696$$

$$ftv = 507.2537$$

$$fyv = 422.7114$$

$$suv = 0.0066488$$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

$$lo/lou, \text{min} = lb/ld = 0.33981258$$

$$suv = 0.4 * esuv\_nominal \text{ ((5.5), TBDY)} = 0.032$$

From table 5A.1, TBDY: esuv\_nominal = 0.08,

considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY  
For calculation of esuv\_nominal and yv, shv, ftv, fyv, it is considered

characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.

y1, sh1, ft1, fy1, are also multiplied by  $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.

with  $f_{sv} = (f_{s,jacket} \cdot A_{sl,mid,jacket} + f_{s,mid} \cdot A_{sl,mid,core}) / A_{sl,mid} = 422.7114$   
with  $E_{sv} = (E_{s,jacket} \cdot A_{sl,mid,jacket} + E_{s,mid} \cdot A_{sl,mid,core}) / A_{sl,mid} = 200000.00$   
 $1 = A_{sl,ten} / (b \cdot d) \cdot (f_{s1} / f_c) = 0.0752324$   
 $2 = A_{sl,com} / (b \cdot d) \cdot (f_{s2} / f_c) = 0.0752324$   
 $v = A_{sl,mid} / (b \cdot d) \cdot (f_{sv} / f_c) = 0.02812438$

and confined core properties:

$b = 390.00$   
 $d = 377.00$   
 $d' = 13.00$   
 $f_{cc} (5A.2, TBDY) = 36.47874$   
 $cc (5A.5, TBDY) = 0.00305417$   
 $c = \text{confinement factor} = 1.10542$   
 $1 = A_{sl,ten} / (b \cdot d) \cdot (f_{s1} / f_c) = 0.09371431$   
 $2 = A_{sl,com} / (b \cdot d) \cdot (f_{s2} / f_c) = 0.09371431$   
 $v = A_{sl,mid} / (b \cdot d) \cdot (f_{sv} / f_c) = 0.03503353$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < v_{s,y2}$  - LHS eq.(4.5) is satisfied

--->

$\mu_u (4.9) = 0.16791801$   
 $\mu_u = M_{Rc} (4.14) = 2.2193E+008$   
 $u = \mu_u (4.1) = 1.9632832E-005$

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

Lap Length:  $l_b/l_d = 0.33981258$

$l_b = 300.00$

$l_d = 882.8396$

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

= 1

$d_b = 16.66667$

Mean strength value of all re-bars:  $f_y = 655.558$

Mean concrete strength:  $f'_c = (f'_{c,jacket} \cdot Area_{jacket} + f'_{c,core} \cdot Area_{core}) / Area_{section} = 28.98765$ , but  $f_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 2.86234$

$A_{tr} = \text{Min}(A_{tr,x}, A_{tr,y}) = 257.6106$

where  $A_{tr,x}$ ,  $A_{tr,y}$  are the sum of the area of all stirrup legs along X and Y local axis

$s = \text{Max}(s_{external}, s_{internal}) = 300.00$

$n = 12.00$

-----  
Calculation of  $\mu_{u2+}$

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Calculation of ultimate curvature  $\mu_u$  according to 4.1, Biskinis/Fardis 2013:

$u = 1.9632832E-005$

$\mu_u = 2.2193E+008$

-----  
with full section properties:

$b = 450.00$

$d = 407.00$

$d' = 43.00$

$v = 0.00124204$

$N = 7506.808$

$f_c = 33.00$

$cc (5A.5, TBDY) = 0.002$

Final value of  $\mu_u$ :  $\mu_u^* = \text{shear\_factor} \cdot \text{Max}(\mu_u, cc) = 0.01393923$

The Shear\_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY:  $\mu_u = 0.01393923$

$w_e$  ((5.4c), TBDY) =  $a_{se} \cdot s_{h,min} \cdot f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.06811101$   
where  $f = a_f \cdot p_f \cdot f_{fe}/f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$f_x = 0.06628267$   
 $a_f = 0.54930041$   
 $b = 450.00$   
 $h = 450.00$   
From EC8 A.4.4.3(6),  $p_f = 2t_f/bw = 0.00451556$   
 $bw = 450.00$   
effective stress from (A.35),  $f_{f,e} = 881.8461$

$f_y = 0.06628267$   
 $a_f = 0.54930041$   
 $b = 450.00$   
 $h = 450.00$   
From EC8 A.4.4.3(6),  $p_f = 2t_f/bw = 0.00451556$   
 $bw = 450.00$   
effective stress from (A.35),  $f_{f,e} = 881.8461$

$R = 40.00$   
Effective FRP thickness,  $t_f = NL \cdot t \cdot \text{Cos}(b_1) = 1.016$   
 $f_{u,f} = 1055.00$   
 $E_f = 64828.00$   
 $u,f = 0.015$   
 $a_{se} \text{ ((5.4d), TBDY) } = (a_{se1} \cdot A_{ext} + a_{se2} \cdot A_{int})/A_{sec} = 0.14546167$   
 $a_{se1} = 0.12623274$   
 $bo\_1 = 390.00$   
 $ho\_1 = 390.00$   
 $bi2\_1 = 608400.00$   
 $a_{se2} = \text{Max}(a_{se1}, a_{se2}) = 0.18853448$   
 $bo\_2 = 242.00$   
 $ho\_2 = 242.00$   
 $bi2\_2 = 234256.00$

$p_{sh,min} \cdot F_{ywe} = \text{Min}(p_{sh,x} \cdot F_{ywe}, p_{sh,y} \cdot F_{ywe}) = 1.38262$   
Expression ((5.4d), TBDY) for  $p_{sh,min} \cdot F_{ywe}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$p_{sh,x} \cdot F_{ywe} = p_{sh1} \cdot F_{ywe1} + p_{sh2} \cdot F_{ywe2} = 1.38262$   
 $ps1 \text{ (external) } = (A_{sh1} \cdot h_1/s_1)/A_{sec} = 0.00116355$   
 $A_{sh1} = A_{stir\_1} \cdot ns\_1 = 157.0796$   
No stirrups,  $ns\_1 = 2.00$   
 $h_1 = 450.00$   
 $ps2 \text{ (internal) } = (A_{sh2} \cdot h_2/s_2)/A_{sec} = 0.00103427$   
 $A_{sh2} = A_{stir\_2} \cdot ns\_2 = 100.531$   
No stirrups,  $ns\_2 = 2.00$   
 $h_2 = 250.00$

$p_{sh,y} \cdot F_{ywe} = p_{sh1} \cdot F_{ywe1} + p_{sh2} \cdot F_{ywe2} = 1.38262$   
 $ps1 \text{ (external) } = (A_{sh1} \cdot h_1/s_1)/A_{sec} = 0.00116355$   
 $A_{sh1} = A_{stir\_1} \cdot ns\_1 = 157.0796$   
No stirrups,  $ns\_1 = 2.00$   
 $h_1 = 450.00$   
 $ps2 \text{ (internal) } = (A_{sh2} \cdot h_2/s_2)/A_{sec} = 0.00103427$   
 $A_{sh2} = A_{stir\_2} \cdot ns\_2 = 100.531$   
No stirrups,  $ns\_2 = 2.00$   
 $h_2 = 250.00$

$A_{sec} = 202500.00$   
 $s_1 = 300.00$   
 $s_2 = 120.00$   
 $f_{ywe1} = 694.45$   
 $f_{ywe2} = 555.55$   
 $f_{ce} = 33.00$   
From ((5.A5), TBDY), TBDY:  $cc = 0.00305417$   
 $c = \text{confinement factor} = 1.10542$   
 $y_1 = 0.00152175$   
 $sh_1 = 0.0048696$

$$ft1 = 479.7871$$

$$fy1 = 399.8226$$

$$su1 = 0.0066488$$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

$$lo/lou,min = lb/l_d = 0.33981258$$

$$su1 = 0.4 * esu1\_nominal ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: esu1\_nominal = 0.08,

For calculation of esu1\_nominal and y1, sh1,ft1,fy1, it is considered  
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by  $\text{Min}(1, 1.25 * (lb/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.

$$\text{with } fs1 = (fs\_jacket * Asl,ten,jacket + fs\_core * Asl,ten,core) / Asl,ten = 399.8226$$

$$\text{with } Es1 = (Es\_jacket * Asl,ten,jacket + Es\_core * Asl,ten,core) / Asl,ten = 200000.00$$

$$y2 = 0.00152175$$

$$sh2 = 0.0048696$$

$$ft2 = 479.7871$$

$$fy2 = 399.8226$$

$$su2 = 0.0066488$$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

$$lo/lou,min = lb/l_b,min = 0.33981258$$

$$su2 = 0.4 * esu2\_nominal ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: esu2\_nominal = 0.08,

For calculation of esu2\_nominal and y2, sh2,ft2,fy2, it is considered  
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by  $\text{Min}(1, 1.25 * (lb/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.

$$\text{with } fs2 = (fs\_jacket * Asl,com,jacket + fs\_core * Asl,com,core) / Asl,com = 399.8226$$

$$\text{with } Es2 = (Es\_jacket * Asl,com,jacket + Es\_core * Asl,com,core) / Asl,com = 200000.00$$

$$yv = 0.00152175$$

$$shv = 0.0048696$$

$$ftv = 507.2537$$

$$fyv = 422.7114$$

$$suv = 0.0066488$$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

$$lo/lou,min = lb/l_d = 0.33981258$$

$$suv = 0.4 * esuv\_nominal ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: esuv\_nominal = 0.08,

considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY

For calculation of esuv\_nominal and yv, shv,ftv,fyv, it is considered  
characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by  $\text{Min}(1, 1.25 * (lb/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.

$$\text{with } fsv = (fs\_jacket * Asl,mid,jacket + fs\_mid * Asl,mid,core) / Asl,mid = 422.7114$$

$$\text{with } Esv = (Es\_jacket * Asl,mid,jacket + Es\_mid * Asl,mid,core) / Asl,mid = 200000.00$$

$$1 = Asl,ten / (b * d) * (fs1 / fc) = 0.0752324$$

$$2 = Asl,com / (b * d) * (fs2 / fc) = 0.0752324$$

$$v = Asl,mid / (b * d) * (fsv / fc) = 0.02812438$$

and confined core properties:

$$b = 390.00$$

$$d = 377.00$$

$$d' = 13.00$$

$$fcc (5A.2, TBDY) = 36.47874$$

$$cc (5A.5, TBDY) = 0.00305417$$

$$c = \text{confinement factor} = 1.10542$$

$$1 = Asl,ten / (b * d) * (fs1 / fc) = 0.09371431$$

$$2 = Asl,com / (b * d) * (fs2 / fc) = 0.09371431$$

$$v = Asl,mid / (b * d) * (fsv / fc) = 0.03503353$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

v < vs,y2 - LHS eq.(4.5) is satisfied

--->

$$su (4.9) = 0.16791801$$

$$Mu = MRc (4.14) = 2.2193E+008$$

$$u = s_u(4.1) = 1.9632832E-005$$

Calculation of ratio  $l_b/l_d$

$$\text{Lap Length: } l_b/l_d = 0.33981258$$

$$l_b = 300.00$$

$$l_d = 882.8396$$

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

$$= 1$$

$$d_b = 16.66667$$

$$\text{Mean strength value of all re-bars: } f_y = 655.558$$

$$\text{Mean concrete strength: } f_c' = (f_c'_{\text{jacket}} \cdot \text{Area}_{\text{jacket}} + f_c'_{\text{core}} \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 28.98765, \text{ but } f_c'^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 25.00$$

$$K_{tr} = 2.86234$$

$$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 257.6106$$

where  $A_{tr_x}, A_{tr_y}$  are the sum of the area of all stirrup legs along X and Y local axis

$$s = \text{Max}(s_{\text{external}}, s_{\text{internal}}) = 300.00$$

$$n = 12.00$$

Calculation of  $\mu_2$

Calculation of ultimate curvature  $u$  according to 4.1, Biskinis/Fardis 2013:

$$u = 1.9632832E-005$$

$$\mu_u = 2.2193E+008$$

with full section properties:

$$b = 450.00$$

$$d = 407.00$$

$$d' = 43.00$$

$$v = 0.00124204$$

$$N = 7506.808$$

$$f_c = 33.00$$

$$c_o \text{ (5A.5, TBDY)} = 0.002$$

$$\text{Final value of } c_u: c_u^* = \text{shear\_factor} * \text{Max}(c_u, c_c) = 0.01393923$$

The Shear\_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } c_u = 0.01393923$$

$$w_e \text{ ((5.4c), TBDY)} = a_{sc} * s_{h, \min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.06811101$$

where  $f = a_f * p_f * f_{fe} / f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.06628267$$

$$a_f = 0.54930041$$

$$b = 450.00$$

$$h = 450.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.00451556$$

$$b_w = 450.00$$

$$\text{effective stress from (A.35), } f_{fe} = 881.8461$$

$$f_y = 0.06628267$$

$$a_f = 0.54930041$$

$$b = 450.00$$

$$h = 450.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.00451556$$

$$b_w = 450.00$$

$$\text{effective stress from (A.35), } f_{fe} = 881.8461$$

$$R = 40.00$$

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

$$f_{u,f} = 1055.00$$

Ef = 64828.00

u,f = 0.015

ase ((5.4d), TBDY) = (ase1\*Aext+ase2\*Aint)/Asec = 0.14546167

ase1 = 0.12623274

bo\_1 = 390.00

ho\_1 = 390.00

bi2\_1 = 608400.00

ase2 = Max(ase1,ase2) = 0.18853448

bo\_2 = 242.00

ho\_2 = 242.00

bi2\_2 = 234256.00

psh,min\*Fywe = Min(psh,x\*Fywe , psh,y\*Fywe) = 1.38262

Expression ((5.4d), TBDY) for psh,min\*Fywe has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

psh\_x\*Fywe = psh1\*Fywe1+ps2\*Fywe2 = 1.38262

ps1 (external) = (Ash1\*h1/s1)/Asec = 0.00116355

Ash1 = Astir\_1\*ns\_1 = 157.0796

No stirrups, ns\_1 = 2.00

h1 = 450.00

ps2 (internal) = (Ash2\*h2/s2)/Asec = 0.00103427

Ash2 = Astir\_2\*ns\_2 = 100.531

No stirrups, ns\_2 = 2.00

h2 = 250.00

psh\_y\*Fywe = psh1\*Fywe1+ps2\*Fywe2 = 1.38262

ps1 (external) = (Ash1\*h1/s1)/Asec = 0.00116355

Ash1 = Astir\_1\*ns\_1 = 157.0796

No stirrups, ns\_1 = 2.00

h1 = 450.00

ps2 (internal) = (Ash2\*h2/s2)/Asec = 0.00103427

Ash2 = Astir\_2\*ns\_2 = 100.531

No stirrups, ns\_2 = 2.00

h2 = 250.00

Asec = 202500.00

s1 = 300.00

s2 = 120.00

fywe1 = 694.45

fywe2 = 555.55

fce = 33.00

From ((5.A5), TBDY), TBDY: cc = 0.00305417

c = confinement factor = 1.10542

y1 = 0.00152175

sh1 = 0.0048696

ft1 = 479.7871

fy1 = 399.8226

su1 = 0.0066488

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00

lo/lou,min = lb/lb = 0.33981258

su1 = 0.4\*esu1\_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu1\_nominal = 0.08,

For calculation of esu1\_nominal and y1, sh1,ft1,fy1, it is considered characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25\*(lb/lb)^2/3), from 10.3.5, ASCE 41-17.

with fs1 = (fs,jacket\*Asl,ten,jacket + fs,core\*Asl,ten,core)/Asl,ten = 399.8226

with Es1 = (Es,jacket\*Asl,ten,jacket + Es,core\*Asl,ten,core)/Asl,ten = 200000.00

y2 = 0.00152175

sh2 = 0.0048696

ft2 = 479.7871

fy2 = 399.8226

su2 = 0.0066488

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00

$$l_o/l_{o,min} = l_b/l_{b,min} = 0.33981258$$

$$s_u = 0.4 \cdot e_{s_u, nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY:  $e_{s_u, nominal} = 0.08$ ,

For calculation of  $e_{s_u, nominal}$  and  $y_2$ ,  $sh_2$ ,  $ft_2$ ,  $fy_2$ , it is considered characteristic value  $f_{s_y} = f_{s_2}/1.2$ , from table 5.1, TBDY.

$y_1$ ,  $sh_1$ ,  $ft_1$ ,  $fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.

$$\text{with } f_{s_2} = (f_{s, jacket} \cdot A_{s, com, jacket} + f_{s, core} \cdot A_{s, com, core}) / A_{s, com} = 399.8226$$

$$\text{with } E_{s_2} = (E_{s, jacket} \cdot A_{s, com, jacket} + E_{s, core} \cdot A_{s, com, core}) / A_{s, com} = 200000.00$$

$$y_v = 0.00152175$$

$$sh_v = 0.0048696$$

$$ft_v = 507.2537$$

$$fy_v = 422.7114$$

$$s_{u_v} = 0.0066488$$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor

and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00

$$l_o/l_{o,min} = l_b/l_d = 0.33981258$$

$$s_{u_v} = 0.4 \cdot e_{s_{u_v}, nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY:  $e_{s_{u_v}, nominal} = 0.08$ ,

considering characteristic value  $f_{s_{u_v}} = f_{s_v}/1.2$ , from table 5.1, TBDY

For calculation of  $e_{s_{u_v}, nominal}$  and  $y_v$ ,  $sh_v$ ,  $ft_v$ ,  $fy_v$ , it is considered characteristic value  $f_{s_{u_v}} = f_{s_v}/1.2$ , from table 5.1, TBDY.

$y_1$ ,  $sh_1$ ,  $ft_1$ ,  $fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.

$$\text{with } f_{s_v} = (f_{s, jacket} \cdot A_{s, mid, jacket} + f_{s, mid} \cdot A_{s, mid, core}) / A_{s, mid} = 422.7114$$

$$\text{with } E_{s_v} = (E_{s, jacket} \cdot A_{s, mid, jacket} + E_{s, mid} \cdot A_{s, mid, core}) / A_{s, mid} = 200000.00$$

$$1 = A_{s, ten} / (b \cdot d) \cdot (f_{s_1} / f_c) = 0.0752324$$

$$2 = A_{s, com} / (b \cdot d) \cdot (f_{s_2} / f_c) = 0.0752324$$

$$v = A_{s, mid} / (b \cdot d) \cdot (f_{s_v} / f_c) = 0.02812438$$

and confined core properties:

$$b = 390.00$$

$$d = 377.00$$

$$d' = 13.00$$

$$f_{cc} (5A.2, TBDY) = 36.47874$$

$$c_c (5A.5, TBDY) = 0.00305417$$

$$c = \text{confinement factor} = 1.10542$$

$$1 = A_{s, ten} / (b \cdot d) \cdot (f_{s_1} / f_c) = 0.09371431$$

$$2 = A_{s, com} / (b \cdot d) \cdot (f_{s_2} / f_c) = 0.09371431$$

$$v = A_{s, mid} / (b \cdot d) \cdot (f_{s_v} / f_c) = 0.03503353$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

---->

$v < v_{s, y_2}$  - LHS eq.(4.5) is satisfied

---->

$$s_u (4.9) = 0.16791801$$

$$\mu_u = M_{Rc} (4.14) = 2.2193E+008$$

$$u = s_u (4.1) = 1.9632832E-005$$

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

Lap Length:  $l_b/l_d = 0.33981258$

$$l_b = 300.00$$

$$l_d = 882.8396$$

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

$$= 1$$

$$d_b = 16.66667$$

Mean strength value of all re-bars:  $f_y = 655.558$

Mean concrete strength:  $f'_c = (f'_{c, jacket} \cdot \text{Area}_{jacket} + f'_{c, core} \cdot \text{Area}_{core}) / \text{Area}_{section} = 28.98765$ , but  $f_c^{0.5} <= 8.3$  MPa (22.5.3.1, ACI 318-14)

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 25.00$$

$$K_{tr} = 2.86234$$

$$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 257.6106$$

where  $A_{tr_x}$ ,  $A_{tr_y}$  are the sum of the area of all stirrup legs along X and Y local axis

$$s = \text{Max}(s_{external}, s_{internal}) = 300.00$$

n = 12.00

Calculation of Shear Strength  $V_r = \text{Min}(V_{r1}, V_{r2}) = 567563.724$

Calculation of Shear Strength at edge 1,  $V_{r1} = 567563.724$

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

$V_{Co10} = 567563.724$

$knl = 1$  (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:  $f_c' = (f_c'_{\text{jacket}} * \text{Area}_{\text{jacket}} + f_c'_{\text{core}} * \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 28.98765$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M / Vd = 2.00$

$\mu_u = 1.4404090E-011$

$V_u = 2.0531359E-031$

$d = 0.8 * h = 360.00$

$N_u = 7506.808$

$A_g = 202500.00$

From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 144280.365$

where:

$V_{s1} = 69813.729$  is calculated for jacket, with:

$d = 360.00$

$A_v = 157079.633$

$f_y = 555.56$

$s = 300.00$

$V_{s1}$  is multiplied by  $Col1 = 0.66666667$

$s/d = 0.833333333$

$V_{s2} = 74466.637$  is calculated for core, with:

$d = 200.00$

$A_v = 100530.965$

$f_y = 444.44$

$s = 120.00$

$V_{s2}$  is multiplied by  $Col2 = 1.00$

$s/d = 0.60$

$V_f \text{ ((11-3)-(11.4), ACI 440)} = 214457.247$

$f = 0.95$ , for fully-wrapped sections

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

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

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

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

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

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

total thickness per orientation,  $tf1 = NL * t / \text{NoDir} = 1.016$

$d_{fv} = d$  (figure 11.2, ACI 440) = 407.00

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

$E_f = 64828.00$

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

with  $f_u = 0.01$

From (11-11), ACI 440:  $V_s + V_f \leq 579413.096$

$bw = 450.00$

Calculation of Shear Strength at edge 2,  $V_{r2} = 567563.724$

$V_{r2} = V_{Co2} \text{ ((10.3), ASCE 41-17)} = knl * V_{Co20}$

$V_{Co20} = 567563.724$

$knl = 1$  (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:  $f_c' = (f_c'_{\text{jacket}} \cdot \text{Area}_{\text{jacket}} + f_c'_{\text{core}} \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 28.98765$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$\mu_u = 1.4404090E-011$

$V_u = 2.0531359E-031$

$d = 0.8 \cdot h = 360.00$

$N_u = 7506.808$

$A_g = 202500.00$

From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 144280.365$

where:

$V_{s1} = 69813.729$  is calculated for jacket, with:

$d = 360.00$

$A_v = 157079.633$

$f_y = 555.56$

$s = 300.00$

$V_{s1}$  is multiplied by  $\text{Col1} = 0.66666667$

$s/d = 0.83333333$

$V_{s2} = 74466.637$  is calculated for core, with:

$d = 200.00$

$A_v = 100530.965$

$f_y = 444.44$

$s = 120.00$

$V_{s2}$  is multiplied by  $\text{Col2} = 1.00$

$s/d = 0.60$

$V_f$  ((11-3)-(11.4), ACI 440) = 214457.247

$f = 0.95$ , for fully-wrapped sections

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

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

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

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

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

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

$d_{fv} = d$  (figure 11.2, ACI 440) = 407.00

$f_{fe}$  ((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:  $V_s + V_f \leq 579413.096$

$b_w = 450.00$

-----  
End Of Calculation of Shear Capacity ratio for element: column JC1 of floor 1

At local axis: 3  
-----

-----  
Start Of Calculation of Shear Capacity ratio for element: column JC1 of floor 1

At Shear local axis: 2

(Bending local axis: 3)

Section Type: rcjrs

Constant Properties  
-----

Knowledge Factor,  $\phi = 0.85$

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,  $f_s = 1.25 * f_{sm} = 694.45$   
Existing Column  
Existing material: Steel Strength,  $f_s = 1.25 * f_{sm} = 555.55$   
#####  
External Height,  $H = 450.00$   
External Width,  $W = 450.00$   
Internal Height,  $H = 250.00$   
Internal Width,  $W = 250.00$   
Cover Thickness,  $c = 25.00$   
Mean Confinement Factor overall section = 1.10542  
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,  $NoDir = 1$   
Fiber orientations,  $b_i: 0.00^\circ$   
Number of layers,  $NL = 1$   
Radius of rounding corners,  $R = 40.00$

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

At local axis: 2  
EDGE -A-  
Shear Force,  $V_a = -2.7162834E-031$   
EDGE -B-  
Shear Force,  $V_b = 2.7162834E-031$   
BOTH EDGES  
Axial Force,  $F = -7506.808$   
Longitudinal Reinforcement Area Distribution (in 2 divisions)  
-Tension:  $A_{sl,t} = 0.00$   
-Compression:  $A_{sl,c} = 2676.637$   
Longitudinal Reinforcement Area Distribution (in 3 divisions)  
-Tension:  $A_{sl,ten} = 1137.257$   
-Compression:  $A_{sl,com} = 1137.257$   
-Middle:  $A_{sl,mid} = 402.1239$

-----  
-----  
Calculation of Shear Capacity ratio,  $V_e/V_r = 0.26068017$   
Member Controlled by Flexure ( $V_e/V_r < 1$ )  
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 147952.607$   
with  
 $M_{pr1} = \text{Max}(M_{u1+}, M_{u1-}) = 2.2193E+008$   
 $M_{u1+} = 2.2193E+008$ , 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  
 $M_{u1-} = 2.2193E+008$ , 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  
 $M_{pr2} = \text{Max}(M_{u2+}, M_{u2-}) = 2.2193E+008$

Mu2+ = 2.2193E+008, is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the the static loading combination

Mu2- = 2.2193E+008, is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the the static loading combination

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

-----  
Calculation of ultimate curvature  $\mu$  according to 4.1, Biskinis/Fardis 2013:

$$\mu = 1.9632832E-005$$

$$Mu = 2.2193E+008$$

-----  
with full section properties:

$$b = 450.00$$

$$d = 407.00$$

$$d' = 43.00$$

$$v = 0.00124204$$

$$N = 7506.808$$

$$f_c = 33.00$$

$$c_o \text{ (5A.5, TBDY)} = 0.002$$

$$\text{Final value of } c_u: c_u^* = \text{shear\_factor} * \text{Max}(c_u, c_c) = 0.01393923$$

The Shear\_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } c_u = 0.01393923$$

$$w_e \text{ ((5.4c), TBDY)} = a_{se} * s_{h,\min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.06811101$$

where  $f = a_f * p_f * f_{fe} / f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

-----  
 $f_x = 0.06628267$

$$a_f = 0.54930041$$

$$b = 450.00$$

$$h = 450.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.00451556$$

$$b_w = 450.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 881.8461$$

-----  
 $f_y = 0.06628267$

$$a_f = 0.54930041$$

$$b = 450.00$$

$$h = 450.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.00451556$$

$$b_w = 450.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 881.8461$$

-----  
 $R = 40.00$

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

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{f} = 0.015$$

$$a_{se} \text{ ((5.4d), TBDY)} = (a_{se1} * A_{ext} + a_{se2} * A_{int}) / A_{sec} = 0.14546167$$

$$a_{se1} = 0.12623274$$

$$b_{o,1} = 390.00$$

$$h_{o,1} = 390.00$$

$$b_{i,1} = 608400.00$$

$$a_{se2} = \text{Max}(a_{se1}, a_{se2}) = 0.18853448$$

$$b_{o,2} = 242.00$$

$$h_{o,2} = 242.00$$

$$b_{i,2} = 234256.00$$

$$p_{sh,\min} * F_{ywe} = \text{Min}(p_{sh,x} * F_{ywe}, p_{sh,y} * F_{ywe}) = 1.38262$$

Expression ((5.4d), TBDY) for  $p_{sh,\min} * F_{ywe}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

-----  
 $p_{sh,x} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{sh2} * F_{ywe2} = 1.38262$

$$p_{s1} \text{ (external)} = (A_{sh1} * h_1 / s_1) / A_{sec} = 0.00116355$$

$$A_{sh1} = A_{stir,1} * n_{s,1} = 157.0796$$

$$\text{No stirrups, } n_{s,1} = 2.00$$

$$h_1 = 450.00$$

$$ps_2 \text{ (internal)} = (Ash_2 * h_2 / s_2) / A_{sec} = 0.00103427$$

$$Ash_2 = Astir_2 * ns_2 = 100.531$$

$$\text{No stirups, } ns_2 = 2.00$$

$$h_2 = 250.00$$

$$psh_y * Fy_{we} = psh_1 * Fy_{we1} + ps_2 * Fy_{we2} = 1.38262$$

$$ps_1 \text{ (external)} = (Ash_1 * h_1 / s_1) / A_{sec} = 0.00116355$$

$$Ash_1 = Astir_1 * ns_1 = 157.0796$$

$$\text{No stirups, } ns_1 = 2.00$$

$$h_1 = 450.00$$

$$ps_2 \text{ (internal)} = (Ash_2 * h_2 / s_2) / A_{sec} = 0.00103427$$

$$Ash_2 = Astir_2 * ns_2 = 100.531$$

$$\text{No stirups, } ns_2 = 2.00$$

$$h_2 = 250.00$$

$$A_{sec} = 202500.00$$

$$s_1 = 300.00$$

$$s_2 = 120.00$$

$$fy_{we1} = 694.45$$

$$fy_{we2} = 555.55$$

$$f_{ce} = 33.00$$

$$\text{From ((5.A.5), TBDY), TBDY: } cc = 0.00305417$$

$$c = \text{confinement factor} = 1.10542$$

$$y_1 = 0.00152175$$

$$sh_1 = 0.0048696$$

$$ft_1 = 479.7871$$

$$fy_1 = 399.8226$$

$$su_1 = 0.0066488$$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

$$lo/lou, \text{min} = lb/ld = 0.33981258$$

$$su_1 = 0.4 * esu_1 \text{ nominal ((5.5), TBDY)} = 0.032$$

$$\text{From table 5A.1, TBDY: } esu_1 \text{ nominal} = 0.08,$$

For calculation of esu\_1 nominal and y\_1, sh\_1, ft\_1, fy\_1, it is considered  
characteristic value fsy\_1 = fs\_1 / 1.2, from table 5.1, TBDY.

$$y_1, sh_1, ft_1, fy_1, \text{ are also multiplied by } \text{Min}(1, 1.25 * (lb/ld)^{2/3}), \text{ from 10.3.5, ASCE 41-17.}$$

$$\text{with } fs_1 = (fs_{jacket} * A_{sl,ten,jacket} + fs_{core} * A_{sl,ten,core}) / A_{sl,ten} = 399.8226$$

$$\text{with } Es_1 = (Es_{jacket} * A_{sl,ten,jacket} + Es_{core} * A_{sl,ten,core}) / A_{sl,ten} = 200000.00$$

$$y_2 = 0.00152175$$

$$sh_2 = 0.0048696$$

$$ft_2 = 479.7871$$

$$fy_2 = 399.8226$$

$$su_2 = 0.0066488$$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

$$lo/lou, \text{min} = lb/lb, \text{min} = 0.33981258$$

$$su_2 = 0.4 * esu_2 \text{ nominal ((5.5), TBDY)} = 0.032$$

$$\text{From table 5A.1, TBDY: } esu_2 \text{ nominal} = 0.08,$$

For calculation of esu\_2 nominal and y\_2, sh\_2, ft\_2, fy\_2, it is considered  
characteristic value fsy\_2 = fs\_2 / 1.2, from table 5.1, TBDY.

$$y_2, sh_2, ft_2, fy_2, \text{ are also multiplied by } \text{Min}(1, 1.25 * (lb/ld)^{2/3}), \text{ from 10.3.5, ASCE 41-17.}$$

$$\text{with } fs_2 = (fs_{jacket} * A_{sl,com,jacket} + fs_{core} * A_{sl,com,core}) / A_{sl,com} = 399.8226$$

$$\text{with } Es_2 = (Es_{jacket} * A_{sl,com,jacket} + Es_{core} * A_{sl,com,core}) / A_{sl,com} = 200000.00$$

$$y_v = 0.00152175$$

$$sh_v = 0.0048696$$

$$ft_v = 507.2537$$

$$fy_v = 422.7114$$

$$su_v = 0.0066488$$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

$$lo/lou, \text{min} = lb/ld = 0.33981258$$

$$su_v = 0.4 * esu_v \text{ nominal ((5.5), TBDY)} = 0.032$$

$$\text{From table 5A.1, TBDY: } esu_v \text{ nominal} = 0.08,$$

considering characteristic value fsy\_v = fs\_v / 1.2, from table 5.1, TBDY

For calculation of  $e_{suv\_nominal}$  and  $\gamma_v$ ,  $sh_v, ft_v, fy_v$ , it is considered characteristic value  $f_{sv} = f_{sv}/1.2$ , from table 5.1, TBDY.

$\gamma_1$ ,  $sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.

with  $f_{sv} = (f_{s,jacket} \cdot A_{s,mid,jacket} + f_{s,mid} \cdot A_{s,mid,core}) / A_{s,mid} = 422.7114$

with  $E_{sv} = (E_{s,jacket} \cdot A_{s,mid,jacket} + E_{s,mid} \cdot A_{s,mid,core}) / A_{s,mid} = 200000.00$

$1 = A_{s,ten} / (b \cdot d) \cdot (f_{s1} / f_c) = 0.0752324$

$2 = A_{s,com} / (b \cdot d) \cdot (f_{s2} / f_c) = 0.0752324$

$v = A_{s,mid} / (b \cdot d) \cdot (f_{sv} / f_c) = 0.02812438$

and confined core properties:

$b = 390.00$

$d = 377.00$

$d' = 13.00$

$f_{cc} (5A.2, TBDY) = 36.47874$

$cc (5A.5, TBDY) = 0.00305417$

$c = \text{confinement factor} = 1.10542$

$1 = A_{s,ten} / (b \cdot d) \cdot (f_{s1} / f_c) = 0.09371431$

$2 = A_{s,com} / (b \cdot d) \cdot (f_{s2} / f_c) = 0.09371431$

$v = A_{s,mid} / (b \cdot d) \cdot (f_{sv} / f_c) = 0.03503353$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < v_{s,y2}$  - LHS eq.(4.5) is satisfied

--->

$\mu_u (4.9) = 0.16791801$

$\mu_u = MR_c (4.14) = 2.2193E+008$

$u = \mu_u (4.1) = 1.9632832E-005$

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

Lap Length:  $l_b/l_d = 0.33981258$

$l_b = 300.00$

$l_d = 882.8396$

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

= 1

$db = 16.66667$

Mean strength value of all re-bars:  $f_y = 655.558$

Mean concrete strength:  $f'_c = (f'_{c,jacket} \cdot Area_{jacket} + f'_{c,core} \cdot Area_{core}) / Area_{section} = 28.98765$ , but  $f_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 2.86234$

$A_{tr} = \text{Min}(A_{tr,x}, A_{tr,y}) = 257.6106$

where  $A_{tr,x}$ ,  $A_{tr,y}$  are the sum of the area of all stirrup legs along X and Y local axis

$s = \text{Max}(s_{external}, s_{internal}) = 300.00$

$n = 12.00$

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

-----  
Calculation of ultimate curvature  $\mu_u$  according to 4.1, Biskinis/Fardis 2013:

$u = 1.9632832E-005$

$\mu_u = 2.2193E+008$

-----  
with full section properties:

$b = 450.00$

$d = 407.00$

$d' = 43.00$

$v = 0.00124204$

$N = 7506.808$

$f_c = 33.00$

$cc (5A.5, TBDY) = 0.002$

Final value of  $c_u$ :  $c_u^* = \text{shear\_factor} * \text{Max}(c_u, c_c) = 0.01393923$

The Shear\_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY:  $c_u = 0.01393923$

$w_e$  ((5.4c), TBDY) =  $ase^* sh_{,min} * fy_{we} / f_{ce} + \text{Min}(f_x, f_y) = 0.06811101$

where  $f = af * pf * f_{fe} / f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

-----  
 $f_x = 0.06628267$

$af = 0.54930041$

$b = 450.00$

$h = 450.00$

From EC8 A.4.4.3(6),  $pf = 2tf/bw = 0.00451556$

$bw = 450.00$

effective stress from (A.35),  $f_{f,e} = 881.8461$

-----  
 $f_y = 0.06628267$

$af = 0.54930041$

$b = 450.00$

$h = 450.00$

From EC8 A.4.4.3(6),  $pf = 2tf/bw = 0.00451556$

$bw = 450.00$

effective stress from (A.35),  $f_{f,e} = 881.8461$

-----  
 $R = 40.00$

Effective FRP thickness,  $tf = NL * t * \text{Cos}(b1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{,f} = 0.015$

$ase$  ((5.4d), TBDY) =  $(ase1 * A_{ext} + ase2 * A_{int}) / A_{sec} = 0.14546167$

$ase1 = 0.12623274$

$bo_{,1} = 390.00$

$ho_{,1} = 390.00$

$bi_{2,1} = 608400.00$

$ase2 = \text{Max}(ase1, ase2) = 0.18853448$

$bo_{,2} = 242.00$

$ho_{,2} = 242.00$

$bi_{2,2} = 234256.00$

$psh_{,min} * fy_{we} = \text{Min}(psh_{,x} * fy_{we}, psh_{,y} * fy_{we}) = 1.38262$

Expression ((5.4d), TBDY) for  $psh_{,min} * fy_{we}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

-----  
 $psh_{,x} * fy_{we} = psh1 * fy_{we1} + ps2 * fy_{we2} = 1.38262$

$ps1$  (external) =  $(Ash1 * h1 / s1) / A_{sec} = 0.00116355$

$Ash1 = Astir_{,1} * ns_{,1} = 157.0796$

No stirrups,  $ns_{,1} = 2.00$

$h1 = 450.00$

$ps2$  (internal) =  $(Ash2 * h2 / s2) / A_{sec} = 0.00103427$

$Ash2 = Astir_{,2} * ns_{,2} = 100.531$

No stirrups,  $ns_{,2} = 2.00$

$h2 = 250.00$

-----  
 $psh_{,y} * fy_{we} = psh1 * fy_{we1} + ps2 * fy_{we2} = 1.38262$

$ps1$  (external) =  $(Ash1 * h1 / s1) / A_{sec} = 0.00116355$

$Ash1 = Astir_{,1} * ns_{,1} = 157.0796$

No stirrups,  $ns_{,1} = 2.00$

$h1 = 450.00$

$ps2$  (internal) =  $(Ash2 * h2 / s2) / A_{sec} = 0.00103427$

$Ash2 = Astir_{,2} * ns_{,2} = 100.531$

No stirrups,  $ns_{,2} = 2.00$

$h2 = 250.00$

-----  
 $A_{sec} = 202500.00$

$s1 = 300.00$

$s2 = 120.00$

$fy_{we1} = 694.45$

$fy_{we2} = 555.55$

$f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.00305417$

$c = \text{confinement factor} = 1.10542$   
 $y1 = 0.00152175$   
 $sh1 = 0.0048696$   
 $ft1 = 479.7871$   
 $fy1 = 399.8226$   
 $su1 = 0.0066488$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 $\text{Shear\_factor} = 1.00$   
 $lo/lou,min = lb/ld = 0.33981258$   
 $su1 = 0.4 * esu1\_nominal ((5.5), \text{TBDY}) = 0.032$   
 From table 5A.1, TBDY:  $esu1\_nominal = 0.08$ ,  
 For calculation of  $esu1\_nominal$  and  $y1, sh1, ft1, fy1$ , it is considered  
 characteristic value  $fsy1 = fs1/1.2$ , from table 5.1, TBDY.  
 $y1, sh1, ft1, fy1$ , are also multiplied by  $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with  $fs1 = (fs,jacket * Asl,ten,jacket + fs,core * Asl,ten,core) / Asl,ten = 399.8226$   
 with  $Es1 = (Es,jacket * Asl,ten,jacket + Es,core * Asl,ten,core) / Asl,ten = 200000.00$   
 $y2 = 0.00152175$   
 $sh2 = 0.0048696$   
 $ft2 = 479.7871$   
 $fy2 = 399.8226$   
 $su2 = 0.0066488$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 $\text{Shear\_factor} = 1.00$   
 $lo/lou,min = lb/lb,min = 0.33981258$   
 $su2 = 0.4 * esu2\_nominal ((5.5), \text{TBDY}) = 0.032$   
 From table 5A.1, TBDY:  $esu2\_nominal = 0.08$ ,  
 For calculation of  $esu2\_nominal$  and  $y2, sh2, ft2, fy2$ , it is considered  
 characteristic value  $fsy2 = fs2/1.2$ , from table 5.1, TBDY.  
 $y1, sh1, ft1, fy1$ , are also multiplied by  $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with  $fs2 = (fs,jacket * Asl,com,jacket + fs,core * Asl,com,core) / Asl,com = 399.8226$   
 with  $Es2 = (Es,jacket * Asl,com,jacket + Es,core * Asl,com,core) / Asl,com = 200000.00$   
 $yv = 0.00152175$   
 $shv = 0.0048696$   
 $ftv = 507.2537$   
 $fyv = 422.7114$   
 $suv = 0.0066488$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 $\text{Shear\_factor} = 1.00$   
 $lo/lou,min = lb/ld = 0.33981258$   
 $suv = 0.4 * esuv\_nominal ((5.5), \text{TBDY}) = 0.032$   
 From table 5A.1, TBDY:  $esuv\_nominal = 0.08$ ,  
 considering characteristic value  $fsyv = fsv/1.2$ , from table 5.1, TBDY  
 For calculation of  $esuv\_nominal$  and  $yv, shv, ftv, fyv$ , it is considered  
 characteristic value  $fsyv = fsv/1.2$ , from table 5.1, TBDY.  
 $y1, sh1, ft1, fy1$ , are also multiplied by  $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with  $fsv = (fs,jacket * Asl,mid,jacket + fs,mid * Asl,mid,core) / Asl,mid = 422.7114$   
 with  $Es_v = (Es,jacket * Asl,mid,jacket + Es,mid * Asl,mid,core) / Asl,mid = 200000.00$   
 $1 = Asl,ten / (b * d) * (fs1 / fc) = 0.0752324$   
 $2 = Asl,com / (b * d) * (fs2 / fc) = 0.0752324$   
 $v = Asl,mid / (b * d) * (fsv / fc) = 0.02812438$   
 and confined core properties:  
 $b = 390.00$   
 $d = 377.00$   
 $d' = 13.00$   
 $fcc (5A.2, \text{TBDY}) = 36.47874$   
 $cc (5A.5, \text{TBDY}) = 0.00305417$   
 $c = \text{confinement factor} = 1.10542$   
 $1 = Asl,ten / (b * d) * (fs1 / fc) = 0.09371431$   
 $2 = Asl,com / (b * d) * (fs2 / fc) = 0.09371431$   
 $v = Asl,mid / (b * d) * (fsv / fc) = 0.03503353$   
 Case/Assumption: Unconfined full section - Steel rupture  
 ' satisfies Eq. (4.3)  
 --->  
 $v < vs,y2$  - LHS eq.(4.5) is satisfied

--->

su (4.9) = 0.16791801  
Mu = MRc (4.14) = 2.2193E+008  
u = su (4.1) = 1.9632832E-005

-----  
Calculation of ratio lb/l<sub>d</sub>

-----  
Lap Length: lb/l<sub>d</sub> = 0.33981258

lb = 300.00

l<sub>d</sub> = 882.8396

Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.  
= 1

db = 16.66667

Mean strength value of all re-bars: fy = 655.558

Mean concrete strength: fc' = (fc'\_jacket\*Area\_jacket + fc'\_core\*Area\_core)/Area\_section = 28.98765, 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 = 2.86234

Atr = Min(Atr\_x,Atr\_y) = 257.6106

where Atr\_x, Atr\_y are the sum of the area of all stirrup legs along X and Y loxal axis

s = Max(s\_external,s\_internal) = 300.00

n = 12.00

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

-----  
-----  
Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

u = 1.9632832E-005

Mu = 2.2193E+008

-----  
with full section properties:

b = 450.00

d = 407.00

d' = 43.00

v = 0.00124204

N = 7506.808

fc = 33.00

co (5A.5, TBDY) = 0.002

Final value of cu: cu\* = shear\_factor \* Max( cu, cc) = 0.01393923

The Shear\_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: cu = 0.01393923

we ((5.4c), TBDY) = ase\* sh,min\*fywe/fce+Min( fx, fy) = 0.06811101

where f = af\*pf\*ffe/fce is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

-----  
fx = 0.06628267

af = 0.54930041

b = 450.00

h = 450.00

From EC8 A.4.4.3(6), pf = 2tf/bw = 0.00451556

bw = 450.00

effective stress from (A.35), ff,e = 881.8461

-----  
fy = 0.06628267

af = 0.54930041

b = 450.00

h = 450.00

From EC8 A.4.4.3(6), pf = 2tf/bw = 0.00451556

bw = 450.00

effective stress from (A.35), ff,e = 881.8461

$R = 40.00$   
 Effective FRP thickness,  $t_f = NL * t * \cos(b_1) = 1.016$   
 $f_{u,f} = 1055.00$   
 $E_f = 64828.00$   
 $u_{,f} = 0.015$   
 $ase((5.4d), TBDY) = (ase_1 * A_{ext} + ase_2 * A_{int}) / A_{sec} = 0.14546167$   
 $ase_1 = 0.12623274$   
 $bo_1 = 390.00$   
 $ho_1 = 390.00$   
 $bi_2_1 = 608400.00$   
 $ase_2 = \text{Max}(ase_1, ase_2) = 0.18853448$   
 $bo_2 = 242.00$   
 $ho_2 = 242.00$   
 $bi_2_2 = 234256.00$

$psh_{,min} * F_{ywe} = \text{Min}(psh_{,x} * F_{ywe}, psh_{,y} * F_{ywe}) = 1.38262$   
 Expression ((5.4d), TBDY) for  $psh_{,min} * F_{ywe}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$psh_{,x} * F_{ywe} = psh_1 * F_{ywe1} + ps_2 * F_{ywe2} = 1.38262$   
 $ps_1 \text{ (external)} = (Ash_1 * h_1 / s_1) / A_{sec} = 0.00116355$   
 $Ash_1 = Astir_1 * ns_1 = 157.0796$   
 No stirrups,  $ns_1 = 2.00$   
 $h_1 = 450.00$   
 $ps_2 \text{ (internal)} = (Ash_2 * h_2 / s_2) / A_{sec} = 0.00103427$   
 $Ash_2 = Astir_2 * ns_2 = 100.531$   
 No stirrups,  $ns_2 = 2.00$   
 $h_2 = 250.00$

$psh_{,y} * F_{ywe} = psh_1 * F_{ywe1} + ps_2 * F_{ywe2} = 1.38262$   
 $ps_1 \text{ (external)} = (Ash_1 * h_1 / s_1) / A_{sec} = 0.00116355$   
 $Ash_1 = Astir_1 * ns_1 = 157.0796$   
 No stirrups,  $ns_1 = 2.00$   
 $h_1 = 450.00$   
 $ps_2 \text{ (internal)} = (Ash_2 * h_2 / s_2) / A_{sec} = 0.00103427$   
 $Ash_2 = Astir_2 * ns_2 = 100.531$   
 No stirrups,  $ns_2 = 2.00$   
 $h_2 = 250.00$

$A_{sec} = 202500.00$   
 $s_1 = 300.00$   
 $s_2 = 120.00$   
 $f_{ywe1} = 694.45$   
 $f_{ywe2} = 555.55$   
 $f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.00305417$   
 $c = \text{confinement factor} = 1.10542$

$y_1 = 0.00152175$   
 $sh_1 = 0.0048696$   
 $ft_1 = 479.7871$   
 $fy_1 = 399.8226$   
 $su_1 = 0.0066488$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 $\text{Shear\_factor} = 1.00$

$lo/lo_{,min} = lb/ld = 0.33981258$   
 $su_1 = 0.4 * esu_1_{nominal}((5.5), TBDY) = 0.032$

From table 5A.1, TBDY:  $esu_1_{nominal} = 0.08$ ,

For calculation of  $esu_1_{nominal}$  and  $y_1, sh_1, ft_1, fy_1$ , it is considered  
 characteristic value  $fsy_1 = fs_1 / 1.2$ , from table 5.1, TBDY.

$y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.

with  $fs_1 = (fs_{jacket} * A_{sl,ten,jacket} + fs_{core} * A_{sl,ten,core}) / A_{sl,ten} = 399.8226$

with  $Es_1 = (Es_{jacket} * A_{sl,ten,jacket} + Es_{core} * A_{sl,ten,core}) / A_{sl,ten} = 200000.00$

$y_2 = 0.00152175$   
 $sh_2 = 0.0048696$   
 $ft_2 = 479.7871$   
 $fy_2 = 399.8226$   
 $su_2 = 0.0066488$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

$$l_o/l_{o,min} = l_b/l_{b,min} = 0.33981258$$

$$s_u2 = 0.4 * e_{s_u2,nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY:  $e_{s_u2,nominal} = 0.08$ ,

For calculation of  $e_{s_u2,nominal}$  and  $y_2, sh_2, ft_2, fy_2$ , it is considered  
characteristic value  $f_{s_y2} = f_{s_2}/1.2$ , from table 5.1, TBDY.

$y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.

$$\text{with } f_{s_2} = (f_{s,jacket} * A_{s_l,com,jacket} + f_{s,core} * A_{s_l,com,core}) / A_{s_l,com} = 399.8226$$

$$\text{with } E_{s_2} = (E_{s,jacket} * A_{s_l,com,jacket} + E_{s,core} * A_{s_l,com,core}) / A_{s_l,com} = 200000.00$$

$$y_v = 0.00152175$$

$$sh_v = 0.0048696$$

$$ft_v = 507.2537$$

$$fy_v = 422.7114$$

$$s_{u_v} = 0.0066488$$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

$$l_o/l_{o,min} = l_b/l_d = 0.33981258$$

$$s_{u_v} = 0.4 * e_{s_{u_v},nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY:  $e_{s_{u_v},nominal} = 0.08$ ,

considering characteristic value  $f_{s_{y_v}} = f_{s_v}/1.2$ , from table 5.1, TBDY

For calculation of  $e_{s_{u_v},nominal}$  and  $y_v, sh_v, ft_v, fy_v$ , it is considered  
characteristic value  $f_{s_{y_v}} = f_{s_v}/1.2$ , from table 5.1, TBDY.

$y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.

$$\text{with } f_{s_v} = (f_{s,jacket} * A_{s_l,mid,jacket} + f_{s,mid} * A_{s_l,mid,core}) / A_{s_l,mid} = 422.7114$$

$$\text{with } E_{s_v} = (E_{s,jacket} * A_{s_l,mid,jacket} + E_{s,mid} * A_{s_l,mid,core}) / A_{s_l,mid} = 200000.00$$

$$1 = A_{s_l,ten} / (b * d) * (f_{s_1} / f_c) = 0.0752324$$

$$2 = A_{s_l,com} / (b * d) * (f_{s_2} / f_c) = 0.0752324$$

$$v = A_{s_l,mid} / (b * d) * (f_{s_v} / f_c) = 0.02812438$$

and confined core properties:

$$b = 390.00$$

$$d = 377.00$$

$$d' = 13.00$$

$$f_{cc} (5A.2, TBDY) = 36.47874$$

$$cc (5A.5, TBDY) = 0.00305417$$

$$c = \text{confinement factor} = 1.10542$$

$$1 = A_{s_l,ten} / (b * d) * (f_{s_1} / f_c) = 0.09371431$$

$$2 = A_{s_l,com} / (b * d) * (f_{s_2} / f_c) = 0.09371431$$

$$v = A_{s_l,mid} / (b * d) * (f_{s_v} / f_c) = 0.03503353$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < v_{s,y_2}$  - LHS eq.(4.5) is satisfied

--->

$$s_u (4.9) = 0.16791801$$

$$\mu = MR_c (4.14) = 2.2193E+008$$

$$u = s_u (4.1) = 1.9632832E-005$$

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

Lap Length:  $l_b/l_d = 0.33981258$

$$l_b = 300.00$$

$$l_d = 882.8396$$

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

$$= 1$$

$$d_b = 16.66667$$

Mean strength value of all re-bars:  $f_y = 655.558$

Mean concrete strength:  $f'_c = (f'_{c,jacket} * Area_{jacket} + f'_{c,core} * Area_{core}) / Area_{section} = 28.98765$ , but  $f_c^{0.5} < =$   
8.3 MPa (22.5.3.1, ACI 318-14)

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 25.00$$

$$K_{tr} = 2.86234$$

$$A_{tr} = \text{Min}(A_{tr\_x}, A_{tr\_y}) = 257.6106$$

where  $A_{tr\_x}$ ,  $A_{tr\_y}$  are the sum of the area of all stirrup legs along X and Y local axis

$$s = \text{Max}(s_{\text{external}}, s_{\text{internal}}) = 300.00$$

$$n = 12.00$$

-----  
-----  
-----  
Calculation of  $\mu_2$ -

-----  
-----  
Calculation of ultimate curvature  $\mu$  according to 4.1, Biskinis/Fardis 2013:

$$\mu = 1.9632832E-005$$

$$\mu_2 = 2.2193E+008$$

-----  
with full section properties:

$$b = 450.00$$

$$d = 407.00$$

$$d' = 43.00$$

$$v = 0.00124204$$

$$N = 7506.808$$

$$f_c = 33.00$$

$$c_o \text{ (5A.5, TBDY)} = 0.002$$

$$\text{Final value of } \mu_c: \mu_c^* = \text{shear\_factor} * \text{Max}(\mu_c, \mu_{cc}) = 0.01393923$$

The Shear\_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \mu_c = 0.01393923$$

$$\mu_{we} \text{ ((5.4c), TBDY)} = a_{se} * s_{h,\text{min}} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.06811101$$

where  $f = a_f * p_f * f_{fe} / f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.06628267$$

$$a_f = 0.54930041$$

$$b = 450.00$$

$$h = 450.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.00451556$$

$$b_w = 450.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 881.8461$$

$$f_y = 0.06628267$$

$$a_f = 0.54930041$$

$$b = 450.00$$

$$h = 450.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.00451556$$

$$b_w = 450.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 881.8461$$

$$R = 40.00$$

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

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{f} = 0.015$$

$$a_{se} \text{ ((5.4d), TBDY)} = (a_{se1} * A_{ext} + a_{se2} * A_{int}) / A_{sec} = 0.14546167$$

$$a_{se1} = 0.12623274$$

$$b_{o,1} = 390.00$$

$$h_{o,1} = 390.00$$

$$b_{i,1} = 608400.00$$

$$a_{se2} = \text{Max}(a_{se1}, a_{se2}) = 0.18853448$$

$$b_{o,2} = 242.00$$

$$h_{o,2} = 242.00$$

$$b_{i,2} = 234256.00$$

$$p_{sh,\text{min}} * f_{ywe} = \text{Min}(p_{sh,x} * f_{ywe}, p_{sh,y} * f_{ywe}) = 1.38262$$

Expression ((5.4d), TBDY) for  $p_{sh,\text{min}} * f_{ywe}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$$p_{sh,x} * f_{ywe} = p_{sh1} * f_{ywe1} + p_{sh2} * f_{ywe2} = 1.38262$$

$$p_{s1} \text{ (external)} = (A_{sh1} * h_1 / s_1) / A_{sec} = 0.00116355$$

$$A_{sh1} = A_{stir,1} * n_{s,1} = 157.0796$$

$$\text{No stirrups, } n_{s,1} = 2.00$$

h1 = 450.00  
ps2 (internal) = (Ash2\*h2/s2)/Asec = 0.00103427  
Ash2 = Astir\_2\*ns\_2 = 100.531  
No stirups, ns\_2 = 2.00  
h2 = 250.00

-----  
psh\_y\*Fywe = psh1\*Fywe1+ps2\*Fywe2 = 1.38262  
ps1 (external) = (Ash1\*h1/s1)/Asec = 0.00116355  
Ash1 = Astir\_1\*ns\_1 = 157.0796  
No stirups, ns\_1 = 2.00  
h1 = 450.00  
ps2 (internal) = (Ash2\*h2/s2)/Asec = 0.00103427  
Ash2 = Astir\_2\*ns\_2 = 100.531  
No stirups, ns\_2 = 2.00  
h2 = 250.00

-----  
Asec = 202500.00  
s1 = 300.00  
s2 = 120.00  
fywe1 = 694.45  
fywe2 = 555.55  
fce = 33.00

From ((5.A5), TBDY), TBDY: cc = 0.00305417  
c = confinement factor = 1.10542

y1 = 0.00152175  
sh1 = 0.0048696  
ft1 = 479.7871  
fy1 = 399.8226  
su1 = 0.0066488

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

lo/lou,min = lb/d = 0.33981258

su1 = 0.4\*esu1\_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu1\_nominal = 0.08,

For calculation of esu1\_nominal and y1, sh1,ft1,fy1, it is considered  
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25\*(lb/d)^ 2/3), from 10.3.5, ASCE 41-17.

with fs1 = (fs,jacket\*Asl,ten,jacket + fs,core\*Asl,ten,core)/Asl,ten = 399.8226

with Es1 = (Es,jacket\*Asl,ten,jacket + Es,core\*Asl,ten,core)/Asl,ten = 200000.00

y2 = 0.00152175  
sh2 = 0.0048696  
ft2 = 479.7871  
fy2 = 399.8226  
su2 = 0.0066488

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

lo/lou,min = lb/lb,min = 0.33981258

su2 = 0.4\*esu2\_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu2\_nominal = 0.08,

For calculation of esu2\_nominal and y2, sh2,ft2,fy2, it is considered  
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25\*(lb/d)^ 2/3), from 10.3.5, ASCE 41-17.

with fs2 = (fs,jacket\*Asl,com,jacket + fs,core\*Asl,com,core)/Asl,com = 399.8226

with Es2 = (Es,jacket\*Asl,com,jacket + Es,core\*Asl,com,core)/Asl,com = 200000.00

yv = 0.00152175  
shv = 0.0048696  
ftv = 507.2537  
fyv = 422.7114  
suv = 0.0066488

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

lo/lou,min = lb/d = 0.33981258

suv = 0.4\*esuv\_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esuv\_nominal = 0.08,

considering characteristic value  $f_{sv} = f_{sv}/1.2$ , from table 5.1, TBDY

For calculation of  $e_{suv\_nominal}$  and  $y_v$ ,  $sh_v$ ,  $ft_v$ ,  $fy_v$ , it is considered characteristic value  $f_{sv} = f_{sv}/1.2$ , from table 5.1, TBDY.

$y_1$ ,  $sh_1$ ,  $ft_1$ ,  $fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.

with  $f_{sv} = (f_{s,jacket} \cdot A_{s,mid,jacket} + f_{s,mid} \cdot A_{s,mid,core}) / A_{s,mid} = 422.7114$

with  $E_{sv} = (E_{s,jacket} \cdot A_{s,mid,jacket} + E_{s,mid} \cdot A_{s,mid,core}) / A_{s,mid} = 200000.00$

$1 = A_{s,ten} / (b \cdot d) \cdot (f_{s1} / f_c) = 0.0752324$

$2 = A_{s,com} / (b \cdot d) \cdot (f_{s2} / f_c) = 0.0752324$

$v = A_{s,mid} / (b \cdot d) \cdot (f_{sv} / f_c) = 0.02812438$

and confined core properties:

$b = 390.00$

$d = 377.00$

$d' = 13.00$

$f_{cc}$  (5A.2, TBDY) = 36.47874

$cc$  (5A.5, TBDY) = 0.00305417

$c$  = confinement factor = 1.10542

$1 = A_{s,ten} / (b \cdot d) \cdot (f_{s1} / f_c) = 0.09371431$

$2 = A_{s,com} / (b \cdot d) \cdot (f_{s2} / f_c) = 0.09371431$

$v = A_{s,mid} / (b \cdot d) \cdot (f_{sv} / f_c) = 0.03503353$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < v_{s,y2}$  - LHS eq.(4.5) is satisfied

--->

$su$  (4.9) = 0.16791801

$Mu = MRc$  (4.14) = 2.2193E+008

$u = su$  (4.1) = 1.9632832E-005

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

Lap Length:  $l_b/l_d = 0.33981258$

$l_b = 300.00$

$l_d = 882.8396$

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

= 1

$db = 16.66667$

Mean strength value of all re-bars:  $f_y = 655.558$

Mean concrete strength:  $f'_c = (f'_{c,jacket} \cdot Area_{jacket} + f'_{c,core} \cdot Area_{core}) / Area_{section} = 28.98765$ , but  $f_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 2.86234$

$A_{tr} = \text{Min}(A_{tr,x}, A_{tr,y}) = 257.6106$

where  $A_{tr,x}$ ,  $A_{tr,y}$  are the sum of the area of all stirrup legs along X and Y loxal axis

$s = \text{Max}(s_{external}, s_{internal}) = 300.00$

$n = 12.00$

-----  
Calculation of Shear Strength  $V_r = \text{Min}(V_{r1}, V_{r2}) = 567563.724$

-----  
Calculation of Shear Strength at edge 1,  $V_{r1} = 567563.724$

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

$V_{Col0} = 567563.724$

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

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

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

-----  
= 1 (normal-weight concrete)

Mean concrete strength:  $f'_c = (f'_{c,jacket} \cdot Area_{jacket} + f'_{c,core} \cdot Area_{core}) / Area_{section} = 28.98765$ , but  $f_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$\mu_u = 1.0463738E-012$   
 $V_u = 2.7162834E-031$   
 $d = 0.8 \cdot h = 360.00$   
 $N_u = 7506.808$   
 $A_g = 202500.00$   
 From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 144280.365$   
 where:  
 $V_{s1} = 69813.729$  is calculated for jacket, with:  
 $d = 360.00$   
 $A_v = 157079.633$   
 $f_y = 555.56$   
 $s = 300.00$   
 $V_{s1}$  is multiplied by  $Col1 = 0.66666667$   
 $s/d = 0.83333333$   
 $V_{s2} = 74466.637$  is calculated for core, with:  
 $d = 200.00$   
 $A_v = 100530.965$   
 $f_y = 444.44$   
 $s = 120.00$   
 $V_{s2}$  is multiplied by  $Col2 = 1.00$   
 $s/d = 0.60$   
 $V_f$  ((11-3)-(11.4), ACI 440) = 214457.247  
 $f = 0.95$ , for fully-wrapped sections  
 $w_f/s_f = 1$  (FRP strips adjacent to one another).  
 In (11.3)  $\sin \theta + \cos \theta$  is replaced with  $(\cot \theta + \cot \alpha) \sin \alpha$  which is more a generalised expression,  
 where  $\theta$  is the angle of the crack direction (see KANEPE).  
 This later relation, considered as a function  $V_f(\theta, \alpha)$ , is implemented for every different fiber orientation  $\alpha_i$ ,  
 as well as for 2 crack directions,  $\theta = 45^\circ$  and  $\theta = -45^\circ$  to take into consideration the cyclic seismic loading.  
 orientation 1:  $\theta = b1 + 90^\circ = 90.00$   
 $V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, \theta)|)$ , with:  
 total thickness per orientation,  $t_{f1} = N_L \cdot t / N_{oDir} = 1.016$   
 $d_{fv} = d$  (figure 11.2, ACI 440) = 407.00  
 $f_{fe}$  ((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:  $V_s + V_f \leq 579413.096$   
 $b_w = 450.00$

Calculation of Shear Strength at edge 2,  $V_{r2} = 567563.724$   
 $V_{r2} = V_{Col}$  ((10.3), ASCE 41-17) =  $k_{nl} \cdot V_{Col0}$   
 $V_{Col0} = 567563.724$   
 $k_{nl} = 1$  (zero step-static loading)

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

$\lambda = 1$  (normal-weight concrete)  
 Mean concrete strength:  $f_c' = (f_c'_{jacket} \cdot Area_{jacket} + f_c'_{core} \cdot Area_{core}) / Area_{section} = 28.98765$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)  
 $M/d = 2.00$   
 $\mu_u = 1.0463738E-012$   
 $V_u = 2.7162834E-031$   
 $d = 0.8 \cdot h = 360.00$   
 $N_u = 7506.808$   
 $A_g = 202500.00$   
 From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 144280.365$   
 where:  
 $V_{s1} = 69813.729$  is calculated for jacket, with:  
 $d = 360.00$   
 $A_v = 157079.633$   
 $f_y = 555.56$   
 $s = 300.00$   
 $V_{s1}$  is multiplied by  $Col1 = 0.66666667$   
 $s/d = 0.83333333$   
 $V_{s2} = 74466.637$  is calculated for core, with:

$d = 200.00$   
 $A_v = 100530.965$   
 $f_y = 444.44$   
 $s = 120.00$   
 Vs2 is multiplied by Col2 = 1.00  
 $s/d = 0.60$   
 $V_f((11-3)-(11.4), \text{ACI 440}) = 214457.247$   
 $f = 0.95$ , for fully-wrapped sections  
 $w_f/s_f = 1$  (FRP strips adjacent to one another).  
 In (11.3)  $\sin + \cos$  is replaced with  $(\cot + \cot a)\sin a$  which is more a generalised expression,  
 where  $a$  is the angle of the crack direction (see KANEPE).  
 This later relation, considered as a function  $V_f(\theta)$ , is implemented for every different fiber orientation  $a_i$ ,  
 as well as for 2 crack directions,  $\theta = 45^\circ$  and  $\theta = -45^\circ$  to take into consideration the cyclic seismic loading.  
 orientation 1:  $\theta_1 = \theta_1 + 90^\circ = 90.00$   
 $V_f = \text{Min}(|V_f(45, \theta_1)|, |V_f(-45, \theta_1)|)$ , with:  
 total thickness per orientation,  $t_{f1} = N_L * t / \text{NoDir} = 1.016$   
 $d_{fv} = d$  (figure 11.2, ACI 440) = 407.00  
 $f_{fe}((11-5), \text{ACI 440}) = 259.312$   
 $E_f = 64828.00$   
 $f_e = 0.004$ , from (11.6a), ACI 440  
 with  $f_u = 0.01$   
 From (11-11), ACI 440:  $V_s + V_f \leq 579413.096$   
 $b_w = 450.00$

-----  
 End Of Calculation of Shear Capacity ratio for element: column JC1 of floor 1  
 At local axis: 2

-----  
 Start Of Calculation of Chord Rotation Capacity for element: column JC1 of floor 1  
 At local axis: 3

Integration Section: (b)  
 Section Type: rcjrs

Constant Properties

-----  
 Knowledge Factor,  $\gamma = 0.85$   
 Chord Rotation is generally considered as Deformation-Controlled Action according to Table C7-1, ASCE 41-17.  
 Mean strengths are used for Deformation-Controlled Actions according to 7.5.1.3, ASCE 41-17  
 Consequently:  
 Jacket  
 New material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 33.00$   
 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,  $E_s = 200000.00$   
 External Height,  $H = 450.00$   
 External Width,  $W = 450.00$   
 Internal Height,  $H = 250.00$   
 Internal Width,  $W = 250.00$   
 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  $135^\circ$ )  
 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,  $M = 0.06012619$   
Shear Force,  $V_2 = 7697.601$   
Shear Force,  $V_3 = -1.7235006E-013$   
Axial Force,  $F = -7503.728$   
Longitudinal Reinforcement Area Distribution (in 2 divisions)  
-Tension:  $As_t = 0.00$   
-Compression:  $As_c = 2676.637$   
Longitudinal Reinforcement Area Distribution (in 3 divisions)  
-Tension:  $As_{ten} = 1137.257$   
-Compression:  $As_{com} = 1137.257$   
-Middle:  $As_{mid} = 402.1239$   
Longitudinal External Reinforcement Area Distribution (in 3 divisions)  
-Tension:  $As_{ten,jacket} = 829.3805$   
-Compression:  $As_{com,jacket} = 829.3805$   
-Middle:  $As_{mid,jacket} = 402.1239$   
Longitudinal Internal Reinforcement Area Distribution (in 3 divisions)  
-Tension:  $As_{ten,core} = 307.8761$   
-Compression:  $As_{com,core} = 307.8761$   
-Middle:  $As_{mid,core} = 0.00$   
Mean Diameter of Tension Reinforcement,  $Db_L = 16.80$

Existing component: From table 7-7, ASCE 41\_17: Final chord rotation Capacity  $u_{R} = u = 0.00055254$   
 $u = y + p = 0.00065005$

- Calculation of  $y$  -

$y = (M_y * L_s / 3) / E_{eff} = 0.00065005$  ((4.29), Biskinis Phd))  
 $M_y = 1.7613E+008$   
 $L_s = M/V$  (with  $L_s > 0.1 * L$  and  $L_s < 2 * L$ ) = 300.00  
From table 10.5, ASCE 41\_17:  $E_{eff} = factor * E_c * I_g = 2.7095E+013$   
factor = 0.30  
 $A_g = 202500.00$   
Mean concrete strength:  $f'_c = (f'_{c,jacket} * Area_{jacket} + f'_{c,core} * Area_{core}) / Area_{section} = 28.98765$   
 $N = 7503.728$   
 $E_c * I_g = E_{c,jacket} * I_{g,jacket} + E_{c,core} * I_{g,core} = 9.0315E+013$

Calculation of Yielding Moment  $M_y$

Calculation of  $y$  and  $M_y$  according to Annex 7 -

$y = \text{Min}(y_{ten}, y_{com})$   
 $y_{ten} = 6.1806747E-006$   
with ((10.1), ASCE 41-17)  $f_y = \text{Min}(f_y, 1.25 * f_y * ((l_b/d)^{2/3})) = 374.3546$   
 $d = 407.00$   
 $y = 0.25591435$   
 $A = 0.0147239$   
 $B = 0.00818869$   
with  $pt = 0.00430549$   
 $pc = 0.00620943$

$p_v = 0.0021956$   
 $N = 7503.728$   
 $b = 450.00$   
 $\rho = 0.10565111$   
 $y_{comp} = 2.2127278E-005$   
 with  $f_c^*$  (12.3, (ACI 440)) = 34.40847  
 $f_c = 33.00$   
 $f_l = 0.82797802$   
 $b = 450.00$   
 $h = 450.00$   
 $A_g = 202500.00$   
 From (12.9), ACI 440:  $k_a = 0.54261599$   
 $g = p_t + p_c + p_v = 0.01461445$   
 $r_c = 40.00$   
 $A_e/A_c = 0.54261599$   
 Effective FRP thickness,  $t_f = N L^* t^* \cos(b_1) = 1.016$   
 effective strain from (12.5) and (12.12),  $\epsilon_{fe} = 0.004$   
 $f_u = 0.01$   
 $E_f = 64828.00$   
 $E_c = 26999.444$   
 $y = 0.25471862$   
 $A = 0.01452515$   
 $B = 0.00807924$   
 with  $E_s = 200000.00$

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

Lap Length:  $l_d/l_{d,min} = 0.42476573$

$l_b = 300.00$

$l_d = 706.2717$

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

$= 1$

$d_b = 16.66667$

Mean strength value of all re-bars:  $f_y = 524.4464$

Mean concrete strength:  $f_c' = (f_c'_{jacket} \cdot Area_{jacket} + f_c'_{core} \cdot Area_{core}) / Area_{section} = 28.98765$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 2.86234$

$A_{tr} = \min(A_{tr_x}, A_{tr_y}) = 257.6106$

where  $A_{tr_x}$ ,  $A_{tr_y}$  are the sum of the area of all stirrup legs along X and Y local axis

$s = \max(s_{external}, s_{internal}) = 300.00$

$n = 12.00$

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

From table 10-8:  $\rho_p = 0.00$

with:

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

shear control ratio  $V_y E / V_{col} O E = 0.26068017$

$d = d_{external} = 407.00$

$s = s_{external} = 0.00$

$t = s_1 + s_2 + 2 \cdot t_f / b_w \cdot (f_{fe} / f_s) = 0.00430549$

jacket:  $s_1 = A_{v1} \cdot h_1 / (s_1 \cdot A_g) = 0.00116355$

$A_{v1} = 157.0796$ , is the total area of all stirrups parallel to loading (shear) direction

$h_1 = 450.00$

$s_1 = 300.00$

core:  $s_2 = A_{v2} \cdot h_2 / (s_2 \cdot A_g) = 0.00103427$

$A_{v2} = 100.531$ , is the total area of all stirrups parallel to loading (shear) direction

$h_2 = 250.00$

$s_2 = 120.00$

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.

$$N_{UD} = 7503.728$$

$$A_g = 202500.00$$

$$f_{cE} = (f_{c\_jacket} \cdot Area\_jacket + f_{c\_core} \cdot Area\_core) / section\_area = 28.98765$$

$$f_{yE} = (f_{y\_ext\_Long\_Reinf} \cdot Area\_ext\_Long\_Reinf + f_{y\_int\_Long\_Reinf} \cdot Area\_int\_Long\_Reinf) / Area\_Tot\_Long\_Rein = 529.9972$$

$$f_{yE} = (f_{y\_ext\_Trans\_Reinf} \cdot s_1 + f_{y\_int\_Trans\_Reinf} \cdot s_2) / (s_1 + s_2) = 503.2682$$

$$p_l = Area\_Tot\_Long\_Rein / (b \cdot d) = 0.01461445$$

$$b = 450.00$$

$$d = 407.00$$

$$f_{cE} = 28.98765$$

End Of Calculation of Chord Rotation Capacity for element: column JC1 of floor 1

At local axis: 3

Integration Section: (b)

## Calculation No. 9

column C1, Floor 1

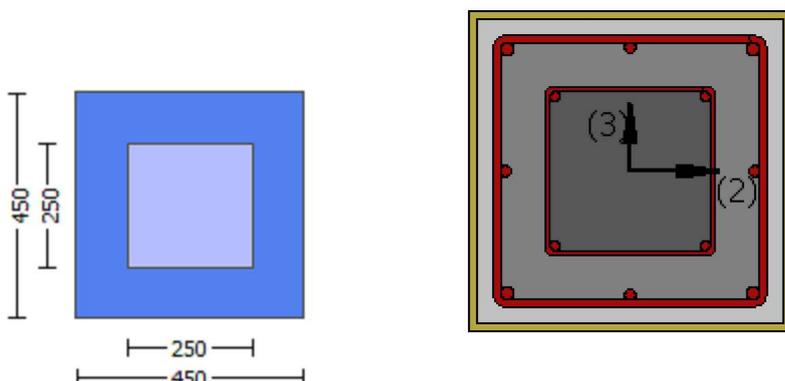
Limit State: Collapse Prevention (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Shear capacity  $V_{Rd}$

Edge: Start

Local Axis: (2)



Start Of Calculation of Shear Capacity for element: column JC1 of floor 1

At local axis: 2

Integration Section: (a)

Section Type: rcjrs

Constant Properties

Knowledge Factor,  $\gamma = 0.85$   
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  $\gamma$  for displacement ductility demand,  
the expected (mean value) strengths are used (7.5.1.3, ASCE 41-17) because bending is considered as  
Deformation-Controlled Action (Table C7-1, ASCE 41-17).  
Jacket  
New material: Concrete Strength,  $f_c = f_{cm} = 33.00$   
New material: Steel Strength,  $f_s = f_{sm} = 555.56$   
Existing Column  
Existing material: Concrete Strength,  $f_c = f_{cm} = 20.00$   
Existing material: Steel Strength,  $f_s = f_{sm} = 444.44$   
#####  
External Height,  $H = 450.00$   
External Width,  $W = 450.00$   
Internal Height,  $H = 250.00$   
Internal Width,  $W = 250.00$   
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,  $M_a = -3.5352E+007$   
Shear Force,  $V_a = -11781.223$   
EDGE -B-  
Bending Moment,  $M_b = 0.09202348$   
Shear Force,  $V_b = 11781.223$   
BOTH EDGES  
Axial Force,  $F = -7502.094$   
Longitudinal Reinforcement Area Distribution (in 2 divisions)  
-Tension:  $As_t = 1137.257$   
-Compression:  $As_c = 1539.38$   
Longitudinal Reinforcement Area Distribution (in 3 divisions)  
-Tension:  $As_{t,ten} = 1137.257$   
-Compression:  $As_{l,com} = 1137.257$   
-Middle:  $As_{l,mid} = 402.1239$

Mean Diameter of Tension Reinforcement,  $Db_{L,ten} = 16.80$

Existing component: From table 7-7, ASCE 41\_17: Final Shear Capacity  $V_R = V_n = 365324.544$   
 $V_n ((10.3), ASCE 41-17) = knl * V_{Col0} = 429793.581$   
 $V_{Col} = 429793.581$   
 $knl = 1.00$

$displacement\_ductility\_demand = 0.05733393$

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:  $fc' = (fc'_{jacket} * Area_{jacket} + fc'_{core} * Area_{core}) / Area_{section} = 22.22222$ , but  $fc'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M/Vd = 4.00$

$Mu = 3.5352E+007$

$Vu = 11781.223$

$d = 0.8 * h = 360.00$

$Nu = 7502.094$

$Ag = 202500.00$

From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 129852.496$

where:

$V_{s1} = 62831.853$  is calculated for jacket, with:

$d = 360.00$

$A_v = 157079.633$

$f_y = 500.00$

$s = 300.00$

$V_{s1}$  is multiplied by  $Col1 = 0.66666667$

$s/d = 0.833333333$

$V_{s2} = 67020.643$  is calculated for core, with:

$d = 200.00$

$A_v = 100530.965$

$f_y = 400.00$

$s = 120.00$

$V_{s2}$  is multiplied by  $Col2 = 1.00$

$s/d = 0.60$

$V_f ((11-3)-(11.4), ACI 440) = 214457.247$

$f = 0.95$ , for fully-wrapped sections

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

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

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

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

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

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

$dfv = d$  (figure 11.2, ACI 440) = 407.00

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

$Ef = 64828.00$

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

with  $fu = 0.01$

From (11-11), ACI 440:  $V_s + V_f \leq 507312.442$

$bw = 450.00$

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

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

From analysis, chord rotation  $\theta = 0.00037279$

$y = (My * Ls / 3) / Eleff = 0.006502$  ((4.29), Biskinis Phd))

$My = 1.7613E+008$

$L_s = M/V$  (with  $L_s > 0.1 \cdot L$  and  $L_s < 2 \cdot L$ ) = 3000.708

From table 10.5, ASCE 41\_17:  $E_{eff} = factor \cdot E_c \cdot I_g = 2.7095E+013$

factor = 0.30

$A_g = 202500.00$

Mean concrete strength:  $f_c' = (f_c'_{jacket} \cdot Area_{jacket} + f_c'_{core} \cdot Area_{core}) / Area_{section} = 28.98765$

$N = 7502.094$

$E_c \cdot I_g = E_{c,jacket} \cdot I_{g,jacket} + E_{c,core} \cdot I_{g,core} = 9.0315E+013$

Calculation of Yielding Moment  $M_y$

Calculation of  $y$  and  $M_y$  according to Annex 7 -

$y = \text{Min}(y_{ten}, y_{com})$

$y_{ten} = 6.1806717E-006$

with ((10.1), ASCE 41-17)  $f_y = \text{Min}(f_y, 1.25 \cdot f_y \cdot (I_b/I_d)^{2/3}) = 374.3546$

$d = 407.00$

$y = 0.25591399$

$A = 0.01472387$

$B = 0.00818866$

with  $pt = 0.00620943$

$pc = 0.00620943$

$pv = 0.0021956$

$N = 7502.094$

$b = 450.00$

$" = 0.10565111$

$y_{comp} = 2.2127287E-005$

with  $f_c^*$  (12.3, (ACI 440)) = 34.40847

$f_c = 33.00$

$f_l = 0.82797802$

$b = 450.00$

$h = 450.00$

$A_g = 202500.00$

From (12.9), ACI 440:  $k_a = 0.54261599$

$g = pt + pc + pv = 0.01461445$

$rc = 40.00$

$A_e/A_c = 0.54261599$

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

effective strain from (12.5) and (12.12),  $e_{fe} = 0.004$

$f_u = 0.01$

$E_f = 64828.00$

$E_c = 26999.444$

$y = 0.25471852$

$A = 0.01452517$

$B = 0.00807924$

with  $E_s = 200000.00$

Calculation of ratio  $I_b/I_d$

Lap Length:  $I_d/I_{d,min} = 0.42476573$

$I_b = 300.00$

$I_d = 706.2717$

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

= 1

$db = 16.66667$

Mean strength value of all re-bars:  $f_y = 524.4464$

Mean concrete strength:  $f_c' = (f_c'_{jacket} \cdot Area_{jacket} + f_c'_{core} \cdot Area_{core}) / Area_{section} = 28.98765$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 2.86234$

$A_{tr} = \text{Min}(A_{tr,x}, A_{tr,y}) = 257.6106$

where  $A_{tr_x}$ ,  $A_{tr_y}$  are the sum of the area of all stirrup legs along X and Y local axis  
 $s = \text{Max}(s_{\text{external}}, s_{\text{internal}}) = 300.00$   
 $n = 12.00$

End Of Calculation of Shear Capacity for element: column JC1 of floor 1  
At local axis: 2  
Integration Section: (a)

## Calculation No. 10

column C1, Floor 1

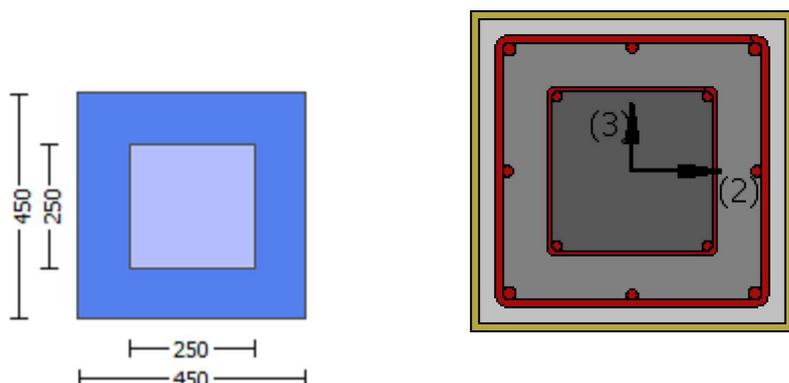
Limit State: Collapse Prevention (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity ( $\phi$ )

Edge: Start

Local Axis: (2)



Start Of Calculation of Shear Capacity ratio for element: column JC1 of floor 1

At Shear local axis: 3

(Bending local axis: 2)

Section Type: rcjrs

Constant Properties

Knowledge Factor,  $\gamma = 0.85$

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 Height,  $H = 450.00$

External Width,  $W = 450.00$

Internal Height,  $H = 250.00$

Internal Width,  $W = 250.00$

Cover Thickness,  $c = 25.00$

Mean Confinement Factor overall section = 1.10542

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: 3

EDGE -A-

Shear Force,  $V_a = 2.0531359E-031$

EDGE -B-

Shear Force,  $V_b = -2.0531359E-031$

BOTH EDGES

Axial Force,  $F = -7506.808$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension:  $A_{sl,t} = 0.00$

-Compression:  $A_{sl,c} = 2676.637$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension:  $A_{sl,ten} = 1137.257$

-Compression:  $A_{sl,com} = 1137.257$

-Middle:  $A_{sl,mid} = 402.1239$

-----  
Calculation of Shear Capacity ratio,  $V_e/V_r = 0.26068017$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 147952.607$

with

$M_{pr1} = \text{Max}(Mu_{1+}, Mu_{1-}) = 2.2193E+008$

$Mu_{1+} = 2.2193E+008$ , 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

$Mu_{1-} = 2.2193E+008$ , 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

$M_{pr2} = \text{Max}(Mu_{2+}, Mu_{2-}) = 2.2193E+008$

$Mu_{2+} = 2.2193E+008$ , 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

$Mu_{2-} = 2.2193E+008$ , is the ultimate moment strength at the edge 2 of the member in the opposite moment

direction which is defined for the the static loading combination

Calculation of Mu1+

Calculation of ultimate curvature  $\mu$  according to 4.1, Biskinis/Fardis 2013:

$$\mu = 1.9632832E-005$$

$$Mu = 2.2193E+008$$

with full section properties:

$$b = 450.00$$

$$d = 407.00$$

$$d' = 43.00$$

$$v = 0.00124204$$

$$N = 7506.808$$

$$f_c = 33.00$$

$$c_o \text{ (5A.5, TBDY)} = 0.002$$

$$\text{Final value of } c_u: c_u^* = \text{shear\_factor} * \text{Max}(c_u, c_c) = 0.01393923$$

The Shear\_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } c_u = 0.01393923$$

$$w_e \text{ ((5.4c), TBDY)} = a_{se} * s_{h,min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.06811101$$

where  $f = a_f * p_f * f_{fe} / f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.06628267$$

$$a_f = 0.54930041$$

$$b = 450.00$$

$$h = 450.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.00451556$$

$$b_w = 450.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 881.8461$$

$$f_y = 0.06628267$$

$$a_f = 0.54930041$$

$$b = 450.00$$

$$h = 450.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.00451556$$

$$b_w = 450.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 881.8461$$

$$R = 40.00$$

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

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$a_{se} \text{ ((5.4d), TBDY)} = (a_{se1} * A_{ext} + a_{se2} * A_{int}) / A_{sec} = 0.14546167$$

$$a_{se1} = 0.12623274$$

$$b_{o,1} = 390.00$$

$$h_{o,1} = 390.00$$

$$b_{i2,1} = 608400.00$$

$$a_{se2} = \text{Max}(a_{se1}, a_{se2}) = 0.18853448$$

$$b_{o,2} = 242.00$$

$$h_{o,2} = 242.00$$

$$b_{i2,2} = 234256.00$$

$$p_{sh,min} * F_{ywe} = \text{Min}(p_{sh,x} * F_{ywe}, p_{sh,y} * F_{ywe}) = 1.38262$$

Expression ((5.4d), TBDY) for  $p_{sh,min} * F_{ywe}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$$p_{sh,x} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{sh2} * F_{ywe2} = 1.38262$$

$$p_{s1} \text{ (external)} = (A_{sh1} * h_1 / s_1) / A_{sec} = 0.00116355$$

$$A_{sh1} = A_{stir,1} * n_{s,1} = 157.0796$$

$$\text{No stirrups, } n_{s,1} = 2.00$$

$$h_1 = 450.00$$

$$p_{s2} \text{ (internal)} = (A_{sh2} * h_2 / s_2) / A_{sec} = 0.00103427$$

$$A_{sh2} = A_{stir,2} * n_{s,2} = 100.531$$

$$\text{No stirrups, } n_{s,2} = 2.00$$

$$h2 = 250.00$$

$$\begin{aligned} psh\_y * Fywe &= psh1 * Fywe1 + ps2 * Fywe2 = 1.38262 \\ ps1 \text{ (external)} &= (Ash1 * h1 / s1) / Asec = 0.00116355 \\ Ash1 &= Astir\_1 * ns\_1 = 157.0796 \\ \text{No stirups, } ns\_1 &= 2.00 \\ h1 &= 450.00 \\ ps2 \text{ (internal)} &= (Ash2 * h2 / s2) / Asec = 0.00103427 \\ Ash2 &= Astir\_2 * ns\_2 = 100.531 \\ \text{No stirups, } ns\_2 &= 2.00 \\ h2 &= 250.00 \end{aligned}$$

$$Asec = 202500.00$$

$$s1 = 300.00$$

$$s2 = 120.00$$

$$fywe1 = 694.45$$

$$fywe2 = 555.55$$

$$fce = 33.00$$

$$\text{From } ((5.A.5), \text{ TBDY}), \text{ TBDY: } cc = 0.00305417$$

$$c = \text{confinement factor} = 1.10542$$

$$y1 = 0.00152175$$

$$sh1 = 0.0048696$$

$$ft1 = 479.7871$$

$$fy1 = 399.8226$$

$$su1 = 0.0066488$$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

$$lo/lou, \text{min} = lb/ld = 0.33981258$$

$$su1 = 0.4 * esu1\_nominal \text{ ((5.5), TBDY)} = 0.032$$

From table 5A.1, TBDY: esu1\_nominal = 0.08,

For calculation of esu1\_nominal and y1, sh1, ft1, fy1, it is considered  
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1, ft1, fy1, are also multiplied by  $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.

$$\text{with } fs1 = (fs\_jacket * Asl, \text{ten, jacket} + fs\_core * Asl, \text{ten, core}) / Asl, \text{ten} = 399.8226$$

$$\text{with } Es1 = (Es\_jacket * Asl, \text{ten, jacket} + Es\_core * Asl, \text{ten, core}) / Asl, \text{ten} = 200000.00$$

$$y2 = 0.00152175$$

$$sh2 = 0.0048696$$

$$ft2 = 479.7871$$

$$fy2 = 399.8226$$

$$su2 = 0.0066488$$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

$$lo/lou, \text{min} = lb/lb, \text{min} = 0.33981258$$

$$su2 = 0.4 * esu2\_nominal \text{ ((5.5), TBDY)} = 0.032$$

From table 5A.1, TBDY: esu2\_nominal = 0.08,

For calculation of esu2\_nominal and y2, sh2, ft2, fy2, it is considered  
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

y1, sh1, ft1, fy1, are also multiplied by  $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.

$$\text{with } fs2 = (fs\_jacket * Asl, \text{com, jacket} + fs\_core * Asl, \text{com, core}) / Asl, \text{com} = 399.8226$$

$$\text{with } Es2 = (Es\_jacket * Asl, \text{com, jacket} + Es\_core * Asl, \text{com, core}) / Asl, \text{com} = 200000.00$$

$$yv = 0.00152175$$

$$shv = 0.0048696$$

$$ftv = 507.2537$$

$$fyv = 422.7114$$

$$suv = 0.0066488$$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

$$lo/lou, \text{min} = lb/ld = 0.33981258$$

$$suv = 0.4 * esuv\_nominal \text{ ((5.5), TBDY)} = 0.032$$

From table 5A.1, TBDY: esuv\_nominal = 0.08,

considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY

For calculation of esuv\_nominal and yv, shv, ftv, fyv, it is considered  
characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.

y1, sh1, ft1, fy1, are also multiplied by  $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.

with  $f_{sv} = (f_{s,jacket} \cdot A_{s,mid,jacket} + f_{s,mid} \cdot A_{s,mid,core}) / A_{s,mid} = 422.7114$   
with  $E_{sv} = (E_{s,jacket} \cdot A_{s,mid,jacket} + E_{s,mid} \cdot A_{s,mid,core}) / A_{s,mid} = 200000.00$   
 $1 = A_{s,ten} / (b \cdot d) \cdot (f_{s1} / f_c) = 0.0752324$   
 $2 = A_{s,com} / (b \cdot d) \cdot (f_{s2} / f_c) = 0.0752324$   
 $v = A_{s,mid} / (b \cdot d) \cdot (f_{sv} / f_c) = 0.02812438$

and confined core properties:

$b = 390.00$   
 $d = 377.00$   
 $d' = 13.00$   
 $f_{cc} (5A.2, TBDY) = 36.47874$   
 $cc (5A.5, TBDY) = 0.00305417$   
 $c = \text{confinement factor} = 1.10542$   
 $1 = A_{s,ten} / (b \cdot d) \cdot (f_{s1} / f_c) = 0.09371431$   
 $2 = A_{s,com} / (b \cdot d) \cdot (f_{s2} / f_c) = 0.09371431$   
 $v = A_{s,mid} / (b \cdot d) \cdot (f_{sv} / f_c) = 0.03503353$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < v_{s,y2}$  - LHS eq.(4.5) is satisfied

--->

$\mu_u (4.9) = 0.16791801$   
 $\mu_u = M_{Rc} (4.14) = 2.2193E+008$   
 $u = \mu_u (4.1) = 1.9632832E-005$

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

Lap Length:  $l_b/l_d = 0.33981258$

$l_b = 300.00$

$l_d = 882.8396$

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

= 1

$d_b = 16.66667$

Mean strength value of all re-bars:  $f_y = 655.558$

Mean concrete strength:  $f'_c = (f'_{c,jacket} \cdot \text{Area}_{jacket} + f'_{c,core} \cdot \text{Area}_{core}) / \text{Area}_{section} = 28.98765$ , but  $f_c^{0.5} \leq 8.3 \text{ MPa}$  (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 2.86234$

$A_{tr} = \text{Min}(A_{tr,x}, A_{tr,y}) = 257.6106$

where  $A_{tr,x}$ ,  $A_{tr,y}$  are the sum of the area of all stirrup legs along X and Y local axis

$s = \text{Max}(s_{external}, s_{internal}) = 300.00$

$n = 12.00$

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

-----  
Calculation of ultimate curvature  $\mu_u$  according to 4.1, Biskinis/Fardis 2013:

$u = 1.9632832E-005$

$\mu_u = 2.2193E+008$

-----  
with full section properties:

$b = 450.00$

$d = 407.00$

$d' = 43.00$

$v = 0.00124204$

$N = 7506.808$

$f_c = 33.00$

$cc (5A.5, TBDY) = 0.002$

Final value of  $\mu_u$ :  $\mu_u^* = \text{shear\_factor} \cdot \text{Max}(\mu_u, cc) = 0.01393923$

The Shear\_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY:  $\mu_u = 0.01393923$

$w_e$  ((5.4c), TBDY) =  $a_{se} \cdot s_{h,min} \cdot f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.06811101$   
where  $f = a_f \cdot p_f \cdot f_{fe}/f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$f_x = 0.06628267$   
 $a_f = 0.54930041$   
 $b = 450.00$   
 $h = 450.00$   
From EC8 A.4.4.3(6),  $p_f = 2t_f/bw = 0.00451556$   
 $bw = 450.00$   
effective stress from (A.35),  $f_{f,e} = 881.8461$

$f_y = 0.06628267$   
 $a_f = 0.54930041$   
 $b = 450.00$   
 $h = 450.00$   
From EC8 A.4.4.3(6),  $p_f = 2t_f/bw = 0.00451556$   
 $bw = 450.00$   
effective stress from (A.35),  $f_{f,e} = 881.8461$

$R = 40.00$   
Effective FRP thickness,  $t_f = NL \cdot t \cdot \text{Cos}(b_1) = 1.016$   
 $f_{u,f} = 1055.00$   
 $E_f = 64828.00$   
 $u,f = 0.015$   
 $a_{se} \text{ ((5.4d), TBDY)} = (a_{se1} \cdot A_{ext} + a_{se2} \cdot A_{int})/A_{sec} = 0.14546167$   
 $a_{se1} = 0.12623274$   
 $bo\_1 = 390.00$   
 $ho\_1 = 390.00$   
 $bi2\_1 = 608400.00$   
 $a_{se2} = \text{Max}(a_{se1}, a_{se2}) = 0.18853448$   
 $bo\_2 = 242.00$   
 $ho\_2 = 242.00$   
 $bi2\_2 = 234256.00$

$p_{sh,min} \cdot F_{ywe} = \text{Min}(p_{sh,x} \cdot F_{ywe}, p_{sh,y} \cdot F_{ywe}) = 1.38262$

Expression ((5.4d), TBDY) for  $p_{sh,min} \cdot F_{ywe}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$p_{sh,x} \cdot F_{ywe} = p_{sh1} \cdot F_{ywe1} + p_{sh2} \cdot F_{ywe2} = 1.38262$   
 $ps1 \text{ (external)} = (A_{sh1} \cdot h_1/s_1)/A_{sec} = 0.00116355$   
 $A_{sh1} = A_{stir\_1} \cdot ns\_1 = 157.0796$   
No stirrups,  $ns\_1 = 2.00$   
 $h_1 = 450.00$   
 $ps2 \text{ (internal)} = (A_{sh2} \cdot h_2/s_2)/A_{sec} = 0.00103427$   
 $A_{sh2} = A_{stir\_2} \cdot ns\_2 = 100.531$   
No stirrups,  $ns\_2 = 2.00$   
 $h_2 = 250.00$

$p_{sh,y} \cdot F_{ywe} = p_{sh1} \cdot F_{ywe1} + p_{sh2} \cdot F_{ywe2} = 1.38262$   
 $ps1 \text{ (external)} = (A_{sh1} \cdot h_1/s_1)/A_{sec} = 0.00116355$   
 $A_{sh1} = A_{stir\_1} \cdot ns\_1 = 157.0796$   
No stirrups,  $ns\_1 = 2.00$   
 $h_1 = 450.00$   
 $ps2 \text{ (internal)} = (A_{sh2} \cdot h_2/s_2)/A_{sec} = 0.00103427$   
 $A_{sh2} = A_{stir\_2} \cdot ns\_2 = 100.531$   
No stirrups,  $ns\_2 = 2.00$   
 $h_2 = 250.00$

$A_{sec} = 202500.00$

$s_1 = 300.00$

$s_2 = 120.00$

$f_{ywe1} = 694.45$

$f_{ywe2} = 555.55$

$f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.00305417$

$c = \text{confinement factor} = 1.10542$

$y_1 = 0.00152175$

$sh_1 = 0.0048696$

$ft1 = 479.7871$   
 $fy1 = 399.8226$   
 $su1 = 0.0066488$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 Shear\_factor = 1.00  
 $lo/lou,min = lb/d = 0.33981258$   
 $su1 = 0.4*esu1\_nominal ((5.5), TBDY) = 0.032$   
 From table 5A.1, TBDY:  $esu1\_nominal = 0.08$ ,  
 For calculation of  $esu1\_nominal$  and  $y1, sh1, ft1, fy1$ , it is considered  
 characteristic value  $fsy1 = fs1/1.2$ , from table 5.1, TBDY.  
 $y1, sh1, ft1, fy1$ , are also multiplied by  $Min(1, 1.25*(lb/d)^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with  $fs1 = (fs,jacket*Asl,ten,jacket + fs,core*Asl,ten,core)/Asl,ten = 399.8226$   
 with  $Es1 = (Es,jacket*Asl,ten,jacket + Es,core*Asl,ten,core)/Asl,ten = 200000.00$   
 $y2 = 0.00152175$   
 $sh2 = 0.0048696$   
 $ft2 = 479.7871$   
 $fy2 = 399.8226$   
 $su2 = 0.0066488$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 Shear\_factor = 1.00  
 $lo/lou,min = lb/lb,min = 0.33981258$   
 $su2 = 0.4*esu2\_nominal ((5.5), TBDY) = 0.032$   
 From table 5A.1, TBDY:  $esu2\_nominal = 0.08$ ,  
 For calculation of  $esu2\_nominal$  and  $y2, sh2, ft2, fy2$ , it is considered  
 characteristic value  $fsy2 = fs2/1.2$ , from table 5.1, TBDY.  
 $y1, sh1, ft1, fy1$ , are also multiplied by  $Min(1, 1.25*(lb/d)^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with  $fs2 = (fs,jacket*Asl,com,jacket + fs,core*Asl,com,core)/Asl,com = 399.8226$   
 with  $Es2 = (Es,jacket*Asl,com,jacket + Es,core*Asl,com,core)/Asl,com = 200000.00$   
 $yv = 0.00152175$   
 $shv = 0.0048696$   
 $ftv = 507.2537$   
 $fyv = 422.7114$   
 $suv = 0.0066488$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 Shear\_factor = 1.00  
 $lo/lou,min = lb/d = 0.33981258$   
 $suv = 0.4*esuv\_nominal ((5.5), TBDY) = 0.032$   
 From table 5A.1, TBDY:  $esuv\_nominal = 0.08$ ,  
 considering characteristic value  $fsyv = fsv/1.2$ , from table 5.1, TBDY  
 For calculation of  $esuv\_nominal$  and  $yv, shv, ftv, fyv$ , it is considered  
 characteristic value  $fsyv = fsv/1.2$ , from table 5.1, TBDY.  
 $y1, sh1, ft1, fy1$ , are also multiplied by  $Min(1, 1.25*(lb/d)^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with  $fsv = (fs,jacket*Asl,mid,jacket + fs,mid*Asl,mid,core)/Asl,mid = 422.7114$   
 with  $Es_v = (Es,jacket*Asl,mid,jacket + Es,mid*Asl,mid,core)/Asl,mid = 200000.00$   
 $1 = Asl,ten/(b*d)*(fs1/fc) = 0.0752324$   
 $2 = Asl,com/(b*d)*(fs2/fc) = 0.0752324$   
 $v = Asl,mid/(b*d)*(fsv/fc) = 0.02812438$   
 and confined core properties:  
 $b = 390.00$   
 $d = 377.00$   
 $d' = 13.00$   
 $fcc (5A.2, TBDY) = 36.47874$   
 $cc (5A.5, TBDY) = 0.00305417$   
 $c = \text{confinement factor} = 1.10542$   
 $1 = Asl,ten/(b*d)*(fs1/fc) = 0.09371431$   
 $2 = Asl,com/(b*d)*(fs2/fc) = 0.09371431$   
 $v = Asl,mid/(b*d)*(fsv/fc) = 0.03503353$   
 Case/Assumption: Unconfined full section - Steel rupture  
 ' satisfies Eq. (4.3)  
 --->  
 $v < vs,y2$  - LHS eq.(4.5) is satisfied  
 --->  
 $su (4.9) = 0.16791801$   
 $Mu = MRc (4.14) = 2.2193E+008$

$$u = s_u(4.1) = 1.9632832E-005$$

Calculation of ratio  $l_b/d$

$$\text{Lap Length: } l_b/d = 0.33981258$$

$$l_b = 300.00$$

$$d = 882.8396$$

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

$$= 1$$

$$d_b = 16.66667$$

$$\text{Mean strength value of all re-bars: } f_y = 655.558$$

$$\text{Mean concrete strength: } f_c' = (f_c'_{\text{jacket}} \cdot \text{Area}_{\text{jacket}} + f_c'_{\text{core}} \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 28.98765, \text{ but } f_c'^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 25.00$$

$$K_{tr} = 2.86234$$

$$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 257.6106$$

where  $A_{tr_x}, A_{tr_y}$  are the sum of the area of all stirrup legs along X and Y local axis

$$s = \text{Max}(s_{\text{external}}, s_{\text{internal}}) = 300.00$$

$$n = 12.00$$

Calculation of  $\mu_{2+}$

Calculation of ultimate curvature  $u$  according to 4.1, Biskinis/Fardis 2013:

$$u = 1.9632832E-005$$

$$\mu_u = 2.2193E+008$$

with full section properties:

$$b = 450.00$$

$$d = 407.00$$

$$d' = 43.00$$

$$v = 0.00124204$$

$$N = 7506.808$$

$$f_c = 33.00$$

$$c_o \text{ (5A.5, TBDY)} = 0.002$$

$$\text{Final value of } c_u: c_u^* = \text{shear\_factor} * \text{Max}(c_u, c_c) = 0.01393923$$

The Shear\_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } c_u = 0.01393923$$

$$w_e \text{ ((5.4c), TBDY)} = a_{sc} * s_{h, \min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.06811101$$

where  $f = a_f * p_f * f_{fe} / f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.06628267$$

$$a_f = 0.54930041$$

$$b = 450.00$$

$$h = 450.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.00451556$$

$$b_w = 450.00$$

$$\text{effective stress from (A.35), } f_{fe} = 881.8461$$

$$f_y = 0.06628267$$

$$a_f = 0.54930041$$

$$b = 450.00$$

$$h = 450.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.00451556$$

$$b_w = 450.00$$

$$\text{effective stress from (A.35), } f_{fe} = 881.8461$$

$$R = 40.00$$

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

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u, f = 0.015$$

$$ase = ((5.4d), TBDY) = (ase1 * A_{ext} + ase2 * A_{int}) / A_{sec} = 0.14546167$$

$$ase1 = 0.12623274$$

$$bo_1 = 390.00$$

$$ho_1 = 390.00$$

$$bi2_1 = 608400.00$$

$$ase2 = \text{Max}(ase1, ase2) = 0.18853448$$

$$bo_2 = 242.00$$

$$ho_2 = 242.00$$

$$bi2_2 = 234256.00$$

$$psh_{min} * F_{ywe} = \text{Min}(psh_x * F_{ywe}, psh_y * F_{ywe}) = 1.38262$$

Expression ((5.4d), TBDY) for  $psh_{min} * F_{ywe}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$$psh_x * F_{ywe} = psh1 * F_{ywe1} + ps2 * F_{ywe2} = 1.38262$$

$$ps1 \text{ (external)} = (A_{sh1} * h1 / s1) / A_{sec} = 0.00116355$$

$$A_{sh1} = A_{stir\_1} * ns_1 = 157.0796$$

$$\text{No stirrups, } ns_1 = 2.00$$

$$h1 = 450.00$$

$$ps2 \text{ (internal)} = (A_{sh2} * h2 / s2) / A_{sec} = 0.00103427$$

$$A_{sh2} = A_{stir\_2} * ns_2 = 100.531$$

$$\text{No stirrups, } ns_2 = 2.00$$

$$h2 = 250.00$$

$$psh_y * F_{ywe} = psh1 * F_{ywe1} + ps2 * F_{ywe2} = 1.38262$$

$$ps1 \text{ (external)} = (A_{sh1} * h1 / s1) / A_{sec} = 0.00116355$$

$$A_{sh1} = A_{stir\_1} * ns_1 = 157.0796$$

$$\text{No stirrups, } ns_1 = 2.00$$

$$h1 = 450.00$$

$$ps2 \text{ (internal)} = (A_{sh2} * h2 / s2) / A_{sec} = 0.00103427$$

$$A_{sh2} = A_{stir\_2} * ns_2 = 100.531$$

$$\text{No stirrups, } ns_2 = 2.00$$

$$h2 = 250.00$$

$$A_{sec} = 202500.00$$

$$s1 = 300.00$$

$$s2 = 120.00$$

$$f_{ywe1} = 694.45$$

$$f_{ywe2} = 555.55$$

$$f_{ce} = 33.00$$

$$\text{From ((5.A5), TBDY), TBDY: } cc = 0.00305417$$

$$c = \text{confinement factor} = 1.10542$$

$$y1 = 0.00152175$$

$$sh1 = 0.0048696$$

$$ft1 = 479.7871$$

$$fy1 = 399.8226$$

$$su1 = 0.0066488$$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00

$$lo/lo_{min} = lb/ld = 0.33981258$$

$$su1 = 0.4 * esu1_{nominal} \text{ ((5.5), TBDY)} = 0.032$$

$$\text{From table 5A.1, TBDY: } esu1_{nominal} = 0.08,$$

For calculation of  $esu1_{nominal}$  and  $y1, sh1, ft1, fy1$ , it is considered characteristic value  $fsy1 = fs1 / 1.2$ , from table 5.1, TBDY.

$$y1, sh1, ft1, fy1, \text{ are also multiplied by } \text{Min}(1, 1.25 * (lb/ld)^{2/3}), \text{ from 10.3.5, ASCE 41-17.}$$

$$\text{with } fs1 = (fs_{jacket} * A_{sl,ten,jacket} + fs_{core} * A_{sl,ten,core}) / A_{sl,ten} = 399.8226$$

$$\text{with } Es1 = (Es_{jacket} * A_{sl,ten,jacket} + Es_{core} * A_{sl,ten,core}) / A_{sl,ten} = 200000.00$$

$$y2 = 0.00152175$$

$$sh2 = 0.0048696$$

$$ft2 = 479.7871$$

$$fy2 = 399.8226$$

$$su2 = 0.0066488$$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00

$$l_o/l_{o,u,min} = l_b/l_{b,min} = 0.33981258$$

$$s_u2 = 0.4 * e_{s_u2,nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY:  $e_{s_u2,nominal} = 0.08$ ,

For calculation of  $e_{s_u2,nominal}$  and  $y_2$ ,  $sh_2$ ,  $ft_2$ ,  $fy_2$ , it is considered characteristic value  $f_{s_y2} = f_{s_2}/1.2$ , from table 5.1, TBDY.

$y_1$ ,  $sh_1$ ,  $ft_1$ ,  $fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.

$$\text{with } f_{s_2} = (f_{s,jacket} * A_{s_l,com,jacket} + f_{s,core} * A_{s_l,com,core}) / A_{s_l,com} = 399.8226$$

$$\text{with } E_{s_2} = (E_{s,jacket} * A_{s_l,com,jacket} + E_{s,core} * A_{s_l,com,core}) / A_{s_l,com} = 200000.00$$

$$y_v = 0.00152175$$

$$sh_v = 0.0048696$$

$$ft_v = 507.2537$$

$$fy_v = 422.7114$$

$$s_{u_v} = 0.0066488$$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor

and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00

$$l_o/l_{o,u,min} = l_b/l_d = 0.33981258$$

$$s_{u_v} = 0.4 * e_{s_{u_v},nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY:  $e_{s_{u_v},nominal} = 0.08$ ,

considering characteristic value  $f_{s_{y_v}} = f_{s_v}/1.2$ , from table 5.1, TBDY

For calculation of  $e_{s_{u_v},nominal}$  and  $y_v$ ,  $sh_v$ ,  $ft_v$ ,  $fy_v$ , it is considered characteristic value  $f_{s_{y_v}} = f_{s_v}/1.2$ , from table 5.1, TBDY.

$y_1$ ,  $sh_1$ ,  $ft_1$ ,  $fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.

$$\text{with } f_{s_v} = (f_{s,jacket} * A_{s_l,mid,jacket} + f_{s,mid} * A_{s_l,mid,core}) / A_{s_l,mid} = 422.7114$$

$$\text{with } E_{s_v} = (E_{s,jacket} * A_{s_l,mid,jacket} + E_{s,mid} * A_{s_l,mid,core}) / A_{s_l,mid} = 200000.00$$

$$1 = A_{s_l,ten} / (b * d) * (f_{s_1} / f_c) = 0.0752324$$

$$2 = A_{s_l,com} / (b * d) * (f_{s_2} / f_c) = 0.0752324$$

$$v = A_{s_l,mid} / (b * d) * (f_{s_v} / f_c) = 0.02812438$$

and confined core properties:

$$b = 390.00$$

$$d = 377.00$$

$$d' = 13.00$$

$$f_{cc} (5A.2, TBDY) = 36.47874$$

$$c_c (5A.5, TBDY) = 0.00305417$$

$$c = \text{confinement factor} = 1.10542$$

$$1 = A_{s_l,ten} / (b * d) * (f_{s_1} / f_c) = 0.09371431$$

$$2 = A_{s_l,com} / (b * d) * (f_{s_2} / f_c) = 0.09371431$$

$$v = A_{s_l,mid} / (b * d) * (f_{s_v} / f_c) = 0.03503353$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

---->

$v < v_{s,y_2}$  - LHS eq.(4.5) is satisfied

---->

$$s_u (4.9) = 0.16791801$$

$$\mu_u = M_{Rc} (4.14) = 2.2193E+008$$

$$u = s_u (4.1) = 1.9632832E-005$$

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

Lap Length:  $l_b/l_d = 0.33981258$

$$l_b = 300.00$$

$$l_d = 882.8396$$

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

$$= 1$$

$$d_b = 16.66667$$

Mean strength value of all re-bars:  $f_y = 655.558$

Mean concrete strength:  $f'_c = (f'_{c,jacket} * Area_{jacket} + f'_{c,core} * Area_{core}) / Area_{section} = 28.98765$ , but  $f_c^{0.5} <= 8.3$  MPa (22.5.3.1, ACI 318-14)

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 25.00$$

$$K_{tr} = 2.86234$$

$$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 257.6106$$

where  $A_{tr_x}$ ,  $A_{tr_y}$  are the sum of the area of all stirrup legs along X and Y local axis

$$s = \text{Max}(s_{external}, s_{internal}) = 300.00$$

n = 12.00

Calculation of Mu2-

Calculation of ultimate curvature  $\phi_u$  according to 4.1, Biskinis/Fardis 2013:

$u = 1.9632832E-005$

$Mu = 2.2193E+008$

with full section properties:

b = 450.00

d = 407.00

d' = 43.00

v = 0.00124204

N = 7506.808

fc = 33.00

cc (5A.5, TBDY) = 0.002

Final value of  $c_u$ :  $c_u = \text{shear\_factor} * \text{Max}(c_u, cc) = 0.01393923$

The Shear\_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY:  $c_u = 0.01393923$

$w_e$  ((5.4c), TBDY) =  $ase * \text{sh}_{,min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.06811101$

where  $f = af * pf * f_{fe} / f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$f_x = 0.06628267$

$af = 0.54930041$

b = 450.00

h = 450.00

From EC8 A.4.4.3(6),  $pf = 2tf/bw = 0.00451556$

bw = 450.00

effective stress from (A.35),  $f_{fe} = 881.8461$

$f_y = 0.06628267$

$af = 0.54930041$

b = 450.00

h = 450.00

From EC8 A.4.4.3(6),  $pf = 2tf/bw = 0.00451556$

bw = 450.00

effective stress from (A.35),  $f_{fe} = 881.8461$

R = 40.00

Effective FRP thickness,  $tf = NL * t * \text{Cos}(b1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{,f} = 0.015$

$ase$  ((5.4d), TBDY) =  $(ase1 * A_{ext} + ase2 * A_{int}) / A_{sec} = 0.14546167$

$ase1 = 0.12623274$

$bo_{,1} = 390.00$

$ho_{,1} = 390.00$

$bi_{,2,1} = 608400.00$

$ase2 = \text{Max}(ase1, ase2) = 0.18853448$

$bo_{,2} = 242.00$

$ho_{,2} = 242.00$

$bi_{,2,2} = 234256.00$

$psh_{,min} * F_{ywe} = \text{Min}(psh_{,x} * F_{ywe}, psh_{,y} * F_{ywe}) = 1.38262$

Expression ((5.4d), TBDY) for  $psh_{,min} * F_{ywe}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$psh_{,x} * F_{ywe} = psh1 * F_{ywe1} + ps2 * F_{ywe2} = 1.38262$

$ps1$  (external) =  $(A_{sh1} * h1 / s1) / A_{sec} = 0.00116355$

$A_{sh1} = A_{stir\_1} * ns_{,1} = 157.0796$

No stirrups,  $ns_{,1} = 2.00$

$h1 = 450.00$

$ps2$  (internal) =  $(A_{sh2} * h2 / s2) / A_{sec} = 0.00103427$

$A_{sh2} = A_{stir\_2} * ns_{,2} = 100.531$

No stirups, ns<sub>2</sub> = 2.00  
h<sub>2</sub> = 250.00

psh<sub>y</sub>\*Fywe = psh<sub>1</sub>\*Fywe<sub>1</sub>+ps<sub>2</sub>\*Fywe<sub>2</sub> = 1.38262  
ps<sub>1</sub> (external) = (Ash<sub>1</sub>\*h<sub>1</sub>/s<sub>1</sub>)/Asec = 0.00116355  
Ash<sub>1</sub> = Astir<sub>1</sub>\*ns<sub>1</sub> = 157.0796  
No stirups, ns<sub>1</sub> = 2.00  
h<sub>1</sub> = 450.00  
ps<sub>2</sub> (internal) = (Ash<sub>2</sub>\*h<sub>2</sub>/s<sub>2</sub>)/Asec = 0.00103427  
Ash<sub>2</sub> = Astir<sub>2</sub>\*ns<sub>2</sub> = 100.531  
No stirups, ns<sub>2</sub> = 2.00  
h<sub>2</sub> = 250.00

Asec = 202500.00

s<sub>1</sub> = 300.00

s<sub>2</sub> = 120.00

fywe<sub>1</sub> = 694.45

fywe<sub>2</sub> = 555.55

fce = 33.00

From ((5.A.5), TBDY), TBDY: cc = 0.00305417

c = confinement factor = 1.10542

y<sub>1</sub> = 0.00152175

sh<sub>1</sub> = 0.0048696

ft<sub>1</sub> = 479.7871

fy<sub>1</sub> = 399.8226

su<sub>1</sub> = 0.0066488

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

lo/lou,min = lb/l<sub>d</sub> = 0.33981258

su<sub>1</sub> = 0.4\*esu<sub>1\_nominal</sub> ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu<sub>1\_nominal</sub> = 0.08,

For calculation of esu<sub>1\_nominal</sub> and y<sub>1</sub>, sh<sub>1</sub>,ft<sub>1</sub>,fy<sub>1</sub>, it is considered  
characteristic value fsy<sub>1</sub> = fs<sub>1</sub>/1.2, from table 5.1, TBDY.

y<sub>1</sub>, sh<sub>1</sub>,ft<sub>1</sub>,fy<sub>1</sub>, are also multiplied by Min(1,1.25\*(lb/l<sub>d</sub>)<sup>2/3</sup>), from 10.3.5, ASCE 41-17.

with fs<sub>1</sub> = (fs<sub>jacket</sub>\*Asl<sub>ten,jacket</sub> + fs<sub>core</sub>\*Asl<sub>ten,core</sub>)/Asl<sub>ten</sub> = 399.8226

with Es<sub>1</sub> = (Es<sub>jacket</sub>\*Asl<sub>ten,jacket</sub> + Es<sub>core</sub>\*Asl<sub>ten,core</sub>)/Asl<sub>ten</sub> = 200000.00

y<sub>2</sub> = 0.00152175

sh<sub>2</sub> = 0.0048696

ft<sub>2</sub> = 479.7871

fy<sub>2</sub> = 399.8226

su<sub>2</sub> = 0.0066488

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

lo/lou,min = lb/l<sub>b,min</sub> = 0.33981258

su<sub>2</sub> = 0.4\*esu<sub>2\_nominal</sub> ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu<sub>2\_nominal</sub> = 0.08,

For calculation of esu<sub>2\_nominal</sub> and y<sub>2</sub>, sh<sub>2</sub>,ft<sub>2</sub>,fy<sub>2</sub>, it is considered  
characteristic value fsy<sub>2</sub> = fs<sub>2</sub>/1.2, from table 5.1, TBDY.

y<sub>2</sub>, sh<sub>2</sub>,ft<sub>2</sub>,fy<sub>2</sub>, are also multiplied by Min(1,1.25\*(lb/l<sub>d</sub>)<sup>2/3</sup>), from 10.3.5, ASCE 41-17.

with fs<sub>2</sub> = (fs<sub>jacket</sub>\*Asl<sub>com,jacket</sub> + fs<sub>core</sub>\*Asl<sub>com,core</sub>)/Asl<sub>com</sub> = 399.8226

with Es<sub>2</sub> = (Es<sub>jacket</sub>\*Asl<sub>com,jacket</sub> + Es<sub>core</sub>\*Asl<sub>com,core</sub>)/Asl<sub>com</sub> = 200000.00

y<sub>v</sub> = 0.00152175

sh<sub>v</sub> = 0.0048696

ft<sub>v</sub> = 507.2537

fy<sub>v</sub> = 422.7114

suv = 0.0066488

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

lo/lou,min = lb/l<sub>d</sub> = 0.33981258

suv = 0.4\*esuv<sub>nominal</sub> ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esuv<sub>nominal</sub> = 0.08,

considering characteristic value fsy<sub>v</sub> = fsv/1.2, from table 5.1, TBDY  
For calculation of esuv<sub>nominal</sub> and y<sub>v</sub>, sh<sub>v</sub>,ft<sub>v</sub>,fy<sub>v</sub>, it is considered  
characteristic value fsy<sub>v</sub> = fsv/1.2, from table 5.1, TBDY.

$y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (l_b/d)^{2/3})$ , from 10.3.5, ASCE 41-17.

with  $f_{sv} = (f_{sjacket} \cdot A_{sl,mid,jacket} + f_{s,mid} \cdot A_{sl,mid,core}) / A_{sl,mid} = 422.7114$

with  $E_{sv} = (E_{sjacket} \cdot A_{sl,mid,jacket} + E_{s,mid} \cdot A_{sl,mid,core}) / A_{sl,mid} = 200000.00$

$1 = A_{sl,ten} / (b \cdot d) \cdot (f_{s1} / f_c) = 0.0752324$

$2 = A_{sl,com} / (b \cdot d) \cdot (f_{s2} / f_c) = 0.0752324$

$v = A_{sl,mid} / (b \cdot d) \cdot (f_{sv} / f_c) = 0.02812438$

and confined core properties:

$b = 390.00$

$d = 377.00$

$d' = 13.00$

$f_{cc} (5A.2, TBDY) = 36.47874$

$cc (5A.5, TBDY) = 0.00305417$

$c = \text{confinement factor} = 1.10542$

$1 = A_{sl,ten} / (b \cdot d) \cdot (f_{s1} / f_c) = 0.09371431$

$2 = A_{sl,com} / (b \cdot d) \cdot (f_{s2} / f_c) = 0.09371431$

$v = A_{sl,mid} / (b \cdot d) \cdot (f_{sv} / f_c) = 0.03503353$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < v_{s,y2}$  - LHS eq.(4.5) is satisfied

--->

$su (4.9) = 0.16791801$

$Mu = MRc (4.14) = 2.2193E+008$

$u = su (4.1) = 1.9632832E-005$

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

Lap Length:  $l_b/d = 0.33981258$

$l_b = 300.00$

$l_d = 882.8396$

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

$= 1$

$db = 16.66667$

Mean strength value of all re-bars:  $f_y = 655.558$

Mean concrete strength:  $f'_c = (f'_{c,jacket} \cdot Area_{jacket} + f'_{c,core} \cdot Area_{core}) / Area_{section} = 28.98765$ , but  $f_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 2.86234$

$A_{tr} = \text{Min}(A_{tr,x}, A_{tr,y}) = 257.6106$

where  $A_{tr,x}, A_{tr,y}$  are the sum of the area of all stirrup legs along X and Y local axis

$s = \text{Max}(s_{external}, s_{internal}) = 300.00$

$n = 12.00$

-----  
Calculation of Shear Strength  $V_r = \text{Min}(V_{r1}, V_{r2}) = 567563.724$

-----  
Calculation of Shear Strength at edge 1,  $V_{r1} = 567563.724$

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

$V_{Col0} = 567563.724$

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

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

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

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

Mean concrete strength:  $f'_c = (f'_{c,jacket} \cdot Area_{jacket} + f'_{c,core} \cdot Area_{core}) / Area_{section} = 28.98765$ , but  $f_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$Mu = 1.4404090E-011$

$Vu = 2.0531359E-031$

$d = 0.8 \cdot h = 360.00$

$N_u = 7506.808$   
 $A_g = 202500.00$   
 From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 144280.365$   
 where:  
 $V_{s1} = 69813.729$  is calculated for jacket, with:  
 $d = 360.00$   
 $A_v = 157079.633$   
 $f_y = 555.56$   
 $s = 300.00$   
 $V_{s1}$  is multiplied by  $Col1 = 0.66666667$   
 $s/d = 0.83333333$   
 $V_{s2} = 74466.637$  is calculated for core, with:  
 $d = 200.00$   
 $A_v = 100530.965$   
 $f_y = 444.44$   
 $s = 120.00$   
 $V_{s2}$  is multiplied by  $Col2 = 1.00$   
 $s/d = 0.60$   
 $V_f$  ((11-3)-(11.4), ACI 440) = 214457.247  
 $f = 0.95$ , for fully-wrapped sections  
 $wf/sf = 1$  (FRP strips adjacent to one another).  
 In (11.3)  $\sin \theta + \cos \theta$  is replaced with  $(\cot \theta + \csc \theta) \sin \alpha$  which is more a generalised expression,  
 where  $\theta$  is the angle of the crack direction (see KANEPE).  
 This later relation, considered as a function  $V_f(\theta, \alpha)$ , is implemented for every different fiber orientation  $\alpha_i$ ,  
 as well as for 2 crack directions,  $\theta = 45^\circ$  and  $\theta = -45^\circ$  to take into consideration the cyclic seismic loading.  
 orientation 1:  $\theta = 45^\circ + 90^\circ = 135^\circ$   
 $V_f = \text{Min}(|V_f(45^\circ, \alpha_1)|, |V_f(-45^\circ, \alpha_1)|)$ , with:  
 total thickness per orientation,  $t_{f1} = NL * t / N_{oDir} = 1.016$   
 $d_{fv} = d$  (figure 11.2, ACI 440) = 407.00  
 $f_{fe}$  ((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:  $V_s + V_f \leq 579413.096$   
 $b_w = 450.00$

Calculation of Shear Strength at edge 2,  $V_{r2} = 567563.724$   
 $V_{r2} = V_{Col}$  ((10.3), ASCE 41-17) =  $k_{nl} * V_{Col0}$   
 $V_{Col0} = 567563.724$   
 $k_{nl} = 1$  (zero step-static loading)

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

$\lambda = 1$  (normal-weight concrete)  
 Mean concrete strength:  $f'_c = (f'_{c,jacket} * Area_{jacket} + f'_{c,core} * Area_{core}) / Area_{section} = 28.98765$ , but  $f'_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)  
 $M/Vd = 2.00$   
 $\mu_u = 1.4404090E-011$   
 $\nu_u = 2.0531359E-031$   
 $d = 0.8 * h = 360.00$   
 $N_u = 7506.808$   
 $A_g = 202500.00$   
 From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 144280.365$   
 where:  
 $V_{s1} = 69813.729$  is calculated for jacket, with:  
 $d = 360.00$   
 $A_v = 157079.633$   
 $f_y = 555.56$   
 $s = 300.00$   
 $V_{s1}$  is multiplied by  $Col1 = 0.66666667$   
 $s/d = 0.83333333$   
 $V_{s2} = 74466.637$  is calculated for core, with:  
 $d = 200.00$   
 $A_v = 100530.965$   
 $f_y = 444.44$

$s = 120.00$   
 $V_{s2}$  is multiplied by  $Col2 = 1.00$   
 $s/d = 0.60$   
 $V_f ((11-3)-(11.4), ACI 440) = 214457.247$   
 $f = 0.95$ , for fully-wrapped sections  
 $w_f/s_f = 1$  (FRP strips adjacent to one another).  
 In (11.3)  $\sin + \cos$  is replaced with  $(\cot + \cot a)\sin a$  which is more a generalised expression,  
 where  $a$  is the angle of the crack direction (see KANEPE).  
 This later relation, considered as a function  $V_f(\theta, a)$ , is implemented for every different fiber orientation  $a_i$ ,  
 as well as for 2 crack directions,  $\theta = 45^\circ$  and  $\theta = -45^\circ$  to take into consideration the cyclic seismic loading.  
 orientation 1:  $\theta = b1 + 90^\circ = 90.00$   
 $V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, a1)|)$ , with:  
 total thickness per orientation,  $t_{f1} = NL * t / NoDir = 1.016$   
 $d_{fv} = d$  (figure 11.2, ACI 440) = 407.00  
 $f_{fe} ((11-5), ACI 440) = 259.312$   
 $E_f = 64828.00$   
 $f_e = 0.004$ , from (11.6a), ACI 440  
 with  $f_u = 0.01$   
 From (11-11), ACI 440:  $V_s + V_f \leq 579413.096$   
 $bw = 450.00$

-----  
 End Of Calculation of Shear Capacity ratio for element: column JC1 of floor 1  
 At local axis: 3  
 -----

Start Of Calculation of Shear Capacity ratio for element: column JC1 of floor 1  
 At Shear local axis: 2  
 (Bending local axis: 3)  
 Section Type: rcjrs

Constant Properties

Knowledge Factor,  $\phi = 0.85$   
 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,  $f_s = 1.25 * f_{sm} = 694.45$   
 Existing Column  
 Existing material: Steel Strength,  $f_s = 1.25 * f_{sm} = 555.55$   
 #####  
 External Height,  $H = 450.00$   
 External Width,  $W = 450.00$   
 Internal Height,  $H = 250.00$   
 Internal Width,  $W = 250.00$   
 Cover Thickness,  $c = 25.00$   
 Mean Confinement Factor overall section = 1.10542  
 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,  $NoDir = 1$

Fiber orientations,  $b_i = 0.00^\circ$

Number of layers,  $NL = 1$

Radius of rounding corners,  $R = 40.00$

Stepwise Properties

At local axis: 2

EDGE -A-

Shear Force,  $V_a = -2.7162834E-031$

EDGE -B-

Shear Force,  $V_b = 2.7162834E-031$

BOTH EDGES

Axial Force,  $F = -7506.808$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension:  $As_t = 0.00$

-Compression:  $As_c = 2676.637$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension:  $As_{t,ten} = 1137.257$

-Compression:  $As_{c,com} = 1137.257$

-Middle:  $As_{mid} = 402.1239$

Calculation of Shear Capacity ratio,  $V_e/V_r = 0.26068017$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 147952.607$

with

$M_{pr1} = \text{Max}(Mu_{1+}, Mu_{1-}) = 2.2193E+008$

$Mu_{1+} = 2.2193E+008$ , 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

$Mu_{1-} = 2.2193E+008$ , 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

$M_{pr2} = \text{Max}(Mu_{2+}, Mu_{2-}) = 2.2193E+008$

$Mu_{2+} = 2.2193E+008$ , 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

$Mu_{2-} = 2.2193E+008$ , 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 curvature  $\phi_u$  according to 4.1, Biskinis/Fardis 2013:

$\phi_u = 1.9632832E-005$

$M_u = 2.2193E+008$

with full section properties:

$b = 450.00$

$d = 407.00$

$d' = 43.00$

$v = 0.00124204$

$N = 7506.808$

$f_c = 33.00$

$\alpha = (5A.5, TBDY) = 0.002$

Final value of  $c_u$ :  $c_u^* = \text{shear\_factor} * \text{Max}(c_u, c_c) = 0.01393923$

The Shear\_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY:  $c_u = 0.01393923$

$w_e$  ((5.4c), TBDY) =  $ase * sh_{min} * fy_{we} / f_{ce} + \text{Min}(f_x, f_y) = 0.06811101$

where  $f = af * pf * f_{fe} / f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

-----  
 $f_x = 0.06628267$

$af = 0.54930041$

$b = 450.00$

$h = 450.00$

From EC8 A.4.4.3(6),  $pf = 2tf/bw = 0.00451556$

$bw = 450.00$

effective stress from (A.35),  $f_{f,e} = 881.8461$

-----  
 $f_y = 0.06628267$

$af = 0.54930041$

$b = 450.00$

$h = 450.00$

From EC8 A.4.4.3(6),  $pf = 2tf/bw = 0.00451556$

$bw = 450.00$

effective stress from (A.35),  $f_{f,e} = 881.8461$

-----  
 $R = 40.00$

Effective FRP thickness,  $tf = NL * t * \text{Cos}(b1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{,f} = 0.015$

$ase$  ((5.4d), TBDY) =  $(ase1 * A_{ext} + ase2 * A_{int}) / A_{sec} = 0.14546167$

$ase1 = 0.12623274$

$bo_{,1} = 390.00$

$ho_{,1} = 390.00$

$bi_{2,1} = 608400.00$

$ase2 = \text{Max}(ase1, ase2) = 0.18853448$

$bo_{,2} = 242.00$

$ho_{,2} = 242.00$

$bi_{2,2} = 234256.00$

$psh_{min} * fy_{we} = \text{Min}(psh_x * fy_{we}, psh_y * fy_{we}) = 1.38262$

Expression ((5.4d), TBDY) for  $psh_{min} * fy_{we}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

-----  
 $psh_x * fy_{we} = psh1 * fy_{we1} + ps2 * fy_{we2} = 1.38262$

$ps1$  (external) =  $(Ash1 * h1 / s1) / A_{sec} = 0.00116355$

$Ash1 = Astir_{,1} * ns_{,1} = 157.0796$

No stirrups,  $ns_{,1} = 2.00$

$h1 = 450.00$

$ps2$  (internal) =  $(Ash2 * h2 / s2) / A_{sec} = 0.00103427$

$Ash2 = Astir_{,2} * ns_{,2} = 100.531$

No stirrups,  $ns_{,2} = 2.00$

$h2 = 250.00$

-----  
 $psh_y * fy_{we} = psh1 * fy_{we1} + ps2 * fy_{we2} = 1.38262$

$ps1$  (external) =  $(Ash1 * h1 / s1) / A_{sec} = 0.00116355$

$Ash1 = Astir_{,1} * ns_{,1} = 157.0796$

No stirrups,  $ns_{,1} = 2.00$

$h1 = 450.00$

$ps2$  (internal) =  $(Ash2 * h2 / s2) / A_{sec} = 0.00103427$

$Ash2 = Astir_{,2} * ns_{,2} = 100.531$

No stirrups,  $ns_{,2} = 2.00$

$h2 = 250.00$

-----  
 $A_{sec} = 202500.00$

$s1 = 300.00$

$s2 = 120.00$

$fy_{we1} = 694.45$

$fy_{we2} = 555.55$

$f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.00305417$

$c = \text{confinement factor} = 1.10542$   
 $y1 = 0.00152175$   
 $sh1 = 0.0048696$   
 $ft1 = 479.7871$   
 $fy1 = 399.8226$   
 $su1 = 0.0066488$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 $\text{Shear\_factor} = 1.00$   
 $lo/lou,min = lb/ld = 0.33981258$   
 $su1 = 0.4 * esu1\_nominal ((5.5), \text{TBDY}) = 0.032$   
 From table 5A.1, TBDY:  $esu1\_nominal = 0.08$ ,  
 For calculation of  $esu1\_nominal$  and  $y1, sh1, ft1, fy1$ , it is considered  
 characteristic value  $fsy1 = fs1/1.2$ , from table 5.1, TBDY.  
 $y1, sh1, ft1, fy1$ , are also multiplied by  $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with  $fs1 = (fs,jacket * Asl,ten,jacket + fs,core * Asl,ten,core) / Asl,ten = 399.8226$   
 with  $Es1 = (Es,jacket * Asl,ten,jacket + Es,core * Asl,ten,core) / Asl,ten = 200000.00$   
 $y2 = 0.00152175$   
 $sh2 = 0.0048696$   
 $ft2 = 479.7871$   
 $fy2 = 399.8226$   
 $su2 = 0.0066488$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 $\text{Shear\_factor} = 1.00$   
 $lo/lou,min = lb/lb,min = 0.33981258$   
 $su2 = 0.4 * esu2\_nominal ((5.5), \text{TBDY}) = 0.032$   
 From table 5A.1, TBDY:  $esu2\_nominal = 0.08$ ,  
 For calculation of  $esu2\_nominal$  and  $y2, sh2, ft2, fy2$ , it is considered  
 characteristic value  $fsy2 = fs2/1.2$ , from table 5.1, TBDY.  
 $y1, sh1, ft1, fy1$ , are also multiplied by  $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with  $fs2 = (fs,jacket * Asl,com,jacket + fs,core * Asl,com,core) / Asl,com = 399.8226$   
 with  $Es2 = (Es,jacket * Asl,com,jacket + Es,core * Asl,com,core) / Asl,com = 200000.00$   
 $yv = 0.00152175$   
 $shv = 0.0048696$   
 $ftv = 507.2537$   
 $fyv = 422.7114$   
 $suv = 0.0066488$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 $\text{Shear\_factor} = 1.00$   
 $lo/lou,min = lb/ld = 0.33981258$   
 $suv = 0.4 * esuv\_nominal ((5.5), \text{TBDY}) = 0.032$   
 From table 5A.1, TBDY:  $esuv\_nominal = 0.08$ ,  
 considering characteristic value  $fsyv = fsv/1.2$ , from table 5.1, TBDY  
 For calculation of  $esuv\_nominal$  and  $yv, shv, ftv, fyv$ , it is considered  
 characteristic value  $fsyv = fsv/1.2$ , from table 5.1, TBDY.  
 $y1, sh1, ft1, fy1$ , are also multiplied by  $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with  $fsv = (fs,jacket * Asl,mid,jacket + fs,mid * Asl,mid,core) / Asl,mid = 422.7114$   
 with  $Es_v = (Es,jacket * Asl,mid,jacket + Es,mid * Asl,mid,core) / Asl,mid = 200000.00$   
 $1 = Asl,ten / (b * d) * (fs1 / fc) = 0.0752324$   
 $2 = Asl,com / (b * d) * (fs2 / fc) = 0.0752324$   
 $v = Asl,mid / (b * d) * (fsv / fc) = 0.02812438$   
 and confined core properties:  
 $b = 390.00$   
 $d = 377.00$   
 $d' = 13.00$   
 $fcc (5A.2, \text{TBDY}) = 36.47874$   
 $cc (5A.5, \text{TBDY}) = 0.00305417$   
 $c = \text{confinement factor} = 1.10542$   
 $1 = Asl,ten / (b * d) * (fs1 / fc) = 0.09371431$   
 $2 = Asl,com / (b * d) * (fs2 / fc) = 0.09371431$   
 $v = Asl,mid / (b * d) * (fsv / fc) = 0.03503353$   
 Case/Assumption: Unconfined full section - Steel rupture  
 ' satisfies Eq. (4.3)  
 --->  
 $v < vs,y2$  - LHS eq.(4.5) is satisfied

--->

su (4.9) = 0.16791801  
Mu = MRc (4.14) = 2.2193E+008  
u = su (4.1) = 1.9632832E-005

-----  
Calculation of ratio lb/l<sub>d</sub>

-----  
Lap Length: lb/l<sub>d</sub> = 0.33981258

lb = 300.00

l<sub>d</sub> = 882.8396

Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.  
= 1

db = 16.66667

Mean strength value of all re-bars: fy = 655.558

Mean concrete strength: fc' = (fc'\_jacket\*Area\_jacket + fc'\_core\*Area\_core)/Area\_section = 28.98765, 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 = 2.86234

Atr = Min(Atr\_x,Atr\_y) = 257.6106

where Atr\_x, Atr\_y are the sum of the area of all stirrup legs along X and Y loxal axis

s = Max(s\_external,s\_internal) = 300.00

n = 12.00

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

-----  
-----  
Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

u = 1.9632832E-005

Mu = 2.2193E+008

-----  
with full section properties:

b = 450.00

d = 407.00

d' = 43.00

v = 0.00124204

N = 7506.808

fc = 33.00

co (5A.5, TBDY) = 0.002

Final value of cu: cu\* = shear\_factor \* Max( cu, cc) = 0.01393923

The Shear\_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: cu = 0.01393923

we ((5.4c), TBDY) = ase\* sh,min\*fywe/fce+Min( fx, fy) = 0.06811101

where f = af\*pf\*ffe/fce is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

-----  
fx = 0.06628267

af = 0.54930041

b = 450.00

h = 450.00

From EC8 A.4.4.3(6), pf = 2tf/bw = 0.00451556

bw = 450.00

effective stress from (A.35), ff,e = 881.8461

-----  
fy = 0.06628267

af = 0.54930041

b = 450.00

h = 450.00

From EC8 A.4.4.3(6), pf = 2tf/bw = 0.00451556

bw = 450.00

effective stress from (A.35), ff,e = 881.8461

R = 40.00  
Effective FRP thickness,  $t_f = NL * t * \cos(b_1) = 1.016$   
 $f_{u,f} = 1055.00$   
 $E_f = 64828.00$   
 $u_{,f} = 0.015$   
 $ase((5.4d), TBDY) = (ase_1 * A_{ext} + ase_2 * A_{int}) / A_{sec} = 0.14546167$   
 $ase_1 = 0.12623274$   
 $bo_1 = 390.00$   
 $ho_1 = 390.00$   
 $bi_2_1 = 608400.00$   
 $ase_2 = \text{Max}(ase_1, ase_2) = 0.18853448$   
 $bo_2 = 242.00$   
 $ho_2 = 242.00$   
 $bi_2_2 = 234256.00$   
 $psh_{,min} * F_{ywe} = \text{Min}(psh_{,x} * F_{ywe}, psh_{,y} * F_{ywe}) = 1.38262$

Expression ((5.4d), TBDY) for  $psh_{,min} * F_{ywe}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

-----  
 $psh_{,x} * F_{ywe} = psh_1 * F_{ywe1} + ps_2 * F_{ywe2} = 1.38262$   
 $ps_1 \text{ (external)} = (A_{sh1} * h_1 / s_1) / A_{sec} = 0.00116355$   
 $A_{sh1} = A_{stir_1} * ns_1 = 157.0796$   
No stirrups,  $ns_1 = 2.00$   
 $h_1 = 450.00$   
 $ps_2 \text{ (internal)} = (A_{sh2} * h_2 / s_2) / A_{sec} = 0.00103427$   
 $A_{sh2} = A_{stir_2} * ns_2 = 100.531$   
No stirrups,  $ns_2 = 2.00$   
 $h_2 = 250.00$

-----  
 $psh_{,y} * F_{ywe} = psh_1 * F_{ywe1} + ps_2 * F_{ywe2} = 1.38262$   
 $ps_1 \text{ (external)} = (A_{sh1} * h_1 / s_1) / A_{sec} = 0.00116355$   
 $A_{sh1} = A_{stir_1} * ns_1 = 157.0796$   
No stirrups,  $ns_1 = 2.00$   
 $h_1 = 450.00$   
 $ps_2 \text{ (internal)} = (A_{sh2} * h_2 / s_2) / A_{sec} = 0.00103427$   
 $A_{sh2} = A_{stir_2} * ns_2 = 100.531$   
No stirrups,  $ns_2 = 2.00$   
 $h_2 = 250.00$

-----  
 $A_{sec} = 202500.00$   
 $s_1 = 300.00$   
 $s_2 = 120.00$   
 $f_{ywe1} = 694.45$   
 $f_{ywe2} = 555.55$   
 $f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.00305417$   
 $c = \text{confinement factor} = 1.10542$

$y_1 = 0.00152175$   
 $sh_1 = 0.0048696$   
 $ft_1 = 479.7871$   
 $fy_1 = 399.8226$   
 $su_1 = 0.0066488$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

$lo/lo_{,min} = lb/ld = 0.33981258$   
 $su_1 = 0.4 * esu_{1,nominal}((5.5), TBDY) = 0.032$

From table 5A.1, TBDY:  $esu_{1,nominal} = 0.08$ ,

For calculation of  $esu_{1,nominal}$  and  $y_1, sh_1, ft_1, fy_1$ , it is considered  
characteristic value  $fsy_1 = fs_1 / 1.2$ , from table 5.1, TBDY.

$y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.

with  $fs_1 = (f_{s,jacket} * A_{sl,ten,jacket} + f_{s,core} * A_{sl,ten,core}) / A_{sl,ten} = 399.8226$

with  $Es_1 = (E_{s,jacket} * A_{sl,ten,jacket} + E_{s,core} * A_{sl,ten,core}) / A_{sl,ten} = 200000.00$

$y_2 = 0.00152175$   
 $sh_2 = 0.0048696$   
 $ft_2 = 479.7871$   
 $fy_2 = 399.8226$   
 $su_2 = 0.0066488$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

$$l_o/l_{o,min} = l_b/l_{b,min} = 0.33981258$$

$$s_u2 = 0.4 * e_{s_u2,nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY:  $e_{s_u2,nominal} = 0.08$ ,

For calculation of  $e_{s_u2,nominal}$  and  $y_2, sh_2, ft_2, fy_2$ , it is considered  
characteristic value  $f_{s_y2} = f_{s_2}/1.2$ , from table 5.1, TBDY.

$y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.

$$\text{with } f_{s_2} = (f_{s,jacket} * A_{s_l,com,jacket} + f_{s,core} * A_{s_l,com,core}) / A_{s_l,com} = 399.8226$$

$$\text{with } E_{s_2} = (E_{s,jacket} * A_{s_l,com,jacket} + E_{s,core} * A_{s_l,com,core}) / A_{s_l,com} = 200000.00$$

$$y_v = 0.00152175$$

$$sh_v = 0.0048696$$

$$ft_v = 507.2537$$

$$fy_v = 422.7114$$

$$s_{u_v} = 0.0066488$$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

$$l_o/l_{o,min} = l_b/l_d = 0.33981258$$

$$s_{u_v} = 0.4 * e_{s_{u_v},nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY:  $e_{s_{u_v},nominal} = 0.08$ ,

considering characteristic value  $f_{s_{y_v}} = f_{s_v}/1.2$ , from table 5.1, TBDY

For calculation of  $e_{s_{u_v},nominal}$  and  $y_v, sh_v, ft_v, fy_v$ , it is considered  
characteristic value  $f_{s_{y_v}} = f_{s_v}/1.2$ , from table 5.1, TBDY.

$y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.

$$\text{with } f_{s_v} = (f_{s,jacket} * A_{s_l,mid,jacket} + f_{s,mid} * A_{s_l,mid,core}) / A_{s_l,mid} = 422.7114$$

$$\text{with } E_{s_v} = (E_{s,jacket} * A_{s_l,mid,jacket} + E_{s,mid} * A_{s_l,mid,core}) / A_{s_l,mid} = 200000.00$$

$$1 = A_{s_l,ten} / (b * d) * (f_{s_1} / f_c) = 0.0752324$$

$$2 = A_{s_l,com} / (b * d) * (f_{s_2} / f_c) = 0.0752324$$

$$v = A_{s_l,mid} / (b * d) * (f_{s_v} / f_c) = 0.02812438$$

and confined core properties:

$$b = 390.00$$

$$d = 377.00$$

$$d' = 13.00$$

$$f_{cc} (5A.2, TBDY) = 36.47874$$

$$cc (5A.5, TBDY) = 0.00305417$$

$$c = \text{confinement factor} = 1.10542$$

$$1 = A_{s_l,ten} / (b * d) * (f_{s_1} / f_c) = 0.09371431$$

$$2 = A_{s_l,com} / (b * d) * (f_{s_2} / f_c) = 0.09371431$$

$$v = A_{s_l,mid} / (b * d) * (f_{s_v} / f_c) = 0.03503353$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < v_{s,y_2}$  - LHS eq.(4.5) is satisfied

--->

$$s_u (4.9) = 0.16791801$$

$$\mu = MR_c (4.14) = 2.2193E+008$$

$$u = s_u (4.1) = 1.9632832E-005$$

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

Lap Length:  $l_b/l_d = 0.33981258$

$$l_b = 300.00$$

$$l_d = 882.8396$$

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

$$= 1$$

$$d_b = 16.66667$$

Mean strength value of all re-bars:  $f_y = 655.558$

Mean concrete strength:  $f'_c = (f'_{c,jacket} * Area_{jacket} + f'_{c,core} * Area_{core}) / Area_{section} = 28.98765$ , but  $f_c^{0.5} < =$   
8.3 MPa (22.5.3.1, ACI 318-14)

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 25.00$$

$$K_{tr} = 2.86234$$

$$A_{tr} = \text{Min}(A_{tr\_x}, A_{tr\_y}) = 257.6106$$

where  $A_{tr\_x}$ ,  $A_{tr\_y}$  are the sum of the area of all stirrup legs along X and Y local axis

$$s = \text{Max}(s_{\text{external}}, s_{\text{internal}}) = 300.00$$

$$n = 12.00$$

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

-----  
-----  
Calculation of ultimate curvature  $\mu$  according to 4.1, Biskinis/Fardis 2013:

$$u = 1.9632832E-005$$

$$\mu = 2.2193E+008$$

-----  
with full section properties:

$$b = 450.00$$

$$d = 407.00$$

$$d' = 43.00$$

$$v = 0.00124204$$

$$N = 7506.808$$

$$f_c = 33.00$$

$$c_o \text{ (5A.5, TBDY)} = 0.002$$

$$\text{Final value of } c_u: c_u^* = \text{shear\_factor} * \text{Max}(c_u, c_c) = 0.01393923$$

The Shear\_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } c_u = 0.01393923$$

$$w_e \text{ ((5.4c), TBDY)} = a_{se} * s_{h,\text{min}} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.06811101$$

where  $f = a_f * p_f * f_{fe} / f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.06628267$$

$$a_f = 0.54930041$$

$$b = 450.00$$

$$h = 450.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.00451556$$

$$b_w = 450.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 881.8461$$

$$f_y = 0.06628267$$

$$a_f = 0.54930041$$

$$b = 450.00$$

$$h = 450.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.00451556$$

$$b_w = 450.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 881.8461$$

$$R = 40.00$$

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

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{f} = 0.015$$

$$a_{se} \text{ ((5.4d), TBDY)} = (a_{se1} * A_{ext} + a_{se2} * A_{int}) / A_{sec} = 0.14546167$$

$$a_{se1} = 0.12623274$$

$$b_{o,1} = 390.00$$

$$h_{o,1} = 390.00$$

$$b_{i,1} = 608400.00$$

$$a_{se2} = \text{Max}(a_{se1}, a_{se2}) = 0.18853448$$

$$b_{o,2} = 242.00$$

$$h_{o,2} = 242.00$$

$$b_{i,2} = 234256.00$$

$$p_{sh,\text{min}} * f_{ywe} = \text{Min}(p_{sh,x} * f_{ywe}, p_{sh,y} * f_{ywe}) = 1.38262$$

Expression ((5.4d), TBDY) for  $p_{sh,\text{min}} * f_{ywe}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$$p_{sh,x} * f_{ywe} = p_{sh1} * f_{ywe1} + p_{sh2} * f_{ywe2} = 1.38262$$

$$p_{s1} \text{ (external)} = (A_{sh1} * h_1 / s_1) / A_{sec} = 0.00116355$$

$$A_{sh1} = A_{stir,1} * n_{s,1} = 157.0796$$

$$\text{No stirrups, } n_{s,1} = 2.00$$

h1 = 450.00  
ps2 (internal) = (Ash2\*h2/s2)/Asec = 0.00103427  
Ash2 = Astir\_2\*ns\_2 = 100.531  
No stirups, ns\_2 = 2.00  
h2 = 250.00

-----  
psh\_y\*Fywe = psh1\*Fywe1+ps2\*Fywe2 = 1.38262  
ps1 (external) = (Ash1\*h1/s1)/Asec = 0.00116355  
Ash1 = Astir\_1\*ns\_1 = 157.0796  
No stirups, ns\_1 = 2.00  
h1 = 450.00  
ps2 (internal) = (Ash2\*h2/s2)/Asec = 0.00103427  
Ash2 = Astir\_2\*ns\_2 = 100.531  
No stirups, ns\_2 = 2.00  
h2 = 250.00

-----  
Asec = 202500.00  
s1 = 300.00  
s2 = 120.00  
fywe1 = 694.45  
fywe2 = 555.55  
fce = 33.00

From ((5.A5), TBDY), TBDY: cc = 0.00305417  
c = confinement factor = 1.10542

y1 = 0.00152175  
sh1 = 0.0048696  
ft1 = 479.7871  
fy1 = 399.8226  
su1 = 0.0066488

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

lo/lou,min = lb/d = 0.33981258

su1 = 0.4\*esu1\_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu1\_nominal = 0.08,

For calculation of esu1\_nominal and y1, sh1,ft1,fy1, it is considered  
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25\*(lb/d)^ 2/3), from 10.3.5, ASCE 41-17.

with fs1 = (fs,jacket\*Asl,ten,jacket + fs,core\*Asl,ten,core)/Asl,ten = 399.8226

with Es1 = (Es,jacket\*Asl,ten,jacket + Es,core\*Asl,ten,core)/Asl,ten = 200000.00

y2 = 0.00152175  
sh2 = 0.0048696  
ft2 = 479.7871  
fy2 = 399.8226  
su2 = 0.0066488

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

lo/lou,min = lb/lb,min = 0.33981258

su2 = 0.4\*esu2\_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu2\_nominal = 0.08,

For calculation of esu2\_nominal and y2, sh2,ft2,fy2, it is considered  
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25\*(lb/d)^ 2/3), from 10.3.5, ASCE 41-17.

with fs2 = (fs,jacket\*Asl,com,jacket + fs,core\*Asl,com,core)/Asl,com = 399.8226

with Es2 = (Es,jacket\*Asl,com,jacket + Es,core\*Asl,com,core)/Asl,com = 200000.00

yv = 0.00152175  
shv = 0.0048696  
ftv = 507.2537  
fyv = 422.7114  
suv = 0.0066488

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

lo/lou,min = lb/d = 0.33981258

suv = 0.4\*esuv\_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esuv\_nominal = 0.08,

considering characteristic value  $f_{sv} = f_{sv}/1.2$ , from table 5.1, TBDY  
For calculation of  $e_{suv\_nominal}$  and  $y_v$ ,  $sh_v$ ,  $ft_v$ ,  $f_{yv}$ , it is considered characteristic value  $f_{sv} = f_{sv}/1.2$ , from table 5.1, TBDY.

$y_1$ ,  $sh_1$ ,  $ft_1$ ,  $f_{y1}$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.

with  $f_{sv} = (f_{s,jacket} \cdot A_{s,mid,jacket} + f_{s,mid} \cdot A_{s,mid,core}) / A_{s,mid} = 422.7114$

with  $E_{sv} = (E_{s,jacket} \cdot A_{s,mid,jacket} + E_{s,mid} \cdot A_{s,mid,core}) / A_{s,mid} = 200000.00$

1 =  $A_{s,ten} / (b \cdot d) \cdot (f_{s1} / f_c) = 0.0752324$

2 =  $A_{s,com} / (b \cdot d) \cdot (f_{s2} / f_c) = 0.0752324$

$v = A_{s,mid} / (b \cdot d) \cdot (f_{sv} / f_c) = 0.02812438$

and confined core properties:

$b = 390.00$

$d = 377.00$

$d' = 13.00$

$f_{cc}$  (5A.2, TBDY) = 36.47874

$cc$  (5A.5, TBDY) = 0.00305417

$c$  = confinement factor = 1.10542

1 =  $A_{s,ten} / (b \cdot d) \cdot (f_{s1} / f_c) = 0.09371431$

2 =  $A_{s,com} / (b \cdot d) \cdot (f_{s2} / f_c) = 0.09371431$

$v = A_{s,mid} / (b \cdot d) \cdot (f_{sv} / f_c) = 0.03503353$

Case/Assumption: Unconfined full section - Steel rupture  
' satisfies Eq. (4.3)

--->

$v < v_{s,y2}$  - LHS eq.(4.5) is satisfied

--->

$su$  (4.9) = 0.16791801

$Mu = MRc$  (4.14) = 2.2193E+008

$u = su$  (4.1) = 1.9632832E-005

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

Lap Length:  $l_b/l_d = 0.33981258$

$l_b = 300.00$

$l_d = 882.8396$

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

= 1

$db = 16.66667$

Mean strength value of all re-bars:  $f_y = 655.558$

Mean concrete strength:  $f'_c = (f'_{c,jacket} \cdot Area_{jacket} + f'_{c,core} \cdot Area_{core}) / Area_{section} = 28.98765$ , but  $f_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 2.86234$

$A_{tr} = \text{Min}(A_{tr,x}, A_{tr,y}) = 257.6106$

where  $A_{tr,x}$ ,  $A_{tr,y}$  are the sum of the area of all stirrup legs along X and Y loxal axis

$s = \text{Max}(s_{external}, s_{internal}) = 300.00$

$n = 12.00$

-----  
Calculation of  $Mu_2$ -

-----  
Calculation of ultimate curvature  $u$  according to 4.1, Biskinis/Fardis 2013:

$u = 1.9632832E-005$

$Mu = 2.2193E+008$

-----  
with full section properties:

$b = 450.00$

$d = 407.00$

$d' = 43.00$

$v = 0.00124204$

$N = 7506.808$

$f_c = 33.00$

co (5A.5, TBDY) = 0.002

Final value of cu:  $cu^* = \text{shear\_factor} * \text{Max}(cu, cc) = 0.01393923$

The Shear\_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY:  $cu = 0.01393923$

we ((5.4c), TBDY) =  $ase * sh_{\min} * fy_{we} / f_{ce} + \text{Min}(fx, fy) = 0.06811101$

where  $f = af * pf * f_{fe} / f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

-----  
 $fx = 0.06628267$

$af = 0.54930041$

$b = 450.00$

$h = 450.00$

From EC8 A.4.4.3(6),  $pf = 2tf/bw = 0.00451556$

$bw = 450.00$

effective stress from (A.35),  $ff,e = 881.8461$

-----  
 $fy = 0.06628267$

$af = 0.54930041$

$b = 450.00$

$h = 450.00$

From EC8 A.4.4.3(6),  $pf = 2tf/bw = 0.00451556$

$bw = 450.00$

effective stress from (A.35),  $ff,e = 881.8461$

-----  
 $R = 40.00$

Effective FRP thickness,  $tf = NL * t * \text{Cos}(b1) = 1.016$

$fu,f = 1055.00$

$Ef = 64828.00$

$u,f = 0.015$

$ase$  ((5.4d), TBDY) =  $(ase1 * A_{ext} + ase2 * A_{int}) / A_{sec} = 0.14546167$

$ase1 = 0.12623274$

$bo\_1 = 390.00$

$ho\_1 = 390.00$

$bi2\_1 = 608400.00$

$ase2 = \text{Max}(ase1, ase2) = 0.18853448$

$bo\_2 = 242.00$

$ho\_2 = 242.00$

$bi2\_2 = 234256.00$

$psh_{\min} * fy_{we} = \text{Min}(psh_x * fy_{we}, psh_y * fy_{we}) = 1.38262$

Expression ((5.4d), TBDY) for  $psh_{\min} * fy_{we}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

-----  
 $psh_x * fy_{we} = psh1 * fy_{we1} + ps2 * fy_{we2} = 1.38262$

$ps1$  (external) =  $(Ash1 * h1 / s1) / A_{sec} = 0.00116355$

$Ash1 = Astir\_1 * ns\_1 = 157.0796$

No stirrups,  $ns\_1 = 2.00$

$h1 = 450.00$

$ps2$  (internal) =  $(Ash2 * h2 / s2) / A_{sec} = 0.00103427$

$Ash2 = Astir\_2 * ns\_2 = 100.531$

No stirrups,  $ns\_2 = 2.00$

$h2 = 250.00$

-----  
 $psh_y * fy_{we} = psh1 * fy_{we1} + ps2 * fy_{we2} = 1.38262$

$ps1$  (external) =  $(Ash1 * h1 / s1) / A_{sec} = 0.00116355$

$Ash1 = Astir\_1 * ns\_1 = 157.0796$

No stirrups,  $ns\_1 = 2.00$

$h1 = 450.00$

$ps2$  (internal) =  $(Ash2 * h2 / s2) / A_{sec} = 0.00103427$

$Ash2 = Astir\_2 * ns\_2 = 100.531$

No stirrups,  $ns\_2 = 2.00$

$h2 = 250.00$

-----  
 $A_{sec} = 202500.00$

$s1 = 300.00$

$s2 = 120.00$

$fy_{we1} = 694.45$

$fy_{we2} = 555.55$

$f_{ce} = 33.00$

From ((5.A.5), TBDY), TBDY:  $cc = 0.00305417$   
 $c = \text{confinement factor} = 1.10542$

$y1 = 0.00152175$

$sh1 = 0.0048696$

$ft1 = 479.7871$

$fy1 = 399.8226$

$su1 = 0.0066488$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

$lo/lou,min = lb/ld = 0.33981258$

$su1 = 0.4 * esu1\_nominal ((5.5), TBDY) = 0.032$

From table 5A.1, TBDY:  $esu1\_nominal = 0.08$ ,

For calculation of  $esu1\_nominal$  and  $y1, sh1, ft1, fy1$ , it is considered  
characteristic value  $fsy1 = fs1/1.2$ , from table 5.1, TBDY.

$y1, sh1, ft1, fy1$ , are also multiplied by  $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.

with  $fs1 = (fs,jacket * Asl,ten,jacket + fs,core * Asl,ten,core) / Asl,ten = 399.8226$

with  $Es1 = (Es,jacket * Asl,ten,jacket + Es,core * Asl,ten,core) / Asl,ten = 200000.00$

$y2 = 0.00152175$

$sh2 = 0.0048696$

$ft2 = 479.7871$

$fy2 = 399.8226$

$su2 = 0.0066488$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

$lo/lou,min = lb/lb,min = 0.33981258$

$su2 = 0.4 * esu2\_nominal ((5.5), TBDY) = 0.032$

From table 5A.1, TBDY:  $esu2\_nominal = 0.08$ ,

For calculation of  $esu2\_nominal$  and  $y2, sh2, ft2, fy2$ , it is considered  
characteristic value  $fsy2 = fs2/1.2$ , from table 5.1, TBDY.

$y1, sh1, ft1, fy1$ , are also multiplied by  $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.

with  $fs2 = (fs,jacket * Asl,com,jacket + fs,core * Asl,com,core) / Asl,com = 399.8226$

with  $Es2 = (Es,jacket * Asl,com,jacket + Es,core * Asl,com,core) / Asl,com = 200000.00$

$yv = 0.00152175$

$shv = 0.0048696$

$ftv = 507.2537$

$fyv = 422.7114$

$suv = 0.0066488$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

$lo/lou,min = lb/ld = 0.33981258$

$suv = 0.4 * esuv\_nominal ((5.5), TBDY) = 0.032$

From table 5A.1, TBDY:  $esuv\_nominal = 0.08$ ,

considering characteristic value  $fsyv = fsv/1.2$ , from table 5.1, TBDY

For calculation of  $esuv\_nominal$  and  $yv, shv, ftv, fyv$ , it is considered  
characteristic value  $fsyv = fsv/1.2$ , from table 5.1, TBDY.

$y1, sh1, ft1, fy1$ , are also multiplied by  $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.

with  $fsv = (fs,jacket * Asl,mid,jacket + fs,mid * Asl,mid,core) / Asl,mid = 422.7114$

with  $Esv = (Es,jacket * Asl,mid,jacket + Es,mid * Asl,mid,core) / Asl,mid = 200000.00$

$1 = Asl,ten / (b * d) * (fs1 / fc) = 0.0752324$

$2 = Asl,com / (b * d) * (fs2 / fc) = 0.0752324$

$v = Asl,mid / (b * d) * (fsv / fc) = 0.02812438$

and confined core properties:

$b = 390.00$

$d = 377.00$

$d' = 13.00$

$fcc (5A.2, TBDY) = 36.47874$

$cc (5A.5, TBDY) = 0.00305417$

$c = \text{confinement factor} = 1.10542$

$1 = Asl,ten / (b * d) * (fs1 / fc) = 0.09371431$

$2 = Asl,com / (b * d) * (fs2 / fc) = 0.09371431$

$v = Asl,mid / (b * d) * (fsv / fc) = 0.03503353$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < v_s, y_2$  - LHS eq.(4.5) is satisfied

--->

$$s_u(4.9) = 0.16791801$$

$$M_u = M_{Rc}(4.14) = 2.2193E+008$$

$$u = s_u(4.1) = 1.9632832E-005$$

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

-----  
Lap Length:  $l_b/l_d = 0.33981258$

$$l_b = 300.00$$

$$l_d = 882.8396$$

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

$$= 1$$

$$d_b = 16.66667$$

Mean strength value of all re-bars:  $f_y = 655.558$

Mean concrete strength:  $f_c' = (f_c'_{jacket} \cdot Area_{jacket} + f_c'_{core} \cdot Area_{core}) / Area_{section} = 28.98765$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 25.00$$

$$K_{tr} = 2.86234$$

$$A_{tr} = \min(A_{tr_x}, A_{tr_y}) = 257.6106$$

where  $A_{tr_x}, A_{tr_y}$  are the sum of the area of all stirrup legs along X and Y local axis

$$s = \max(s_{external}, s_{internal}) = 300.00$$

$$n = 12.00$$

-----  
-----  
-----  
Calculation of Shear Strength  $V_r = \min(V_{r1}, V_{r2}) = 567563.724$

-----  
Calculation of Shear Strength at edge 1,  $V_{r1} = 567563.724$

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

$$V_{Col0} = 567563.724$$

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

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

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

Mean concrete strength:  $f_c' = (f_c'_{jacket} \cdot Area_{jacket} + f_c'_{core} \cdot Area_{core}) / Area_{section} = 28.98765$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$$M/Vd = 2.00$$

$$M_u = 1.0463738E-012$$

$$V_u = 2.7162834E-031$$

$$d = 0.8 \cdot h = 360.00$$

$$N_u = 7506.808$$

$$A_g = 202500.00$$

$$\text{From (11.5.4.8), ACI 318-14: } V_s = V_{s1} + V_{s2} = 144280.365$$

where:

$V_{s1} = 69813.729$  is calculated for jacket, with:

$$d = 360.00$$

$$A_v = 157079.633$$

$$f_y = 555.56$$

$$s = 300.00$$

$V_{s1}$  is multiplied by  $Col1 = 0.66666667$

$$s/d = 0.83333333$$

$V_{s2} = 74466.637$  is calculated for core, with:

$$d = 200.00$$

$$A_v = 100530.965$$

$$f_y = 444.44$$

$$s = 120.00$$

$V_{s2}$  is multiplied by  $Col2 = 1.00$

$$s/d = 0.60$$

$$V_f \text{ ((11-3)-(11.4), ACI 440) } = 214457.247$$

$f = 0.95$ , for fully-wrapped sections  
 $wf/sf = 1$  (FRP strips adjacent to one another).  
 In (11.3)  $\sin + \cos$  is replaced with  $(\cot + \cot a)\sin a$  which is more a generalised expression,  
 where  $a$  is the angle of the crack direction (see KANEPE).  
 This later relation, considered as a function  $V_f(\theta)$ , is implemented for every different fiber orientation  $a_i$ ,  
 as well as for 2 crack directions,  $\theta = 45^\circ$  and  $\theta = -45^\circ$  to take into consideration the cyclic seismic loading.  
 orientation 1:  $\theta = b1 + 90^\circ = 90.00$   
 $V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, a1)|)$ , with:  
 total thickness per orientation,  $tf1 = NL * t / \text{NoDir} = 1.016$   
 $dfv = d$  (figure 11.2, ACI 440) = 407.00  
 $ffe$  ((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:  $V_s + V_f \leq 579413.096$   
 $bw = 450.00$

Calculation of Shear Strength at edge 2,  $V_{r2} = 567563.724$   
 $V_{r2} = V_{Col}$  ((10.3), ASCE 41-17) =  $knl * V_{Col0}$   
 $V_{Col0} = 567563.724$   
 $knl = 1$  (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).

$\gamma_c = 1$  (normal-weight concrete)  
 Mean concrete strength:  $f'_c = (f'_{c\_jacket} * Area\_jacket + f'_{c\_core} * Area\_core) / Area\_section = 28.98765$ , but  $f_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M/d = 2.00$   
 $\mu_u = 1.0463738E-012$   
 $\nu_u = 2.7162834E-031$   
 $d = 0.8 * h = 360.00$   
 $N_u = 7506.808$   
 $A_g = 202500.00$   
 From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 144280.365$   
 where:

$V_{s1} = 69813.729$  is calculated for jacket, with:  
 $d = 360.00$   
 $A_v = 157079.633$   
 $f_y = 555.56$   
 $s = 300.00$

$V_{s1}$  is multiplied by  $Col1 = 0.66666667$   
 $s/d = 0.833333333$

$V_{s2} = 74466.637$  is calculated for core, with:  
 $d = 200.00$   
 $A_v = 100530.965$   
 $f_y = 444.44$   
 $s = 120.00$

$V_{s2}$  is multiplied by  $Col2 = 1.00$   
 $s/d = 0.60$

$V_f$  ((11-3)-(11.4), ACI 440) = 214457.247  
 $f = 0.95$ , for fully-wrapped sections

$wf/sf = 1$  (FRP strips adjacent to one another).  
 In (11.3)  $\sin + \cos$  is replaced with  $(\cot + \cot a)\sin a$  which is more a generalised expression,  
 where  $a$  is the angle of the crack direction (see KANEPE).  
 This later relation, considered as a function  $V_f(\theta)$ , is implemented for every different fiber orientation  $a_i$ ,  
 as well as for 2 crack directions,  $\theta = 45^\circ$  and  $\theta = -45^\circ$  to take into consideration the cyclic seismic loading.

orientation 1:  $\theta = b1 + 90^\circ = 90.00$   
 $V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, a1)|)$ , with:  
 total thickness per orientation,  $tf1 = NL * t / \text{NoDir} = 1.016$   
 $dfv = d$  (figure 11.2, ACI 440) = 407.00  
 $ffe$  ((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:  $V_s + V_f \leq 579413.096$

bw = 450.00

End Of Calculation of Shear Capacity ratio for element: column JC1 of floor 1  
At local axis: 2

Start Of Calculation of Chord Rotation Capacity for element: column JC1 of floor 1

At local axis: 2

Integration Section: (a)

Section Type: rcjrs

Constant Properties

Knowledge Factor,  $\gamma = 0.85$

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

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

Consequently:

Jacket

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

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,  $E_s = 200000.00$

External Height,  $H = 450.00$

External Width,  $W = 450.00$

Internal Height,  $H = 250.00$

Internal Width,  $W = 250.00$

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,  $M = -5.3402437E-010$

Shear Force,  $V_2 = -11781.223$

Shear Force,  $V_3 = 2.6378276E-013$

Axial Force,  $F = -7502.094$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension:  $As_t = 1137.257$

-Compression:  $As_c = 1539.38$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension:  $As_{l,ten} = 1137.257$

-Compression:  $As_{l,com} = 1137.257$

-Middle: Asl,mid = 402.1239

Longitudinal External Reinforcement Area Distribution (in 3 divisions)

-Tension: Asl,ten,jacket = 829.3805

-Compression: Asl,com,jacket = 829.3805

-Middle: Asl,mid,jacket = 402.1239

Longitudinal Internal Reinforcement Area Distribution (in 3 divisions)

-Tension: Asl,ten,core = 307.8761

-Compression: Asl,com,core = 307.8761

-Middle: Asl,mid,core = 0.00

Mean Diameter of Tension Reinforcement, DbL = 16.80

Existing component: From table 7-7, ASCE 41\_17: Final chord rotation Capacity  $u,R = \frac{1}{2} u = 0.03558642$   
 $u = y + p = 0.04186638$

- Calculation of  $y$  -

$y = (M_y * L_s / 3) / E_{eff} = 0.00325023$  ((4.29),Biskinis Phd)

$M_y = 1.7613E+008$

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

From table 10.5, ASCE 41\_17:  $E_{eff} = factor * E_c * I_g = 2.7095E+013$

factor = 0.30

$A_g = 202500.00$

Mean concrete strength:  $fc' = (fc'_{jacket} * Area_{jacket} + fc'_{core} * Area_{core}) / Area_{section} = 28.98765$

$N = 7502.094$

$E_c * I_g = E_{c,jacket} * I_{g,jacket} + E_{c,core} * I_{g,core} = 9.0315E+013$

Calculation of Yielding Moment  $M_y$

Calculation of  $y$  and  $M_y$  according to Annex 7 -

$y = \text{Min}(y_{ten}, y_{com})$

$y_{ten} = 6.1806717E-006$

with ((10.1), ASCE 41-17)  $f_y = \text{Min}(f_y, 1.25 * f_y * ((l_b / d)^{2/3})) = 374.3546$

$d = 407.00$

$y = 0.25591399$

$A = 0.01472387$

$B = 0.00818866$

with  $pt = 0.00430549$

$pc = 0.00620943$

$pv = 0.0021956$

$N = 7502.094$

$b = 450.00$

$" = 0.10565111$

$y_{comp} = 2.2127287E-005$

with  $fc^*$  (12.3, (ACI 440)) = 34.40847

$fc = 33.00$

$fl = 0.82797802$

$b = 450.00$

$h = 450.00$

$A_g = 202500.00$

From (12.9), ACI 440:  $ka = 0.54261599$

$g = pt + pc + pv = 0.01461445$

$rc = 40.00$

$A_e / A_c = 0.54261599$

Effective FRP thickness,  $tf = NL * t * \text{Cos}(b1) = 1.016$

effective strain from (12.5) and (12.12),  $e_{fe} = 0.004$

$fu = 0.01$

$E_f = 64828.00$

$E_c = 26999.444$

$y = 0.25471852$

$A = 0.01452517$

B = 0.00807924  
with Es = 200000.00

Calculation of ratio  $l_b/l_d$

Lap Length:  $l_d/l_{d,min} = 0.42476573$

$l_b = 300.00$

$l_d = 706.2717$

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

$\lambda = 1$

$d_b = 16.66667$

Mean strength value of all re-bars:  $f_y = 524.4464$

Mean concrete strength:  $f'_c = (f'_{c,jacket} \cdot Area_{jacket} + f'_{c,core} \cdot Area_{core}) / Area_{section} = 28.98765$ , but  $f_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 2.86234$

$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 257.6106$

where  $A_{tr_x}$ ,  $A_{tr_y}$  are the sum of the area of all stirrup legs along X and Y local axis

$s = \text{Max}(s_{external}, s_{internal}) = 300.00$

$n = 12.00$

- Calculation of  $\rho$  -

From table 10-8:  $\rho = 0.03861614$

with:

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

shear control ratio  $V_y E / V_{col} O E = 0.26068017$

$d = d_{external} = 407.00$

$s = s_{external} = 0.00$

$t = s_1 + s_2 + 2 \cdot t_f / b_w \cdot (f_{fe} / f_s) = 0.00430549$

jacket:  $s_1 = A_{v1} \cdot h_1 / (s_1 \cdot A_g) = 0.00116355$

$A_{v1} = 157.0796$ , is the total area of all stirrups parallel to loading (shear) direction

$h_1 = 450.00$

$s_1 = 300.00$

core:  $s_2 = A_{v2} \cdot h_2 / (s_2 \cdot A_g) = 0.00103427$

$A_{v2} = 100.531$ , is the total area of all stirrups parallel to loading (shear) direction

$h_2 = 250.00$

$s_2 = 120.00$

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.

$N_{UD} = 7502.094$

$A_g = 202500.00$

$f'_c E = (f'_{c,jacket} \cdot Area_{jacket} + f'_{c,core} \cdot Area_{core}) / section\_area = 28.98765$

$f_{yI} E = (f_{y,ext\_Long\_Reinf} \cdot Area_{ext\_Long\_Reinf} + f_{y,int\_Long\_Reinf} \cdot Area_{int\_Long\_Reinf}) / Area_{Tot\_Long\_Rein} = 529.9972$

$f_{yT} E = (f_{y,ext\_Trans\_Reinf} \cdot s_1 + f_{y,int\_Trans\_Reinf} \cdot s_2) / (s_1 + s_2) = 503.2682$

$\rho_l = Area_{Tot\_Long\_Rein} / (b \cdot d) = 0.01461445$

$b = 450.00$

$d = 407.00$

$f'_c E = 28.98765$

End Of Calculation of Chord Rotation Capacity for element: column JC1 of floor 1

At local axis: 2

Integration Section: (a)

## Calculation No. 11

column C1, Floor 1

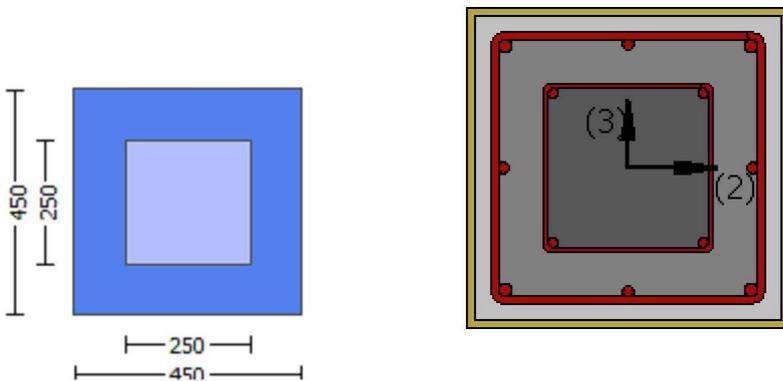
Limit State: Collapse Prevention (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Shear capacity VRd

Edge: Start

Local Axis: (3)



Start Of Calculation of Shear Capacity for element: column JC1 of floor 1

At local axis: 3

Integration Section: (a)

Section Type: rcjrs

Constant Properties

Knowledge Factor,  $\gamma = 0.85$

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  $\gamma$  for displacement ductility demand, the expected (mean value) strengths are used (7.5.1.3, ASCE 41-17) because bending is considered as Deformation-Controlled Action (Table C7-1, ASCE 41-17).

Jacket

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

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

Existing Column

Existing material: Concrete Strength,  $f_c = f_{cm} = 20.00$   
 Existing material: Steel Strength,  $f_s = f_{sm} = 444.44$   
 #####  
 External Height,  $H = 450.00$   
 External Width,  $W = 450.00$   
 Internal Height,  $H = 250.00$   
 Internal Width,  $W = 250.00$   
 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,  $M_a = -5.3402437E-010$   
 Shear Force,  $V_a = 2.6378276E-013$   
 EDGE -B-  
 Bending Moment,  $M_b = -2.5732098E-010$   
 Shear Force,  $V_b = -2.6378276E-013$   
 BOTH EDGES  
 Axial Force,  $F = -7502.094$   
 Longitudinal Reinforcement Area Distribution (in 2 divisions)  
 -Tension:  $A_{sl,t} = 1137.257$   
 -Compression:  $A_{sl,c} = 1539.38$   
 Longitudinal Reinforcement Area Distribution (in 3 divisions)  
 -Tension:  $A_{sl,ten} = 1137.257$   
 -Compression:  $A_{sl,com} = 1137.257$   
 -Middle:  $A_{sl,mid} = 402.1239$   
 Mean Diameter of Tension Reinforcement,  $Db_{L,ten} = 16.80$

-----  
 Existing component: From table 7-7, ASCE 41\_17: Final Shear Capacity  $V_R = \phi V_n = 447100.239$   
 $V_n ((10.3), ASCE 41-17) = knl * V_{CoI0} = 526000.281$   
 $V_{CoI} = 526000.281$   
 $knl = 1.00$   
 $displacement\_ductility\_demand = 0.00$

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

-----  
 $= 1$  (normal-weight concrete)  
 Mean concrete strength:  $f_c' = (f_c'_{jacket} * Area_{jacket} + f_c'_{core} * Area_{core}) / Area_{section} = 22.22222$ , but  $f_c'^{0.5} < =$   
 8.3 MPa (22.5.3.1, ACI 318-14)  
 $M / Vd = 2.00$   
 $M_u = 5.3402437E-010$   
 $V_u = 2.6378276E-013$   
 $d = 0.8 * h = 360.00$   
 $N_u = 7502.094$

Ag = 202500.00  
From (11.5.4.8), ACI 318-14: Vs = Vs1 + Vs2 = 129852.496  
where:

Vs1 = 62831.853 is calculated for jacket, with:  
d = 360.00  
Av = 157079.633  
fy = 500.00  
s = 300.00

Vs1 is multiplied by Col1 = 0.66666667  
s/d = 0.83333333

Vs2 = 67020.643 is calculated for core, with:  
d = 200.00  
Av = 100530.965  
fy = 400.00  
s = 120.00

Vs2 is multiplied by Col2 = 1.00  
s/d = 0.60

Vf ((11-3)-(11.4), ACI 440) = 214457.247  
f = 0.95, for fully-wrapped sections

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

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

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

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

Vf = Min(|Vf(45,  $\theta$ )|, |Vf(-45, a1)|), with:  
total thickness per orientation, tf1 = NL\*t/NoDir = 1.016

dfv = d (figure 11.2, ACI 440) = 407.00

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 <= 507312.442  
bw = 450.00

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

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

-----  
From analysis, chord rotation  $\theta = 7.9205223E-023$

y = (My\*Ls/3)/Elev = 0.00325023 ((4.29), Biskinis Phd)

My = 1.7613E+008

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

From table 10.5, ASCE 41\_17: Elev = factor\*Ec\*Ig = 2.7095E+013

factor = 0.30

Ag = 202500.00

Mean concrete strength: fc' = (fc'\_jacket\*Area\_jacket + fc'\_core\*Area\_core)/Area\_section = 28.98765

N = 7502.094

Ec\*Ig = Ec\_jacket\*Ig\_jacket + Ec\_core\*Ig\_core = 9.0315E+013

-----  
Calculation of Yielding Moment My

-----  
Calculation of  $\delta / y$  and My according to Annex 7 -

-----  
y = Min( y\_ten, y\_com)

y\_ten = 6.1806717E-006

with ((10.1), ASCE 41-17) fy = Min(fy, 1.25\*fy\*(lb/d)^2/3) = 374.3546

d = 407.00

y = 0.25591399

A = 0.01472387

B = 0.00818866

with pt = 0.00620943

pc = 0.00620943  
pv = 0.0021956  
N = 7502.094  
b = 450.00  
" = 0.10565111  
y\_comp = 2.2127287E-005  
with fc\* (12.3, (ACI 440)) = 34.40847  
fc = 33.00  
fl = 0.82797802  
b = 450.00  
h = 450.00  
Ag = 202500.00  
From (12.9), ACI 440: ka = 0.54261599  
g = pt + pc + pv = 0.01461445  
rc = 40.00  
Ae/Ac = 0.54261599  
Effective FRP thickness, tf = NL\*t\*Cos(b1) = 1.016  
effective strain from (12.5) and (12.12), efe = 0.004  
fu = 0.01  
Ef = 64828.00  
Ec = 26999.444  
y = 0.25471852  
A = 0.01452517  
B = 0.00807924  
with Es = 200000.00

-----  
-----  
Calculation of ratio lb/ld

-----  
Lap Length: ld/ld,min = 0.42476573

lb = 300.00

ld = 706.2717

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

= 1

db = 16.66667

Mean strength value of all re-bars: fy = 524.4464

Mean concrete strength: fc' = (fc'\_jacket\*Area\_jacket + fc'\_core\*Area\_core)/Area\_section = 28.98765, 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 = 2.86234

Atr = Min(Atr\_x,Atr\_y) = 257.6106

where Atr\_x, Atr\_y are the sum of the area of all stirrup legs along X and Y local axis

s = Max(s\_external,s\_internal) = 300.00

n = 12.00

-----  
End Of Calculation of Shear Capacity for element: column JC1 of floor 1

At local axis: 3

Integration Section: (a)

-----  
**Calculation No. 12**

column C1, Floor 1

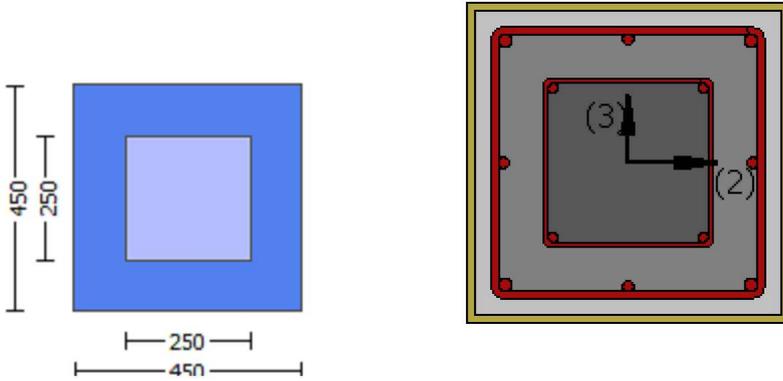
Limit State: Collapse Prevention (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity ( $\theta_u$ )

Edge: Start

Local Axis: (3)



Start Of Calculation of Shear Capacity ratio for element: column JC1 of floor 1

At Shear local axis: 3

(Bending local axis: 2)

Section Type: rcjrs

Constant Properties

Knowledge Factor,  $\gamma = 0.85$

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 Height,  $H = 450.00$

External Width,  $W = 450.00$

Internal Height,  $H = 250.00$

Internal Width,  $W = 250.00$

Cover Thickness,  $c = 25.00$

Mean Confinement Factor overall section = 1.10542

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,  $ε_{fu} = 0.01$

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

Fiber orientations,  $b_i = 0.00^\circ$

Number of layers,  $N_L = 1$

Radius of rounding corners,  $R = 40.00$

Stepwise Properties

At local axis: 3

EDGE -A-

Shear Force,  $V_a = 2.0531359E-031$

EDGE -B-

Shear Force,  $V_b = -2.0531359E-031$

BOTH EDGES

Axial Force,  $F = -7506.808$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension:  $A_{sl,t} = 0.00$

-Compression:  $A_{sl,c} = 2676.637$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension:  $A_{sl,ten} = 1137.257$

-Compression:  $A_{sl,com} = 1137.257$

-Middle:  $A_{sl,mid} = 402.1239$

Calculation of Shear Capacity ratio,  $V_e/V_r = 0.26068017$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 147952.607$

with

$M_{pr1} = \text{Max}(M_{u1+}, M_{u1-}) = 2.2193E+008$

$M_{u1+} = 2.2193E+008$ , 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

$M_{u1-} = 2.2193E+008$ , 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

$M_{pr2} = \text{Max}(M_{u2+}, M_{u2-}) = 2.2193E+008$

$M_{u2+} = 2.2193E+008$ , 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

$M_{u2-} = 2.2193E+008$ , 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 curvature  $\phi_u$  according to 4.1, Biskinis/Fardis 2013:

$\phi_u = 1.9632832E-005$

$M_u = 2.2193E+008$

with full section properties:

$b = 450.00$

$d = 407.00$

$d' = 43.00$

$v = 0.00124204$

$N = 7506.808$

$f_c = 33.00$

$\phi_0$  (5A.5, TBDY) = 0.002

Final value of  $c_u$ :  $c_u^* = \text{shear\_factor} * \text{Max}(c_u, c_c) = 0.01393923$

The Shear\_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY:  $c_u = 0.01393923$

$w_e$  ((5.4c), TBDY) =  $ase * sh_{min} * fy_{we} / f_{ce} + \text{Min}(f_x, f_y) = 0.06811101$

where  $f = af * pf * f_{fe} / f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

-----  
 $f_x = 0.06628267$

$af = 0.54930041$

$b = 450.00$

$h = 450.00$

From EC8 A.4.4.3(6),  $pf = 2tf/bw = 0.00451556$

$bw = 450.00$

effective stress from (A.35),  $f_{f,e} = 881.8461$

-----  
 $f_y = 0.06628267$

$af = 0.54930041$

$b = 450.00$

$h = 450.00$

From EC8 A.4.4.3(6),  $pf = 2tf/bw = 0.00451556$

$bw = 450.00$

effective stress from (A.35),  $f_{f,e} = 881.8461$

-----  
 $R = 40.00$

Effective FRP thickness,  $tf = NL * t * \text{Cos}(b1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{,f} = 0.015$

$ase$  ((5.4d), TBDY) =  $(ase1 * A_{ext} + ase2 * A_{int}) / A_{sec} = 0.14546167$

$ase1 = 0.12623274$

$bo_{,1} = 390.00$

$ho_{,1} = 390.00$

$bi_{2,1} = 608400.00$

$ase2 = \text{Max}(ase1, ase2) = 0.18853448$

$bo_{,2} = 242.00$

$ho_{,2} = 242.00$

$bi_{2,2} = 234256.00$

$psh_{min} * fy_{we} = \text{Min}(psh_x * fy_{we}, psh_y * fy_{we}) = 1.38262$

Expression ((5.4d), TBDY) for  $psh_{min} * fy_{we}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

-----  
 $psh_x * fy_{we} = psh1 * fy_{we1} + ps2 * fy_{we2} = 1.38262$

$ps1$  (external) =  $(Ash1 * h1 / s1) / A_{sec} = 0.00116355$

$Ash1 = Astir_{,1} * ns_{,1} = 157.0796$

No stirrups,  $ns_{,1} = 2.00$

$h1 = 450.00$

$ps2$  (internal) =  $(Ash2 * h2 / s2) / A_{sec} = 0.00103427$

$Ash2 = Astir_{,2} * ns_{,2} = 100.531$

No stirrups,  $ns_{,2} = 2.00$

$h2 = 250.00$

-----  
 $psh_y * fy_{we} = psh1 * fy_{we1} + ps2 * fy_{we2} = 1.38262$

$ps1$  (external) =  $(Ash1 * h1 / s1) / A_{sec} = 0.00116355$

$Ash1 = Astir_{,1} * ns_{,1} = 157.0796$

No stirrups,  $ns_{,1} = 2.00$

$h1 = 450.00$

$ps2$  (internal) =  $(Ash2 * h2 / s2) / A_{sec} = 0.00103427$

$Ash2 = Astir_{,2} * ns_{,2} = 100.531$

No stirrups,  $ns_{,2} = 2.00$

$h2 = 250.00$

-----  
 $A_{sec} = 202500.00$

$s1 = 300.00$

$s2 = 120.00$

$fy_{we1} = 694.45$

$fy_{we2} = 555.55$

$f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.00305417$

$c = \text{confinement factor} = 1.10542$   
 $y1 = 0.00152175$   
 $sh1 = 0.0048696$   
 $ft1 = 479.7871$   
 $fy1 = 399.8226$   
 $su1 = 0.0066488$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 Shear\_factor = 1.00  
 $lo/lou,min = lb/ld = 0.33981258$   
 $su1 = 0.4 * esu1\_nominal ((5.5), TBDY) = 0.032$   
 From table 5A.1, TBDY:  $esu1\_nominal = 0.08$ ,  
 For calculation of  $esu1\_nominal$  and  $y1, sh1, ft1, fy1$ , it is considered  
 characteristic value  $fsy1 = fs1/1.2$ , from table 5.1, TBDY.  
 $y1, sh1, ft1, fy1$ , are also multiplied by  $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with  $fs1 = (fs,jacket * Asl,ten,jacket + fs,core * Asl,ten,core) / Asl,ten = 399.8226$   
 with  $Es1 = (Es,jacket * Asl,ten,jacket + Es,core * Asl,ten,core) / Asl,ten = 200000.00$   
 $y2 = 0.00152175$   
 $sh2 = 0.0048696$   
 $ft2 = 479.7871$   
 $fy2 = 399.8226$   
 $su2 = 0.0066488$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 Shear\_factor = 1.00  
 $lo/lou,min = lb/lb,min = 0.33981258$   
 $su2 = 0.4 * esu2\_nominal ((5.5), TBDY) = 0.032$   
 From table 5A.1, TBDY:  $esu2\_nominal = 0.08$ ,  
 For calculation of  $esu2\_nominal$  and  $y2, sh2, ft2, fy2$ , it is considered  
 characteristic value  $fsy2 = fs2/1.2$ , from table 5.1, TBDY.  
 $y1, sh1, ft1, fy1$ , are also multiplied by  $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with  $fs2 = (fs,jacket * Asl,com,jacket + fs,core * Asl,com,core) / Asl,com = 399.8226$   
 with  $Es2 = (Es,jacket * Asl,com,jacket + Es,core * Asl,com,core) / Asl,com = 200000.00$   
 $yv = 0.00152175$   
 $shv = 0.0048696$   
 $ftv = 507.2537$   
 $fyv = 422.7114$   
 $su2 = 0.0066488$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 Shear\_factor = 1.00  
 $lo/lou,min = lb/ld = 0.33981258$   
 $su2 = 0.4 * esuv\_nominal ((5.5), TBDY) = 0.032$   
 From table 5A.1, TBDY:  $esuv\_nominal = 0.08$ ,  
 considering characteristic value  $fsyv = fsv/1.2$ , from table 5.1, TBDY  
 For calculation of  $esuv\_nominal$  and  $yv, shv, ftv, fyv$ , it is considered  
 characteristic value  $fsyv = fsv/1.2$ , from table 5.1, TBDY.  
 $y1, sh1, ft1, fy1$ , are also multiplied by  $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with  $fsv = (fs,jacket * Asl,mid,jacket + fs,mid * Asl,mid,core) / Asl,mid = 422.7114$   
 with  $Es2 = (Es,jacket * Asl,mid,jacket + Es,mid * Asl,mid,core) / Asl,mid = 200000.00$   
 $1 = Asl,ten / (b * d) * (fs1 / fc) = 0.0752324$   
 $2 = Asl,com / (b * d) * (fs2 / fc) = 0.0752324$   
 $v = Asl,mid / (b * d) * (fsv / fc) = 0.02812438$   
 and confined core properties:  
 $b = 390.00$   
 $d = 377.00$   
 $d' = 13.00$   
 $fcc (5A.2, TBDY) = 36.47874$   
 $cc (5A.5, TBDY) = 0.00305417$   
 $c = \text{confinement factor} = 1.10542$   
 $1 = Asl,ten / (b * d) * (fs1 / fc) = 0.09371431$   
 $2 = Asl,com / (b * d) * (fs2 / fc) = 0.09371431$   
 $v = Asl,mid / (b * d) * (fsv / fc) = 0.03503353$   
 Case/Assumption: Unconfined full section - Steel rupture  
 ' satisfies Eq. (4.3)  
 --->  
 $v < vs,y2$  - LHS eq.(4.5) is satisfied

--->

su (4.9) = 0.16791801  
Mu = MRc (4.14) = 2.2193E+008  
u = su (4.1) = 1.9632832E-005

-----  
Calculation of ratio lb/l<sub>d</sub>

-----  
Lap Length: lb/l<sub>d</sub> = 0.33981258

lb = 300.00

l<sub>d</sub> = 882.8396

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

= 1

db = 16.66667

Mean strength value of all re-bars: fy = 655.558

Mean concrete strength: fc' = (fc'\_jacket\*Area\_jacket + fc'\_core\*Area\_core)/Area\_section = 28.98765, 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 = 2.86234

Atr = Min(Atr\_x,Atr\_y) = 257.6106

where Atr\_x, Atr\_y are the sum of the area of all stirrup legs along X and Y loxal axis

s = Max(s\_external,s\_internal) = 300.00

n = 12.00

-----  
Calculation of Mu1-

-----  
Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

u = 1.9632832E-005

Mu = 2.2193E+008

-----  
with full section properties:

b = 450.00

d = 407.00

d' = 43.00

v = 0.00124204

N = 7506.808

fc = 33.00

co (5A.5, TBDY) = 0.002

Final value of cu: cu\* = shear\_factor \* Max( cu, cc) = 0.01393923

The Shear\_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: cu = 0.01393923

we ((5.4c), TBDY) = ase\* sh,min\*fywe/fce+Min( fx, fy) = 0.06811101

where f = af\*pf\*ffe/fce is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

-----  
fx = 0.06628267

af = 0.54930041

b = 450.00

h = 450.00

From EC8 A.4.4.3(6), pf = 2tf/bw = 0.00451556

bw = 450.00

effective stress from (A.35), ff,e = 881.8461

-----  
fy = 0.06628267

af = 0.54930041

b = 450.00

h = 450.00

From EC8 A.4.4.3(6), pf = 2tf/bw = 0.00451556

bw = 450.00

effective stress from (A.35), ff,e = 881.8461

$R = 40.00$   
 Effective FRP thickness,  $t_f = NL * t * \cos(b_1) = 1.016$   
 $f_{u,f} = 1055.00$   
 $E_f = 64828.00$   
 $u_{,f} = 0.015$   
 $ase((5.4d), TBDY) = (ase_1 * A_{ext} + ase_2 * A_{int}) / A_{sec} = 0.14546167$   
 $ase_1 = 0.12623274$   
 $bo_1 = 390.00$   
 $ho_1 = 390.00$   
 $bi_2_1 = 608400.00$   
 $ase_2 = \max(ase_1, ase_2) = 0.18853448$   
 $bo_2 = 242.00$   
 $ho_2 = 242.00$   
 $bi_2_2 = 234256.00$

$psh_{,min} * F_{ywe} = \min(psh_{,x} * F_{ywe}, psh_{,y} * F_{ywe}) = 1.38262$

Expression ((5.4d), TBDY) for  $psh_{,min} * F_{ywe}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$psh_{,x} * F_{ywe} = psh_1 * F_{ywe1} + ps_2 * F_{ywe2} = 1.38262$   
 $ps_1 \text{ (external)} = (Ash_1 * h_1 / s_1) / A_{sec} = 0.00116355$   
 $Ash_1 = Astir_1 * ns_1 = 157.0796$   
 No stirrups,  $ns_1 = 2.00$   
 $h_1 = 450.00$   
 $ps_2 \text{ (internal)} = (Ash_2 * h_2 / s_2) / A_{sec} = 0.00103427$   
 $Ash_2 = Astir_2 * ns_2 = 100.531$   
 No stirrups,  $ns_2 = 2.00$   
 $h_2 = 250.00$

$psh_{,y} * F_{ywe} = psh_1 * F_{ywe1} + ps_2 * F_{ywe2} = 1.38262$   
 $ps_1 \text{ (external)} = (Ash_1 * h_1 / s_1) / A_{sec} = 0.00116355$   
 $Ash_1 = Astir_1 * ns_1 = 157.0796$   
 No stirrups,  $ns_1 = 2.00$   
 $h_1 = 450.00$   
 $ps_2 \text{ (internal)} = (Ash_2 * h_2 / s_2) / A_{sec} = 0.00103427$   
 $Ash_2 = Astir_2 * ns_2 = 100.531$   
 No stirrups,  $ns_2 = 2.00$   
 $h_2 = 250.00$

$A_{sec} = 202500.00$   
 $s_1 = 300.00$   
 $s_2 = 120.00$   
 $f_{ywe1} = 694.45$   
 $f_{ywe2} = 555.55$   
 $f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.00305417$   
 $c = \text{confinement factor} = 1.10542$

$y_1 = 0.00152175$   
 $sh_1 = 0.0048696$   
 $ft_1 = 479.7871$   
 $fy_1 = 399.8226$   
 $su_1 = 0.0066488$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00

$lo/lo_{,min} = lb/ld = 0.33981258$   
 $su_1 = 0.4 * esu_1_{nominal}((5.5), TBDY) = 0.032$

From table 5A.1, TBDY:  $esu_1_{nominal} = 0.08$ ,

For calculation of  $esu_1_{nominal}$  and  $y_1, sh_1, ft_1, fy_1$ , it is considered characteristic value  $fsy_1 = fs_1 / 1.2$ , from table 5.1, TBDY.

$y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\min(1, 1.25 * (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.

with  $fs_1 = (fs_{jacket} * A_{sl,ten,jacket} + fs_{core} * A_{sl,ten,core}) / A_{sl,ten} = 399.8226$

with  $Es_1 = (Es_{jacket} * A_{sl,ten,jacket} + Es_{core} * A_{sl,ten,core}) / A_{sl,ten} = 200000.00$

$y_2 = 0.00152175$   
 $sh_2 = 0.0048696$   
 $ft_2 = 479.7871$   
 $fy_2 = 399.8226$   
 $su_2 = 0.0066488$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

$$l_o/l_{o,min} = l_b/l_{b,min} = 0.33981258$$

$$s_u2 = 0.4 * e_{s_u2,nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY:  $e_{s_u2,nominal} = 0.08$ ,

For calculation of  $e_{s_u2,nominal}$  and  $y_2, sh_2, ft_2, fy_2$ , it is considered  
characteristic value  $f_{s_y2} = f_{s_2}/1.2$ , from table 5.1, TBDY.

$y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.

$$\text{with } f_{s_2} = (f_{s,jacket} * A_{s_l,com,jacket} + f_{s,core} * A_{s_l,com,core}) / A_{s_l,com} = 399.8226$$

$$\text{with } E_{s_2} = (E_{s,jacket} * A_{s_l,com,jacket} + E_{s,core} * A_{s_l,com,core}) / A_{s_l,com} = 200000.00$$

$$y_v = 0.00152175$$

$$sh_v = 0.0048696$$

$$ft_v = 507.2537$$

$$fy_v = 422.7114$$

$$s_{u_v} = 0.0066488$$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

$$l_o/l_{o,min} = l_b/l_d = 0.33981258$$

$$s_{u_v} = 0.4 * e_{s_{u_v},nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY:  $e_{s_{u_v},nominal} = 0.08$ ,

considering characteristic value  $f_{s_{y_v}} = f_{s_v}/1.2$ , from table 5.1, TBDY

For calculation of  $e_{s_{u_v},nominal}$  and  $y_v, sh_v, ft_v, fy_v$ , it is considered  
characteristic value  $f_{s_{y_v}} = f_{s_v}/1.2$ , from table 5.1, TBDY.

$y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.

$$\text{with } f_{s_v} = (f_{s,jacket} * A_{s_l,mid,jacket} + f_{s,mid} * A_{s_l,mid,core}) / A_{s_l,mid} = 422.7114$$

$$\text{with } E_{s_v} = (E_{s,jacket} * A_{s_l,mid,jacket} + E_{s,mid} * A_{s_l,mid,core}) / A_{s_l,mid} = 200000.00$$

$$1 = A_{s_l,ten} / (b * d) * (f_{s_1} / f_c) = 0.0752324$$

$$2 = A_{s_l,com} / (b * d) * (f_{s_2} / f_c) = 0.0752324$$

$$v = A_{s_l,mid} / (b * d) * (f_{s_v} / f_c) = 0.02812438$$

and confined core properties:

$$b = 390.00$$

$$d = 377.00$$

$$d' = 13.00$$

$$f_{cc} (5A.2, TBDY) = 36.47874$$

$$cc (5A.5, TBDY) = 0.00305417$$

$$c = \text{confinement factor} = 1.10542$$

$$1 = A_{s_l,ten} / (b * d) * (f_{s_1} / f_c) = 0.09371431$$

$$2 = A_{s_l,com} / (b * d) * (f_{s_2} / f_c) = 0.09371431$$

$$v = A_{s_l,mid} / (b * d) * (f_{s_v} / f_c) = 0.03503353$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < v_{s,y_2}$  - LHS eq.(4.5) is satisfied

--->

$$s_u (4.9) = 0.16791801$$

$$\mu = MR_c (4.14) = 2.2193E+008$$

$$u = s_u (4.1) = 1.9632832E-005$$

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

Lap Length:  $l_b/l_d = 0.33981258$

$$l_b = 300.00$$

$$l_d = 882.8396$$

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

$$= 1$$

$$d_b = 16.66667$$

Mean strength value of all re-bars:  $f_y = 655.558$

Mean concrete strength:  $f'_c = (f'_c_{jacket} * Area_{jacket} + f'_c_{core} * Area_{core}) / Area_{section} = 28.98765$ , but  $f_c^{0.5} < =$   
8.3 MPa (22.5.3.1, ACI 318-14)

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 25.00$$

$$K_{tr} = 2.86234$$

$$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 257.6106$$

where  $A_{tr_x}$ ,  $A_{tr_y}$  are the sum of the area of all stirrup legs along X and Y local axis

$$s = \text{Max}(s_{\text{external}}, s_{\text{internal}}) = 300.00$$

$$n = 12.00$$

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

-----  
-----  
Calculation of ultimate curvature  $\mu$  according to 4.1, Biskinis/Fardis 2013:

$$\mu = 1.9632832E-005$$

$$M_u = 2.2193E+008$$

-----  
with full section properties:

$$b = 450.00$$

$$d = 407.00$$

$$d' = 43.00$$

$$v = 0.00124204$$

$$N = 7506.808$$

$$f_c = 33.00$$

$$c_o \text{ (5A.5, TBDY)} = 0.002$$

$$\text{Final value of } \mu_c: \mu_c^* = \text{shear\_factor} * \text{Max}(\mu_c, \mu_{cc}) = 0.01393923$$

The Shear\_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \mu_c = 0.01393923$$

$$\mu_{we} \text{ ((5.4c), TBDY)} = a_{se} * \text{sh}_{\text{min}} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.06811101$$

where  $f = a_f * p_f * f_{fe} / f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.06628267$$

$$a_f = 0.54930041$$

$$b = 450.00$$

$$h = 450.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.00451556$$

$$b_w = 450.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 881.8461$$

$$f_y = 0.06628267$$

$$a_f = 0.54930041$$

$$b = 450.00$$

$$h = 450.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.00451556$$

$$b_w = 450.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 881.8461$$

$$R = 40.00$$

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

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$a_{se} \text{ ((5.4d), TBDY)} = (a_{se1} * A_{ext} + a_{se2} * A_{int}) / A_{sec} = 0.14546167$$

$$a_{se1} = 0.12623274$$

$$b_{o,1} = 390.00$$

$$h_{o,1} = 390.00$$

$$b_{i,1} = 608400.00$$

$$a_{se2} = \text{Max}(a_{se1}, a_{se2}) = 0.18853448$$

$$b_{o,2} = 242.00$$

$$h_{o,2} = 242.00$$

$$b_{i,2} = 234256.00$$

$$p_{sh,\text{min}} * f_{ywe} = \text{Min}(p_{sh,x} * f_{ywe}, p_{sh,y} * f_{ywe}) = 1.38262$$

Expression ((5.4d), TBDY) for  $p_{sh,\text{min}} * f_{ywe}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$$p_{sh_x} * f_{ywe} = p_{sh1} * f_{ywe1} + p_{sh2} * f_{ywe2} = 1.38262$$

$$p_{s1} \text{ (external)} = (A_{sh1} * h_1 / s_1) / A_{sec} = 0.00116355$$

$$A_{sh1} = A_{stir,1} * n_{s,1} = 157.0796$$

$$\text{No stirrups, } n_{s,1} = 2.00$$

h1 = 450.00  
ps2 (internal) = (Ash2\*h2/s2)/Asec = 0.00103427  
Ash2 = Astir\_2\*ns\_2 = 100.531  
No stirups, ns\_2 = 2.00  
h2 = 250.00

-----  
psh\_y\*Fywe = psh1\*Fywe1+ps2\*Fywe2 = 1.38262  
ps1 (external) = (Ash1\*h1/s1)/Asec = 0.00116355  
Ash1 = Astir\_1\*ns\_1 = 157.0796  
No stirups, ns\_1 = 2.00  
h1 = 450.00  
ps2 (internal) = (Ash2\*h2/s2)/Asec = 0.00103427  
Ash2 = Astir\_2\*ns\_2 = 100.531  
No stirups, ns\_2 = 2.00  
h2 = 250.00

-----  
Asec = 202500.00  
s1 = 300.00  
s2 = 120.00  
fywe1 = 694.45  
fywe2 = 555.55  
fce = 33.00

From ((5.A5), TBDY), TBDY: cc = 0.00305417  
c = confinement factor = 1.10542

y1 = 0.00152175  
sh1 = 0.0048696  
ft1 = 479.7871  
fy1 = 399.8226  
su1 = 0.0066488

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

lo/lou,min = lb/d = 0.33981258

su1 = 0.4\*esu1\_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu1\_nominal = 0.08,

For calculation of esu1\_nominal and y1, sh1,ft1,fy1, it is considered  
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25\*(lb/d)^ 2/3), from 10.3.5, ASCE 41-17.

with fs1 = (fs,jacket\*Asl,ten,jacket + fs,core\*Asl,ten,core)/Asl,ten = 399.8226

with Es1 = (Es,jacket\*Asl,ten,jacket + Es,core\*Asl,ten,core)/Asl,ten = 200000.00

y2 = 0.00152175  
sh2 = 0.0048696  
ft2 = 479.7871  
fy2 = 399.8226  
su2 = 0.0066488

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

lo/lou,min = lb/lb,min = 0.33981258

su2 = 0.4\*esu2\_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu2\_nominal = 0.08,

For calculation of esu2\_nominal and y2, sh2,ft2,fy2, it is considered  
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25\*(lb/d)^ 2/3), from 10.3.5, ASCE 41-17.

with fs2 = (fs,jacket\*Asl,com,jacket + fs,core\*Asl,com,core)/Asl,com = 399.8226

with Es2 = (Es,jacket\*Asl,com,jacket + Es,core\*Asl,com,core)/Asl,com = 200000.00

yv = 0.00152175  
shv = 0.0048696  
ftv = 507.2537  
fyv = 422.7114  
suv = 0.0066488

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

lo/lou,min = lb/d = 0.33981258

suv = 0.4\*esuv\_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esuv\_nominal = 0.08,

considering characteristic value  $f_{sv} = f_{sv}/1.2$ , from table 5.1, TBDY  
For calculation of  $e_{suv\_nominal}$  and  $y_v, sh_v, ft_v, fy_v$ , it is considered characteristic value  $f_{sv} = f_{sv}/1.2$ , from table 5.1, TBDY.

$y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.

with  $f_{sv} = (f_{s,jacket} \cdot A_{s,mid,jacket} + f_{s,mid} \cdot A_{s,mid,core}) / A_{s,mid} = 422.7114$

with  $E_{sv} = (E_{s,jacket} \cdot A_{s,mid,jacket} + E_{s,mid} \cdot A_{s,mid,core}) / A_{s,mid} = 200000.00$

1 =  $A_{s,ten} / (b \cdot d) \cdot (f_{s1} / f_c) = 0.0752324$

2 =  $A_{s,com} / (b \cdot d) \cdot (f_{s2} / f_c) = 0.0752324$

$v = A_{s,mid} / (b \cdot d) \cdot (f_{sv} / f_c) = 0.02812438$

and confined core properties:

$b = 390.00$

$d = 377.00$

$d' = 13.00$

$f_{cc}$  (5A.2, TBDY) = 36.47874

$cc$  (5A.5, TBDY) = 0.00305417

$c$  = confinement factor = 1.10542

1 =  $A_{s,ten} / (b \cdot d) \cdot (f_{s1} / f_c) = 0.09371431$

2 =  $A_{s,com} / (b \cdot d) \cdot (f_{s2} / f_c) = 0.09371431$

$v = A_{s,mid} / (b \cdot d) \cdot (f_{sv} / f_c) = 0.03503353$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < v_{s,y2}$  - LHS eq.(4.5) is satisfied

--->

$su$  (4.9) = 0.16791801

$Mu = MRc$  (4.14) = 2.2193E+008

$u = su$  (4.1) = 1.9632832E-005

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

Lap Length:  $l_b/l_d = 0.33981258$

$l_b = 300.00$

$l_d = 882.8396$

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

= 1

$db = 16.66667$

Mean strength value of all re-bars:  $f_y = 655.558$

Mean concrete strength:  $f'_c = (f'_{c,jacket} \cdot Area_{jacket} + f'_{c,core} \cdot Area_{core}) / Area_{section} = 28.98765$ , but  $f_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 2.86234$

$A_{tr} = \text{Min}(A_{tr,x}, A_{tr,y}) = 257.6106$

where  $A_{tr,x}, A_{tr,y}$  are the sum of the area of all stirrup legs along X and Y loxal axis

$s = \text{Max}(s_{external}, s_{internal}) = 300.00$

$n = 12.00$

-----  
Calculation of  $Mu_2$ -

-----  
Calculation of ultimate curvature  $u$  according to 4.1, Biskinis/Fardis 2013:

$u = 1.9632832E-005$

$Mu = 2.2193E+008$

-----  
with full section properties:

$b = 450.00$

$d = 407.00$

$d' = 43.00$

$v = 0.00124204$

$N = 7506.808$

$f_c = 33.00$

$$c_o (5A.5, TBDY) = 0.002$$

$$\text{Final value of } c_u: c_u^* = \text{shear\_factor} * \text{Max}(c_u, c_c) = 0.01393923$$

The Shear\_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } c_u = 0.01393923$$

$$w_e ((5.4c), TBDY) = a_{se} * s_{h,min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.06811101$$

where  $f = a_f * p_f * f_{fe}/f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.06628267$$

$$a_f = 0.54930041$$

$$b = 450.00$$

$$h = 450.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.00451556$$

$$b_w = 450.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 881.8461$$

$$f_y = 0.06628267$$

$$a_f = 0.54930041$$

$$b = 450.00$$

$$h = 450.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.00451556$$

$$b_w = 450.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 881.8461$$

$$R = 40.00$$

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

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$a_{se} ((5.4d), TBDY) = (a_{se1} * A_{ext} + a_{se2} * A_{int})/A_{sec} = 0.14546167$$

$$a_{se1} = 0.12623274$$

$$b_{o,1} = 390.00$$

$$h_{o,1} = 390.00$$

$$b_{i,2,1} = 608400.00$$

$$a_{se2} = \text{Max}(a_{se1}, a_{se2}) = 0.18853448$$

$$b_{o,2} = 242.00$$

$$h_{o,2} = 242.00$$

$$b_{i,2,2} = 234256.00$$

$$p_{sh,min} * F_{ywe} = \text{Min}(p_{sh,x} * F_{ywe}, p_{sh,y} * F_{ywe}) = 1.38262$$

Expression ((5.4d), TBDY) for  $p_{sh,min} * F_{ywe}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$$p_{sh,x} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{sh2} * F_{ywe2} = 1.38262$$

$$p_{s1} (\text{external}) = (A_{sh1} * h_1/s_1)/A_{sec} = 0.00116355$$

$$A_{sh1} = A_{stir,1} * n_{s,1} = 157.0796$$

$$\text{No stirrups, } n_{s,1} = 2.00$$

$$h_1 = 450.00$$

$$p_{s2} (\text{internal}) = (A_{sh2} * h_2/s_2)/A_{sec} = 0.00103427$$

$$A_{sh2} = A_{stir,2} * n_{s,2} = 100.531$$

$$\text{No stirrups, } n_{s,2} = 2.00$$

$$h_2 = 250.00$$

$$p_{sh,y} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{sh2} * F_{ywe2} = 1.38262$$

$$p_{s1} (\text{external}) = (A_{sh1} * h_1/s_1)/A_{sec} = 0.00116355$$

$$A_{sh1} = A_{stir,1} * n_{s,1} = 157.0796$$

$$\text{No stirrups, } n_{s,1} = 2.00$$

$$h_1 = 450.00$$

$$p_{s2} (\text{internal}) = (A_{sh2} * h_2/s_2)/A_{sec} = 0.00103427$$

$$A_{sh2} = A_{stir,2} * n_{s,2} = 100.531$$

$$\text{No stirrups, } n_{s,2} = 2.00$$

$$h_2 = 250.00$$

$$A_{sec} = 202500.00$$

$$s_1 = 300.00$$

$$s_2 = 120.00$$

$$f_{ywe1} = 694.45$$

$$f_{ywe2} = 555.55$$

$$f_{ce} = 33.00$$

From ((5.A.5), TBDY), TBDY:  $cc = 0.00305417$   
 $c = \text{confinement factor} = 1.10542$

$y1 = 0.00152175$

$sh1 = 0.0048696$

$ft1 = 479.7871$

$fy1 = 399.8226$

$su1 = 0.0066488$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

$lo/lou,min = lb/ld = 0.33981258$

$su1 = 0.4 * esu1\_nominal ((5.5), TBDY) = 0.032$

From table 5A.1, TBDY:  $esu1\_nominal = 0.08$ ,

For calculation of  $esu1\_nominal$  and  $y1, sh1, ft1, fy1$ , it is considered  
characteristic value  $fsy1 = fs1/1.2$ , from table 5.1, TBDY.

$y1, sh1, ft1, fy1$ , are also multiplied by  $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.

with  $fs1 = (fs\_jacket * Asl,ten,jacket + fs\_core * Asl,ten,core) / Asl,ten = 399.8226$

with  $Es1 = (Es\_jacket * Asl,ten,jacket + Es\_core * Asl,ten,core) / Asl,ten = 200000.00$

$y2 = 0.00152175$

$sh2 = 0.0048696$

$ft2 = 479.7871$

$fy2 = 399.8226$

$su2 = 0.0066488$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

$lo/lou,min = lb/lb,min = 0.33981258$

$su2 = 0.4 * esu2\_nominal ((5.5), TBDY) = 0.032$

From table 5A.1, TBDY:  $esu2\_nominal = 0.08$ ,

For calculation of  $esu2\_nominal$  and  $y2, sh2, ft2, fy2$ , it is considered  
characteristic value  $fsy2 = fs2/1.2$ , from table 5.1, TBDY.

$y1, sh1, ft1, fy1$ , are also multiplied by  $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.

with  $fs2 = (fs\_jacket * Asl,com,jacket + fs\_core * Asl,com,core) / Asl,com = 399.8226$

with  $Es2 = (Es\_jacket * Asl,com,jacket + Es\_core * Asl,com,core) / Asl,com = 200000.00$

$yv = 0.00152175$

$shv = 0.0048696$

$ftv = 507.2537$

$fyv = 422.7114$

$suv = 0.0066488$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

$lo/lou,min = lb/ld = 0.33981258$

$suv = 0.4 * esuv\_nominal ((5.5), TBDY) = 0.032$

From table 5A.1, TBDY:  $esuv\_nominal = 0.08$ ,

considering characteristic value  $fsyv = fsv/1.2$ , from table 5.1, TBDY

For calculation of  $esuv\_nominal$  and  $yv, shv, ftv, fyv$ , it is considered  
characteristic value  $fsyv = fsv/1.2$ , from table 5.1, TBDY.

$y1, sh1, ft1, fy1$ , are also multiplied by  $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.

with  $fsv = (fs\_jacket * Asl,mid,jacket + fs\_mid * Asl,mid,core) / Asl,mid = 422.7114$

with  $Esv = (Es\_jacket * Asl,mid,jacket + Es\_mid * Asl,mid,core) / Asl,mid = 200000.00$

$1 = Asl,ten / (b * d) * (fs1 / fc) = 0.0752324$

$2 = Asl,com / (b * d) * (fs2 / fc) = 0.0752324$

$v = Asl,mid / (b * d) * (fsv / fc) = 0.02812438$

and confined core properties:

$b = 390.00$

$d = 377.00$

$d' = 13.00$

$fcc (5A.2, TBDY) = 36.47874$

$cc (5A.5, TBDY) = 0.00305417$

$c = \text{confinement factor} = 1.10542$

$1 = Asl,ten / (b * d) * (fs1 / fc) = 0.09371431$

$2 = Asl,com / (b * d) * (fs2 / fc) = 0.09371431$

$v = Asl,mid / (b * d) * (fsv / fc) = 0.03503353$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < v_s, y_2$  - LHS eq.(4.5) is satisfied

--->

$$s_u(4.9) = 0.16791801$$

$$M_u = M_{Rc}(4.14) = 2.2193E+008$$

$$u = s_u(4.1) = 1.9632832E-005$$

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

-----  
Lap Length:  $l_b/l_d = 0.33981258$

$$l_b = 300.00$$

$$l_d = 882.8396$$

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

$$= 1$$

$$d_b = 16.66667$$

Mean strength value of all re-bars:  $f_y = 655.558$

Mean concrete strength:  $f_c' = (f_c'_{jacket} \cdot Area_{jacket} + f_c'_{core} \cdot Area_{core}) / Area_{section} = 28.98765$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 25.00$$

$$K_{tr} = 2.86234$$

$$A_{tr} = \min(A_{tr_x}, A_{tr_y}) = 257.6106$$

where  $A_{tr_x}, A_{tr_y}$  are the sum of the area of all stirrup legs along X and Y local axis

$$s = \max(s_{external}, s_{internal}) = 300.00$$

$$n = 12.00$$

-----  
-----  
-----  
Calculation of Shear Strength  $V_r = \min(V_{r1}, V_{r2}) = 567563.724$

-----  
Calculation of Shear Strength at edge 1,  $V_{r1} = 567563.724$

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

$$V_{Col0} = 567563.724$$

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

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

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

Mean concrete strength:  $f_c' = (f_c'_{jacket} \cdot Area_{jacket} + f_c'_{core} \cdot Area_{core}) / Area_{section} = 28.98765$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$$M/Vd = 2.00$$

$$M_u = 1.4404090E-011$$

$$V_u = 2.0531359E-031$$

$$d = 0.8 \cdot h = 360.00$$

$$N_u = 7506.808$$

$$A_g = 202500.00$$

$$\text{From (11.5.4.8), ACI 318-14: } V_s = V_{s1} + V_{s2} = 144280.365$$

where:

$V_{s1} = 69813.729$  is calculated for jacket, with:

$$d = 360.00$$

$$A_v = 157079.633$$

$$f_y = 555.56$$

$$s = 300.00$$

$V_{s1}$  is multiplied by  $Col1 = 0.66666667$

$$s/d = 0.83333333$$

$V_{s2} = 74466.637$  is calculated for core, with:

$$d = 200.00$$

$$A_v = 100530.965$$

$$f_y = 444.44$$

$$s = 120.00$$

$V_{s2}$  is multiplied by  $Col2 = 1.00$

$$s/d = 0.60$$

$$V_f \text{ ((11-3)-(11.4), ACI 440) } = 214457.247$$

$f = 0.95$ , for fully-wrapped sections  
 $wf/sf = 1$  (FRP strips adjacent to one another).  
 In (11.3)  $\sin + \cos$  is replaced with  $(\cot + \cot a)\sin a$  which is more a generalised expression,  
 where  $a$  is the angle of the crack direction (see KANEPE).  
 This later relation, considered as a function  $V_f(\theta)$ , is implemented for every different fiber orientation  $a_i$ ,  
 as well as for 2 crack directions,  $\theta = 45^\circ$  and  $\theta = -45^\circ$  to take into consideration the cyclic seismic loading.  
 orientation 1:  $\theta = b1 + 90^\circ = 90.00$   
 $V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, a1)|)$ , with:  
 total thickness per orientation,  $tf1 = NL * t / \text{NoDir} = 1.016$   
 $dfv = d$  (figure 11.2, ACI 440) = 407.00  
 $ffe$  ((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:  $V_s + V_f \leq 579413.096$   
 $bw = 450.00$

Calculation of Shear Strength at edge 2,  $V_{r2} = 567563.724$   
 $V_{r2} = V_{Col}$  ((10.3), ASCE 41-17) =  $knl * V_{Col0}$   
 $V_{Col0} = 567563.724$   
 $knl = 1$  (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).

$\gamma = 1$  (normal-weight concrete)  
 Mean concrete strength:  $f_c' = (f_c'_{jacket} * Area_{jacket} + f_c'_{core} * Area_{core}) / Area_{section} = 28.98765$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M / Vd = 2.00$   
 $\mu_u = 1.4404090E-011$   
 $\nu_u = 2.0531359E-031$   
 $d = 0.8 * h = 360.00$   
 $N_u = 7506.808$   
 $A_g = 202500.00$   
 From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 144280.365$   
 where:

$V_{s1} = 69813.729$  is calculated for jacket, with:  
 $d = 360.00$   
 $A_v = 157079.633$   
 $f_y = 555.56$   
 $s = 300.00$

$V_{s1}$  is multiplied by  $Col1 = 0.66666667$   
 $s/d = 0.833333333$

$V_{s2} = 74466.637$  is calculated for core, with:  
 $d = 200.00$   
 $A_v = 100530.965$   
 $f_y = 444.44$   
 $s = 120.00$

$V_{s2}$  is multiplied by  $Col2 = 1.00$   
 $s/d = 0.60$

$V_f$  ((11-3)-(11.4), ACI 440) = 214457.247  
 $f = 0.95$ , for fully-wrapped sections

$wf/sf = 1$  (FRP strips adjacent to one another).  
 In (11.3)  $\sin + \cos$  is replaced with  $(\cot + \cot a)\sin a$  which is more a generalised expression,  
 where  $a$  is the angle of the crack direction (see KANEPE).  
 This later relation, considered as a function  $V_f(\theta)$ , is implemented for every different fiber orientation  $a_i$ ,  
 as well as for 2 crack directions,  $\theta = 45^\circ$  and  $\theta = -45^\circ$  to take into consideration the cyclic seismic loading.

orientation 1:  $\theta = b1 + 90^\circ = 90.00$   
 $V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, a1)|)$ , with:  
 total thickness per orientation,  $tf1 = NL * t / \text{NoDir} = 1.016$   
 $dfv = d$  (figure 11.2, ACI 440) = 407.00  
 $ffe$  ((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:  $V_s + V_f \leq 579413.096$

bw = 450.00

End Of Calculation of Shear Capacity ratio for element: column JC1 of floor 1  
At local axis: 3

Start Of Calculation of Shear Capacity ratio for element: column JC1 of floor 1  
At Shear local axis: 2  
(Bending local axis: 3)  
Section Type: rcjrs

Constant Properties

Knowledge Factor,  $\gamma = 0.85$   
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 Height,  $H = 450.00$

External Width,  $W = 450.00$

Internal Height,  $H = 250.00$

Internal Width,  $W = 250.00$

Cover Thickness,  $c = 25.00$

Mean Confinement Factor overall section = 1.10542

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,  $NoDir = 1$

Fiber orientations,  $bi: 0.00^\circ$

Number of layers,  $NL = 1$

Radius of rounding corners,  $R = 40.00$

Stepwise Properties

At local axis: 2

EDGE -A-

Shear Force,  $V_a = -2.7162834E-031$

EDGE -B-

Shear Force,  $V_b = 2.7162834E-031$

BOTH EDGES

Axial Force,  $F = -7506.808$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension:  $As_{lt} = 0.00$

-Compression:  $As_{lc} = 2676.637$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension:  $As_{l,ten} = 1137.257$

-Compression:  $As_{l,com} = 1137.257$

-Middle:  $As_{l,mid} = 402.1239$

Calculation of Shear Capacity ratio,  $V_e/V_r = 0.26068017$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 147952.607$

with

$M_{pr1} = \text{Max}(Mu_{1+}, Mu_{1-}) = 2.2193E+008$

$Mu_{1+} = 2.2193E+008$ , 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

$Mu_{1-} = 2.2193E+008$ , 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

$M_{pr2} = \text{Max}(Mu_{2+}, Mu_{2-}) = 2.2193E+008$

$Mu_{2+} = 2.2193E+008$ , 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

$Mu_{2-} = 2.2193E+008$ , 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 curvature  $\phi_u$  according to 4.1, Biskinis/Fardis 2013:

$\phi_u = 1.9632832E-005$

$M_u = 2.2193E+008$

with full section properties:

$b = 450.00$

$d = 407.00$

$d' = 43.00$

$v = 0.00124204$

$N = 7506.808$

$f_c = 33.00$

$\alpha_{co}$  (5A.5, TBDY) = 0.002

Final value of  $\phi_u$ :  $\phi_u^* = \text{shear\_factor} * \text{Max}(\phi_u, \phi_c) = 0.01393923$

The Shear\_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY:  $\phi_u = 0.01393923$

$\phi_{we}$  ((5.4c), TBDY) =  $\alpha_{se} * \phi_{sh,min} * f_{ywe}/f_{ce} + \text{Min}(\phi_x, \phi_y) = 0.06811101$

where  $\phi = \alpha_{se} * \phi_{sh,min} * f_{ywe}/f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$\phi_x = 0.06628267$

$\alpha_{se} = 0.54930041$

$b = 450.00$

$h = 450.00$

From EC8 A.4.4.3(6),  $\phi_{sh} = 2t_f/b_w = 0.00451556$

$b_w = 450.00$

effective stress from (A.35),  $f_{f,e} = 881.8461$

$\phi_y = 0.06628267$

$\alpha_{se} = 0.54930041$

$b = 450.00$

$h = 450.00$

From EC8 A.4.4.3(6),  $\phi_{sh} = 2t_f/b_w = 0.00451556$

bw = 450.00  
effective stress from (A.35),  $f_{f,e} = 881.8461$

R = 40.00  
Effective FRP thickness,  $t_f = NL * t * \cos(b_1) = 1.016$   
 $f_{u,f} = 1055.00$   
 $E_f = 64828.00$   
 $u_{,f} = 0.015$   
 $ase((5.4d), TBDY) = (ase_1 * A_{ext} + ase_2 * A_{int}) / A_{sec} = 0.14546167$   
 $ase_1 = 0.12623274$   
 $bo_1 = 390.00$   
 $ho_1 = 390.00$   
 $bi_2_1 = 608400.00$   
 $ase_2 = \max(ase_1, ase_2) = 0.18853448$   
 $bo_2 = 242.00$   
 $ho_2 = 242.00$   
 $bi_2_2 = 234256.00$

$p_{sh,min} * F_{ywe} = \min(p_{sh,x} * F_{ywe}, p_{sh,y} * F_{ywe}) = 1.38262$   
Expression ((5.4d), TBDY) for  $p_{sh,min} * F_{ywe}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$p_{sh,x} * F_{ywe} = p_{sh1} * F_{ywe1} + ps_2 * F_{ywe2} = 1.38262$   
 $ps_1$  (external) =  $(Ash_1 * h_1 / s_1) / A_{sec} = 0.00116355$   
 $Ash_1 = Astir_1 * ns_1 = 157.0796$   
No stirrups,  $ns_1 = 2.00$   
 $h_1 = 450.00$   
 $ps_2$  (internal) =  $(Ash_2 * h_2 / s_2) / A_{sec} = 0.00103427$   
 $Ash_2 = Astir_2 * ns_2 = 100.531$   
No stirrups,  $ns_2 = 2.00$   
 $h_2 = 250.00$

$p_{sh,y} * F_{ywe} = p_{sh1} * F_{ywe1} + ps_2 * F_{ywe2} = 1.38262$   
 $ps_1$  (external) =  $(Ash_1 * h_1 / s_1) / A_{sec} = 0.00116355$   
 $Ash_1 = Astir_1 * ns_1 = 157.0796$   
No stirrups,  $ns_1 = 2.00$   
 $h_1 = 450.00$   
 $ps_2$  (internal) =  $(Ash_2 * h_2 / s_2) / A_{sec} = 0.00103427$   
 $Ash_2 = Astir_2 * ns_2 = 100.531$   
No stirrups,  $ns_2 = 2.00$   
 $h_2 = 250.00$

$A_{sec} = 202500.00$   
 $s_1 = 300.00$   
 $s_2 = 120.00$   
 $f_{ywe1} = 694.45$   
 $f_{ywe2} = 555.55$   
 $f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.00305417$   
 $c =$  confinement factor = 1.10542

$y_1 = 0.00152175$   
 $sh_1 = 0.0048696$   
 $ft_1 = 479.7871$   
 $fy_1 = 399.8226$   
 $su_1 = 0.0066488$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

$lo/lo_{u,min} = lb/ld = 0.33981258$   
 $su_1 = 0.4 * esu_{1,nominal}((5.5), TBDY) = 0.032$

From table 5A.1, TBDY:  $esu_{1,nominal} = 0.08$ ,

For calculation of  $esu_{1,nominal}$  and  $y_1, sh_1, ft_1, fy_1$ , it is considered  
characteristic value  $fs_1 = fs_1 / 1.2$ , from table 5.1, TBDY.

$y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\min(1, 1.25 * (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.

with  $fs_1 = (fs_{jacket} * A_{sl,ten,jacket} + fs_{core} * A_{sl,ten,core}) / A_{sl,ten} = 399.8226$

with  $Es_1 = (Es_{jacket} * A_{sl,ten,jacket} + Es_{core} * A_{sl,ten,core}) / A_{sl,ten} = 200000.00$

$y_2 = 0.00152175$   
 $sh_2 = 0.0048696$

$$ft2 = 479.7871$$

$$fy2 = 399.8226$$

$$su2 = 0.0066488$$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

$$lo/lou,min = lb/lb,min = 0.33981258$$

$$su2 = 0.4*esu2\_nominal ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: esu2\_nominal = 0.08,

For calculation of esu2\_nominal and y2, sh2,ft2,fy2, it is considered  
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by  $\text{Min}(1, 1.25*(lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.

$$\text{with } fs2 = (fs\_jacket*Asl,com,jacket + fs\_core*Asl,com,core)/Asl,com = 399.8226$$

$$\text{with } Es2 = (Es\_jacket*Asl,com,jacket + Es\_core*Asl,com,core)/Asl,com = 200000.00$$

$$yv = 0.00152175$$

$$shv = 0.0048696$$

$$ftv = 507.2537$$

$$fyv = 422.7114$$

$$suv = 0.0066488$$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

$$lo/lou,min = lb/ld = 0.33981258$$

$$suv = 0.4*esuv\_nominal ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: esuv\_nominal = 0.08,

considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY

For calculation of esuv\_nominal and yv, shv,ftv,fyv, it is considered  
characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by  $\text{Min}(1, 1.25*(lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.

$$\text{with } fsv = (fs\_jacket*Asl,mid,jacket + fs\_mid*Asl,mid,core)/Asl,mid = 422.7114$$

$$\text{with } Esv = (Es\_jacket*Asl,mid,jacket + Es\_mid*Asl,mid,core)/Asl,mid = 200000.00$$

$$1 = Asl,ten/(b*d)*(fs1/fc) = 0.0752324$$

$$2 = Asl,com/(b*d)*(fs2/fc) = 0.0752324$$

$$v = Asl,mid/(b*d)*(fsv/fc) = 0.02812438$$

and confined core properties:

$$b = 390.00$$

$$d = 377.00$$

$$d' = 13.00$$

$$fcc (5A.2, TBDY) = 36.47874$$

$$cc (5A.5, TBDY) = 0.00305417$$

$$c = \text{confinement factor} = 1.10542$$

$$1 = Asl,ten/(b*d)*(fs1/fc) = 0.09371431$$

$$2 = Asl,com/(b*d)*(fs2/fc) = 0.09371431$$

$$v = Asl,mid/(b*d)*(fsv/fc) = 0.03503353$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

---->

$v < vs,y2$  - LHS eq.(4.5) is satisfied

---->

$$su (4.9) = 0.16791801$$

$$Mu = MRc (4.14) = 2.2193E+008$$

$$u = su (4.1) = 1.9632832E-005$$

-----  
Calculation of ratio lb/ld

-----  
Lap Length: lb/ld = 0.33981258

$$lb = 300.00$$

$$ld = 882.8396$$

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

$$= 1$$

$$db = 16.66667$$

Mean strength value of all re-bars: fy = 655.558

Mean concrete strength: fc' = (fc'\_jacket\*Area\_jacket + fc'\_core\*Area\_core)/Area\_section = 28.98765, 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 = 2.86234  
Atr = Min(Atr\_x,Atr\_y) = 257.6106  
where Atr\_x, Atr\_y are the sum of the area of all stirrup legs along X and Y loxal axis  
s = Max(s\_external,s\_internal) = 300.00  
n = 12.00

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

-----  
-----  
Calculation of ultimate curvature  $\phi_u$  according to 4.1, Biskinis/Fardis 2013:  
u = 1.9632832E-005  
Mu = 2.2193E+008

-----  
with full section properties:

b = 450.00  
d = 407.00  
d' = 43.00  
v = 0.00124204  
N = 7506.808  
fc = 33.00  
co (5A.5, TBDY) = 0.002  
Final value of  $\phi_u$ :  $\phi_u^* = \text{shear\_factor} * \text{Max}(\phi_u, \phi_c) = 0.01393923$   
The Shear\_factor is considered equal to 1 (pure moment strength)  
From (5.4b), TBDY:  $\phi_u = 0.01393923$   
 $\phi_{we}$  ((5.4c), TBDY) =  $\text{ase} * \text{sh}_{\min} * \text{fy}_{we} / \text{f}_{ce} + \text{Min}(\phi_x, \phi_y) = 0.06811101$   
where  $\phi = \text{af} * \text{pf} * \text{ff}_e / \text{f}_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

-----  
 $\phi_x = 0.06628267$   
 $\text{af} = 0.54930041$   
b = 450.00  
h = 450.00  
From EC8 A.4.4.3(6),  $\text{pf} = 2t_f / b_w = 0.00451556$   
b\_w = 450.00  
effective stress from (A.35),  $\text{ff}_e = 881.8461$

-----  
 $\phi_y = 0.06628267$   
 $\text{af} = 0.54930041$   
b = 450.00  
h = 450.00  
From EC8 A.4.4.3(6),  $\text{pf} = 2t_f / b_w = 0.00451556$   
b\_w = 450.00  
effective stress from (A.35),  $\text{ff}_e = 881.8461$

-----  
R = 40.00  
Effective FRP thickness,  $t_f = \text{NL} * t * \text{Cos}(b_1) = 1.016$   
 $f_{u,f} = 1055.00$   
 $E_f = 64828.00$   
 $u_{,f} = 0.015$   
 $\text{ase}$  ((5.4d), TBDY) =  $(\text{ase}_1 * A_{\text{ext}} + \text{ase}_2 * A_{\text{int}}) / A_{\text{sec}} = 0.14546167$   
 $\text{ase}_1 = 0.12623274$   
bo\_1 = 390.00  
ho\_1 = 390.00  
bi2\_1 = 608400.00  
 $\text{ase}_2 = \text{Max}(\text{ase}_1, \text{ase}_2) = 0.18853448$   
bo\_2 = 242.00  
ho\_2 = 242.00  
bi2\_2 = 234256.00

$\text{psh}_{\min} * \text{Fy}_{we} = \text{Min}(\text{psh}_{x} * \text{Fy}_{we}, \text{psh}_{y} * \text{Fy}_{we}) = 1.38262$   
Expression ((5.4d), TBDY) for  $\text{psh}_{\min} * \text{Fy}_{we}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

-----  
 $\text{psh}_x * \text{Fy}_{we} = \text{psh}_1 * \text{Fy}_{we1} + \text{ps}_2 * \text{Fy}_{we2} = 1.38262$

$$ps1 \text{ (external)} = (Ash1 \cdot h1 / s1) / Asec = 0.00116355$$

$$Ash1 = Astir_1 \cdot ns_1 = 157.0796$$

$$\text{No stirups, } ns_1 = 2.00$$

$$h1 = 450.00$$

$$ps2 \text{ (internal)} = (Ash2 \cdot h2 / s2) / Asec = 0.00103427$$

$$Ash2 = Astir_2 \cdot ns_2 = 100.531$$

$$\text{No stirups, } ns_2 = 2.00$$

$$h2 = 250.00$$

---

$$psh_y \cdot Fywe = psh1 \cdot Fywe1 + ps2 \cdot Fywe2 = 1.38262$$

$$ps1 \text{ (external)} = (Ash1 \cdot h1 / s1) / Asec = 0.00116355$$

$$Ash1 = Astir_1 \cdot ns_1 = 157.0796$$

$$\text{No stirups, } ns_1 = 2.00$$

$$h1 = 450.00$$

$$ps2 \text{ (internal)} = (Ash2 \cdot h2 / s2) / Asec = 0.00103427$$

$$Ash2 = Astir_2 \cdot ns_2 = 100.531$$

$$\text{No stirups, } ns_2 = 2.00$$

$$h2 = 250.00$$

---

$$Asec = 202500.00$$

$$s1 = 300.00$$

$$s2 = 120.00$$

$$fywe1 = 694.45$$

$$fywe2 = 555.55$$

$$fce = 33.00$$

$$\text{From } ((5.A5), \text{ TBDY}), \text{ TBDY: } cc = 0.00305417$$

$$c = \text{confinement factor} = 1.10542$$

$$y1 = 0.00152175$$

$$sh1 = 0.0048696$$

$$ft1 = 479.7871$$

$$fy1 = 399.8226$$

$$su1 = 0.0066488$$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

$$lo/lou, \text{min} = lb/ld = 0.33981258$$

$$su1 = 0.4 \cdot esu1_{\text{nominal}} ((5.5), \text{ TBDY}) = 0.032$$

From table 5A.1, TBDY:  $esu1_{\text{nominal}} = 0.08$ ,

For calculation of  $esu1_{\text{nominal}}$  and  $y1, sh1, ft1, fy1$ , it is considered  
characteristic value  $fsy1 = fs1/1.2$ , from table 5.1, TBDY.

$y1, sh1, ft1, fy1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.

$$\text{with } fs1 = (fs_{\text{jacket}} \cdot Asl, \text{ten, jacket} + fs_{\text{core}} \cdot Asl, \text{ten, core}) / Asl, \text{ten} = 399.8226$$

$$\text{with } Es1 = (Es_{\text{jacket}} \cdot Asl, \text{ten, jacket} + Es_{\text{core}} \cdot Asl, \text{ten, core}) / Asl, \text{ten} = 200000.00$$

$$y2 = 0.00152175$$

$$sh2 = 0.0048696$$

$$ft2 = 479.7871$$

$$fy2 = 399.8226$$

$$su2 = 0.0066488$$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

$$lo/lou, \text{min} = lb/lb, \text{min} = 0.33981258$$

$$su2 = 0.4 \cdot esu2_{\text{nominal}} ((5.5), \text{ TBDY}) = 0.032$$

From table 5A.1, TBDY:  $esu2_{\text{nominal}} = 0.08$ ,

For calculation of  $esu2_{\text{nominal}}$  and  $y2, sh2, ft2, fy2$ , it is considered  
characteristic value  $fsy2 = fs2/1.2$ , from table 5.1, TBDY.

$y1, sh1, ft1, fy1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.

$$\text{with } fs2 = (fs_{\text{jacket}} \cdot Asl, \text{com, jacket} + fs_{\text{core}} \cdot Asl, \text{com, core}) / Asl, \text{com} = 399.8226$$

$$\text{with } Es2 = (Es_{\text{jacket}} \cdot Asl, \text{com, jacket} + Es_{\text{core}} \cdot Asl, \text{com, core}) / Asl, \text{com} = 200000.00$$

$$yv = 0.00152175$$

$$shv = 0.0048696$$

$$ftv = 507.2537$$

$$fyv = 422.7114$$

$$suv = 0.0066488$$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

$$l_0/l_{ou,min} = l_b/l_d = 0.33981258$$

$$s_{uv} = 0.4 * e_{suv\_nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY:  $e_{suv\_nominal} = 0.08$ ,

considering characteristic value  $f_{sv} = f_{sv}/1.2$ , from table 5.1, TBDY

For calculation of  $e_{suv\_nominal}$  and  $\gamma_v$ ,  $sh_v, ft_v, fy_v$ , it is considered

characteristic value  $f_{sv} = f_{sv}/1.2$ , from table 5.1, TBDY.

$\gamma_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.

$$\text{with } f_{sv} = (f_{s,jacket} * A_{s,mid,jacket} + f_{s,mid} * A_{s,mid,core}) / A_{s,mid} = 422.7114$$

$$\text{with } E_{sv} = (E_{s,jacket} * A_{s,mid,jacket} + E_{s,mid} * A_{s,mid,core}) / A_{s,mid} = 200000.00$$

$$1 = A_{s,ten} / (b * d) * (f_{s1} / f_c) = 0.0752324$$

$$2 = A_{s,com} / (b * d) * (f_{s2} / f_c) = 0.0752324$$

$$v = A_{s,mid} / (b * d) * (f_{sv} / f_c) = 0.02812438$$

and confined core properties:

$$b = 390.00$$

$$d = 377.00$$

$$d' = 13.00$$

$$f_{cc} (5A.2, TBDY) = 36.47874$$

$$c_c (5A.5, TBDY) = 0.00305417$$

$$c = \text{confinement factor} = 1.10542$$

$$1 = A_{s,ten} / (b * d) * (f_{s1} / f_c) = 0.09371431$$

$$2 = A_{s,com} / (b * d) * (f_{s2} / f_c) = 0.09371431$$

$$v = A_{s,mid} / (b * d) * (f_{sv} / f_c) = 0.03503353$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < v_{s,y2}$  - LHS eq.(4.5) is satisfied

--->

$$s_u (4.9) = 0.16791801$$

$$M_u = M_{Rc} (4.14) = 2.2193E+008$$

$$u = s_u (4.1) = 1.9632832E-005$$

Calculation of ratio  $l_b/l_d$

Lap Length:  $l_b/l_d = 0.33981258$

$$l_b = 300.00$$

$$l_d = 882.8396$$

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

$$= 1$$

$$d_b = 16.66667$$

Mean strength value of all re-bars:  $f_y = 655.558$

Mean concrete strength:  $f'_c = (f'_{c,jacket} * Area_{jacket} + f'_{c,core} * Area_{core}) / Area_{section} = 28.98765$ , but  $f_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 25.00$$

$$K_{tr} = 2.86234$$

$$A_{tr} = \text{Min}(A_{tr,x}, A_{tr,y}) = 257.6106$$

where  $A_{tr,x}, A_{tr,y}$  are the sum of the area of all stirrup legs along X and Y local axis

$$s = \text{Max}(s_{external}, s_{internal}) = 300.00$$

$$n = 12.00$$

Calculation of  $M_u2+$

Calculation of ultimate curvature  $u$  according to 4.1, Biskinis/Fardis 2013:

$$u = 1.9632832E-005$$

$$M_u = 2.2193E+008$$

with full section properties:

$$b = 450.00$$

$$d = 407.00$$

$$d' = 43.00$$

$$v = 0.00124204$$

$$N = 7506.808$$

$$fc = 33.00$$

$$co \text{ (5A.5, TBDY)} = 0.002$$

$$\text{Final value of } cu^* = \text{shear\_factor} * \text{Max}(cu, cc) = 0.01393923$$

The Shear\_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } cu = 0.01393923$$

$$\text{we ((5.4c), TBDY)} = ase * sh_{min} * fy_{we} / f_{ce} + \text{Min}(fx, fy) = 0.06811101$$

where  $f = af * pf * f_{fe} / f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$fx = 0.06628267$$

$$af = 0.54930041$$

$$b = 450.00$$

$$h = 450.00$$

$$\text{From EC8 A.4.4.3(6), } pf = 2tf/bw = 0.00451556$$

$$bw = 450.00$$

$$\text{effective stress from (A.35), } ff,e = 881.8461$$

$$fy = 0.06628267$$

$$af = 0.54930041$$

$$b = 450.00$$

$$h = 450.00$$

$$\text{From EC8 A.4.4.3(6), } pf = 2tf/bw = 0.00451556$$

$$bw = 450.00$$

$$\text{effective stress from (A.35), } ff,e = 881.8461$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } tf = NL * t * \text{Cos}(b1) = 1.016$$

$$fu,f = 1055.00$$

$$Ef = 64828.00$$

$$u,f = 0.015$$

$$ase \text{ ((5.4d), TBDY)} = (ase1 * A_{ext} + ase2 * A_{int}) / A_{sec} = 0.14546167$$

$$ase1 = 0.12623274$$

$$bo\_1 = 390.00$$

$$ho\_1 = 390.00$$

$$bi2\_1 = 608400.00$$

$$ase2 = \text{Max}(ase1, ase2) = 0.18853448$$

$$bo\_2 = 242.00$$

$$ho\_2 = 242.00$$

$$bi2\_2 = 234256.00$$

$$psh_{min} * Fy_{we} = \text{Min}(psh_x * Fy_{we}, psh_y * Fy_{we}) = 1.38262$$

Expression ((5.4d), TBDY) for  $psh_{min} * Fy_{we}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$$psh_x * Fy_{we} = psh1 * Fy_{we1} + ps2 * Fy_{we2} = 1.38262$$

$$ps1 \text{ (external)} = (Ash1 * h1 / s1) / A_{sec} = 0.00116355$$

$$Ash1 = Astir\_1 * ns\_1 = 157.0796$$

$$\text{No stirrups, } ns\_1 = 2.00$$

$$h1 = 450.00$$

$$ps2 \text{ (internal)} = (Ash2 * h2 / s2) / A_{sec} = 0.00103427$$

$$Ash2 = Astir\_2 * ns\_2 = 100.531$$

$$\text{No stirrups, } ns\_2 = 2.00$$

$$h2 = 250.00$$

$$psh_y * Fy_{we} = psh1 * Fy_{we1} + ps2 * Fy_{we2} = 1.38262$$

$$ps1 \text{ (external)} = (Ash1 * h1 / s1) / A_{sec} = 0.00116355$$

$$Ash1 = Astir\_1 * ns\_1 = 157.0796$$

$$\text{No stirrups, } ns\_1 = 2.00$$

$$h1 = 450.00$$

$$ps2 \text{ (internal)} = (Ash2 * h2 / s2) / A_{sec} = 0.00103427$$

$$Ash2 = Astir\_2 * ns\_2 = 100.531$$

$$\text{No stirrups, } ns\_2 = 2.00$$

$$h2 = 250.00$$

$$A_{sec} = 202500.00$$

$$s1 = 300.00$$

$$s2 = 120.00$$

fywe1 = 694.45  
fywe2 = 555.55  
fce = 33.00

From ((5.A.5), TBDY), TBDY: cc = 0.00305417  
c = confinement factor = 1.10542

y1 = 0.00152175  
sh1 = 0.0048696  
ft1 = 479.7871  
fy1 = 399.8226  
su1 = 0.0066488

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

lo/lou,min = lb/ld = 0.33981258

su1 = 0.4\*esu1\_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu1\_nominal = 0.08,

For calculation of esu1\_nominal and y1, sh1,ft1,fy1, it is considered  
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by  $\text{Min}(1, 1.25 \cdot (\text{lb}/\text{ld})^{2/3})$ , from 10.3.5, ASCE 41-17.

with fs1 = (fs,jacket\*Asl,ten,jacket + fs,core\*Asl,ten,core)/Asl,ten = 399.8226

with Es1 = (Es,jacket\*Asl,ten,jacket + Es,core\*Asl,ten,core)/Asl,ten = 200000.00

y2 = 0.00152175  
sh2 = 0.0048696  
ft2 = 479.7871  
fy2 = 399.8226  
su2 = 0.0066488

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

lo/lou,min = lb/lb,min = 0.33981258

su2 = 0.4\*esu2\_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu2\_nominal = 0.08,

For calculation of esu2\_nominal and y2, sh2,ft2,fy2, it is considered  
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by  $\text{Min}(1, 1.25 \cdot (\text{lb}/\text{ld})^{2/3})$ , from 10.3.5, ASCE 41-17.

with fs2 = (fs,jacket\*Asl,com,jacket + fs,core\*Asl,com,core)/Asl,com = 399.8226

with Es2 = (Es,jacket\*Asl,com,jacket + Es,core\*Asl,com,core)/Asl,com = 200000.00

yv = 0.00152175  
shv = 0.0048696  
ftv = 507.2537  
fyv = 422.7114  
suv = 0.0066488

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

lo/lou,min = lb/ld = 0.33981258

suv = 0.4\*esuv\_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esuv\_nominal = 0.08,

considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY

For calculation of esuv\_nominal and yv, shv,ftv,fyv, it is considered  
characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by  $\text{Min}(1, 1.25 \cdot (\text{lb}/\text{ld})^{2/3})$ , from 10.3.5, ASCE 41-17.

with fsv = (fs,jacket\*Asl,mid,jacket + fs,mid\*Asl,mid,core)/Asl,mid = 422.7114

with Esv = (Es,jacket\*Asl,mid,jacket + Es,mid\*Asl,mid,core)/Asl,mid = 200000.00

1 = Asl,ten/(b\*d)\*(fs1/fc) = 0.0752324

2 = Asl,com/(b\*d)\*(fs2/fc) = 0.0752324

v = Asl,mid/(b\*d)\*(fsv/fc) = 0.02812438

and confined core properties:

b = 390.00  
d = 377.00  
d' = 13.00

fcc (5A.2, TBDY) = 36.47874

cc (5A.5, TBDY) = 0.00305417

c = confinement factor = 1.10542

1 = Asl,ten/(b\*d)\*(fs1/fc) = 0.09371431

2 = Asl,com/(b\*d)\*(fs2/fc) = 0.09371431

v = Asl,mid/(b\*d)\*(fsv/fc) = 0.03503353

Case/Assumption: Unconfined full section - Steel rupture  
' satisfies Eq. (4.3)

--->  
v < vs,y2 - LHS eq.(4.5) is satisfied

--->  
su (4.9) = 0.16791801  
Mu = MRc (4.14) = 2.2193E+008  
u = su (4.1) = 1.9632832E-005

-----  
Calculation of ratio lb/l<sub>d</sub>

-----  
Lap Length: lb/l<sub>d</sub> = 0.33981258

lb = 300.00

l<sub>d</sub> = 882.8396

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

= 1

db = 16.66667

Mean strength value of all re-bars: fy = 655.558

Mean concrete strength: fc' = (fc'\_jacket\*Area\_jacket + fc'\_core\*Area\_core)/Area\_section = 28.98765, 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 = 2.86234

Atr = Min(Atr\_x,Atr\_y) = 257.6106

where Atr\_x, Atr\_y are the sum of the area of all stirrup legs along X and Y local axis

s = Max(s\_external,s\_internal) = 300.00

n = 12.00

-----  
Calculation of Mu2-

-----  
Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

u = 1.9632832E-005

Mu = 2.2193E+008

-----  
with full section properties:

b = 450.00

d = 407.00

d' = 43.00

v = 0.00124204

N = 7506.808

fc = 33.00

co (5A.5, TBDY) = 0.002

Final value of cu: cu\* = shear\_factor \* Max( cu, cc) = 0.01393923

The Shear\_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: cu = 0.01393923

we ((5.4c), TBDY) = ase\* sh,min\*fywe/fce+ Min( fx, fy) = 0.06811101

where f = af\*pf\*ffe/fce is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

-----  
fx = 0.06628267

af = 0.54930041

b = 450.00

h = 450.00

From EC8 A.4.4.3(6), pf = 2tf/bw = 0.00451556

bw = 450.00

effective stress from (A.35), ffe = 881.8461

-----  
fy = 0.06628267

af = 0.54930041

b = 450.00

h = 450.00

From EC8 A.4.4.3(6),  $pf = 2tf/bw = 0.00451556$   
 $bw = 450.00$   
effective stress from (A.35),  $ff,e = 881.8461$

-----  
 $R = 40.00$   
Effective FRP thickness,  $tf = NL*t*\text{Cos}(b1) = 1.016$   
 $f_{u,f} = 1055.00$   
 $E_f = 64828.00$   
 $u_{,f} = 0.015$   
 $ase((5.4d), \text{TBDY}) = (ase1*A_{ext} + ase2*A_{int})/A_{sec} = 0.14546167$   
 $ase1 = 0.12623274$   
 $bo_1 = 390.00$   
 $ho_1 = 390.00$   
 $bi2_1 = 608400.00$   
 $ase2 = \text{Max}(ase1, ase2) = 0.18853448$   
 $bo_2 = 242.00$   
 $ho_2 = 242.00$   
 $bi2_2 = 234256.00$

$psh_{,min}*F_{ywe} = \text{Min}(psh_{,x}*F_{ywe}, psh_{,y}*F_{ywe}) = 1.38262$   
Expression ((5.4d), TBDY) for  $psh_{,min}*F_{ywe}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

-----  
 $psh_{,x}*F_{ywe} = psh1*F_{ywe1} + ps2*F_{ywe2} = 1.38262$   
 $ps1(\text{external}) = (Ash1*h1/s1)/A_{sec} = 0.00116355$   
 $Ash1 = Astir_1*ns_1 = 157.0796$   
No stirrups,  $ns_1 = 2.00$   
 $h1 = 450.00$   
 $ps2(\text{internal}) = (Ash2*h2/s2)/A_{sec} = 0.00103427$   
 $Ash2 = Astir_2*ns_2 = 100.531$   
No stirrups,  $ns_2 = 2.00$   
 $h2 = 250.00$

-----  
 $psh_{,y}*F_{ywe} = psh1*F_{ywe1} + ps2*F_{ywe2} = 1.38262$   
 $ps1(\text{external}) = (Ash1*h1/s1)/A_{sec} = 0.00116355$   
 $Ash1 = Astir_1*ns_1 = 157.0796$   
No stirrups,  $ns_1 = 2.00$   
 $h1 = 450.00$   
 $ps2(\text{internal}) = (Ash2*h2/s2)/A_{sec} = 0.00103427$   
 $Ash2 = Astir_2*ns_2 = 100.531$   
No stirrups,  $ns_2 = 2.00$   
 $h2 = 250.00$

-----  
 $A_{sec} = 202500.00$   
 $s1 = 300.00$   
 $s2 = 120.00$   
 $f_{ywe1} = 694.45$   
 $f_{ywe2} = 555.55$   
 $f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.00305417$   
 $c = \text{confinement factor} = 1.10542$

$y1 = 0.00152175$   
 $sh1 = 0.0048696$   
 $ft1 = 479.7871$   
 $fy1 = 399.8226$   
 $su1 = 0.0066488$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
 $\text{Shear\_factor} = 1.00$

$lo/lo_{,min} = lb/d = 0.33981258$   
 $su1 = 0.4*esu1_{,nominal}((5.5), \text{TBDY}) = 0.032$

From table 5A.1, TBDY:  $esu1_{,nominal} = 0.08$ ,

For calculation of  $esu1_{,nominal}$  and  $y1, sh1, ft1, fy1$ , it is considered  
characteristic value  $fsy1 = fs1/1.2$ , from table 5.1, TBDY.

$y1, sh1, ft1, fy1$ , are also multiplied by  $\text{Min}(1, 1.25*(lb/d)^{2/3})$ , from 10.3.5, ASCE 41-17.

with  $fs1 = (fs_{,jacket}*A_{sl,ten,jacket} + fs_{,core}*A_{sl,ten,core})/A_{sl,ten} = 399.8226$

with  $Es1 = (Es_{,jacket}*A_{sl,ten,jacket} + Es_{,core}*A_{sl,ten,core})/A_{sl,ten} = 200000.00$

$y2 = 0.00152175$

$sh_2 = 0.0048696$   
 $ft_2 = 479.7871$   
 $fy_2 = 399.8226$   
 $su_2 = 0.0066488$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 Shear\_factor = 1.00  
 $lo/lo_{min} = lb/lb_{min} = 0.33981258$   
 $su_2 = 0.4 * esu_{2,nominal} ((5.5), TBDY) = 0.032$   
 From table 5A.1, TBDY:  $esu_{2,nominal} = 0.08$ ,  
 For calculation of  $esu_{2,nominal}$  and  $y_2, sh_2, ft_2, fy_2$ , it is considered  
 characteristic value  $fsy_2 = fs_2/1.2$ , from table 5.1, TBDY.  
 $y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $Min(1, 1.25 * (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with  $fs_2 = (fs_{jacket} * Asl_{com,jacket} + fs_{core} * Asl_{com,core}) / Asl_{com} = 399.8226$   
 with  $Es_2 = (Es_{jacket} * Asl_{com,jacket} + Es_{core} * Asl_{com,core}) / Asl_{com} = 200000.00$   
 $yv = 0.00152175$   
 $shv = 0.0048696$   
 $ftv = 507.2537$   
 $fyv = 422.7114$   
 $suv = 0.0066488$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 Shear\_factor = 1.00  
 $lo/lo_{min} = lb/ld = 0.33981258$   
 $suv = 0.4 * esuv_{nominal} ((5.5), TBDY) = 0.032$   
 From table 5A.1, TBDY:  $esuv_{nominal} = 0.08$ ,  
 considering characteristic value  $fsyv = fsv/1.2$ , from table 5.1, TBDY  
 For calculation of  $esuv_{nominal}$  and  $yv, shv, ftv, fyv$ , it is considered  
 characteristic value  $fsyv = fsv/1.2$ , from table 5.1, TBDY.  
 $y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $Min(1, 1.25 * (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with  $fsv = (fs_{jacket} * Asl_{mid,jacket} + fs_{mid} * Asl_{mid,core}) / Asl_{mid} = 422.7114$   
 with  $Es_v = (Es_{jacket} * Asl_{mid,jacket} + Es_{mid} * Asl_{mid,core}) / Asl_{mid} = 200000.00$   
 $1 = Asl_{ten} / (b * d) * (fs_1 / fc) = 0.0752324$   
 $2 = Asl_{com} / (b * d) * (fs_2 / fc) = 0.0752324$   
 $v = Asl_{mid} / (b * d) * (fsv / fc) = 0.02812438$

and confined core properties:

$b = 390.00$   
 $d = 377.00$   
 $d' = 13.00$   
 $fcc (5A.2, TBDY) = 36.47874$   
 $cc (5A.5, TBDY) = 0.00305417$   
 $c = \text{confinement factor} = 1.10542$   
 $1 = Asl_{ten} / (b * d) * (fs_1 / fc) = 0.09371431$   
 $2 = Asl_{com} / (b * d) * (fs_2 / fc) = 0.09371431$   
 $v = Asl_{mid} / (b * d) * (fsv / fc) = 0.03503353$

Case/Assumption: Unconfined full section - Steel rupture  
 ' satisfies Eq. (4.3)

--->  
 $v < v_{s,y_2}$  - LHS eq.(4.5) is satisfied  
 --->  
 $su (4.9) = 0.16791801$   
 $Mu = MRc (4.14) = 2.2193E+008$   
 $u = su (4.1) = 1.9632832E-005$

Calculation of ratio  $lb/ld$

Lap Length:  $lb/ld = 0.33981258$   
 $lb = 300.00$   
 $ld = 882.8396$   
 Calculation of  $lb_{min}$  according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.  
 $= 1$   
 $db = 16.66667$   
 Mean strength value of all re-bars:  $fy = 655.558$   
 Mean concrete strength:  $fc' = (fc'_{jacket} * Area_{jacket} + fc'_{core} * Area_{core}) / Area_{section} = 28.98765$ , but  $fc'^{0.5} <=$   
 $8.3 \text{ MPa}$  (22.5.3.1, ACI 318-14)  
 $t = 1.00$

$s = 0.80$   
 $e = 1.00$   
 $cb = 25.00$   
 $Ktr = 2.86234$   
 $Atr = \text{Min}(Atr_x, Atr_y) = 257.6106$   
 where  $Atr_x, Atr_y$  are the sum of the area of all stirrup legs along X and Y loxal axis  
 $s = \text{Max}(s_{\text{external}}, s_{\text{internal}}) = 300.00$   
 $n = 12.00$

-----  
 Calculation of Shear Strength  $Vr = \text{Min}(Vr1, Vr2) = 567563.724$   
 -----

Calculation of Shear Strength at edge 1,  $Vr1 = 567563.724$

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

$VCol0 = 567563.724$

$knl = 1$  (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:  $fc' = (fc'_{\text{jacket}} * Area_{\text{jacket}} + fc'_{\text{core}} * Area_{\text{core}}) / Area_{\text{section}} = 28.98765$ , but  $fc'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$Mu = 1.0463738E-012$

$Vu = 2.7162834E-031$

$d = 0.8 * h = 360.00$

$Nu = 7506.808$

$Ag = 202500.00$

From (11.5.4.8), ACI 318-14:  $Vs = Vs1 + Vs2 = 144280.365$

where:

$Vs1 = 69813.729$  is calculated for jacket, with:

$d = 360.00$

$Av = 157079.633$

$fy = 555.56$

$s = 300.00$

$Vs1$  is multiplied by  $Col1 = 0.66666667$

$s/d = 0.83333333$

$Vs2 = 74466.637$  is calculated for core, with:

$d = 200.00$

$Av = 100530.965$

$fy = 444.44$

$s = 120.00$

$Vs2$  is multiplied by  $Col2 = 1.00$

$s/d = 0.60$

$Vf$  ((11-3)-(11.4), ACI 440) =  $214457.247$

$f = 0.95$ , 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  $Vf(, )$ , is implemented for every different fiber orientation  $ai$ , as well as for 2 crack directions,  $= 45^\circ$  and  $= -45^\circ$  to take into consideration the cyclic seismic loading.

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

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

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

$dfv = d$  (figure 11.2, ACI 440) =  $407.00$

$ffe$  ((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:  $Vs + Vf \leq 579413.096$

$bw = 450.00$

-----  
 Calculation of Shear Strength at edge 2,  $Vr2 = 567563.724$   
 -----

Vr2 = VCol ((10.3), ASCE 41-17) = knl\*VCol0

VCol0 = 567563.724

kn1 = 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 = 28.98765, but fc'^0.5 <= 8.3 MPa (22.5.3.1, ACI 318-14)

M/Vd = 2.00

Mu = 1.0463738E-012

Vu = 2.7162834E-031

d = 0.8\*h = 360.00

Nu = 7506.808

Ag = 202500.00

From (11.5.4.8), ACI 318-14: Vs = Vs1 + Vs2 = 144280.365

where:

Vs1 = 69813.729 is calculated for jacket, with:

d = 360.00

Av = 157079.633

fy = 555.56

s = 300.00

Vs1 is multiplied by Col1 = 0.66666667

s/d = 0.83333333

Vs2 = 74466.637 is calculated for core, with:

d = 200.00

Av = 100530.965

fy = 444.44

s = 120.00

Vs2 is multiplied by Col2 = 1.00

s/d = 0.60

Vf ((11-3)-(11.4), ACI 440) = 214457.247

f = 0.95, for fully-wrapped sections

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

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

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

orientation 1: 1 = b1 + 90° = 90.00

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

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

dfv = d (figure 11.2, ACI 440) = 407.00

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 <= 579413.096

bw = 450.00

End Of Calculation of Shear Capacity ratio for element: column JC1 of floor 1

At local axis: 2

Start Of Calculation of Chord Rotation Capacity for element: column JC1 of floor 1

At local axis: 3

Integration Section: (a)

Section Type: rcjrs

Constant Properties

Knowledge Factor, = 0.85

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

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

Consequently:

Jacket

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

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,  $E_s = 200000.00$

External Height,  $H = 450.00$

External Width,  $W = 450.00$

Internal Height,  $H = 250.00$

Internal Width,  $W = 250.00$

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,  $M = -3.5352E+007$

Shear Force,  $V_2 = -11781.223$

Shear Force,  $V_3 = 2.6378276E-013$

Axial Force,  $F = -7502.094$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension:  $A_{sl,t} = 1137.257$

-Compression:  $A_{sl,c} = 1539.38$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension:  $A_{sl,ten} = 1137.257$

-Compression:  $A_{sl,com} = 1137.257$

-Middle:  $A_{sl,mid} = 402.1239$

Longitudinal External Reinforcement Area Distribution (in 3 divisions)

-Tension:  $A_{sl,ten,jacket} = 829.3805$

-Compression:  $A_{sl,com,jacket} = 829.3805$

-Middle:  $A_{sl,mid,jacket} = 402.1239$

Longitudinal Internal Reinforcement Area Distribution (in 3 divisions)

-Tension:  $A_{sl,ten,core} = 307.8761$

-Compression:  $A_{sl,com,core} = 307.8761$

-Middle:  $A_{sl,mid,core} = 0.00$

Mean Diameter of Tension Reinforcement,  $DbL = 16.80$

-----  
Existing component: From table 7-7, ASCE 41\_17: Final chord rotation Capacity  $u_{,R} = \alpha \cdot u = 0.03835042$

$u = \gamma + \rho = 0.04511814$

-----  
- Calculation of  $\gamma$  -

$y = (M_y * L_s / 3) / E_{eff} = 0.006502$  ((4.29), Biskinis Phd)  
 $M_y = 1.7613E+008$   
 $L_s = M/V$  (with  $L_s > 0.1 * L$  and  $L_s < 2 * L$ ) = 3000.708  
 From table 10.5, ASCE 41\_17:  $E_{eff} = factor * E_c * I_g = 2.7095E+013$   
 $factor = 0.30$   
 $A_g = 202500.00$   
 Mean concrete strength:  $f'_c = (f'_{c\_jacket} * Area_{jacket} + f'_{c\_core} * Area_{core}) / Area_{section} = 28.98765$   
 $N = 7502.094$   
 $E_c * I_g = E_{c\_jacket} * I_{g\_jacket} + E_{c\_core} * I_{g\_core} = 9.0315E+013$

Calculation of Yielding Moment  $M_y$

Calculation of  $y$  and  $M_y$  according to Annex 7 -

$y = \text{Min}(y_{ten}, y_{com})$   
 $y_{ten} = 6.1806717E-006$   
 with ((10.1), ASCE 41-17)  $f_y = \text{Min}(f_y, 1.25 * f_y * (I_b / I_d)^{2/3}) = 374.3546$   
 $d = 407.00$   
 $y = 0.25591399$   
 $A = 0.01472387$   
 $B = 0.00818866$   
 with  $pt = 0.00430549$   
 $pc = 0.00620943$   
 $pv = 0.0021956$   
 $N = 7502.094$   
 $b = 450.00$   
 $" = 0.10565111$   
 $y_{comp} = 2.2127287E-005$   
 with  $f'_c$  (12.3, (ACI 440)) = 34.40847  
 $f_c = 33.00$   
 $f_l = 0.82797802$   
 $b = 450.00$   
 $h = 450.00$   
 $A_g = 202500.00$   
 From (12.9), ACI 440:  $k_a = 0.54261599$   
 $g = pt + pc + pv = 0.01461445$   
 $rc = 40.00$   
 $A_e / A_c = 0.54261599$   
 Effective FRP thickness,  $t_f = N L * t * \text{Cos}(b_1) = 1.016$   
 effective strain from (12.5) and (12.12),  $\epsilon_{fe} = 0.004$   
 $f_u = 0.01$   
 $E_f = 64828.00$   
 $E_c = 26999.444$   
 $y = 0.25471852$   
 $A = 0.01452517$   
 $B = 0.00807924$   
 with  $E_s = 200000.00$

Calculation of ratio  $I_b / I_d$

Lap Length:  $I_d / I_{d,min} = 0.42476573$

$I_b = 300.00$

$I_d = 706.2717$

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

= 1

$db = 16.66667$

Mean strength value of all re-bars:  $f_y = 524.4464$

Mean concrete strength:  $f'_c = (f'_{c\_jacket} * Area_{jacket} + f'_{c\_core} * Area_{core}) / Area_{section} = 28.98765$ , but  $f_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$   
 $K_{tr} = 2.86234$   
 $A_{tr} = \text{Min}(A_{tr\_x}, A_{tr\_y}) = 257.6106$   
 where  $A_{tr\_x}$ ,  $A_{tr\_y}$  are the sum of the area of all stirrup legs along X and Y local axis  
 $s = \text{Max}(s_{\text{external}}, s_{\text{internal}}) = 300.00$   
 $n = 12.00$

-----  
 - Calculation of  $p$  -  
 -----

From table 10-8:  $p = 0.03861614$

with:

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

shear control ratio  $V_{yE}/V_{CoIE} = 0.26068017$

$d = d_{\text{external}} = 407.00$

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

$t = s_1 + s_2 + 2*tf/bw*(ffe/fs) = 0.00430549$

jacket:  $s_1 = A_{v1}*h_1/(s_1*Ag) = 0.00116355$

$A_{v1} = 157.0796$ , is the total area of all stirrups parallel to loading (shear) direction

$h_1 = 450.00$

$s_1 = 300.00$

core:  $s_2 = A_{v2}*h_2/(s_2*Ag) = 0.00103427$

$A_{v2} = 100.531$ , is the total area of all stirrups parallel to loading (shear) direction

$h_2 = 250.00$

$s_2 = 120.00$

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

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

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

For the normalisation  $f_s$  of jacket is used.

$NUD = 7502.094$

$Ag = 202500.00$

$f_{cE} = (f_{c\_jacket}*Area_{\text{jacket}} + f_{c\_core}*Area_{\text{core}})/section\_area = 28.98765$

$f_{yIE} = (f_{y\_ext\_Long\_Reinf}*Area_{\text{ext\_Long\_Reinf}} + f_{y\_int\_Long\_Reinf}*Area_{\text{int\_Long\_Reinf}})/Area_{\text{Tot\_Long\_Rein}} = 529.9972$

$f_{ytE} = (f_{y\_ext\_Trans\_Reinf}*s_1 + f_{y\_int\_Trans\_Reinf}*s_2)/(s_1 + s_2) = 503.2682$

$p_l = Area_{\text{Tot\_Long\_Rein}}/(b*d) = 0.01461445$

$b = 450.00$

$d = 407.00$

$f_{cE} = 28.98765$

-----  
 End Of Calculation of Chord Rotation Capacity for element: column JC1 of floor 1

At local axis: 3

Integration Section: (a)  
 -----

**Calculation No. 13**

column C1, Floor 1

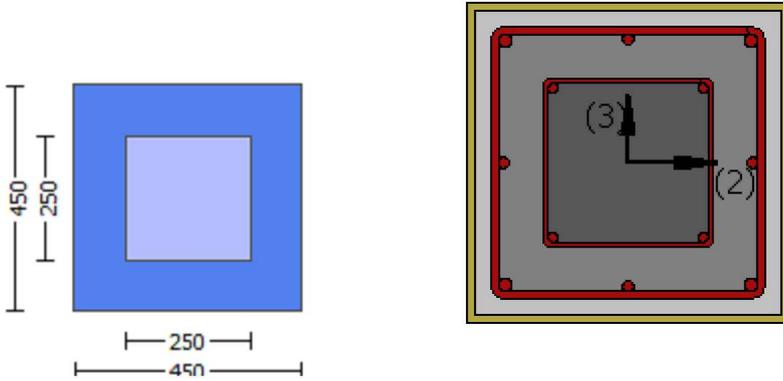
Limit State: Collapse Prevention (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Shear capacity VRd

Edge: End

Local Axis: (2)



Start Of Calculation of Shear Capacity for element: column JC1 of floor 1

At local axis: 2

Integration Section: (b)

Section Type: rcjrs

Constant Properties

Knowledge Factor,  $\gamma = 0.85$

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  $\gamma$  for displacement ductility demand, the expected (mean value) strengths are used (7.5.1.3, ASCE 41-17) because bending is considered as Deformation-Controlled Action (Table C7-1, ASCE 41-17).

Jacket

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

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

Existing Column

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

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

#####

External Height,  $H = 450.00$

External Width,  $W = 450.00$

Internal Height,  $H = 250.00$

Internal Width,  $W = 250.00$

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,  $M_a = -3.5352E+007$   
Shear Force,  $V_a = -11781.223$   
EDGE -B-  
Bending Moment,  $M_b = 0.09202348$   
Shear Force,  $V_b = 11781.223$   
BOTH EDGES  
Axial Force,  $F = -7502.094$   
Longitudinal Reinforcement Area Distribution (in 2 divisions)  
-Tension:  $A_{sl,t} = 0.00$   
-Compression:  $A_{sl,c} = 2676.637$   
Longitudinal Reinforcement Area Distribution (in 3 divisions)  
-Tension:  $A_{sl,ten} = 1137.257$   
-Compression:  $A_{sl,com} = 1137.257$   
-Middle:  $A_{sl,mid} = 402.1239$   
Mean Diameter of Tension Reinforcement,  $Db_{L,ten} = 16.80$

Existing component: From table 7-7, ASCE 41\_17: Final Shear Capacity  $V_R = \phi V_n = 447100.239$   
 $V_n$  ((10.3), ASCE 41-17) =  $k_n \phi V_{CoI0} = 526000.281$   
 $V_{CoI} = 526000.281$   
 $k_n = 1.00$   
displacement\_ductility\_demand = 0.30104645

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:  $f_c' = (f_c'_{jacket} \cdot Area_{jacket} + f_c'_{core} \cdot Area_{core}) / Area_{section} = 22.22222$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)  
 $M/Vd = 2.00$   
 $M_u = 0.09202348$   
 $V_u = 11781.223$   
 $d = 0.8 \cdot h = 360.00$   
 $N_u = 7502.094$   
 $A_g = 202500.00$   
From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 129852.496$   
where:  
 $V_{s1} = 62831.853$  is calculated for jacket, with:  
 $d = 360.00$   
 $A_v = 157079.633$   
 $f_y = 500.00$   
 $s = 300.00$   
 $V_{s1}$  is multiplied by  $Col1 = 0.66666667$   
 $s/d = 0.83333333$

Vs2 = 67020.643 is calculated for core, with:

$$d = 200.00$$

$$A_v = 100530.965$$

$$f_y = 400.00$$

$$s = 120.00$$

Vs2 is multiplied by Col2 = 1.00

$$s/d = 0.60$$

Vf ((11-3)-(11.4), ACI 440) = 214457.247

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

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(  $\theta$  ), 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 = Min(|Vf(45,  $\theta$ )|, |Vf(-45,  $\theta$ )|), with:

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

dfv = d (figure 11.2, ACI 440) = 407.00

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

$$E_f = 64828.00$$

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

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

From (11-11), ACI 440: Vs + Vf <= 507312.442

$$b_w = 450.00$$

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

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

for rotation axis 3 and integ. section (b)

-----  
From analysis, chord rotation  $\theta = 0.00019569$

$$y = (M_y * L_s / 3) / E_{eff} = 0.00065005 \text{ ((4.29), Biskinis Phd)}$$

$$M_y = 1.7613E+008$$

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

From table 10.5, ASCE 41\_17:  $E_{eff} = \text{factor} * E_c * I_g = 2.7095E+013$

$$\text{factor} = 0.30$$

$$A_g = 202500.00$$

$$\text{Mean concrete strength: } f'_c = (f'_{c\_jacket} * \text{Area}_{jacket} + f'_{c\_core} * \text{Area}_{core}) / \text{Area}_{section} = 28.98765$$

$$N = 7502.094$$

$$E_c * I_g = E_{c\_jacket} * I_{g\_jacket} + E_{c\_core} * I_{g\_core} = 9.0315E+013$$

-----  
Calculation of Yielding Moment My

-----  
Calculation of  $\delta / y$  and My according to Annex 7 -

$$y = \text{Min}(y_{ten}, y_{com})$$

$$y_{ten} = 6.1806717E-006$$

with ((10.1), ASCE 41-17)  $f_y = \text{Min}(f_y, 1.25 * f_y * (I_b / I_d)^{2/3}) = 374.3546$

$$d = 407.00$$

$$y = 0.25591399$$

$$A = 0.01472387$$

$$B = 0.00818866$$

$$\text{with } p_t = 0.00620943$$

$$p_c = 0.00620943$$

$$p_v = 0.0021956$$

$$N = 7502.094$$

$$b = 450.00$$

$$\theta = 0.10565111$$

$$y_{comp} = 2.2127287E-005$$

with  $f'_c$  (12.3, (ACI 440)) = 34.40847

$$f_c = 33.00$$

$$f_l = 0.82797802$$

$$b = 450.00$$

h = 450.00  
Ag = 202500.00  
From (12.9), ACI 440: ka = 0.54261599  
g = pt + pc + pv = 0.01461445  
rc = 40.00  
Ae/Ac = 0.54261599  
Effective FRP thickness, tf = NL\*t\*Cos(b1) = 1.016  
effective strain from (12.5) and (12.12), efe = 0.004  
fu = 0.01  
Ef = 64828.00  
Ec = 26999.444  
y = 0.25471852  
A = 0.01452517  
B = 0.00807924  
with Es = 200000.00

-----  
-----  
Calculation of ratio lb/ld

-----  
Lap Length: ld/ld,min = 0.42476573

lb = 300.00

ld = 706.2717

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

= 1

db = 16.66667

Mean strength value of all re-bars: fy = 524.4464

Mean concrete strength: fc' = (fc'\_jacket\*Area\_jacket + fc'\_core\*Area\_core)/Area\_section = 28.98765, 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 = 2.86234

Atr = Min(Atr\_x,Atr\_y) = 257.6106

where Atr\_x, Atr\_y are the sum of the area of all stirrup legs along X and Y local axis

s = Max(s\_external,s\_internal) = 300.00

n = 12.00

-----  
End Of Calculation of Shear Capacity for element: column JC1 of floor 1

At local axis: 2

Integration Section: (b)

## Calculation No. 14

column C1, Floor 1

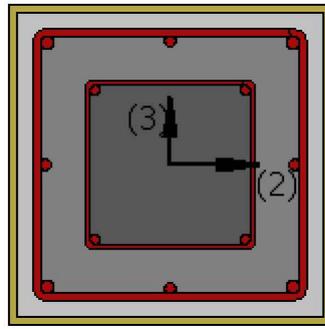
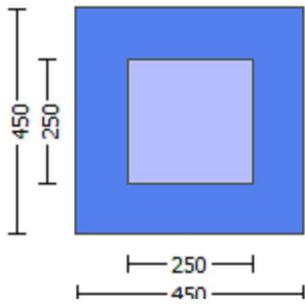
Limit State: Collapse Prevention (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity ( u)

Edge: End

Local Axis: (2)



Start Of Calculation of Shear Capacity ratio for element: column JC1 of floor 1

At Shear local axis: 3

(Bending local axis: 2)

Section Type: rcjrs

Constant Properties

Knowledge Factor,  $\gamma = 0.85$

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 Height,  $H = 450.00$

External Width,  $W = 450.00$

Internal Height,  $H = 250.00$

Internal Width,  $W = 250.00$

Cover Thickness,  $c = 25.00$

Mean Confinement Factor overall section = 1.10542

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,  $NoDir = 1$

Fiber orientations,  $b_i = 0.00^\circ$

Number of layers,  $NL = 1$

Radius of rounding corners,  $R = 40.00$

## Stepwise Properties

At local axis: 3

EDGE -A-

Shear Force,  $V_a = 2.0531359E-031$

EDGE -B-

Shear Force,  $V_b = -2.0531359E-031$

BOTH EDGES

Axial Force,  $F = -7506.808$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension:  $As_t = 0.00$

-Compression:  $As_c = 2676.637$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension:  $As_{t,ten} = 1137.257$

-Compression:  $As_{l,com} = 1137.257$

-Middle:  $As_{l,mid} = 402.1239$

Calculation of Shear Capacity ratio,  $V_e/V_r = 0.26068017$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 147952.607$

with  
 $M_{pr1} = \text{Max}(M_{u1+}, M_{u1-}) = 2.2193E+008$   
 $M_{u1+} = 2.2193E+008$ , 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  
 $M_{u1-} = 2.2193E+008$ , 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  
 $M_{pr2} = \text{Max}(M_{u2+}, M_{u2-}) = 2.2193E+008$   
 $M_{u2+} = 2.2193E+008$ , 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  
 $M_{u2-} = 2.2193E+008$ , 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 curvature  $\phi_u$  according to 4.1, Biskinis/Fardis 2013:

$\phi_u = 1.9632832E-005$

$M_u = 2.2193E+008$

with full section properties:

$b = 450.00$

$d = 407.00$

$d' = 43.00$

$v = 0.00124204$

$N = 7506.808$

$f_c = 33.00$

$\alpha$  (5A.5, TBDY) = 0.002

Final value of  $\phi_u$ :  $\phi_u^* = \text{shear\_factor} * \text{Max}(\phi_u, \phi_c) = 0.01393923$

The Shear\_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY:  $\phi_u = 0.01393923$

where  $\phi_u$  ((5.4c), TBDY) =  $\alpha s_e * \text{sh}_{\min} * f_{ywe} / f_{ce} + \text{Min}(\phi_x, \phi_y) = 0.06811101$

where  $\phi_x = \alpha s_e * p_f * f_{fe} / f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$\phi_x = 0.06628267$

$\alpha s_e = 0.54930041$

$b = 450.00$

$h = 450.00$

From EC8 A.4.4.3(6),  $p_f = 2t_f/b_w = 0.00451556$

$b_w = 450.00$

effective stress from (A.35),  $f_{fe} = 881.8461$

fy = 0.06628267  
af = 0.54930041  
b = 450.00  
h = 450.00  
From EC8 A.4.4.3(6), pf = 2tf/bw = 0.00451556  
bw = 450.00  
effective stress from (A.35), ff,e = 881.8461

R = 40.00  
Effective FRP thickness, tf = NL\*t\*Cos(b1) = 1.016  
fu,f = 1055.00  
Ef = 64828.00  
u,f = 0.015  
ase ((5.4d), TBDY) = (ase1\*Aext+ase2\*Aint)/Asec = 0.14546167  
ase1 = 0.12623274  
bo\_1 = 390.00  
ho\_1 = 390.00  
bi2\_1 = 608400.00  
ase2 = Max(ase1,ase2) = 0.18853448  
bo\_2 = 242.00  
ho\_2 = 242.00  
bi2\_2 = 234256.00  
psh,min\*Fywe = Min(psh,x\*Fywe , psh,y\*Fywe) = 1.38262

Expression ((5.4d), TBDY) for psh,min\*Fywe has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

psh\_x\*Fywe = psh1\*Fywe1+ps2\*Fywe2 = 1.38262  
ps1 (external) = (Ash1\*h1/s1)/Asec = 0.00116355  
Ash1 = Astir\_1\*ns\_1 = 157.0796  
No stirrups, ns\_1 = 2.00  
h1 = 450.00  
ps2 (internal) = (Ash2\*h2/s2)/Asec = 0.00103427  
Ash2 = Astir\_2\*ns\_2 = 100.531  
No stirrups, ns\_2 = 2.00  
h2 = 250.00

psh\_y\*Fywe = psh1\*Fywe1+ps2\*Fywe2 = 1.38262  
ps1 (external) = (Ash1\*h1/s1)/Asec = 0.00116355  
Ash1 = Astir\_1\*ns\_1 = 157.0796  
No stirrups, ns\_1 = 2.00  
h1 = 450.00  
ps2 (internal) = (Ash2\*h2/s2)/Asec = 0.00103427  
Ash2 = Astir\_2\*ns\_2 = 100.531  
No stirrups, ns\_2 = 2.00  
h2 = 250.00

Asec = 202500.00  
s1 = 300.00  
s2 = 120.00  
fywe1 = 694.45  
fywe2 = 555.55  
fce = 33.00

From ((5.A5), TBDY), TBDY: cc = 0.00305417  
c = confinement factor = 1.10542

y1 = 0.00152175  
sh1 = 0.0048696  
ft1 = 479.7871  
fy1 = 399.8226  
su1 = 0.0066488

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

lo/lou,min = lb/d = 0.33981258

su1 = 0.4\*esu1\_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu1\_nominal = 0.08,

For calculation of esu1\_nominal and y1, sh1,ft1,fy1, it is considered

characteristic value  $f_{sy1} = f_{s1}/1.2$ , from table 5.1, TBDY.

$y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.

with  $f_{s1} = (f_{s,jacket} \cdot A_{s,ten,jacket} + f_{s,core} \cdot A_{s,ten,core})/A_{s,ten} = 399.8226$

with  $E_{s1} = (E_{s,jacket} \cdot A_{s,ten,jacket} + E_{s,core} \cdot A_{s,ten,core})/A_{s,ten} = 200000.00$

$y_2 = 0.00152175$

$sh_2 = 0.0048696$

$ft_2 = 479.7871$

$fy_2 = 399.8226$

$su_2 = 0.0066488$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor

and also multiplied by the shear\_factor according to 15.7.1.4, with

Shear\_factor = 1.00

$l_o/l_{o,min} = l_b/l_{b,min} = 0.33981258$

$su_2 = 0.4 \cdot esu_{2,nominal} ((5.5), TBDY) = 0.032$

From table 5A.1, TBDY:  $esu_{2,nominal} = 0.08$ ,

For calculation of  $esu_{2,nominal}$  and  $y_2, sh_2, ft_2, fy_2$ , it is considered

characteristic value  $f_{sy2} = f_{s2}/1.2$ , from table 5.1, TBDY.

$y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.

with  $f_{s2} = (f_{s,jacket} \cdot A_{s,com,jacket} + f_{s,core} \cdot A_{s,com,core})/A_{s,com} = 399.8226$

with  $E_{s2} = (E_{s,jacket} \cdot A_{s,com,jacket} + E_{s,core} \cdot A_{s,com,core})/A_{s,com} = 200000.00$

$y_v = 0.00152175$

$sh_v = 0.0048696$

$ft_v = 507.2537$

$fy_v = 422.7114$

$su_v = 0.0066488$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor

and also multiplied by the shear\_factor according to 15.7.1.4, with

Shear\_factor = 1.00

$l_o/l_{o,min} = l_b/l_d = 0.33981258$

$su_v = 0.4 \cdot esu_{v,nominal} ((5.5), TBDY) = 0.032$

From table 5A.1, TBDY:  $esu_{v,nominal} = 0.08$ ,

considering characteristic value  $f_{syv} = f_{sv}/1.2$ , from table 5.1, TBDY

For calculation of  $esu_{v,nominal}$  and  $y_v, sh_v, ft_v, fy_v$ , it is considered

characteristic value  $f_{syv} = f_{sv}/1.2$ , from table 5.1, TBDY.

$y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.

with  $f_{sv} = (f_{s,jacket} \cdot A_{s,mid,jacket} + f_{s,mid} \cdot A_{s,mid,core})/A_{s,mid} = 422.7114$

with  $E_{sv} = (E_{s,jacket} \cdot A_{s,mid,jacket} + E_{s,mid} \cdot A_{s,mid,core})/A_{s,mid} = 200000.00$

$1 = A_{s,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.0752324$

$2 = A_{s,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.0752324$

$v = A_{s,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.02812438$

and confined core properties:

$b = 390.00$

$d = 377.00$

$d' = 13.00$

$f_{cc} (5A.2, TBDY) = 36.47874$

$cc (5A.5, TBDY) = 0.00305417$

$c = \text{confinement factor} = 1.10542$

$1 = A_{s,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.09371431$

$2 = A_{s,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.09371431$

$v = A_{s,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.03503353$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < v_{s,y2}$  - LHS eq.(4.5) is satisfied

--->

$su (4.9) = 0.16791801$

$Mu = MRc (4.14) = 2.2193E+008$

$u = su (4.1) = 1.9632832E-005$

Calculation of ratio  $l_b/l_d$

Lap Length:  $l_b/l_d = 0.33981258$

$l_b = 300.00$

$l_d = 882.8396$

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

= 1

$db = 16.66667$   
 Mean strength value of all re-bars:  $f_y = 655.558$   
 Mean concrete strength:  $f_c' = (f_c'_{jacket} \cdot Area_{jacket} + f_c'_{core} \cdot Area_{core}) / Area_{section} = 28.98765$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)  
 $t = 1.00$   
 $s = 0.80$   
 $e = 1.00$   
 $cb = 25.00$   
 $K_{tr} = 2.86234$   
 $A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 257.6106$   
 where  $A_{tr_x}$ ,  $A_{tr_y}$  are the sum of the area of all stirrup legs along X and Y local axis  
 $s = \text{Max}(s_{external}, s_{internal}) = 300.00$   
 $n = 12.00$

-----  
 -----  
 -----  
 Calculation of  $\mu_1$ -  
 -----

Calculation of ultimate curvature  $\mu$  according to 4.1, Biskinis/Fardis 2013:  
 $\mu = 1.9632832E-005$   
 $\mu_u = 2.2193E+008$

-----  
 with full section properties:

$b = 450.00$   
 $d = 407.00$   
 $d' = 43.00$   
 $v = 0.00124204$   
 $N = 7506.808$   
 $f_c = 33.00$   
 $\alpha_1$  (5A.5, TBDY) = 0.002  
 Final value of  $\mu_c$ :  $\mu_c^* = \text{shear\_factor} \cdot \text{Max}(\mu_c, \mu_{cc}) = 0.01393923$   
 The Shear\_factor is considered equal to 1 (pure moment strength)  
 From (5.4b), TBDY:  $\mu_c = 0.01393923$   
 $\mu_{ve}$  ((5.4c), TBDY) =  $\alpha_{se} \cdot \text{sh}_{min} \cdot f_{yve} / f_{ce} + \text{Min}(f_x, f_y) = 0.06811101$   
 where  $f = \alpha_f \cdot \rho_f \cdot f_{fe} / f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

-----  
 $f_x = 0.06628267$   
 $\alpha_f = 0.54930041$   
 $b = 450.00$   
 $h = 450.00$   
 From EC8 A.4.4.3(6),  $\rho_f = 2t_f / bw = 0.00451556$   
 $bw = 450.00$   
 effective stress from (A.35),  $f_{fe} = 881.8461$

-----  
 $f_y = 0.06628267$   
 $\alpha_f = 0.54930041$   
 $b = 450.00$   
 $h = 450.00$   
 From EC8 A.4.4.3(6),  $\rho_f = 2t_f / bw = 0.00451556$   
 $bw = 450.00$   
 effective stress from (A.35),  $f_{fe} = 881.8461$

-----  
 $R = 40.00$   
 Effective FRP thickness,  $t_f = NL \cdot t \cdot \text{Cos}(b_1) = 1.016$   
 $f_{u,f} = 1055.00$   
 $E_f = 64828.00$   
 $u_f = 0.015$   
 $\alpha_{se}$  ((5.4d), TBDY) =  $(\alpha_{se1} \cdot A_{ext} + \alpha_{se2} \cdot A_{int}) / A_{sec} = 0.14546167$   
 $\alpha_{se1} = 0.12623274$   
 $bo_1 = 390.00$   
 $ho_1 = 390.00$   
 $bi_2_1 = 608400.00$   
 $\alpha_{se2} = \text{Max}(\alpha_{se1}, \alpha_{se2}) = 0.18853448$   
 $bo_2 = 242.00$   
 $ho_2 = 242.00$

$$bi_{2,2} = 234256.00$$

$$psh_{min} * Fy_{we} = \text{Min}(psh_x * Fy_{we}, psh_y * Fy_{we}) = 1.38262$$

Expression ((5.4d), TBDY) for  $psh_{min} * Fy_{we}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$$psh_x * Fy_{we} = psh_1 * Fy_{we1} + ps_2 * Fy_{we2} = 1.38262$$

$$ps_1 \text{ (external)} = (Ash_1 * h_1 / s_1) / A_{sec} = 0.00116355$$

$$Ash_1 = Astir_1 * ns_1 = 157.0796$$

$$\text{No stirrups, } ns_1 = 2.00$$

$$h_1 = 450.00$$

$$ps_2 \text{ (internal)} = (Ash_2 * h_2 / s_2) / A_{sec} = 0.00103427$$

$$Ash_2 = Astir_2 * ns_2 = 100.531$$

$$\text{No stirrups, } ns_2 = 2.00$$

$$h_2 = 250.00$$

$$psh_y * Fy_{we} = psh_1 * Fy_{we1} + ps_2 * Fy_{we2} = 1.38262$$

$$ps_1 \text{ (external)} = (Ash_1 * h_1 / s_1) / A_{sec} = 0.00116355$$

$$Ash_1 = Astir_1 * ns_1 = 157.0796$$

$$\text{No stirrups, } ns_1 = 2.00$$

$$h_1 = 450.00$$

$$ps_2 \text{ (internal)} = (Ash_2 * h_2 / s_2) / A_{sec} = 0.00103427$$

$$Ash_2 = Astir_2 * ns_2 = 100.531$$

$$\text{No stirrups, } ns_2 = 2.00$$

$$h_2 = 250.00$$

$$A_{sec} = 202500.00$$

$$s_1 = 300.00$$

$$s_2 = 120.00$$

$$fy_{we1} = 694.45$$

$$fy_{we2} = 555.55$$

$$f_{ce} = 33.00$$

$$\text{From ((5.A5), TBDY), TBDY: } cc = 0.00305417$$

$$c = \text{confinement factor} = 1.10542$$

$$y_1 = 0.00152175$$

$$sh_1 = 0.0048696$$

$$ft_1 = 479.7871$$

$$fy_1 = 399.8226$$

$$su_1 = 0.0066488$$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00

$$lo/lou_{min} = lb/l_d = 0.33981258$$

$$su_1 = 0.4 * esu_{1\_nominal} \text{ ((5.5), TBDY)} = 0.032$$

$$\text{From table 5A.1, TBDY: } esu_{1\_nominal} = 0.08,$$

For calculation of  $esu_{1\_nominal}$  and  $y_1, sh_1, ft_1, fy_1$ , it is considered characteristic value  $fsy_1 = fs_1 / 1.2$ , from table 5.1, TBDY.

$y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 * (lb/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.

$$\text{with } fs_1 = (fs_{jacket} * A_{sl,ten,jacket} + fs_{core} * A_{sl,ten,core}) / A_{sl,ten} = 399.8226$$

$$\text{with } Es_1 = (Es_{jacket} * A_{sl,ten,jacket} + Es_{core} * A_{sl,ten,core}) / A_{sl,ten} = 200000.00$$

$$y_2 = 0.00152175$$

$$sh_2 = 0.0048696$$

$$ft_2 = 479.7871$$

$$fy_2 = 399.8226$$

$$su_2 = 0.0066488$$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00

$$lo/lou_{min} = lb/l_{b,min} = 0.33981258$$

$$su_2 = 0.4 * esu_{2\_nominal} \text{ ((5.5), TBDY)} = 0.032$$

$$\text{From table 5A.1, TBDY: } esu_{2\_nominal} = 0.08,$$

For calculation of  $esu_{2\_nominal}$  and  $y_2, sh_2, ft_2, fy_2$ , it is considered characteristic value  $fsy_2 = fs_2 / 1.2$ , from table 5.1, TBDY.

$y_2, sh_2, ft_2, fy_2$ , are also multiplied by  $\text{Min}(1, 1.25 * (lb/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.

$$\text{with } fs_2 = (fs_{jacket} * A_{sl,com,jacket} + fs_{core} * A_{sl,com,core}) / A_{sl,com} = 399.8226$$

$$\text{with } Es_2 = (Es_{jacket} * A_{sl,com,jacket} + Es_{core} * A_{sl,com,core}) / A_{sl,com} = 200000.00$$

$$y_v = 0.00152175$$

$$sh_v = 0.0048696$$

$$f_{tv} = 507.2537$$

$$f_{yv} = 422.7114$$

$$s_{uv} = 0.0066488$$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

$$l_o/l_{ou,min} = l_b/l_d = 0.33981258$$

$$s_{uv} = 0.4 * e_{suv,nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY:  $e_{suv,nominal} = 0.08$ ,

considering characteristic value  $f_{sv} = f_{sv}/1.2$ , from table 5.1, TBDY

For calculation of  $e_{suv,nominal}$  and  $\gamma_v$ ,  $sh_v, f_{tv}, f_{yv}$ , it is considered  
characteristic value  $f_{sv} = f_{sv}/1.2$ , from table 5.1, TBDY.

$\gamma_1$ ,  $sh_1, f_{t1}, f_{y1}$ , are also multiplied by  $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.

$$\text{with } f_{sv} = (f_{s,jacket} * A_{sl,mid,jacket} + f_{s,mid} * A_{sl,mid,core}) / A_{sl,mid} = 422.7114$$

$$\text{with } E_{sv} = (E_{s,jacket} * A_{sl,mid,jacket} + E_{s,mid} * A_{sl,mid,core}) / A_{sl,mid} = 200000.00$$

$$1 = A_{sl,ten} / (b * d) * (f_{s1} / f_c) = 0.0752324$$

$$2 = A_{sl,com} / (b * d) * (f_{s2} / f_c) = 0.0752324$$

$$v = A_{sl,mid} / (b * d) * (f_{sv} / f_c) = 0.02812438$$

and confined core properties:

$$b = 390.00$$

$$d = 377.00$$

$$d' = 13.00$$

$$f_{cc} (5A.2, TBDY) = 36.47874$$

$$c_c (5A.5, TBDY) = 0.00305417$$

$$c = \text{confinement factor} = 1.10542$$

$$1 = A_{sl,ten} / (b * d) * (f_{s1} / f_c) = 0.09371431$$

$$2 = A_{sl,com} / (b * d) * (f_{s2} / f_c) = 0.09371431$$

$$v = A_{sl,mid} / (b * d) * (f_{sv} / f_c) = 0.03503353$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < v_{s,y2}$  - LHS eq.(4.5) is satisfied

--->

$$s_u (4.9) = 0.16791801$$

$$\mu_u = M_{Rc} (4.14) = 2.2193E+008$$

$$u = s_u (4.1) = 1.9632832E-005$$

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

-----  
Lap Length:  $l_b/l_d = 0.33981258$

$$l_b = 300.00$$

$$l_d = 882.8396$$

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

$$= 1$$

$$d_b = 16.66667$$

Mean strength value of all re-bars:  $f_y = 655.558$

Mean concrete strength:  $f'_c = (f'_{c,jacket} * Area_{jacket} + f'_{c,core} * Area_{core}) / Area_{section} = 28.98765$ , but  $f_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 25.00$$

$$K_{tr} = 2.86234$$

$$A_{tr} = \text{Min}(A_{tr,x}, A_{tr,y}) = 257.6106$$

where  $A_{tr,x}$ ,  $A_{tr,y}$  are the sum of the area of all stirrup legs along X and Y local axis

$$s = \text{Max}(s_{external}, s_{internal}) = 300.00$$

$$n = 12.00$$

-----  
Calculation of  $\mu_{u2+}$

-----  
Calculation of ultimate curvature  $\mu_u$  according to 4.1, Biskinis/Fardis 2013:

$$u = 1.9632832E-005$$

Mu = 2.2193E+008

with full section properties:

b = 450.00

d = 407.00

d' = 43.00

v = 0.00124204

N = 7506.808

fc = 33.00

co (5A.5, TBDY) = 0.002

Final value of cu: cu\* = shear\_factor \* Max( cu, cc) = 0.01393923

The Shear\_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: cu = 0.01393923

we ((5.4c), TBDY) = ase\* sh,min\*fywe/fce+ Min( fx, fy) = 0.06811101

where f = af\*pf\*ffe/fce is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

fx = 0.06628267

af = 0.54930041

b = 450.00

h = 450.00

From EC8 A.4.4.3(6), pf = 2tf/bw = 0.00451556

bw = 450.00

effective stress from (A.35), ffe = 881.8461

fy = 0.06628267

af = 0.54930041

b = 450.00

h = 450.00

From EC8 A.4.4.3(6), pf = 2tf/bw = 0.00451556

bw = 450.00

effective stress from (A.35), ffe = 881.8461

R = 40.00

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

fu,f = 1055.00

Ef = 64828.00

u,f = 0.015

ase ((5.4d), TBDY) = (ase1\*Aext+ase2\*Aint)/Asec = 0.14546167

ase1 = 0.12623274

bo\_1 = 390.00

ho\_1 = 390.00

bi2\_1 = 608400.00

ase2 = Max(ase1,ase2) = 0.18853448

bo\_2 = 242.00

ho\_2 = 242.00

bi2\_2 = 234256.00

psh,min\*Fywe = Min(psh,x\*Fywe , psh,y\*Fywe) = 1.38262

Expression ((5.4d), TBDY) for psh,min\*Fywe has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

psh\_x\*Fywe = psh1\*Fywe1+ps2\*Fywe2 = 1.38262

ps1 (external) = (Ash1\*h1/s1)/Asec = 0.00116355

Ash1 = Astir\_1\*ns\_1 = 157.0796

No stirrups, ns\_1 = 2.00

h1 = 450.00

ps2 (internal) = (Ash2\*h2/s2)/Asec = 0.00103427

Ash2 = Astir\_2\*ns\_2 = 100.531

No stirrups, ns\_2 = 2.00

h2 = 250.00

psh\_y\*Fywe = psh1\*Fywe1+ps2\*Fywe2 = 1.38262

ps1 (external) = (Ash1\*h1/s1)/Asec = 0.00116355

Ash1 = Astir\_1\*ns\_1 = 157.0796

No stirrups, ns\_1 = 2.00

h1 = 450.00

ps2 (internal) = (Ash2\*h2/s2)/Asec = 0.00103427

Ash2 = Astir\_2\*ns\_2 = 100.531

No stirrups, ns\_2 = 2.00  
h2 = 250.00

Asec = 202500.00

s1 = 300.00

s2 = 120.00

fywe1 = 694.45

fywe2 = 555.55

fce = 33.00

From ((5.A.5), TBDY), TBDY: cc = 0.00305417

c = confinement factor = 1.10542

y1 = 0.00152175

sh1 = 0.0048696

ft1 = 479.7871

fy1 = 399.8226

su1 = 0.0066488

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

lo/lou,min = lb/lc = 0.33981258

su1 = 0.4\*esu1\_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu1\_nominal = 0.08,

For calculation of esu1\_nominal and y1, sh1,ft1,fy1, it is considered  
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/lc)^{2/3})$ , from 10.3.5, ASCE 41-17.

with fs1 = (fs,jacket\*Asl,ten,jacket + fs,core\*Asl,ten,core)/Asl,ten = 399.8226

with Es1 = (Es,jacket\*Asl,ten,jacket + Es,core\*Asl,ten,core)/Asl,ten = 200000.00

y2 = 0.00152175

sh2 = 0.0048696

ft2 = 479.7871

fy2 = 399.8226

su2 = 0.0066488

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

lo/lou,min = lb/lb,min = 0.33981258

su2 = 0.4\*esu2\_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu2\_nominal = 0.08,

For calculation of esu2\_nominal and y2, sh2,ft2,fy2, it is considered  
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/lc)^{2/3})$ , from 10.3.5, ASCE 41-17.

with fs2 = (fs,jacket\*Asl,com,jacket + fs,core\*Asl,com,core)/Asl,com = 399.8226

with Es2 = (Es,jacket\*Asl,com,jacket + Es,core\*Asl,com,core)/Asl,com = 200000.00

yv = 0.00152175

shv = 0.0048696

ftv = 507.2537

fyv = 422.7114

suv = 0.0066488

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

lo/lou,min = lb/lc = 0.33981258

suv = 0.4\*esuv\_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esuv\_nominal = 0.08,

considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY  
For calculation of esuv\_nominal and yv, shv,ftv,fyv, it is considered

characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/lc)^{2/3})$ , from 10.3.5, ASCE 41-17.

with fsv = (fs,jacket\*Asl,mid,jacket + fs,mid\*Asl,mid,core)/Asl,mid = 422.7114

with Esv = (Es,jacket\*Asl,mid,jacket + Es,mid\*Asl,mid,core)/Asl,mid = 200000.00

1 = Asl,ten/(b\*d)\*(fs1/fc) = 0.0752324

2 = Asl,com/(b\*d)\*(fs2/fc) = 0.0752324

v = Asl,mid/(b\*d)\*(fsv/fc) = 0.02812438

and confined core properties:

b = 390.00

d = 377.00

d' = 13.00

fcc (5A.2, TBDY) = 36.47874  
cc (5A.5, TBDY) = 0.00305417  
c = confinement factor = 1.10542  
1 =  $Asl,ten/(b*d)*(fs1/fc) = 0.09371431$   
2 =  $Asl,com/(b*d)*(fs2/fc) = 0.09371431$   
v =  $Asl,mid/(b*d)*(fsv/fc) = 0.03503353$   
Case/Assumption: Unconfined full section - Steel rupture  
' satisfies Eq. (4.3)

--->  
v < vs,y2 - LHS eq.(4.5) is satisfied

--->  
su (4.9) = 0.16791801  
Mu = MRc (4.14) = 2.2193E+008  
u = su (4.1) = 1.9632832E-005

-----  
Calculation of ratio lb/l<sub>d</sub>

-----  
Lap Length: lb/l<sub>d</sub> = 0.33981258

lb = 300.00

ld = 882.8396

Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.  
= 1

db = 16.66667

Mean strength value of all re-bars: fy = 655.558

Mean concrete strength: fc' = (fc'\_jacket\*Area\_jacket + fc'\_core\*Area\_core)/Area\_section = 28.98765, 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 = 2.86234

Atr = Min(Atr\_x,Atr\_y) = 257.6106

where Atr\_x, Atr\_y are the sum of the area of all stirrup legs along X and Y local axis

s = Max(s\_external,s\_internal) = 300.00

n = 12.00

-----  
Calculation of Mu2-

-----  
Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

u = 1.9632832E-005

Mu = 2.2193E+008

-----  
with full section properties:

b = 450.00

d = 407.00

d' = 43.00

v = 0.00124204

N = 7506.808

fc = 33.00

co (5A.5, TBDY) = 0.002

Final value of cu: cu\* = shear\_factor \* Max( cu, cc) = 0.01393923

The Shear\_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: cu = 0.01393923

we ((5.4c), TBDY) = ase\* sh,min\*fywe/fce+Min( fx, fy) = 0.06811101

where f = af\*pf\*ffe/fce is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

-----  
fx = 0.06628267

af = 0.54930041

b = 450.00

h = 450.00

From EC8 A 4.4.3(6), pf = 2tf/bw = 0.00451556

bw = 450.00

effective stress from (A.35),  $f_{f,e} = 881.8461$

$f_y = 0.06628267$

$a_f = 0.54930041$

$b = 450.00$

$h = 450.00$

From EC8 A.4.4.3(6),  $p_f = 2t_f/b_w = 0.00451556$

$b_w = 450.00$

effective stress from (A.35),  $f_{f,e} = 881.8461$

$R = 40.00$

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

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{,f} = 0.015$

$a_{se} ((5.4d), TBDY) = (a_{se1}*A_{ext} + a_{se2}*A_{int})/A_{sec} = 0.14546167$

$a_{se1} = 0.12623274$

$b_{o,1} = 390.00$

$h_{o,1} = 390.00$

$b_{i2,1} = 608400.00$

$a_{se2} = \text{Max}(a_{se1}, a_{se2}) = 0.18853448$

$b_{o,2} = 242.00$

$h_{o,2} = 242.00$

$b_{i2,2} = 234256.00$

$p_{sh,min}*F_{ywe} = \text{Min}(p_{sh,x}*F_{ywe}, p_{sh,y}*F_{ywe}) = 1.38262$

Expression ((5.4d), TBDY) for  $p_{sh,min}*F_{ywe}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$p_{sh,x}*F_{ywe} = p_{sh1}*F_{ywe1} + p_{s2}*F_{ywe2} = 1.38262$

$p_{s1} \text{ (external)} = (A_{sh1}*h_1/s_1)/A_{sec} = 0.00116355$

$A_{sh1} = A_{stir,1}*n_{s,1} = 157.0796$

No stirrups,  $n_{s,1} = 2.00$

$h_1 = 450.00$

$p_{s2} \text{ (internal)} = (A_{sh2}*h_2/s_2)/A_{sec} = 0.00103427$

$A_{sh2} = A_{stir,2}*n_{s,2} = 100.531$

No stirrups,  $n_{s,2} = 2.00$

$h_2 = 250.00$

$p_{sh,y}*F_{ywe} = p_{sh1}*F_{ywe1} + p_{s2}*F_{ywe2} = 1.38262$

$p_{s1} \text{ (external)} = (A_{sh1}*h_1/s_1)/A_{sec} = 0.00116355$

$A_{sh1} = A_{stir,1}*n_{s,1} = 157.0796$

No stirrups,  $n_{s,1} = 2.00$

$h_1 = 450.00$

$p_{s2} \text{ (internal)} = (A_{sh2}*h_2/s_2)/A_{sec} = 0.00103427$

$A_{sh2} = A_{stir,2}*n_{s,2} = 100.531$

No stirrups,  $n_{s,2} = 2.00$

$h_2 = 250.00$

$A_{sec} = 202500.00$

$s_1 = 300.00$

$s_2 = 120.00$

$f_{ywe1} = 694.45$

$f_{ywe2} = 555.55$

$f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY:  $c_c = 0.00305417$

$c = \text{confinement factor} = 1.10542$

$y_1 = 0.00152175$

$sh_1 = 0.0048696$

$ft_1 = 479.7871$

$fy_1 = 399.8226$

$su_1 = 0.0066488$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00

$l_o/l_{o,min} = l_b/d = 0.33981258$

$su_1 = 0.4*es_{u1,nominal} ((5.5), TBDY) = 0.032$

From table 5A.1, TBDY:  $es_{u1,nominal} = 0.08$ ,

For calculation of  $es1_{nominal}$  and  $y1, sh1, ft1, fy1$ , it is considered characteristic value  $fsy1 = fs1/1.2$ , from table 5.1, TBDY.

$y1, sh1, ft1, fy1$ , are also multiplied by  $Min(1, 1.25 \cdot (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.

with  $fs1 = (fs_{jacket} \cdot Asl_{ten,jacket} + fs_{core} \cdot Asl_{ten,core}) / Asl_{ten} = 399.8226$

with  $Es1 = (Es_{jacket} \cdot Asl_{ten,jacket} + Es_{core} \cdot Asl_{ten,core}) / Asl_{ten} = 200000.00$

$y2 = 0.00152175$

$sh2 = 0.0048696$

$ft2 = 479.7871$

$fy2 = 399.8226$

$su2 = 0.0066488$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00

$lo/lo_{ou,min} = lb/lb_{,min} = 0.33981258$

$su2 = 0.4 \cdot esu2_{nominal} ((5.5), TBDY) = 0.032$

From table 5A.1, TBDY:  $esu2_{nominal} = 0.08$ ,

For calculation of  $esu2_{nominal}$  and  $y2, sh2, ft2, fy2$ , it is considered characteristic value  $fsy2 = fs2/1.2$ , from table 5.1, TBDY.

$y1, sh1, ft1, fy1$ , are also multiplied by  $Min(1, 1.25 \cdot (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.

with  $fs2 = (fs_{jacket} \cdot Asl_{com,jacket} + fs_{core} \cdot Asl_{com,core}) / Asl_{com} = 399.8226$

with  $Es2 = (Es_{jacket} \cdot Asl_{com,jacket} + Es_{core} \cdot Asl_{com,core}) / Asl_{com} = 200000.00$

$yv = 0.00152175$

$shv = 0.0048696$

$ftv = 507.2537$

$fyv = 422.7114$

$suv = 0.0066488$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00

$lo/lo_{ou,min} = lb/ld = 0.33981258$

$suv = 0.4 \cdot esuv_{nominal} ((5.5), TBDY) = 0.032$

From table 5A.1, TBDY:  $esuv_{nominal} = 0.08$ ,

considering characteristic value  $fsyv = fsv/1.2$ , from table 5.1, TBDY

For calculation of  $esuv_{nominal}$  and  $yv, shv, ftv, fyv$ , it is considered characteristic value  $fsyv = fsv/1.2$ , from table 5.1, TBDY.

$y1, sh1, ft1, fy1$ , are also multiplied by  $Min(1, 1.25 \cdot (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.

with  $fsv = (fs_{jacket} \cdot Asl_{mid,jacket} + fs_{mid} \cdot Asl_{mid,core}) / Asl_{mid} = 422.7114$

with  $Es_v = (Es_{jacket} \cdot Asl_{mid,jacket} + Es_{mid} \cdot Asl_{mid,core}) / Asl_{mid} = 200000.00$

$1 = Asl_{ten} / (b \cdot d) \cdot (fs1 / fc) = 0.0752324$

$2 = Asl_{com} / (b \cdot d) \cdot (fs2 / fc) = 0.0752324$

$v = Asl_{mid} / (b \cdot d) \cdot (fsv / fc) = 0.02812438$

and confined core properties:

$b = 390.00$

$d = 377.00$

$d' = 13.00$

$fcc (5A.2, TBDY) = 36.47874$

$cc (5A.5, TBDY) = 0.00305417$

$c = \text{confinement factor} = 1.10542$

$1 = Asl_{ten} / (b \cdot d) \cdot (fs1 / fc) = 0.09371431$

$2 = Asl_{com} / (b \cdot d) \cdot (fs2 / fc) = 0.09371431$

$v = Asl_{mid} / (b \cdot d) \cdot (fsv / fc) = 0.03503353$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < vs_{y2}$  - LHS eq.(4.5) is satisfied

--->

$su (4.9) = 0.16791801$

$Mu = MRc (4.14) = 2.2193E+008$

$u = su (4.1) = 1.9632832E-005$

Calculation of ratio  $lb/ld$

Lap Length:  $lb/ld = 0.33981258$

$lb = 300.00$

$ld = 882.8396$

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

$$= 1$$

$$db = 16.66667$$

Mean strength value of all re-bars:  $f_y = 655.558$

Mean concrete strength:  $f_c' = (f_c'_{\text{jacket}} \cdot \text{Area}_{\text{jacket}} + f_c'_{\text{core}} \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 28.98765$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$cb = 25.00$$

$$K_{tr} = 2.86234$$

$$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 257.6106$$

where  $A_{tr_x}$ ,  $A_{tr_y}$  are the sum of the area of all stirrup legs along X and Y local axis

$$s = \text{Max}(s_{\text{external}}, s_{\text{internal}}) = 300.00$$

$$n = 12.00$$

Calculation of Shear Strength  $V_r = \text{Min}(V_{r1}, V_{r2}) = 567563.724$

Calculation of Shear Strength at edge 1,  $V_{r1} = 567563.724$

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

$$V_{\text{Col}0} = 567563.724$$

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

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

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

Mean concrete strength:  $f_c' = (f_c'_{\text{jacket}} \cdot \text{Area}_{\text{jacket}} + f_c'_{\text{core}} \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 28.98765$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$$M/Vd = 2.00$$

$$M_u = 1.4404090E-011$$

$$V_u = 2.0531359E-031$$

$$d = 0.8 \cdot h = 360.00$$

$$N_u = 7506.808$$

$$A_g = 202500.00$$

From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 144280.365$

where:

$V_{s1} = 69813.729$  is calculated for jacket, with:

$$d = 360.00$$

$$A_v = 157079.633$$

$$f_y = 555.56$$

$$s = 300.00$$

$V_{s1}$  is multiplied by  $Col1 = 0.66666667$

$$s/d = 0.83333333$$

$V_{s2} = 74466.637$  is calculated for core, with:

$$d = 200.00$$

$$A_v = 100530.965$$

$$f_y = 444.44$$

$$s = 120.00$$

$V_{s2}$  is multiplied by  $Col2 = 1.00$

$$s/d = 0.60$$

$V_f$  ((11-3)-(11.4), ACI 440) = 214457.247

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

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

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

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

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

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

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

$d_{fv} = d$  (figure 11.2, ACI 440) = 407.00

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

$$E_f = 64828.00$$

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

with  $f_u = 0.01$

From (11-11), ACI 440:  $V_s + V_f \leq 579413.096$   
 $bw = 450.00$

Calculation of Shear Strength at edge 2,  $V_{r2} = 567563.724$   
 $V_{r2} = V_{Col} ((10.3), ASCE 41-17) = knl * V_{Col0}$   
 $V_{Col0} = 567563.724$   
 $knl = 1$  (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:  $f_c' = (f_c'_{jacket} * Area_{jacket} + f_c'_{core} * Area_{core}) / Area_{section} = 28.98765$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M / Vd = 2.00$

$\mu_u = 1.4404090E-011$

$V_u = 2.0531359E-031$

$d = 0.8 * h = 360.00$

$N_u = 7506.808$

$A_g = 202500.00$

From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 144280.365$

where:

$V_{s1} = 69813.729$  is calculated for jacket, with:

$d = 360.00$

$A_v = 157079.633$

$f_y = 555.56$

$s = 300.00$

$V_{s1}$  is multiplied by  $Col1 = 0.66666667$

$s/d = 0.83333333$

$V_{s2} = 74466.637$  is calculated for core, with:

$d = 200.00$

$A_v = 100530.965$

$f_y = 444.44$

$s = 120.00$

$V_{s2}$  is multiplied by  $Col2 = 1.00$

$s/d = 0.60$

$V_f ((11-3)-(11.4), ACI 440) = 214457.247$

$f = 0.95$ , for fully-wrapped sections

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

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

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

orientation 1:  $a_1 = b_1 + 90^\circ = 90.00$

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

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

$d_{fv} = d$  (figure 11.2, ACI 440) = 407.00

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

$E_f = 64828.00$

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

with  $f_u = 0.01$

From (11-11), ACI 440:  $V_s + V_f \leq 579413.096$   
 $bw = 450.00$

End Of Calculation of Shear Capacity ratio for element: column JC1 of floor 1  
At local axis: 3

Start Of Calculation of Shear Capacity ratio for element: column JC1 of floor 1  
At Shear local axis: 2  
(Bending local axis: 3)  
Section Type: rcjrs

Constant Properties

Knowledge Factor,  $\gamma = 0.85$

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 Height,  $H = 450.00$

External Width,  $W = 450.00$

Internal Height,  $H = 250.00$

Internal Width,  $W = 250.00$

Cover Thickness,  $c = 25.00$

Mean Confinement Factor overall section = 1.10542

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: 2

EDGE -A-

Shear Force,  $V_a = -2.7162834E-031$

EDGE -B-

Shear Force,  $V_b = 2.7162834E-031$

BOTH EDGES

Axial Force,  $F = -7506.808$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension:  $A_{sl,t} = 0.00$

-Compression:  $A_{sl,c} = 2676.637$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension:  $A_{sl,ten} = 1137.257$

-Compression:  $A_{sl,com} = 1137.257$

-Middle:  $A_{sl,mid} = 402.1239$

Calculation of Shear Capacity ratio ,  $V_e/V_r = 0.26068017$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 147952.607$

with  
 $M_{pr1} = \text{Max}(M_{u1+}, M_{u1-}) = 2.2193E+008$   
 $M_{u1+} = 2.2193E+008$ , 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  
 $M_{u1-} = 2.2193E+008$ , 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  
 $M_{pr2} = \text{Max}(M_{u2+}, M_{u2-}) = 2.2193E+008$   
 $M_{u2+} = 2.2193E+008$ , 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  
 $M_{u2-} = 2.2193E+008$ , 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 curvature  $\phi_u$  according to 4.1, Biskinis/Fardis 2013:

$\phi_u = 1.9632832E-005$

$M_u = 2.2193E+008$

with full section properties:

$b = 450.00$

$d = 407.00$

$d' = 43.00$

$v = 0.00124204$

$N = 7506.808$

$f_c = 33.00$

$\phi_c$  (5A.5, TBDY) = 0.002

Final value of  $\phi_u$ :  $\phi_u^* = \text{shear\_factor} * \text{Max}(\phi_u, \phi_c) = 0.01393923$

The Shear\_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY:  $\phi_u = 0.01393923$

$\phi_{we}$  ((5.4c), TBDY) =  $a_{se} * \phi_{sh, \min} * f_{ywe} / f_{ce} + \text{Min}(\phi_x, \phi_y) = 0.06811101$

where  $\phi_x = a_f * \phi_{f, e} / f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$\phi_x = 0.06628267$

$a_f = 0.54930041$

$b = 450.00$

$h = 450.00$

From EC8 A.4.4.3(6),  $\phi_{f, e} = 2t_f/bw = 0.00451556$

$bw = 450.00$

effective stress from (A.35),  $f_{f, e} = 881.8461$

$\phi_y = 0.06628267$

$a_f = 0.54930041$

$b = 450.00$

$h = 450.00$

From EC8 A.4.4.3(6),  $\phi_{f, e} = 2t_f/bw = 0.00451556$

$bw = 450.00$

effective stress from (A.35),  $f_{f, e} = 881.8461$

$R = 40.00$

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

$f_{u, f} = 1055.00$

$E_f = 64828.00$

$u_{, f} = 0.015$

$a_{se}$  ((5.4d), TBDY) =  $(a_{se1} * A_{ext} + a_{se2} * A_{int}) / A_{sec} = 0.14546167$

$a_{se1} = 0.12623274$

$b_{o, 1} = 390.00$

$h_{o, 1} = 390.00$

$b_{i, 2, 1} = 608400.00$

$$ase2 = \text{Max}(ase1, ase2) = 0.18853448$$

$$bo\_2 = 242.00$$

$$ho\_2 = 242.00$$

$$bi2\_2 = 234256.00$$

$$psh, \text{min} * Fywe = \text{Min}(psh, x * Fywe, psh, y * Fywe) = 1.38262$$

Expression ((5.4d), TBDY) for psh,min\*Fywe has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$$psh\_x * Fywe = psh1 * Fywe1 + ps2 * Fywe2 = 1.38262$$

$$ps1 \text{ (external)} = (Ash1 * h1 / s1) / Asec = 0.00116355$$

$$Ash1 = Astir\_1 * ns\_1 = 157.0796$$

No stirrups, ns<sub>1</sub> = 2.00

$$h1 = 450.00$$

$$ps2 \text{ (internal)} = (Ash2 * h2 / s2) / Asec = 0.00103427$$

$$Ash2 = Astir\_2 * ns\_2 = 100.531$$

No stirrups, ns<sub>2</sub> = 2.00

$$h2 = 250.00$$

$$psh\_y * Fywe = psh1 * Fywe1 + ps2 * Fywe2 = 1.38262$$

$$ps1 \text{ (external)} = (Ash1 * h1 / s1) / Asec = 0.00116355$$

$$Ash1 = Astir\_1 * ns\_1 = 157.0796$$

No stirrups, ns<sub>1</sub> = 2.00

$$h1 = 450.00$$

$$ps2 \text{ (internal)} = (Ash2 * h2 / s2) / Asec = 0.00103427$$

$$Ash2 = Astir\_2 * ns\_2 = 100.531$$

No stirrups, ns<sub>2</sub> = 2.00

$$h2 = 250.00$$

$$Asec = 202500.00$$

$$s1 = 300.00$$

$$s2 = 120.00$$

$$fywe1 = 694.45$$

$$fywe2 = 555.55$$

$$fce = 33.00$$

From ((5.A5), TBDY), TBDY: cc = 0.00305417

c = confinement factor = 1.10542

$$y1 = 0.00152175$$

$$sh1 = 0.0048696$$

$$ft1 = 479.7871$$

$$fy1 = 399.8226$$

$$su1 = 0.0066488$$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00

$$lo/lou, \text{min} = lb/ld = 0.33981258$$

$$su1 = 0.4 * esu1\_nominal \text{ ((5.5), TBDY)} = 0.032$$

From table 5A.1, TBDY: esu1\_nominal = 0.08,

For calculation of esu1\_nominal and y1, sh1, ft1, fy1, it is considered characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1, ft1, fy1, are also multiplied by Min(1, 1.25 \* (lb/ld)<sup>2/3</sup>), from 10.3.5, ASCE 41-17.

$$\text{with } fs1 = (fs, \text{jacket} * Asl, \text{ten, jacket} + fs, \text{core} * Asl, \text{ten, core}) / Asl, \text{ten} = 399.8226$$

$$\text{with } Es1 = (Es, \text{jacket} * Asl, \text{ten, jacket} + Es, \text{core} * Asl, \text{ten, core}) / Asl, \text{ten} = 200000.00$$

$$y2 = 0.00152175$$

$$sh2 = 0.0048696$$

$$ft2 = 479.7871$$

$$fy2 = 399.8226$$

$$su2 = 0.0066488$$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00

$$lo/lou, \text{min} = lb/lb, \text{min} = 0.33981258$$

$$su2 = 0.4 * esu2\_nominal \text{ ((5.5), TBDY)} = 0.032$$

From table 5A.1, TBDY: esu2\_nominal = 0.08,

For calculation of esu2\_nominal and y2, sh2, ft2, fy2, it is considered characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

y1, sh1, ft1, fy1, are also multiplied by Min(1, 1.25 \* (lb/ld)<sup>2/3</sup>), from 10.3.5, ASCE 41-17.

$$\text{with } fs2 = (fs, \text{jacket} * Asl, \text{com, jacket} + fs, \text{core} * Asl, \text{com, core}) / Asl, \text{com} = 399.8226$$

with  $E_{s2} = (E_{s,jacket} \cdot A_{s,com,jacket} + E_{s,core} \cdot A_{s,com,core}) / A_{s,com} = 200000.00$   
 $y_v = 0.00152175$   
 $sh_v = 0.0048696$   
 $ft_v = 507.2537$   
 $fy_v = 422.7114$   
 $su_v = 0.0066488$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 Shear\_factor = 1.00  
 $l_o/l_{o,min} = l_b/l_d = 0.33981258$   
 $su_v = 0.4 \cdot esuv\_nominal((5.5), TBDY) = 0.032$   
 From table 5A.1, TBDY:  $esuv\_nominal = 0.08$ ,  
 considering characteristic value  $fs_y = f_{sv}/1.2$ , from table 5.1, TBDY  
 For calculation of  $esuv\_nominal$  and  $y_v, sh_v, ft_v, fy_v$ , it is considered  
 characteristic value  $fs_y = f_{sv}/1.2$ , from table 5.1, TBDY.  
 $y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with  $f_{sv} = (f_{s,jacket} \cdot A_{s,mid,jacket} + f_{s,mid} \cdot A_{s,mid,core}) / A_{s,mid} = 422.7114$   
 with  $E_{sv} = (E_{s,jacket} \cdot A_{s,mid,jacket} + E_{s,mid} \cdot A_{s,mid,core}) / A_{s,mid} = 200000.00$   
 $1 = A_{s,ten} / (b \cdot d) \cdot (f_{s1} / f_c) = 0.0752324$   
 $2 = A_{s,com} / (b \cdot d) \cdot (f_{s2} / f_c) = 0.0752324$   
 $v = A_{s,mid} / (b \cdot d) \cdot (f_{sv} / f_c) = 0.02812438$   
 and confined core properties:  
 $b = 390.00$   
 $d = 377.00$   
 $d' = 13.00$   
 $f_{cc}(5A.2, TBDY) = 36.47874$   
 $cc(5A.5, TBDY) = 0.00305417$   
 $c = \text{confinement factor} = 1.10542$   
 $1 = A_{s,ten} / (b \cdot d) \cdot (f_{s1} / f_c) = 0.09371431$   
 $2 = A_{s,com} / (b \cdot d) \cdot (f_{s2} / f_c) = 0.09371431$   
 $v = A_{s,mid} / (b \cdot d) \cdot (f_{sv} / f_c) = 0.03503353$   
 Case/Assumption: Unconfined full section - Steel rupture  
 ' satisfies Eq. (4.3)  
 --->  
 $v < v_{s,y2}$  - LHS eq.(4.5) is satisfied  
 --->  
 $su(4.9) = 0.16791801$   
 $Mu = MRc(4.14) = 2.2193E+008$   
 $u = su(4.1) = 1.9632832E-005$   
 -----  
 Calculation of ratio  $l_b/l_d$   
 -----  
 Lap Length:  $l_b/l_d = 0.33981258$   
 $l_b = 300.00$   
 $l_d = 882.8396$   
 Calculation of  $l_b,min$  according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.  
 $= 1$   
 $db = 16.66667$   
 Mean strength value of all re-bars:  $f_y = 655.558$   
 Mean concrete strength:  $f_c' = (f_c'_{jacket} \cdot Area_{jacket} + f_c'_{core} \cdot Area_{core}) / Area_{section} = 28.98765$ , but  $f_c'^{0.5} < =$   
 8.3 MPa (22.5.3.1, ACI 318-14)  
 $t = 1.00$   
 $s = 0.80$   
 $e = 1.00$   
 $cb = 25.00$   
 $K_{tr} = 2.86234$   
 $A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 257.6106$   
 where  $A_{tr_x}, A_{tr_y}$  are the sum of the area of all stirrup legs along X and Y loxal axis  
 $s = \text{Max}(s_{external}, s_{internal}) = 300.00$   
 $n = 12.00$   
 -----  
 -----  
 Calculation of  $Mu1$ -  
 -----

Calculation of ultimate curvature  $\phi_u$  according to 4.1, Biskinis/Fardis 2013:

$$u = 1.9632832E-005$$

$$Mu = 2.2193E+008$$

with full section properties:

$$b = 450.00$$

$$d = 407.00$$

$$d' = 43.00$$

$$v = 0.00124204$$

$$N = 7506.808$$

$$f_c = 33.00$$

$$\alpha_{co} (5A.5, TBDY) = 0.002$$

$$\text{Final value of } \phi_u: \phi_u^* = \text{shear\_factor} * \text{Max}(\phi_{cu}, \phi_{cc}) = 0.01393923$$

The Shear\_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \phi_{cu} = 0.01393923$$

$$\phi_{we} ((5.4c), TBDY) = \alpha_{se} * \phi_{sh, \min} * f_{ywe} / f_{ce} + \text{Min}(\phi_{fx}, \phi_{fy}) = 0.06811101$$

where  $\phi_f = \alpha_f * \rho_f * f_{fe} / f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$\phi_{fx} = 0.06628267$$

$$\alpha_f = 0.54930041$$

$$b = 450.00$$

$$h = 450.00$$

$$\text{From EC8 A.4.4.3(6), } \rho_f = 2t_f / bw = 0.00451556$$

$$bw = 450.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 881.8461$$

$$\phi_{fy} = 0.06628267$$

$$\alpha_f = 0.54930041$$

$$b = 450.00$$

$$h = 450.00$$

$$\text{From EC8 A.4.4.3(6), } \rho_f = 2t_f / bw = 0.00451556$$

$$bw = 450.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 881.8461$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = NL * t * \text{Cos}(b1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$\alpha_{se} ((5.4d), TBDY) = (\alpha_{se1} * A_{ext} + \alpha_{se2} * A_{int}) / A_{sec} = 0.14546167$$

$$\alpha_{se1} = 0.12623274$$

$$b_{o,1} = 390.00$$

$$h_{o,1} = 390.00$$

$$b_{i2,1} = 608400.00$$

$$\alpha_{se2} = \text{Max}(\alpha_{se1}, \alpha_{se2}) = 0.18853448$$

$$b_{o,2} = 242.00$$

$$h_{o,2} = 242.00$$

$$b_{i2,2} = 234256.00$$

$$\phi_{sh, \min} * f_{ywe} = \text{Min}(\phi_{sh,x} * f_{ywe}, \phi_{sh,y} * f_{ywe}) = 1.38262$$

Expression ((5.4d), TBDY) for  $\phi_{sh, \min} * f_{ywe}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$$\phi_{sh,x} * f_{ywe} = \phi_{sh1} * f_{ywe1} + \phi_{sh2} * f_{ywe2} = 1.38262$$

$$\phi_{sh1} \text{ (external)} = (A_{sh1} * h1 / s1) / A_{sec} = 0.00116355$$

$$A_{sh1} = A_{stir,1} * n_{s,1} = 157.0796$$

$$\text{No stirrups, } n_{s,1} = 2.00$$

$$h1 = 450.00$$

$$\phi_{sh2} \text{ (internal)} = (A_{sh2} * h2 / s2) / A_{sec} = 0.00103427$$

$$A_{sh2} = A_{stir,2} * n_{s,2} = 100.531$$

$$\text{No stirrups, } n_{s,2} = 2.00$$

$$h2 = 250.00$$

$$\phi_{sh,y} * f_{ywe} = \phi_{sh1} * f_{ywe1} + \phi_{sh2} * f_{ywe2} = 1.38262$$

$$\phi_{sh1} \text{ (external)} = (A_{sh1} * h1 / s1) / A_{sec} = 0.00116355$$

$$A_{sh1} = A_{stir,1} * n_{s,1} = 157.0796$$

$$\text{No stirrups, } n_{s,1} = 2.00$$

h1 = 450.00  
ps2 (internal) = (Ash2\*h2/s2)/Asec = 0.00103427  
Ash2 = Astir\_2\*ns\_2 = 100.531  
No stirups, ns\_2 = 2.00  
h2 = 250.00

-----  
Asec = 202500.00  
s1 = 300.00  
s2 = 120.00  
fywe1 = 694.45  
fywe2 = 555.55  
fce = 33.00

From ((5.A5), TBDY), TBDY: cc = 0.00305417  
c = confinement factor = 1.10542

y1 = 0.00152175  
sh1 = 0.0048696  
ft1 = 479.7871  
fy1 = 399.8226  
su1 = 0.0066488

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

lo/lou,min = lb/d = 0.33981258

su1 = 0.4\*esu1\_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu1\_nominal = 0.08,

For calculation of esu1\_nominal and y1, sh1,ft1,fy1, it is considered  
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/d)^{2/3})$ , from 10.3.5, ASCE 41-17.

with fs1 = (fs,jacket\*Asl,ten,jacket + fs,core\*Asl,ten,core)/Asl,ten = 399.8226

with Es1 = (Es,jacket\*Asl,ten,jacket + Es,core\*Asl,ten,core)/Asl,ten = 200000.00

y2 = 0.00152175  
sh2 = 0.0048696  
ft2 = 479.7871  
fy2 = 399.8226  
su2 = 0.0066488

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

lo/lou,min = lb/lb,min = 0.33981258

su2 = 0.4\*esu2\_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu2\_nominal = 0.08,

For calculation of esu2\_nominal and y2, sh2,ft2,fy2, it is considered  
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/d)^{2/3})$ , from 10.3.5, ASCE 41-17.

with fs2 = (fs,jacket\*Asl,com,jacket + fs,core\*Asl,com,core)/Asl,com = 399.8226

with Es2 = (Es,jacket\*Asl,com,jacket + Es,core\*Asl,com,core)/Asl,com = 200000.00

yv = 0.00152175  
shv = 0.0048696  
ftv = 507.2537  
fyv = 422.7114  
suv = 0.0066488

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

lo/lou,min = lb/d = 0.33981258

suv = 0.4\*esuv\_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esuv\_nominal = 0.08,

considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY

For calculation of esuv\_nominal and yv, shv,ftv,fyv, it is considered  
characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by  $\text{Min}(1, 1.25 \cdot (lb/d)^{2/3})$ , from 10.3.5, ASCE 41-17.

with fsv = (fs,jacket\*Asl,mid,jacket + fs,mid\*Asl,mid,core)/Asl,mid = 422.7114

with Esv = (Es,jacket\*Asl,mid,jacket + Es,mid\*Asl,mid,core)/Asl,mid = 200000.00

1 = Asl,ten/(b\*d)\*(fs1/fc) = 0.0752324

2 = Asl,com/(b\*d)\*(fs2/fc) = 0.0752324

v = Asl,mid/(b\*d)\*(fsv/fc) = 0.02812438

and confined core properties:

$b = 390.00$   
 $d = 377.00$   
 $d' = 13.00$   
 $f_{cc} (5A.2, TBDY) = 36.47874$   
 $cc (5A.5, TBDY) = 0.00305417$   
 $c = \text{confinement factor} = 1.10542$   
 $1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.09371431$   
 $2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.09371431$   
 $v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.03503353$   
 Case/Assumption: Unconfined full section - Steel rupture  
 ' satisfies Eq. (4.3)

--->  
 $v < v_{s,y2}$  - LHS eq.(4.5) is satisfied  
 --->  
 $su (4.9) = 0.16791801$   
 $Mu = MRc (4.14) = 2.2193E+008$   
 $u = su (4.1) = 1.9632832E-005$

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

Lap Length:  $l_b/l_d = 0.33981258$   
 $l_b = 300.00$   
 $l_d = 882.8396$   
 Calculation of  $l_b, \min$  according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.  
 $= 1$   
 $db = 16.66667$   
 Mean strength value of all re-bars:  $f_y = 655.558$   
 Mean concrete strength:  $f_c' = (f_c'_{jacket} * Area_{jacket} + f_c'_{core} * Area_{core}) / Area_{section} = 28.98765$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)  
 $t = 1.00$   
 $s = 0.80$   
 $e = 1.00$   
 $cb = 25.00$   
 $K_{tr} = 2.86234$   
 $A_{tr} = \text{Min}(A_{tr,x}, A_{tr,y}) = 257.6106$   
 where  $A_{tr,x}, A_{tr,y}$  are the sum of the area of all stirrup legs along X and Y loxal axis  
 $s = \text{Max}(s_{external}, s_{internal}) = 300.00$   
 $n = 12.00$

-----  
 Calculation of  $Mu_{2+}$   
 -----

-----  
 Calculation of ultimate curvature  $u$  according to 4.1, Biskinis/Fardis 2013:

$u = 1.9632832E-005$   
 $Mu = 2.2193E+008$

-----  
 with full section properties:

$b = 450.00$   
 $d = 407.00$   
 $d' = 43.00$   
 $v = 0.00124204$   
 $N = 7506.808$   
 $f_c = 33.00$   
 $co (5A.5, TBDY) = 0.002$   
 Final value of  $cu$ :  $cu^* = \text{shear\_factor} * \text{Max}(cu, cc) = 0.01393923$   
 The Shear\_factor is considered equal to 1 (pure moment strength)  
 From (5.4b), TBDY:  $cu = 0.01393923$   
 $we ((5.4c), TBDY) = ase * sh_{,min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.06811101$   
 where  $f = af * pf * f_{fe} / f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)  
 -----  
 $f_x = 0.06628267$   
 $af = 0.54930041$   
 $b = 450.00$

h = 450.00  
From EC8 A.4.4.3(6),  $pf = 2tf/bw = 0.00451556$   
bw = 450.00  
effective stress from (A.35),  $ff,e = 881.8461$

fy = 0.06628267  
af = 0.54930041  
b = 450.00  
h = 450.00  
From EC8 A.4.4.3(6),  $pf = 2tf/bw = 0.00451556$   
bw = 450.00  
effective stress from (A.35),  $ff,e = 881.8461$

R = 40.00  
Effective FRP thickness,  $tf = NL*t*Cos(b1) = 1.016$   
fu,f = 1055.00  
Ef = 64828.00  
u,f = 0.015  
 $ase ((5.4d), TBDY) = (ase1*Aext+ase2*Aint)/Asec = 0.14546167$   
ase1 = 0.12623274  
bo\_1 = 390.00  
ho\_1 = 390.00  
bi2\_1 = 608400.00  
ase2 = Max(ase1,ase2) = 0.18853448  
bo\_2 = 242.00  
ho\_2 = 242.00  
bi2\_2 = 234256.00

$psh,min*Fywe = Min(psh,x*Fywe, psh,y*Fywe) = 1.38262$   
Expression ((5.4d), TBDY) for  $psh,min*Fywe$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$psh_x*Fywe = psh1*Fywe1+ps2*Fywe2 = 1.38262$   
ps1 (external) =  $(Ash1*h1/s1)/Asec = 0.00116355$   
Ash1 = Astir\_1\*ns\_1 = 157.0796  
No stirrups, ns\_1 = 2.00  
h1 = 450.00  
ps2 (internal) =  $(Ash2*h2/s2)/Asec = 0.00103427$   
Ash2 = Astir\_2\*ns\_2 = 100.531  
No stirrups, ns\_2 = 2.00  
h2 = 250.00

$psh_y*Fywe = psh1*Fywe1+ps2*Fywe2 = 1.38262$   
ps1 (external) =  $(Ash1*h1/s1)/Asec = 0.00116355$   
Ash1 = Astir\_1\*ns\_1 = 157.0796  
No stirrups, ns\_1 = 2.00  
h1 = 450.00  
ps2 (internal) =  $(Ash2*h2/s2)/Asec = 0.00103427$   
Ash2 = Astir\_2\*ns\_2 = 100.531  
No stirrups, ns\_2 = 2.00  
h2 = 250.00

Asec = 202500.00  
s1 = 300.00  
s2 = 120.00  
fywe1 = 694.45  
fywe2 = 555.55  
fce = 33.00

From ((5.A5), TBDY), TBDY:  $cc = 0.00305417$   
c = confinement factor = 1.10542

y1 = 0.00152175  
sh1 = 0.0048696  
ft1 = 479.7871  
fy1 = 399.8226  
su1 = 0.0066488

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

$$l_0/l_{0u,min} = l_b/l_d = 0.33981258$$

$$s_u = 0.4 \cdot e_{s1,nominal} ((5.5), TBDY) = 0.032$$

$$\text{From table 5A.1, TBDY: } e_{s1,nominal} = 0.08,$$

For calculation of  $e_{s1,nominal}$  and  $y_1, sh_1, ft_1, fy_1$ , it is considered characteristic value  $f_{sy1} = f_{s1}/1.2$ , from table 5.1, TBDY.

$y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.

$$\text{with } f_{s1} = (f_{s,jacket} \cdot A_{s,ten,jacket} + f_{s,core} \cdot A_{s,ten,core}) / A_{s,ten} = 399.8226$$

$$\text{with } E_{s1} = (E_{s,jacket} \cdot A_{s,ten,jacket} + E_{s,core} \cdot A_{s,ten,core}) / A_{s,ten} = 200000.00$$

$$y_2 = 0.00152175$$

$$sh_2 = 0.0048696$$

$$ft_2 = 479.7871$$

$$fy_2 = 399.8226$$

$$s_u = 0.0066488$$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00

$$l_0/l_{0u,min} = l_b/l_{b,min} = 0.33981258$$

$$s_u = 0.4 \cdot e_{s2,nominal} ((5.5), TBDY) = 0.032$$

$$\text{From table 5A.1, TBDY: } e_{s2,nominal} = 0.08,$$

For calculation of  $e_{s2,nominal}$  and  $y_2, sh_2, ft_2, fy_2$ , it is considered characteristic value  $f_{sy2} = f_{s2}/1.2$ , from table 5.1, TBDY.

$y_2, sh_2, ft_2, fy_2$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.

$$\text{with } f_{s2} = (f_{s,jacket} \cdot A_{s,com,jacket} + f_{s,core} \cdot A_{s,com,core}) / A_{s,com} = 399.8226$$

$$\text{with } E_{s2} = (E_{s,jacket} \cdot A_{s,com,jacket} + E_{s,core} \cdot A_{s,com,core}) / A_{s,com} = 200000.00$$

$$y_v = 0.00152175$$

$$sh_v = 0.0048696$$

$$ft_v = 507.2537$$

$$fy_v = 422.7114$$

$$s_u = 0.0066488$$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00

$$l_0/l_{0u,min} = l_b/l_d = 0.33981258$$

$$s_u = 0.4 \cdot e_{suv,nominal} ((5.5), TBDY) = 0.032$$

$$\text{From table 5A.1, TBDY: } e_{suv,nominal} = 0.08,$$

considering characteristic value  $f_{syv} = f_{sv}/1.2$ , from table 5.1, TBDY  
For calculation of  $e_{suv,nominal}$  and  $y_v, sh_v, ft_v, fy_v$ , it is considered characteristic value  $f_{syv} = f_{sv}/1.2$ , from table 5.1, TBDY.

$y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.

$$\text{with } f_{sv} = (f_{s,jacket} \cdot A_{s,mid,jacket} + f_{s,mid} \cdot A_{s,mid,core}) / A_{s,mid} = 422.7114$$

$$\text{with } E_{sv} = (E_{s,jacket} \cdot A_{s,mid,jacket} + E_{s,mid} \cdot A_{s,mid,core}) / A_{s,mid} = 200000.00$$

$$1 = A_{s,ten} / (b \cdot d) \cdot (f_{s1} / f_c) = 0.0752324$$

$$2 = A_{s,com} / (b \cdot d) \cdot (f_{s2} / f_c) = 0.0752324$$

$$v = A_{s,mid} / (b \cdot d) \cdot (f_{sv} / f_c) = 0.02812438$$

and confined core properties:

$$b = 390.00$$

$$d = 377.00$$

$$d' = 13.00$$

$$f_{cc} (5A.2, TBDY) = 36.47874$$

$$c_c (5A.5, TBDY) = 0.00305417$$

$$c = \text{confinement factor} = 1.10542$$

$$1 = A_{s,ten} / (b \cdot d) \cdot (f_{s1} / f_c) = 0.09371431$$

$$2 = A_{s,com} / (b \cdot d) \cdot (f_{s2} / f_c) = 0.09371431$$

$$v = A_{s,mid} / (b \cdot d) \cdot (f_{sv} / f_c) = 0.03503353$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < v_{s,y2}$  - LHS eq.(4.5) is satisfied

--->

$$s_u (4.9) = 0.16791801$$

$$\mu = M_{Rc} (4.14) = 2.2193E+008$$

$$u = s_u (4.1) = 1.9632832E-005$$

Calculation of ratio  $l_b/l_d$

$$\text{Lap Length: } l_b/l_d = 0.33981258$$

lb = 300.00

ld = 882.8396

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

= 1

db = 16.66667

Mean strength value of all re-bars: fy = 655.558

Mean concrete strength: fc' = (fc'\_jacket\*Area\_jacket + fc'\_core\*Area\_core)/Area\_section = 28.98765, 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 = 2.86234

Atr = Min(Atr\_x,Atr\_y) = 257.6106

where Atr\_x, Atr\_y are the sum of the area of all stirrup legs along X and Y loxal axis

s = Max(s\_external,s\_internal) = 300.00

n = 12.00

Calculation of Mu2-

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

u = 1.9632832E-005

Mu = 2.2193E+008

with full section properties:

b = 450.00

d = 407.00

d' = 43.00

v = 0.00124204

N = 7506.808

fc = 33.00

co (5A.5, TBDY) = 0.002

Final value of cu: cu\* = shear\_factor \* Max( cu, cc) = 0.01393923

The Shear\_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: cu = 0.01393923

we ((5.4c), TBDY) = ase\* sh,min\*fywe/fce+Min( fx, fy) = 0.06811101

where f = af\*pf\*ffe/fce is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

fx = 0.06628267

af = 0.54930041

b = 450.00

h = 450.00

From EC8 A.4.4.3(6), pf = 2tf/bw = 0.00451556

bw = 450.00

effective stress from (A.35), ff,e = 881.8461

fy = 0.06628267

af = 0.54930041

b = 450.00

h = 450.00

From EC8 A.4.4.3(6), pf = 2tf/bw = 0.00451556

bw = 450.00

effective stress from (A.35), ff,e = 881.8461

R = 40.00

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

fu,f = 1055.00

Ef = 64828.00

u,f = 0.015

ase ((5.4d), TBDY) = (ase1\*Aext+ase2\*Aint)/Asec = 0.14546167

ase1 = 0.12623274

bo\_1 = 390.00

ho\_1 = 390.00

bi2\_1 = 608400.00  
ase2 = Max(ase1,ase2) = 0.18853448  
bo\_2 = 242.00  
ho\_2 = 242.00  
bi2\_2 = 234256.00

psh,min\*Fywe = Min(psh,x\*Fywe , psh,y\*Fywe) = 1.38262

Expression ((5.4d), TBDY) for psh,min\*Fywe has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

psh\_x\*Fywe = psh1\*Fywe1+ps2\*Fywe2 = 1.38262  
ps1 (external) = (Ash1\*h1/s1)/Asec = 0.00116355  
Ash1 = Astir\_1\*ns\_1 = 157.0796  
No stirrups, ns\_1 = 2.00  
h1 = 450.00  
ps2 (internal) = (Ash2\*h2/s2)/Asec = 0.00103427  
Ash2 = Astir\_2\*ns\_2 = 100.531  
No stirrups, ns\_2 = 2.00  
h2 = 250.00

psh\_y\*Fywe = psh1\*Fywe1+ps2\*Fywe2 = 1.38262  
ps1 (external) = (Ash1\*h1/s1)/Asec = 0.00116355  
Ash1 = Astir\_1\*ns\_1 = 157.0796  
No stirrups, ns\_1 = 2.00  
h1 = 450.00  
ps2 (internal) = (Ash2\*h2/s2)/Asec = 0.00103427  
Ash2 = Astir\_2\*ns\_2 = 100.531  
No stirrups, ns\_2 = 2.00  
h2 = 250.00

Asec = 202500.00  
s1 = 300.00  
s2 = 120.00  
fywe1 = 694.45  
fywe2 = 555.55  
fce = 33.00

From ((5.A5), TBDY), TBDY: cc = 0.00305417  
c = confinement factor = 1.10542

y1 = 0.00152175  
sh1 = 0.0048696  
ft1 = 479.7871  
fy1 = 399.8226  
su1 = 0.0066488

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

lo/lou,min = lb/lb,min = 0.33981258

su1 = 0.4\*esu1\_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu1\_nominal = 0.08,

For calculation of esu1\_nominal and y1, sh1,ft1,fy1, it is considered  
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25\*(lb/lb,min)^ 2/3), from 10.3.5, ASCE 41-17.

with fs1 = (fs,jacket\*Asl,ten,jacket + fs,core\*Asl,ten,core)/Asl,ten = 399.8226

with Es1 = (Es,jacket\*Asl,ten,jacket + Es,core\*Asl,ten,core)/Asl,ten = 200000.00

y2 = 0.00152175  
sh2 = 0.0048696  
ft2 = 479.7871  
fy2 = 399.8226  
su2 = 0.0066488

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

lo/lou,min = lb/lb,min = 0.33981258

su2 = 0.4\*esu2\_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu2\_nominal = 0.08,

For calculation of esu2\_nominal and y2, sh2,ft2,fy2, it is considered  
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25\*(lb/lb,min)^ 2/3), from 10.3.5, ASCE 41-17.

$with fs2 = (fs_{jacket} \cdot Asl_{com,jacket} + fs_{core} \cdot Asl_{com,core}) / Asl_{com} = 399.8226$   
 $with Es2 = (Es_{jacket} \cdot Asl_{com,jacket} + Es_{core} \cdot Asl_{com,core}) / Asl_{com} = 200000.00$   
 $yv = 0.00152175$   
 $shv = 0.0048696$   
 $ftv = 507.2537$   
 $fyv = 422.7114$   
 $suv = 0.0066488$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 $Shear\_factor = 1.00$   
 $lo/lou,min = lb/ld = 0.33981258$   
 $suv = 0.4 \cdot esuv\_nominal ((5.5), TBDY) = 0.032$   
 From table 5A.1, TBDY:  $esuv\_nominal = 0.08$ ,  
 considering characteristic value  $fsyv = fsv/1.2$ , from table 5.1, TBDY  
 For calculation of  $esuv\_nominal$  and  $yv, shv,ftv,fyv$ , it is considered  
 characteristic value  $fsyv = fsv/1.2$ , from table 5.1, TBDY.  
 $y1, sh1,ft1,fy1$ , are also multiplied by  $Min(1,1.25 \cdot (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.  
 $with fsv = (fs_{jacket} \cdot Asl_{mid,jacket} + fs_{mid} \cdot Asl_{mid,core}) / Asl_{mid} = 422.7114$   
 $with Esv = (Es_{jacket} \cdot Asl_{mid,jacket} + Es_{mid} \cdot Asl_{mid,core}) / Asl_{mid} = 200000.00$   
 $1 = Asl_{ten} / (b \cdot d) \cdot (fs1 / fc) = 0.0752324$   
 $2 = Asl_{com} / (b \cdot d) \cdot (fs2 / fc) = 0.0752324$   
 $v = Asl_{mid} / (b \cdot d) \cdot (fsv / fc) = 0.02812438$

and confined core properties:

$b = 390.00$   
 $d = 377.00$   
 $d' = 13.00$   
 $fcc (5A.2, TBDY) = 36.47874$   
 $cc (5A.5, TBDY) = 0.00305417$   
 $c = \text{confinement factor} = 1.10542$   
 $1 = Asl_{ten} / (b \cdot d) \cdot (fs1 / fc) = 0.09371431$   
 $2 = Asl_{com} / (b \cdot d) \cdot (fs2 / fc) = 0.09371431$   
 $v = Asl_{mid} / (b \cdot d) \cdot (fsv / fc) = 0.03503353$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

---

$v < v_{s,y2}$  - LHS eq.(4.5) is satisfied

---

$su (4.9) = 0.16791801$   
 $Mu = MRc (4.14) = 2.2193E+008$   
 $u = su (4.1) = 1.9632832E-005$

Calculation of ratio  $lb/ld$

Lap Length:  $lb/ld = 0.33981258$

$lb = 300.00$

$ld = 882.8396$

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

= 1

$db = 16.66667$

Mean strength value of all re-bars:  $fy = 655.558$

Mean concrete strength:  $fc' = (fc'_{jacket} \cdot Area_{jacket} + fc'_{core} \cdot Area_{core}) / Area_{section} = 28.98765$ , but  $fc'^{0.5} <=$

8.3 MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$Ktr = 2.86234$

$Atr = Min(Atr_x, Atr_y) = 257.6106$

where  $Atr_x, Atr_y$  are the sum of the area of all stirrup legs along X and Y loxal axis

$s = Max(s_{external}, s_{internal}) = 300.00$

$n = 12.00$

Calculation of Shear Strength  $Vr = Min(Vr1, Vr2) = 567563.724$

-----  
Calculation of Shear Strength at edge 1,  $V_{r1} = 567563.724$

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

$V_{ColO} = 567563.724$

$kn1 = 1$  (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:  $f_c' = (f_c'_{jacket} * Area_{jacket} + f_c'_{core} * Area_{core}) / Area_{section} = 28.98765$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M / Vd = 2.00$

$\mu_u = 1.0463738E-012$

$\nu_u = 2.7162834E-031$

$d = 0.8 * h = 360.00$

$N_u = 7506.808$

$A_g = 202500.00$

From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 144280.365$

where:

$V_{s1} = 69813.729$  is calculated for jacket, with:

$d = 360.00$

$A_v = 157079.633$

$f_y = 555.56$

$s = 300.00$

$V_{s1}$  is multiplied by  $Col1 = 0.66666667$

$s/d = 0.83333333$

$V_{s2} = 74466.637$  is calculated for core, with:

$d = 200.00$

$A_v = 100530.965$

$f_y = 444.44$

$s = 120.00$

$V_{s2}$  is multiplied by  $Col2 = 1.00$

$s/d = 0.60$

$V_f$  ((11-3)-(11.4), ACI 440) = 214457.247

$f = 0.95$ , for fully-wrapped sections

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

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

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

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

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

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

$d_{fv} = d$  (figure 11.2, ACI 440) = 407.00

$f_{fe}$  ((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:  $V_s + V_f \leq 579413.096$

$bw = 450.00$

-----  
Calculation of Shear Strength at edge 2,  $V_{r2} = 567563.724$

$V_{r2} = V_{Col} ((10.3), ASCE 41-17) = knl * V_{ColO}$

$V_{ColO} = 567563.724$

$kn1 = 1$  (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:  $f_c' = (f_c'_{jacket} * Area_{jacket} + f_c'_{core} * Area_{core}) / Area_{section} = 28.98765$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M / Vd = 2.00$

$\mu_u = 1.0463738E-012$

$\nu_u = 2.7162834E-031$

$d = 0.8 \cdot h = 360.00$   
 $Nu = 7506.808$   
 $Ag = 202500.00$   
 From (11.5.4.8), ACI 318-14:  $Vs = Vs1 + Vs2 = 144280.365$   
 where:  
 $Vs1 = 69813.729$  is calculated for jacket, with:  
 $d = 360.00$   
 $Av = 157079.633$   
 $fy = 555.56$   
 $s = 300.00$   
 $Vs1$  is multiplied by  $Col1 = 0.66666667$   
 $s/d = 0.833333333$   
 $Vs2 = 74466.637$  is calculated for core, with:  
 $d = 200.00$   
 $Av = 100530.965$   
 $fy = 444.44$   
 $s = 120.00$   
 $Vs2$  is multiplied by  $Col2 = 1.00$   
 $s/d = 0.60$   
 $Vf$  ((11-3)-(11.4), ACI 440) = 214457.247  
 $f = 0.95$ , 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  $Vf( , )$ , is implemented for every different fiber orientation  $a_i$ ,  
 as well as for 2 crack directions,  $a = 45^\circ$  and  $a = -45^\circ$  to take into consideration the cyclic seismic loading.  
 orientation 1:  $a = b1 + 90^\circ = 90.00$   
 $Vf = \text{Min}(|Vf(45, 1)|, |Vf(-45, a1)|)$ , with:  
 total thickness per orientation,  $tf1 = NL \cdot t / NoDir = 1.016$   
 $dfv = d$  (figure 11.2, ACI 440) = 407.00  
 $ffe$  ((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:  $Vs + Vf \leq 579413.096$   
 $bw = 450.00$

-----  
 End Of Calculation of Shear Capacity ratio for element: column JC1 of floor 1  
 At local axis: 2

-----  
 Start Of Calculation of Chord Rotation Capacity for element: column JC1 of floor 1  
 At local axis: 2  
 Integration Section: (b)  
 Section Type: rcjrs

Constant Properties

-----  
 Knowledge Factor,  $\phi = 0.85$   
 Chord Rotation is generally considered as Deformation-Controlled Action according to Table C7-1, ASCE 41-17.  
 Mean strengths are used for Deformation-Controlled Actions according to 7.5.1.3, ASCE 41-17  
 Consequently:  
 Jacket  
 New material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 33.00$   
 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,  $E_s = 200000.00$   
 External Height,  $H = 450.00$   
 External Width,  $W = 450.00$

Internal Height, H = 250.00  
Internal Width, W = 250.00  
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 = -2.5732098E-010  
Shear Force, V2 = 11781.223  
Shear Force, V3 = -2.6378276E-013  
Axial Force, F = -7502.094  
Longitudinal Reinforcement Area Distribution (in 2 divisions)  
-Tension:  $A_{sl,t} = 0.00$   
-Compression:  $A_{sl,c} = 2676.637$   
Longitudinal Reinforcement Area Distribution (in 3 divisions)  
-Tension:  $A_{sl,ten} = 1137.257$   
-Compression:  $A_{sl,com} = 1137.257$   
-Middle:  $A_{sl,mid} = 402.1239$   
Longitudinal External Reinforcement Area Distribution (in 3 divisions)  
-Tension:  $A_{sl,ten,jacket} = 829.3805$   
-Compression:  $A_{sl,com,jacket} = 829.3805$   
-Middle:  $A_{sl,mid,jacket} = 402.1239$   
Longitudinal Internal Reinforcement Area Distribution (in 3 divisions)  
-Tension:  $A_{sl,ten,core} = 307.8761$   
-Compression:  $A_{sl,com,core} = 307.8761$   
-Middle:  $A_{sl,mid,core} = 0.00$   
Mean Diameter of Tension Reinforcement,  $DbL = 16.80$

-----  
Existing component: From table 7-7, ASCE 41\_17: Final chord rotation Capacity  $u_{,R} = * u = 0.03558642$   
 $u = y + p = 0.04186638$

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

$y = (My * L_s / 3) / E_{eff} = 0.00325023$  ((4.29), Biskinis Phd))  
 $My = 1.7613E+008$   
 $L_s = M/V$  (with  $L_s > 0.1 * L$  and  $L_s < 2 * L$ ) = 1500.00  
From table 10.5, ASCE 41\_17:  $E_{eff} = factor * E_c * I_g = 2.7095E+013$   
factor = 0.30  
 $Ag = 202500.00$   
Mean concrete strength:  $fc' = (fc'_{jacket} * Area_{jacket} + fc'_{core} * Area_{core}) / Area_{section} = 28.98765$   
N = 7502.094  
 $Ec * I_g = Ec_{jacket} * I_{g,jacket} + Ec_{core} * I_{g,core} = 9.0315E+013$   
-----

Calculation of Yielding Moment  $M_y$

Calculation of  $\rho_y$  and  $M_y$  according to Annex 7 -

$$y = \text{Min}(y_{\text{ten}}, y_{\text{com}})$$

$$y_{\text{ten}} = 6.1806717\text{E-}006$$

$$\text{with } ((10.1), \text{ASCE 41-17}) f_y = \text{Min}(f_y, 1.25 \cdot f_y \cdot (l_b/d)^{2/3}) = 374.3546$$

$$d = 407.00$$

$$y = 0.25591399$$

$$A = 0.01472387$$

$$B = 0.00818866$$

$$\text{with } p_t = 0.00430549$$

$$p_c = 0.00620943$$

$$p_v = 0.0021956$$

$$N = 7502.094$$

$$b = 450.00$$

$$\rho = 0.10565111$$

$$y_{\text{comp}} = 2.2127287\text{E-}005$$

$$\text{with } f_c^* (12.3, \text{ACI 440}) = 34.40847$$

$$f_c = 33.00$$

$$f_l = 0.82797802$$

$$b = 450.00$$

$$h = 450.00$$

$$A_g = 202500.00$$

$$\text{From (12.9), ACI 440: } k_a = 0.54261599$$

$$g = p_t + p_c + p_v = 0.01461445$$

$$r_c = 40.00$$

$$A_e/A_c = 0.54261599$$

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

$$\text{effective strain from (12.5) and (12.12), } \epsilon_{fe} = 0.004$$

$$f_u = 0.01$$

$$E_f = 64828.00$$

$$E_c = 26999.444$$

$$y = 0.25471852$$

$$A = 0.01452517$$

$$B = 0.00807924$$

$$\text{with } E_s = 200000.00$$

Calculation of ratio  $l_b/d$

$$\text{Lap Length: } l_d/d, \text{min} = 0.42476573$$

$$l_b = 300.00$$

$$d = 706.2717$$

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

$$= 1$$

$$d_b = 16.66667$$

$$\text{Mean strength value of all re-bars: } f_y = 524.4464$$

$$\text{Mean concrete strength: } f_c' = (f_c'_{\text{jacket}} \cdot \text{Area}_{\text{jacket}} + f_c'_{\text{core}} \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 28.98765, \text{ but } f_c'^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 25.00$$

$$K_{tr} = 2.86234$$

$$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 257.6106$$

where  $A_{tr_x}$ ,  $A_{tr_y}$  are the sum of the area of all stirrup legs along X and Y local axis

$$s = \text{Max}(s_{\text{external}}, s_{\text{internal}}) = 300.00$$

$$n = 12.00$$

- Calculation of  $\rho_p$  -

$$\text{From table 10-8: } \rho_p = 0.03861614$$

with:

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

shear control ratio  $V_y E / V_{Col} O E = 0.26068017$

$d = d_{external} = 407.00$

$s = s_{external} = 0.00$

$t = s_1 + s_2 + 2 * t_f / b_w * (f_{fe} / f_s) = 0.00430549$

jacket:  $s_1 = A_{v1} * h_1 / (s_1 * A_g) = 0.00116355$

$A_{v1} = 157.0796$ , is the total area of all stirrups parallel to loading (shear) direction

$h_1 = 450.00$

$s_1 = 300.00$

core:  $s_2 = A_{v2} * h_2 / (s_2 * A_g) = 0.00103427$

$A_{v2} = 100.531$ , is the total area of all stirrups parallel to loading (shear) direction

$h_2 = 250.00$

$s_2 = 120.00$

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

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

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

For the normalisation  $f_s$  of jacket is used.

$NUD = 7502.094$

$A_g = 202500.00$

$f_{cE} = (f_{c,jacket} * Area_{jacket} + f_{c,core} * Area_{core}) / section\_area = 28.98765$

$f_{yIE} = (f_{y,ext\_Long\_Reinf} * Area_{ext\_Long\_Reinf} + f_{y,int\_Long\_Reinf} * Area_{int\_Long\_Reinf}) / Area_{Tot\_Long\_Rein} = 529.9972$

$f_{ytE} = (f_{y,ext\_Trans\_Reinf} * s_1 + f_{y,int\_Trans\_Reinf} * s_2) / (s_1 + s_2) = 503.2682$

$\rho_l = Area_{Tot\_Long\_Rein} / (b * d) = 0.01461445$

$b = 450.00$

$d = 407.00$

$f_{cE} = 28.98765$

-----  
End Of Calculation of Chord Rotation Capacity for element: column JC1 of floor 1

At local axis: 2

Integration Section: (b)

-----

## Calculation No. 15

column C1, Floor 1

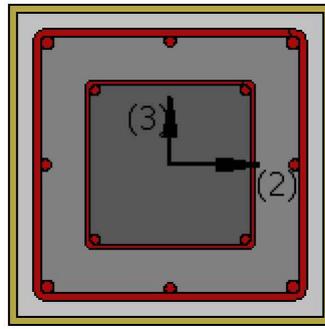
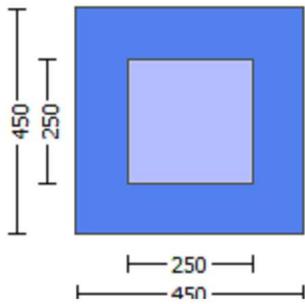
Limit State: Collapse Prevention (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Shear capacity VRd

Edge: End

Local Axis: (3)



Start Of Calculation of Shear Capacity for element: column JC1 of floor 1

At local axis: 3

Integration Section: (b)

Section Type: rcjrs

Constant Properties

Knowledge Factor,  $\gamma = 0.85$

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  $\gamma$  for displacement ductility demand, the expected (mean value) strengths are used (7.5.1.3, ASCE 41-17) because bending is considered as Deformation-Controlled Action (Table C7-1, ASCE 41-17).

Jacket

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

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

Existing Column

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

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

#####

External Height,  $H = 450.00$

External Width,  $W = 450.00$

Internal Height,  $H = 250.00$

Internal Width,  $W = 250.00$

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,  $\theta_i$ : 0.00°  
Number of layers, NL = 1  
Radius of rounding corners, R = 40.00

-----  
Stepwise Properties

-----  
EDGE -A-  
Bending Moment,  $M_a$  = -5.3402437E-010  
Shear Force,  $V_a$  = 2.6378276E-013  
EDGE -B-  
Bending Moment,  $M_b$  = -2.5732098E-010  
Shear Force,  $V_b$  = -2.6378276E-013  
BOTH EDGES  
Axial Force, F = -7502.094  
Longitudinal Reinforcement Area Distribution (in 2 divisions)  
-Tension:  $A_{st}$  = 0.00  
-Compression:  $A_{sc}$  = 2676.637  
Longitudinal Reinforcement Area Distribution (in 3 divisions)  
-Tension:  $A_{st,ten}$  = 1137.257  
-Compression:  $A_{sc,com}$  = 1137.257  
-Middle:  $A_{st,mid}$  = 402.1239  
Mean Diameter of Tension Reinforcement,  $D_{bL,ten}$  = 16.80

-----  
Existing component: From table 7-7, ASCE 41\_17: Final Shear Capacity  $V_R = \phi V_n = 447100.239$   
 $V_n$  ((10.3), ASCE 41-17) =  $k_n \phi V_{Co1} = 526000.281$   
 $V_{Co1} = 526000.281$   
 $k_n = 1.00$   
displacement\_ductility\_demand = 0.00

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

-----  
= 1 (normal-weight concrete)  
Mean concrete strength:  $f_c' = (f_c'_{jacket} \cdot Area_{jacket} + f_c'_{core} \cdot Area_{core}) / Area_{section} = 22.22222$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)  
 $M / Vd = 2.00$   
 $M_u = 2.5732098E-010$   
 $V_u = 2.6378276E-013$   
 $d = 0.8 \cdot h = 360.00$   
 $N_u = 7502.094$   
 $A_g = 202500.00$   
From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 129852.496$   
where:  
 $V_{s1} = 62831.853$  is calculated for jacket, with:  
 $d = 360.00$   
 $A_v = 157079.633$   
 $f_y = 500.00$   
 $s = 300.00$   
 $V_{s1}$  is multiplied by  $Col1 = 0.66666667$   
 $s/d = 0.83333333$   
 $V_{s2} = 67020.643$  is calculated for core, with:  
 $d = 200.00$   
 $A_v = 100530.965$   
 $f_y = 400.00$   
 $s = 120.00$   
 $V_{s2}$  is multiplied by  $Col2 = 1.00$   
 $s/d = 0.60$   
 $V_f$  ((11-3)-(11.4), ACI 440) = 214457.247  
 $\phi = 0.95$ , for fully-wrapped sections  
 $w_f / s_f = 1$  (FRP strips adjacent to one another).  
In (11.3)  $\sin \theta + \cos \theta$  is replaced with  $(\cot \theta + \cot \alpha) \sin \alpha$  which is more a generalised expression,  
where  $\theta$  is the angle of the crack direction (see KANEPE).  
This later relation, considered as a function  $V_f(\theta, \alpha)$ , is implemented for every different fiber orientation  $\theta_i$ ,

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

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

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

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

$d_{fv} = d$  (figure 11.2, ACI 440) = 407.00

$f_{fe}$  ((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:  $V_s + V_f \leq 507312.442$

$b_w = 450.00$

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

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

for rotation axis 2 and integ. section (b)

From analysis, chord rotation  $\theta = 1.4313203E-022$

$y = (M_y \cdot L_s / 3) / E_{\text{eff}} = 0.00325023$  ((4.29), Biskinis Phd)

$M_y = 1.7613E+008$

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

From table 10.5, ASCE 41\_17:  $E_{\text{eff}} = \text{factor} \cdot E_c \cdot I_g = 2.7095E+013$

factor = 0.30

$A_g = 202500.00$

Mean concrete strength:  $f_c' = (f_c'_{\text{jacket}} \cdot \text{Area}_{\text{jacket}} + f_c'_{\text{core}} \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 28.98765$

$N = 7502.094$

$E_c \cdot I_g = E_{c,\text{jacket}} \cdot I_{g,\text{jacket}} + E_{c,\text{core}} \cdot I_{g,\text{core}} = 9.0315E+013$

Calculation of Yielding Moment  $M_y$

Calculation of  $\delta / y$  and  $M_y$  according to Annex 7 -

$y = \text{Min}(y_{\text{ten}}, y_{\text{com}})$

$y_{\text{ten}} = 6.1806717E-006$

with ((10.1), ASCE 41-17)  $f_y = \text{Min}(f_y, 1.25 \cdot f_y \cdot (I_b / I_d)^{2/3}) = 374.3546$

$d = 407.00$

$y = 0.25591399$

$A = 0.01472387$

$B = 0.00818866$

with  $p_t = 0.00620943$

$p_c = 0.00620943$

$p_v = 0.0021956$

$N = 7502.094$

$b = 450.00$

$\theta = 0.10565111$

$y_{\text{comp}} = 2.2127287E-005$

with  $f_c^*$  (12.3, (ACI 440)) = 34.40847

$f_c = 33.00$

$f_l = 0.82797802$

$b = 450.00$

$h = 450.00$

$A_g = 202500.00$

From (12.9), ACI 440:  $k_a = 0.54261599$

$g = p_t + p_c + p_v = 0.01461445$

$r_c = 40.00$

$A_e / A_c = 0.54261599$

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

effective strain from (12.5) and (12.12),  $e_{fe} = 0.004$

$f_u = 0.01$

$E_f = 64828.00$

$E_c = 26999.444$

$y = 0.25471852$

$A = 0.01452517$

$B = 0.00807924$   
with  $E_s = 200000.00$

Calculation of ratio  $l_b/d$

Lap Length:  $l_d/l_{d,min} = 0.42476573$

$l_b = 300.00$

$l_d = 706.2717$

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

$= 1$

$d_b = 16.66667$

Mean strength value of all re-bars:  $f_y = 524.4464$

Mean concrete strength:  $f_c' = (f_c'_{jacket} \cdot Area_{jacket} + f_c'_{core} \cdot Area_{core}) / Area_{section} = 28.98765$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$c_b = 25.00$

$K_{tr} = 2.86234$

$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 257.6106$

where  $A_{tr_x}$ ,  $A_{tr_y}$  are the sum of the area of all stirrup legs along X and Y local axis

$s = \text{Max}(s_{external}, s_{internal}) = 300.00$

$n = 12.00$

End Of Calculation of Shear Capacity for element: column JC1 of floor 1

At local axis: 3

Integration Section: (b)

## Calculation No. 16

column C1, Floor 1

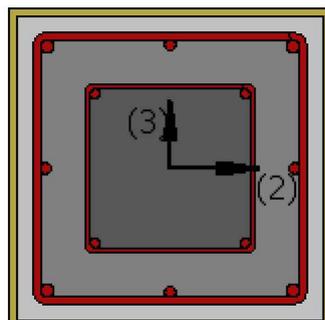
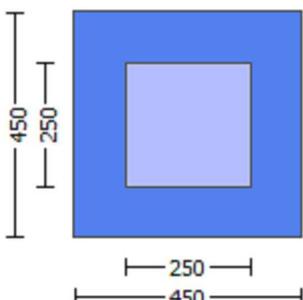
Limit State: Collapse Prevention (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity ( $\phi_r$ )

Edge: End

Local Axis: (3)



Start Of Calculation of Shear Capacity ratio for element: column JC1 of floor 1

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

Constant Properties

Knowledge Factor,  $\gamma = 0.85$   
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 Height,  $H = 450.00$

External Width,  $W = 450.00$

Internal Height,  $H = 250.00$

Internal Width,  $W = 250.00$

Cover Thickness,  $c = 25.00$

Mean Confinement Factor overall section = 1.10542

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,  $V_a = 2.0531359E-031$

EDGE -B-

Shear Force,  $V_b = -2.0531359E-031$

BOTH EDGES

Axial Force,  $F = -7506.808$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension:  $A_{st} = 0.00$

-Compression:  $As_c = 2676.637$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension:  $As_{ten} = 1137.257$

-Compression:  $As_{com} = 1137.257$

-Middle:  $As_{mid} = 402.1239$

Calculation of Shear Capacity ratio ,  $V_e/V_r = 0.26068017$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 147952.607$

with

$M_{pr1} = \text{Max}(Mu_{1+}, Mu_{1-}) = 2.2193E+008$

$Mu_{1+} = 2.2193E+008$ , 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

$Mu_{1-} = 2.2193E+008$ , 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

$M_{pr2} = \text{Max}(Mu_{2+}, Mu_{2-}) = 2.2193E+008$

$Mu_{2+} = 2.2193E+008$ , 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

$Mu_{2-} = 2.2193E+008$ , 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 curvature  $\phi_u$  according to 4.1, Biskinis/Fardis 2013:

$\phi_u = 1.9632832E-005$

$M_u = 2.2193E+008$

with full section properties:

$b = 450.00$

$d = 407.00$

$d' = 43.00$

$v = 0.00124204$

$N = 7506.808$

$f_c = 33.00$

$\phi_c$  (5A.5, TBDY) = 0.002

Final value of  $\phi_u$ :  $\phi_u^* = \text{shear\_factor} * \text{Max}(\phi_u, \phi_c) = 0.01393923$

The Shear\_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY:  $\phi_u = 0.01393923$

$\phi_{we}$  ((5.4c), TBDY) =  $\phi_u * \text{sh}_{min} * f_{ywe}/f_{ce} + \text{Min}(\phi_x, \phi_y) = 0.06811101$

where  $\phi = \phi_u * \rho_f * f_{fe}/f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$\phi_x = 0.06628267$

$\phi_f = 0.54930041$

$b = 450.00$

$h = 450.00$

From EC8 A.4.4.3(6),  $\rho_f = 2t_f/bw = 0.00451556$

$bw = 450.00$

effective stress from (A.35),  $f_{fe} = 881.8461$

$\phi_y = 0.06628267$

$\phi_f = 0.54930041$

$b = 450.00$

$h = 450.00$

From EC8 A.4.4.3(6),  $\rho_f = 2t_f/bw = 0.00451556$

$bw = 450.00$

effective stress from (A.35),  $f_{fe} = 881.8461$

$R = 40.00$

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

$f_{u,f} = 1055.00$

$E_f = 64828.00$

u,f = 0.015

ase ((5.4d), TBDY) = (ase1\*Aext+ase2\*Aint)/Asec = 0.14546167

ase1 = 0.12623274

bo\_1 = 390.00

ho\_1 = 390.00

bi2\_1 = 608400.00

ase2 = Max(ase1,ase2) = 0.18853448

bo\_2 = 242.00

ho\_2 = 242.00

bi2\_2 = 234256.00

psh,min\*Fywe = Min(psh,x\*Fywe , psh,y\*Fywe) = 1.38262

Expression ((5.4d), TBDY) for psh,min\*Fywe has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

psh\_x\*Fywe = psh1\*Fywe1+ps2\*Fywe2 = 1.38262

ps1 (external) = (Ash1\*h1/s1)/Asec = 0.00116355

Ash1 = Astir\_1\*ns\_1 = 157.0796

No stirrups, ns\_1 = 2.00

h1 = 450.00

ps2 (internal) = (Ash2\*h2/s2)/Asec = 0.00103427

Ash2 = Astir\_2\*ns\_2 = 100.531

No stirrups, ns\_2 = 2.00

h2 = 250.00

psh\_y\*Fywe = psh1\*Fywe1+ps2\*Fywe2 = 1.38262

ps1 (external) = (Ash1\*h1/s1)/Asec = 0.00116355

Ash1 = Astir\_1\*ns\_1 = 157.0796

No stirrups, ns\_1 = 2.00

h1 = 450.00

ps2 (internal) = (Ash2\*h2/s2)/Asec = 0.00103427

Ash2 = Astir\_2\*ns\_2 = 100.531

No stirrups, ns\_2 = 2.00

h2 = 250.00

Asec = 202500.00

s1 = 300.00

s2 = 120.00

fywe1 = 694.45

fywe2 = 555.55

fce = 33.00

From ((5.A5), TBDY), TBDY: cc = 0.00305417

c = confinement factor = 1.10542

y1 = 0.00152175

sh1 = 0.0048696

ft1 = 479.7871

fy1 = 399.8226

su1 = 0.0066488

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00

lo/lou,min = lb/d = 0.33981258

su1 = 0.4\*esu1\_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu1\_nominal = 0.08,

For calculation of esu1\_nominal and y1, sh1,ft1,fy1, it is considered characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25\*(lb/d)^2/3), from 10.3.5, ASCE 41-17.

with fs1 = (fs,jacket\*Asl,ten,jacket + fs,core\*Asl,ten,core)/Asl,ten = 399.8226

with Es1 = (Es,jacket\*Asl,ten,jacket + Es,core\*Asl,ten,core)/Asl,ten = 200000.00

y2 = 0.00152175

sh2 = 0.0048696

ft2 = 479.7871

fy2 = 399.8226

su2 = 0.0066488

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00

lo/lou,min = lb/lb,min = 0.33981258

$$su_2 = 0.4 * esu_2\_nominal ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY:  $esu_2\_nominal = 0.08$ ,

For calculation of  $esu_2\_nominal$  and  $y_2, sh_2, ft_2, fy_2$ , it is considered characteristic value  $fs_2 = fs_2/1.2$ , from table 5.1, TBDY.

$y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.

$$\text{with } fs_2 = (fs\_jacket * Asl\_com\_jacket + fs\_core * Asl\_com\_core) / Asl\_com = 399.8226$$

$$\text{with } Es_2 = (Es\_jacket * Asl\_com\_jacket + Es\_core * Asl\_com\_core) / Asl\_com = 200000.00$$

$$y_v = 0.00152175$$

$$sh_v = 0.0048696$$

$$ft_v = 507.2537$$

$$fy_v = 422.7114$$

$$suv = 0.0066488$$

using (30) in Biskinis/Fardis (2013) multiplied with  $shear\_factor$

and also multiplied by the  $shear\_factor$  according to 15.7.1.4, with

$$Shear\_factor = 1.00$$

$$lo/lo_{u,min} = lb/ld = 0.33981258$$

$$suv = 0.4 * esuv\_nominal ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY:  $esuv\_nominal = 0.08$ ,

considering characteristic value  $fs_v = fs_v/1.2$ , from table 5.1, TBDY

For calculation of  $esuv\_nominal$  and  $y_v, sh_v, ft_v, fy_v$ , it is considered characteristic value  $fs_v = fs_v/1.2$ , from table 5.1, TBDY.

$y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.

$$\text{with } fs_v = (fs\_jacket * Asl\_mid\_jacket + fs\_mid * Asl\_mid\_core) / Asl\_mid = 422.7114$$

$$\text{with } Es_v = (Es\_jacket * Asl\_mid\_jacket + Es\_mid * Asl\_mid\_core) / Asl\_mid = 200000.00$$

$$1 = Asl\_ten / (b * d) * (fs_1 / fc) = 0.0752324$$

$$2 = Asl\_com / (b * d) * (fs_2 / fc) = 0.0752324$$

$$v = Asl\_mid / (b * d) * (fs_v / fc) = 0.02812438$$

and confined core properties:

$$b = 390.00$$

$$d = 377.00$$

$$d' = 13.00$$

$$fcc (5A.2, TBDY) = 36.47874$$

$$cc (5A.5, TBDY) = 0.00305417$$

$$c = \text{confinement factor} = 1.10542$$

$$1 = Asl\_ten / (b * d) * (fs_1 / fc) = 0.09371431$$

$$2 = Asl\_com / (b * d) * (fs_2 / fc) = 0.09371431$$

$$v = Asl\_mid / (b * d) * (fs_v / fc) = 0.03503353$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < v_{s,y_2}$  - LHS eq.(4.5) is satisfied

--->

$$su (4.9) = 0.16791801$$

$$Mu = MRc (4.14) = 2.2193E+008$$

$$u = su (4.1) = 1.9632832E-005$$

-----  
Calculation of ratio  $lb/ld$

Lap Length:  $lb/ld = 0.33981258$

$$lb = 300.00$$

$$ld = 882.8396$$

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

$$= 1$$

$$db = 16.66667$$

Mean strength value of all re-bars:  $fy = 655.558$

Mean concrete strength:  $fc' = (fc'_jacket * Area\_jacket + fc'_core * Area\_core) / Area\_section = 28.98765$ , but  $fc'^{0.5} < = 8.3$  MPa (22.5.3.1, ACI 318-14)

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$cb = 25.00$$

$$K_{tr} = 2.86234$$

$$A_{tr} = \text{Min}(A_{tr\_x}, A_{tr\_y}) = 257.6106$$

where  $A_{tr\_x}, A_{tr\_y}$  are the sum of the area of all stirrup legs along X and Y local axis

$$s = \text{Max}(s_{external}, s_{internal}) = 300.00$$

$$n = 12.00$$

Calculation of Mu1-

Calculation of ultimate curvature  $\mu$  according to 4.1, Biskinis/Fardis 2013:

$$\mu = 1.9632832E-005$$

$$Mu = 2.2193E+008$$

with full section properties:

$$b = 450.00$$

$$d = 407.00$$

$$d' = 43.00$$

$$v = 0.00124204$$

$$N = 7506.808$$

$$f_c = 33.00$$

$$c_o \text{ (5A.5, TBDY)} = 0.002$$

$$\text{Final value of } c_u: c_u^* = \text{shear\_factor} * \text{Max}(c_u, c_c) = 0.01393923$$

The Shear\_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } c_u = 0.01393923$$

$$w_e \text{ ((5.4c), TBDY)} = a_{se} * s_{h,min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.06811101$$

where  $f = a_f * p_f * f_{fe} / f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.06628267$$

$$a_f = 0.54930041$$

$$b = 450.00$$

$$h = 450.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.00451556$$

$$b_w = 450.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 881.8461$$

$$f_y = 0.06628267$$

$$a_f = 0.54930041$$

$$b = 450.00$$

$$h = 450.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.00451556$$

$$b_w = 450.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 881.8461$$

$$R = 40.00$$

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

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$a_{se} \text{ ((5.4d), TBDY)} = (a_{se1} * A_{ext} + a_{se2} * A_{int}) / A_{sec} = 0.14546167$$

$$a_{se1} = 0.12623274$$

$$b_{o,1} = 390.00$$

$$h_{o,1} = 390.00$$

$$b_{i,2,1} = 608400.00$$

$$a_{se2} = \text{Max}(a_{se1}, a_{se2}) = 0.18853448$$

$$b_{o,2} = 242.00$$

$$h_{o,2} = 242.00$$

$$b_{i,2,2} = 234256.00$$

$$p_{sh,min} * F_{ywe} = \text{Min}(p_{sh,x} * F_{ywe}, p_{sh,y} * F_{ywe}) = 1.38262$$

Expression ((5.4d), TBDY) for  $p_{sh,min} * F_{ywe}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$$p_{sh,x} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{sh2} * F_{ywe2} = 1.38262$$

$$p_{s1} \text{ (external)} = (A_{sh1} * h_1 / s_1) / A_{sec} = 0.00116355$$

$$A_{sh1} = A_{stir,1} * n_{s,1} = 157.0796$$

$$\text{No stirrups, } n_{s,1} = 2.00$$

$$h_1 = 450.00$$

$$p_{s2} \text{ (internal)} = (A_{sh2} * h_2 / s_2) / A_{sec} = 0.00103427$$

$$A_{sh2} = A_{stir,2} * n_{s,2} = 100.531$$

$$\text{No stirrups, } n_{s,2} = 2.00$$

$$h2 = 250.00$$

$$\begin{aligned} \text{psh}_y * \text{Fywe} &= \text{psh}_1 * \text{Fywe}_1 + \text{ps}_2 * \text{Fywe}_2 = 1.38262 \\ \text{ps}_1 \text{ (external)} &= (\text{Ash}_1 * h_1 / s_1) / \text{Asec} = 0.00116355 \\ \text{Ash}_1 &= \text{Astir}_1 * \text{ns}_1 = 157.0796 \\ \text{No stirups, ns}_1 &= 2.00 \\ h_1 &= 450.00 \\ \text{ps}_2 \text{ (internal)} &= (\text{Ash}_2 * h_2 / s_2) / \text{Asec} = 0.00103427 \\ \text{Ash}_2 &= \text{Astir}_2 * \text{ns}_2 = 100.531 \\ \text{No stirups, ns}_2 &= 2.00 \\ h_2 &= 250.00 \end{aligned}$$

$$\text{Asec} = 202500.00$$

$$s_1 = 300.00$$

$$s_2 = 120.00$$

$$\text{fywe}_1 = 694.45$$

$$\text{fywe}_2 = 555.55$$

$$\text{fce} = 33.00$$

$$\text{From } ((5.A.5), \text{ TBDY}), \text{ TBDY: } cc = 0.00305417$$

$$c = \text{confinement factor} = 1.10542$$

$$y_1 = 0.00152175$$

$$sh_1 = 0.0048696$$

$$ft_1 = 479.7871$$

$$fy_1 = 399.8226$$

$$su_1 = 0.0066488$$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

$$lo/lou, \text{min} = lb/ld = 0.33981258$$

$$su_1 = 0.4 * \text{esu}_1 \text{ nominal } ((5.5), \text{ TBDY}) = 0.032$$

From table 5A.1, TBDY: esu1\_nominal = 0.08,

For calculation of esu1\_nominal and y1, sh1, ft1, fy1, it is considered  
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1, ft1, fy1, are also multiplied by  $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.

$$\text{with } fs_1 = (fs_{\text{jacket}} * \text{Asl,ten,jacket} + fs_{\text{core}} * \text{Asl,ten,core}) / \text{Asl,ten} = 399.8226$$

$$\text{with } Es_1 = (Es_{\text{jacket}} * \text{Asl,ten,jacket} + Es_{\text{core}} * \text{Asl,ten,core}) / \text{Asl,ten} = 200000.00$$

$$y_2 = 0.00152175$$

$$sh_2 = 0.0048696$$

$$ft_2 = 479.7871$$

$$fy_2 = 399.8226$$

$$su_2 = 0.0066488$$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

$$lo/lou, \text{min} = lb/lb, \text{min} = 0.33981258$$

$$su_2 = 0.4 * \text{esu}_2 \text{ nominal } ((5.5), \text{ TBDY}) = 0.032$$

From table 5A.1, TBDY: esu2\_nominal = 0.08,

For calculation of esu2\_nominal and y2, sh2, ft2, fy2, it is considered  
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

y1, sh1, ft1, fy1, are also multiplied by  $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.

$$\text{with } fs_2 = (fs_{\text{jacket}} * \text{Asl,com,jacket} + fs_{\text{core}} * \text{Asl,com,core}) / \text{Asl,com} = 399.8226$$

$$\text{with } Es_2 = (Es_{\text{jacket}} * \text{Asl,com,jacket} + Es_{\text{core}} * \text{Asl,com,core}) / \text{Asl,com} = 200000.00$$

$$y_v = 0.00152175$$

$$sh_v = 0.0048696$$

$$ft_v = 507.2537$$

$$fy_v = 422.7114$$

$$su_v = 0.0066488$$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

$$lo/lou, \text{min} = lb/ld = 0.33981258$$

$$su_v = 0.4 * \text{esuv}_v \text{ nominal } ((5.5), \text{ TBDY}) = 0.032$$

From table 5A.1, TBDY: esuv\_nominal = 0.08,

considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY  
For calculation of esuv\_nominal and yv, shv, ftv, fyv, it is considered

characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.

y1, sh1, ft1, fy1, are also multiplied by  $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.

with  $f_{sv} = (f_{s,jacket} \cdot A_{s,mid,jacket} + f_{s,mid} \cdot A_{s,mid,core}) / A_{s,mid} = 422.7114$   
with  $E_{sv} = (E_{s,jacket} \cdot A_{s,mid,jacket} + E_{s,mid} \cdot A_{s,mid,core}) / A_{s,mid} = 200000.00$   
 $1 = A_{s,ten} / (b \cdot d) \cdot (f_{s1} / f_c) = 0.0752324$   
 $2 = A_{s,com} / (b \cdot d) \cdot (f_{s2} / f_c) = 0.0752324$   
 $v = A_{s,mid} / (b \cdot d) \cdot (f_{sv} / f_c) = 0.02812438$

and confined core properties:

$b = 390.00$   
 $d = 377.00$   
 $d' = 13.00$   
 $f_{cc} (5A.2, TBDY) = 36.47874$   
 $cc (5A.5, TBDY) = 0.00305417$   
 $c = \text{confinement factor} = 1.10542$   
 $1 = A_{s,ten} / (b \cdot d) \cdot (f_{s1} / f_c) = 0.09371431$   
 $2 = A_{s,com} / (b \cdot d) \cdot (f_{s2} / f_c) = 0.09371431$   
 $v = A_{s,mid} / (b \cdot d) \cdot (f_{sv} / f_c) = 0.03503353$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < v_{s,y2}$  - LHS eq.(4.5) is satisfied

--->

$\mu_u (4.9) = 0.16791801$   
 $M_u = M_{Rc} (4.14) = 2.2193E+008$   
 $u = \mu_u (4.1) = 1.9632832E-005$

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

-----  
Lap Length:  $l_b/l_d = 0.33981258$

$l_b = 300.00$   
 $l_d = 882.8396$

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

= 1

$d_b = 16.66667$

Mean strength value of all re-bars:  $f_y = 655.558$

Mean concrete strength:  $f'_c = (f'_{c,jacket} \cdot Area_{jacket} + f'_{c,core} \cdot Area_{core}) / Area_{section} = 28.98765$ , but  $f_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 2.86234$

$A_{tr} = \text{Min}(A_{tr,x}, A_{tr,y}) = 257.6106$

where  $A_{tr,x}$ ,  $A_{tr,y}$  are the sum of the area of all stirrup legs along X and Y local axis

$s = \text{Max}(s_{external}, s_{internal}) = 300.00$

$n = 12.00$

-----  
Calculation of  $\mu_{u2+}$

-----  
Calculation of ultimate curvature  $\mu_u$  according to 4.1, Biskinis/Fardis 2013:

$u = 1.9632832E-005$

$M_u = 2.2193E+008$

-----  
with full section properties:

$b = 450.00$

$d = 407.00$

$d' = 43.00$

$v = 0.00124204$

$N = 7506.808$

$f_c = 33.00$

$co (5A.5, TBDY) = 0.002$

Final value of  $\mu_u$ :  $\mu_u^* = \text{shear\_factor} \cdot \text{Max}(c_u, cc) = 0.01393923$

The Shear\_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY:  $\mu_u = 0.01393923$

$w_e ((5.4c), TBDY) = a_{se} \cdot s_{h,min} \cdot f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.06811101$   
where  $f = a_f \cdot p_f \cdot f_{fe}/f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$f_x = 0.06628267$   
 $a_f = 0.54930041$   
 $b = 450.00$   
 $h = 450.00$   
From EC8 A.4.4.3(6),  $p_f = 2t_f/bw = 0.00451556$   
 $bw = 450.00$   
effective stress from (A.35),  $f_{f,e} = 881.8461$

$f_y = 0.06628267$   
 $a_f = 0.54930041$   
 $b = 450.00$   
 $h = 450.00$   
From EC8 A.4.4.3(6),  $p_f = 2t_f/bw = 0.00451556$   
 $bw = 450.00$   
effective stress from (A.35),  $f_{f,e} = 881.8461$

$R = 40.00$   
Effective FRP thickness,  $t_f = NL \cdot t \cdot \text{Cos}(b_1) = 1.016$   
 $f_{u,f} = 1055.00$   
 $E_f = 64828.00$   
 $u,f = 0.015$   
 $a_{se} ((5.4d), TBDY) = (a_{se1} \cdot A_{ext} + a_{se2} \cdot A_{int})/A_{sec} = 0.14546167$   
 $a_{se1} = 0.12623274$   
 $bo\_1 = 390.00$   
 $ho\_1 = 390.00$   
 $bi2\_1 = 608400.00$   
 $a_{se2} = \text{Max}(a_{se1}, a_{se2}) = 0.18853448$   
 $bo\_2 = 242.00$   
 $ho\_2 = 242.00$   
 $bi2\_2 = 234256.00$

$p_{sh,min} \cdot F_{ywe} = \text{Min}(p_{sh,x} \cdot F_{ywe}, p_{sh,y} \cdot F_{ywe}) = 1.38262$   
Expression ((5.4d), TBDY) for  $p_{sh,min} \cdot F_{ywe}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$p_{sh,x} \cdot F_{ywe} = p_{sh1} \cdot F_{ywe1} + p_{sh2} \cdot F_{ywe2} = 1.38262$   
 $ps1$  (external) =  $(A_{sh1} \cdot h_1/s_1)/A_{sec} = 0.00116355$   
 $A_{sh1} = A_{stir\_1} \cdot ns\_1 = 157.0796$   
No stirrups,  $ns\_1 = 2.00$   
 $h_1 = 450.00$   
 $ps2$  (internal) =  $(A_{sh2} \cdot h_2/s_2)/A_{sec} = 0.00103427$   
 $A_{sh2} = A_{stir\_2} \cdot ns\_2 = 100.531$   
No stirrups,  $ns\_2 = 2.00$   
 $h_2 = 250.00$

$p_{sh,y} \cdot F_{ywe} = p_{sh1} \cdot F_{ywe1} + p_{sh2} \cdot F_{ywe2} = 1.38262$   
 $ps1$  (external) =  $(A_{sh1} \cdot h_1/s_1)/A_{sec} = 0.00116355$   
 $A_{sh1} = A_{stir\_1} \cdot ns\_1 = 157.0796$   
No stirrups,  $ns\_1 = 2.00$   
 $h_1 = 450.00$   
 $ps2$  (internal) =  $(A_{sh2} \cdot h_2/s_2)/A_{sec} = 0.00103427$   
 $A_{sh2} = A_{stir\_2} \cdot ns\_2 = 100.531$   
No stirrups,  $ns\_2 = 2.00$   
 $h_2 = 250.00$

$A_{sec} = 202500.00$   
 $s_1 = 300.00$   
 $s_2 = 120.00$   
 $f_{ywe1} = 694.45$   
 $f_{ywe2} = 555.55$   
 $f_{ce} = 33.00$   
From ((5.A5), TBDY), TBDY:  $cc = 0.00305417$   
 $c = \text{confinement factor} = 1.10542$   
 $y_1 = 0.00152175$   
 $sh_1 = 0.0048696$

$$ft1 = 479.7871$$

$$fy1 = 399.8226$$

$$su1 = 0.0066488$$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

$$lo/lou,min = lb/ld = 0.33981258$$

$$su1 = 0.4*esu1\_nominal ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: esu1\_nominal = 0.08,

For calculation of esu1\_nominal and y1, sh1,ft1,fy1, it is considered  
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by  $\text{Min}(1, 1.25*(lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.

$$\text{with } fs1 = (fs,jacket*Asl,ten,jacket + fs,core*Asl,ten,core)/Asl,ten = 399.8226$$

$$\text{with } Es1 = (Es,jacket*Asl,ten,jacket + Es,core*Asl,ten,core)/Asl,ten = 200000.00$$

$$y2 = 0.00152175$$

$$sh2 = 0.0048696$$

$$ft2 = 479.7871$$

$$fy2 = 399.8226$$

$$su2 = 0.0066488$$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

$$lo/lou,min = lb/lb,min = 0.33981258$$

$$su2 = 0.4*esu2\_nominal ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: esu2\_nominal = 0.08,

For calculation of esu2\_nominal and y2, sh2,ft2,fy2, it is considered  
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by  $\text{Min}(1, 1.25*(lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.

$$\text{with } fs2 = (fs,jacket*Asl,com,jacket + fs,core*Asl,com,core)/Asl,com = 399.8226$$

$$\text{with } Es2 = (Es,jacket*Asl,com,jacket + Es,core*Asl,com,core)/Asl,com = 200000.00$$

$$yv = 0.00152175$$

$$shv = 0.0048696$$

$$ftv = 507.2537$$

$$fyv = 422.7114$$

$$suv = 0.0066488$$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

$$lo/lou,min = lb/ld = 0.33981258$$

$$suv = 0.4*esuv\_nominal ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: esuv\_nominal = 0.08,

considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY

For calculation of esuv\_nominal and yv, shv,ftv,fyv, it is considered  
characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by  $\text{Min}(1, 1.25*(lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.

$$\text{with } fsv = (fs,jacket*Asl,mid,jacket + fs,mid*Asl,mid,core)/Asl,mid = 422.7114$$

$$\text{with } Esv = (Es,jacket*Asl,mid,jacket + Es,mid*Asl,mid,core)/Asl,mid = 200000.00$$

$$1 = Asl,ten/(b*d)*(fs1/fc) = 0.0752324$$

$$2 = Asl,com/(b*d)*(fs2/fc) = 0.0752324$$

$$v = Asl,mid/(b*d)*(fsv/fc) = 0.02812438$$

and confined core properties:

$$b = 390.00$$

$$d = 377.00$$

$$d' = 13.00$$

$$fcc (5A.2, TBDY) = 36.47874$$

$$cc (5A.5, TBDY) = 0.00305417$$

$$c = \text{confinement factor} = 1.10542$$

$$1 = Asl,ten/(b*d)*(fs1/fc) = 0.09371431$$

$$2 = Asl,com/(b*d)*(fs2/fc) = 0.09371431$$

$$v = Asl,mid/(b*d)*(fsv/fc) = 0.03503353$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

---->

v < vs,y2 - LHS eq.(4.5) is satisfied

---->

$$su (4.9) = 0.16791801$$

$$Mu = MRc (4.14) = 2.2193E+008$$

$$u = s_u(4.1) = 1.9632832E-005$$

Calculation of ratio  $l_b/d$

$$\text{Lap Length: } l_b/d = 0.33981258$$

$$l_b = 300.00$$

$$d = 882.8396$$

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

$$= 1$$

$$d_b = 16.66667$$

$$\text{Mean strength value of all re-bars: } f_y = 655.558$$

$$\text{Mean concrete strength: } f_c' = (f_c'_{\text{jacket}} \cdot \text{Area}_{\text{jacket}} + f_c'_{\text{core}} \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 28.98765, \text{ but } f_c'^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 25.00$$

$$K_{tr} = 2.86234$$

$$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 257.6106$$

where  $A_{tr_x}, A_{tr_y}$  are the sum of the area of all stirrup legs along X and Y local axis

$$s = \text{Max}(s_{\text{external}}, s_{\text{internal}}) = 300.00$$

$$n = 12.00$$

Calculation of  $\mu_2$

Calculation of ultimate curvature  $u$  according to 4.1, Biskinis/Fardis 2013:

$$u = 1.9632832E-005$$

$$\mu_u = 2.2193E+008$$

with full section properties:

$$b = 450.00$$

$$d = 407.00$$

$$d' = 43.00$$

$$v = 0.00124204$$

$$N = 7506.808$$

$$f_c = 33.00$$

$$c_o \text{ (5A.5, TBDY)} = 0.002$$

$$\text{Final value of } c_u: c_u^* = \text{shear\_factor} * \text{Max}(c_u, c_c) = 0.01393923$$

The Shear\_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } c_u = 0.01393923$$

$$w_e \text{ ((5.4c), TBDY)} = a_{se} * s_{h, \min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.06811101$$

where  $f = a_f * p_f * f_{fe} / f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.06628267$$

$$a_f = 0.54930041$$

$$b = 450.00$$

$$h = 450.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.00451556$$

$$b_w = 450.00$$

$$\text{effective stress from (A.35), } f_{fe} = 881.8461$$

$$f_y = 0.06628267$$

$$a_f = 0.54930041$$

$$b = 450.00$$

$$h = 450.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.00451556$$

$$b_w = 450.00$$

$$\text{effective stress from (A.35), } f_{fe} = 881.8461$$

$$R = 40.00$$

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

$$f_{u,f} = 1055.00$$

Ef = 64828.00

u,f = 0.015

ase ((5.4d), TBDY) = (ase1\*Aext+ase2\*Aint)/Asec = 0.14546167

ase1 = 0.12623274

bo\_1 = 390.00

ho\_1 = 390.00

bi2\_1 = 608400.00

ase2 = Max(ase1,ase2) = 0.18853448

bo\_2 = 242.00

ho\_2 = 242.00

bi2\_2 = 234256.00

psh,min\*Fywe = Min(psh,x\*Fywe , psh,y\*Fywe) = 1.38262

Expression ((5.4d), TBDY) for psh,min\*Fywe has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

psh\_x\*Fywe = psh1\*Fywe1+ps2\*Fywe2 = 1.38262

ps1 (external) = (Ash1\*h1/s1)/Asec = 0.00116355

Ash1 = Astir\_1\*ns\_1 = 157.0796

No stirrups, ns\_1 = 2.00

h1 = 450.00

ps2 (internal) = (Ash2\*h2/s2)/Asec = 0.00103427

Ash2 = Astir\_2\*ns\_2 = 100.531

No stirrups, ns\_2 = 2.00

h2 = 250.00

psh\_y\*Fywe = psh1\*Fywe1+ps2\*Fywe2 = 1.38262

ps1 (external) = (Ash1\*h1/s1)/Asec = 0.00116355

Ash1 = Astir\_1\*ns\_1 = 157.0796

No stirrups, ns\_1 = 2.00

h1 = 450.00

ps2 (internal) = (Ash2\*h2/s2)/Asec = 0.00103427

Ash2 = Astir\_2\*ns\_2 = 100.531

No stirrups, ns\_2 = 2.00

h2 = 250.00

Asec = 202500.00

s1 = 300.00

s2 = 120.00

fywe1 = 694.45

fywe2 = 555.55

fce = 33.00

From ((5.A5), TBDY), TBDY: cc = 0.00305417

c = confinement factor = 1.10542

y1 = 0.00152175

sh1 = 0.0048696

ft1 = 479.7871

fy1 = 399.8226

su1 = 0.0066488

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00

lo/lou,min = lb/ld = 0.33981258

su1 = 0.4\*esu1\_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu1\_nominal = 0.08,

For calculation of esu1\_nominal and y1, sh1,ft1,fy1, it is considered characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25\*(lb/ld)^2/3), from 10.3.5, ASCE 41-17.

with fs1 = (fs,jacket\*Asl,ten,jacket + fs,core\*Asl,ten,core)/Asl,ten = 399.8226

with Es1 = (Es,jacket\*Asl,ten,jacket + Es,core\*Asl,ten,core)/Asl,ten = 200000.00

y2 = 0.00152175

sh2 = 0.0048696

ft2 = 479.7871

fy2 = 399.8226

su2 = 0.0066488

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00

$$l_0/l_{0u,min} = l_b/l_{b,min} = 0.33981258$$

$$s_u = 0.4 \cdot e_{su2,nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY:  $e_{su2,nominal} = 0.08$ ,

For calculation of  $e_{su2,nominal}$  and  $y_2$ ,  $sh_2$ ,  $ft_2$ ,  $fy_2$ , it is considered characteristic value  $f_{sy2} = f_{s2}/1.2$ , from table 5.1, TBDY.

$y_1$ ,  $sh_1$ ,  $ft_1$ ,  $fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.

$$\text{with } f_{s2} = (f_{s,jacket} \cdot A_{s1,com,jacket} + f_{s,core} \cdot A_{s1,com,core}) / A_{s1,com} = 399.8226$$

$$\text{with } E_{s2} = (E_{s,jacket} \cdot A_{s1,com,jacket} + E_{s,core} \cdot A_{s1,com,core}) / A_{s1,com} = 200000.00$$

$$y_v = 0.00152175$$

$$sh_v = 0.0048696$$

$$ft_v = 507.2537$$

$$fy_v = 422.7114$$

$$s_{uv} = 0.0066488$$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor

and also multiplied by the shear\_factor according to 15.7.1.4, with Shear\_factor = 1.00

$$l_0/l_{0u,min} = l_b/l_d = 0.33981258$$

$$s_{uv} = 0.4 \cdot e_{suv,nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY:  $e_{suv,nominal} = 0.08$ ,

considering characteristic value  $f_{sv} = f_{sv}/1.2$ , from table 5.1, TBDY

For calculation of  $e_{suv,nominal}$  and  $y_v$ ,  $sh_v$ ,  $ft_v$ ,  $fy_v$ , it is considered characteristic value  $f_{sv} = f_{sv}/1.2$ , from table 5.1, TBDY.

$y_1$ ,  $sh_1$ ,  $ft_1$ ,  $fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.

$$\text{with } f_{sv} = (f_{s,jacket} \cdot A_{s,mid,jacket} + f_{s,mid} \cdot A_{s,mid,core}) / A_{s,mid} = 422.7114$$

$$\text{with } E_{sv} = (E_{s,jacket} \cdot A_{s,mid,jacket} + E_{s,mid} \cdot A_{s,mid,core}) / A_{s,mid} = 200000.00$$

$$1 = A_{s1,ten} / (b \cdot d) \cdot (f_{s1} / f_c) = 0.0752324$$

$$2 = A_{s1,com} / (b \cdot d) \cdot (f_{s2} / f_c) = 0.0752324$$

$$v = A_{s1,mid} / (b \cdot d) \cdot (f_{sv} / f_c) = 0.02812438$$

and confined core properties:

$$b = 390.00$$

$$d = 377.00$$

$$d' = 13.00$$

$$f_{cc} (5A.2, TBDY) = 36.47874$$

$$c_c (5A.5, TBDY) = 0.00305417$$

$$c = \text{confinement factor} = 1.10542$$

$$1 = A_{s1,ten} / (b \cdot d) \cdot (f_{s1} / f_c) = 0.09371431$$

$$2 = A_{s1,com} / (b \cdot d) \cdot (f_{s2} / f_c) = 0.09371431$$

$$v = A_{s1,mid} / (b \cdot d) \cdot (f_{sv} / f_c) = 0.03503353$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

---->

$v < v_{s,y2}$  - LHS eq.(4.5) is satisfied

---->

$$s_u (4.9) = 0.16791801$$

$$M_u = M_{Rc} (4.14) = 2.2193E+008$$

$$u = s_u (4.1) = 1.9632832E-005$$

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

Lap Length:  $l_b/l_d = 0.33981258$

$$l_b = 300.00$$

$$l_d = 882.8396$$

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

$$= 1$$

$$d_b = 16.66667$$

Mean strength value of all re-bars:  $f_y = 655.558$

Mean concrete strength:  $f'_c = (f'_{c,jacket} \cdot \text{Area}_{jacket} + f'_{c,core} \cdot \text{Area}_{core}) / \text{Area}_{section} = 28.98765$ , but  $f_c^{0.5} <= 8.3$  MPa (22.5.3.1, ACI 318-14)

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 25.00$$

$$K_{tr} = 2.86234$$

$$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 257.6106$$

where  $A_{tr_x}$ ,  $A_{tr_y}$  are the sum of the area of all stirrup legs along X and Y local axis

$$s = \text{Max}(s_{external}, s_{internal}) = 300.00$$

n = 12.00

Calculation of Shear Strength  $V_r = \text{Min}(V_{r1}, V_{r2}) = 567563.724$

Calculation of Shear Strength at edge 1,  $V_{r1} = 567563.724$

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

$V_{Co1} = 567563.724$

$k_{nl} = 1$  (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:  $f_c' = (f_c'_{\text{jacket}} * \text{Area}_{\text{jacket}} + f_c'_{\text{core}} * \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 28.98765$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M / Vd = 2.00$

$\mu_u = 1.4404090E-011$

$V_u = 2.0531359E-031$

$d = 0.8 * h = 360.00$

$N_u = 7506.808$

$A_g = 202500.00$

From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 144280.365$

where:

$V_{s1} = 69813.729$  is calculated for jacket, with:

$d = 360.00$

$A_v = 157079.633$

$f_y = 555.56$

$s = 300.00$

$V_{s1}$  is multiplied by  $Col1 = 0.66666667$

$s/d = 0.833333333$

$V_{s2} = 74466.637$  is calculated for core, with:

$d = 200.00$

$A_v = 100530.965$

$f_y = 444.44$

$s = 120.00$

$V_{s2}$  is multiplied by  $Col2 = 1.00$

$s/d = 0.60$

$V_f ((11-3)-(11.4), \text{ACI } 440) = 214457.247$

$f = 0.95$ , for fully-wrapped sections

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

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

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

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

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

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

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

$d_{fv} = d$  (figure 11.2, ACI 440) = 407.00

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

$E_f = 64828.00$

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

with  $f_u = 0.01$

From (11-11), ACI 440:  $V_s + V_f \leq 579413.096$

$b_w = 450.00$

Calculation of Shear Strength at edge 2,  $V_{r2} = 567563.724$

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

$V_{Co2} = 567563.724$

$k_{nl} = 1$  (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:  $f_c' = (f_c'_{\text{jacket}} \cdot \text{Area}_{\text{jacket}} + f_c'_{\text{core}} \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 28.98765$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$\mu_u = 1.4404090E-011$

$V_u = 2.0531359E-031$

$d = 0.8 \cdot h = 360.00$

$N_u = 7506.808$

$A_g = 202500.00$

From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 144280.365$

where:

$V_{s1} = 69813.729$  is calculated for jacket, with:

$d = 360.00$

$A_v = 157079.633$

$f_y = 555.56$

$s = 300.00$

$V_{s1}$  is multiplied by  $\text{Col1} = 0.66666667$

$s/d = 0.83333333$

$V_{s2} = 74466.637$  is calculated for core, with:

$d = 200.00$

$A_v = 100530.965$

$f_y = 444.44$

$s = 120.00$

$V_{s2}$  is multiplied by  $\text{Col2} = 1.00$

$s/d = 0.60$

$V_f$  ((11-3)-(11.4), ACI 440) = 214457.247

$f = 0.95$ , for fully-wrapped sections

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

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

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

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

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

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

$d_{fv} = d$  (figure 11.2, ACI 440) = 407.00

$f_{fe}$  ((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:  $V_s + V_f \leq 579413.096$

$b_w = 450.00$

-----  
End Of Calculation of Shear Capacity ratio for element: column JC1 of floor 1

At local axis: 3  
-----

-----  
Start Of Calculation of Shear Capacity ratio for element: column JC1 of floor 1

At Shear local axis: 2

(Bending local axis: 3)

Section Type: rcjrs

Constant Properties  
-----

Knowledge Factor,  $\phi = 0.85$

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 Height,  $H = 450.00$   
External Width,  $W = 450.00$   
Internal Height,  $H = 250.00$   
Internal Width,  $W = 250.00$   
Cover Thickness,  $c = 25.00$   
Mean Confinement Factor overall section = 1.10542  
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,  $V_a = -2.7162834E-031$   
EDGE -B-  
Shear Force,  $V_b = 2.7162834E-031$   
BOTH EDGES  
Axial Force,  $F = -7506.808$   
Longitudinal Reinforcement Area Distribution (in 2 divisions)  
-Tension:  $A_{sl,t} = 0.00$   
-Compression:  $A_{sl,c} = 2676.637$   
Longitudinal Reinforcement Area Distribution (in 3 divisions)  
-Tension:  $A_{sl,ten} = 1137.257$   
-Compression:  $A_{sl,com} = 1137.257$   
-Middle:  $A_{sl,mid} = 402.1239$

-----  
-----  
Calculation of Shear Capacity ratio,  $V_e/V_r = 0.26068017$   
Member Controlled by Flexure ( $V_e/V_r < 1$ )  
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 147952.607$   
with  
 $M_{pr1} = \text{Max}(M_{u1+}, M_{u1-}) = 2.2193E+008$   
 $M_{u1+} = 2.2193E+008$ , 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  
 $M_{u1-} = 2.2193E+008$ , 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  
 $M_{pr2} = \text{Max}(M_{u2+}, M_{u2-}) = 2.2193E+008$

Mu2+ = 2.2193E+008, is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the the static loading combination

Mu2- = 2.2193E+008, is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the the static loading combination

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

-----  
Calculation of ultimate curvature  $\mu$  according to 4.1, Biskinis/Fardis 2013:

$$\mu = 1.9632832E-005$$

$$Mu = 2.2193E+008$$

-----  
with full section properties:

$$b = 450.00$$

$$d = 407.00$$

$$d' = 43.00$$

$$v = 0.00124204$$

$$N = 7506.808$$

$$f_c = 33.00$$

$$c_o \text{ (5A.5, TBDY)} = 0.002$$

$$\text{Final value of } c_u: c_u^* = \text{shear\_factor} * \text{Max}(c_u, c_c) = 0.01393923$$

The Shear\_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } c_u = 0.01393923$$

$$w_e \text{ ((5.4c), TBDY)} = a_{se} * s_{h,\min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.06811101$$

where  $f = a_f * p_f * f_{fe} / f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

-----  
 $f_x = 0.06628267$

$$a_f = 0.54930041$$

$$b = 450.00$$

$$h = 450.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.00451556$$

$$b_w = 450.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 881.8461$$

-----  
 $f_y = 0.06628267$

$$a_f = 0.54930041$$

$$b = 450.00$$

$$h = 450.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.00451556$$

$$b_w = 450.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 881.8461$$

-----  
 $R = 40.00$

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

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{f} = 0.015$$

$$a_{se} \text{ ((5.4d), TBDY)} = (a_{se1} * A_{ext} + a_{se2} * A_{int}) / A_{sec} = 0.14546167$$

$$a_{se1} = 0.12623274$$

$$b_{o,1} = 390.00$$

$$h_{o,1} = 390.00$$

$$b_{i,2,1} = 608400.00$$

$$a_{se2} = \text{Max}(a_{se1}, a_{se2}) = 0.18853448$$

$$b_{o,2} = 242.00$$

$$h_{o,2} = 242.00$$

$$b_{i,2,2} = 234256.00$$

$$p_{sh,\min} * F_{ywe} = \text{Min}(p_{sh,x} * F_{ywe}, p_{sh,y} * F_{ywe}) = 1.38262$$

Expression ((5.4d), TBDY) for  $p_{sh,\min} * F_{ywe}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

-----  
 $p_{sh,x} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{sh2} * F_{ywe2} = 1.38262$

$$p_{s1} \text{ (external)} = (A_{sh1} * h_1 / s_1) / A_{sec} = 0.00116355$$

$$A_{sh1} = A_{stir,1} * n_{s,1} = 157.0796$$

$$\text{No stirrups, } n_{s,1} = 2.00$$

$$h_1 = 450.00$$

$$ps_2 \text{ (internal)} = (Ash_2 * h_2 / s_2) / A_{sec} = 0.00103427$$

$$Ash_2 = Astir_2 * ns_2 = 100.531$$

$$\text{No stirups, } ns_2 = 2.00$$

$$h_2 = 250.00$$

$$psh_y * Fywe = psh_1 * Fywe_1 + ps_2 * Fywe_2 = 1.38262$$

$$ps_1 \text{ (external)} = (Ash_1 * h_1 / s_1) / A_{sec} = 0.00116355$$

$$Ash_1 = Astir_1 * ns_1 = 157.0796$$

$$\text{No stirups, } ns_1 = 2.00$$

$$h_1 = 450.00$$

$$ps_2 \text{ (internal)} = (Ash_2 * h_2 / s_2) / A_{sec} = 0.00103427$$

$$Ash_2 = Astir_2 * ns_2 = 100.531$$

$$\text{No stirups, } ns_2 = 2.00$$

$$h_2 = 250.00$$

$$A_{sec} = 202500.00$$

$$s_1 = 300.00$$

$$s_2 = 120.00$$

$$fywe_1 = 694.45$$

$$fywe_2 = 555.55$$

$$f_{ce} = 33.00$$

$$\text{From ((5.A.5), TBDY), TBDY: } cc = 0.00305417$$

$$c = \text{confinement factor} = 1.10542$$

$$y_1 = 0.00152175$$

$$sh_1 = 0.0048696$$

$$ft_1 = 479.7871$$

$$fy_1 = 399.8226$$

$$su_1 = 0.0066488$$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

$$lo/lou, \text{min} = lb/ld = 0.33981258$$

$$su_1 = 0.4 * esu_1 \text{ nominal ((5.5), TBDY)} = 0.032$$

$$\text{From table 5A.1, TBDY: } esu_1 \text{ nominal} = 0.08,$$

For calculation of esu\_1 nominal and y\_1, sh\_1, ft\_1, fy\_1, it is considered  
characteristic value fsy\_1 = fs\_1 / 1.2, from table 5.1, TBDY.

$$y_1, sh_1, ft_1, fy_1, \text{ are also multiplied by } \text{Min}(1, 1.25 * (lb/ld)^{2/3}), \text{ from 10.3.5, ASCE 41-17.}$$

$$\text{with } fs_1 = (fs_{jacket} * A_{sl,ten,jacket} + fs_{core} * A_{sl,ten,core}) / A_{sl,ten} = 399.8226$$

$$\text{with } Es_1 = (Es_{jacket} * A_{sl,ten,jacket} + Es_{core} * A_{sl,ten,core}) / A_{sl,ten} = 200000.00$$

$$y_2 = 0.00152175$$

$$sh_2 = 0.0048696$$

$$ft_2 = 479.7871$$

$$fy_2 = 399.8226$$

$$su_2 = 0.0066488$$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

$$lo/lou, \text{min} = lb/lb, \text{min} = 0.33981258$$

$$su_2 = 0.4 * esu_2 \text{ nominal ((5.5), TBDY)} = 0.032$$

$$\text{From table 5A.1, TBDY: } esu_2 \text{ nominal} = 0.08,$$

For calculation of esu\_2 nominal and y\_2, sh\_2, ft\_2, fy\_2, it is considered  
characteristic value fsy\_2 = fs\_2 / 1.2, from table 5.1, TBDY.

$$y_2, sh_2, ft_2, fy_2, \text{ are also multiplied by } \text{Min}(1, 1.25 * (lb/ld)^{2/3}), \text{ from 10.3.5, ASCE 41-17.}$$

$$\text{with } fs_2 = (fs_{jacket} * A_{sl,com,jacket} + fs_{core} * A_{sl,com,core}) / A_{sl,com} = 399.8226$$

$$\text{with } Es_2 = (Es_{jacket} * A_{sl,com,jacket} + Es_{core} * A_{sl,com,core}) / A_{sl,com} = 200000.00$$

$$y_v = 0.00152175$$

$$sh_v = 0.0048696$$

$$ft_v = 507.2537$$

$$fy_v = 422.7114$$

$$su_v = 0.0066488$$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

$$lo/lou, \text{min} = lb/ld = 0.33981258$$

$$su_v = 0.4 * esuv \text{ nominal ((5.5), TBDY)} = 0.032$$

$$\text{From table 5A.1, TBDY: } esuv \text{ nominal} = 0.08,$$

considering characteristic value fsyv = fsv / 1.2, from table 5.1, TBDY

For calculation of  $e_{suv\_nominal}$  and  $\gamma_v$ ,  $sh_v$ ,  $ft_v$ ,  $fy_v$ , it is considered characteristic value  $f_{sv} = f_{sv}/1.2$ , from table 5.1, TBDY.

$y_1$ ,  $sh_1$ ,  $ft_1$ ,  $fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.

with  $f_{sv} = (f_{s,jacket} \cdot A_{s,mid,jacket} + f_{s,mid} \cdot A_{s,mid,core})/A_{s,mid} = 422.7114$

with  $E_{sv} = (E_{s,jacket} \cdot A_{s,mid,jacket} + E_{s,mid} \cdot A_{s,mid,core})/A_{s,mid} = 200000.00$

$1 = A_{s,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.0752324$

$2 = A_{s,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.0752324$

$v = A_{s,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.02812438$

and confined core properties:

$b = 390.00$

$d = 377.00$

$d' = 13.00$

$f_{cc}$  (5A.2, TBDY) = 36.47874

$cc$  (5A.5, TBDY) = 0.00305417

$c = \text{confinement factor} = 1.10542$

$1 = A_{s,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.09371431$

$2 = A_{s,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.09371431$

$v = A_{s,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.03503353$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < v_{s,y2}$  - LHS eq.(4.5) is satisfied

--->

$\mu_u$  (4.9) = 0.16791801

$\mu_u = MR_c$  (4.14) = 2.2193E+008

$u = \mu_u$  (4.1) = 1.9632832E-005

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

Lap Length:  $l_b/l_d = 0.33981258$

$l_b = 300.00$

$l_d = 882.8396$

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

= 1

$d_b = 16.66667$

Mean strength value of all re-bars:  $f_y = 655.558$

Mean concrete strength:  $f'_c = (f'_{c,jacket} \cdot Area_{jacket} + f'_{c,core} \cdot Area_{core})/Area_{section} = 28.98765$ , but  $f_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 2.86234$

$A_{tr} = \text{Min}(A_{tr,x}, A_{tr,y}) = 257.6106$

where  $A_{tr,x}$ ,  $A_{tr,y}$  are the sum of the area of all stirrup legs along X and Y local axis

$s = \text{Max}(s_{external}, s_{internal}) = 300.00$

$n = 12.00$

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

-----  
Calculation of ultimate curvature  $\mu_u$  according to 4.1, Biskinis/Fardis 2013:

$u = 1.9632832E-005$

$\mu_u = 2.2193E+008$

-----  
with full section properties:

$b = 450.00$

$d = 407.00$

$d' = 43.00$

$v = 0.00124204$

$N = 7506.808$

$f_c = 33.00$

$cc$  (5A.5, TBDY) = 0.002

Final value of  $c_u$ :  $c_u^* = \text{shear\_factor} * \text{Max}(c_u, c_c) = 0.01393923$

The Shear\_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY:  $c_u = 0.01393923$

$w_e$  ((5.4c), TBDY) =  $ase * \text{sh\_min} * fy_{we} / f_{ce} + \text{Min}(f_x, f_y) = 0.06811101$

where  $f = af * pf * f_{fe} / f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

-----  
 $f_x = 0.06628267$

$af = 0.54930041$

$b = 450.00$

$h = 450.00$

From EC8 A.4.4.3(6),  $pf = 2tf/bw = 0.00451556$

$bw = 450.00$

effective stress from (A.35),  $f_{f,e} = 881.8461$

-----  
 $f_y = 0.06628267$

$af = 0.54930041$

$b = 450.00$

$h = 450.00$

From EC8 A.4.4.3(6),  $pf = 2tf/bw = 0.00451556$

$bw = 450.00$

effective stress from (A.35),  $f_{f,e} = 881.8461$

-----  
 $R = 40.00$

Effective FRP thickness,  $tf = NL * t * \text{Cos}(b1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{,f} = 0.015$

$ase$  ((5.4d), TBDY) =  $(ase1 * A_{ext} + ase2 * A_{int}) / A_{sec} = 0.14546167$

$ase1 = 0.12623274$

$bo_{,1} = 390.00$

$ho_{,1} = 390.00$

$bi_{2,1} = 608400.00$

$ase2 = \text{Max}(ase1, ase2) = 0.18853448$

$bo_{,2} = 242.00$

$ho_{,2} = 242.00$

$bi_{2,2} = 234256.00$

$p_{sh, \text{min}} * F_{ywe} = \text{Min}(p_{sh,x} * F_{ywe}, p_{sh,y} * F_{ywe}) = 1.38262$

Expression ((5.4d), TBDY) for  $p_{sh, \text{min}} * F_{ywe}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

-----  
 $p_{sh,x} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{sh2} * F_{ywe2} = 1.38262$

$ps1$  (external) =  $(Ash1 * h1 / s1) / A_{sec} = 0.00116355$

$Ash1 = Astir_{,1} * ns_{,1} = 157.0796$

No stirrups,  $ns_{,1} = 2.00$

$h1 = 450.00$

$ps2$  (internal) =  $(Ash2 * h2 / s2) / A_{sec} = 0.00103427$

$Ash2 = Astir_{,2} * ns_{,2} = 100.531$

No stirrups,  $ns_{,2} = 2.00$

$h2 = 250.00$

-----  
 $p_{sh,y} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{sh2} * F_{ywe2} = 1.38262$

$ps1$  (external) =  $(Ash1 * h1 / s1) / A_{sec} = 0.00116355$

$Ash1 = Astir_{,1} * ns_{,1} = 157.0796$

No stirrups,  $ns_{,1} = 2.00$

$h1 = 450.00$

$ps2$  (internal) =  $(Ash2 * h2 / s2) / A_{sec} = 0.00103427$

$Ash2 = Astir_{,2} * ns_{,2} = 100.531$

No stirrups,  $ns_{,2} = 2.00$

$h2 = 250.00$

-----  
 $A_{sec} = 202500.00$

$s1 = 300.00$

$s2 = 120.00$

$fy_{we1} = 694.45$

$fy_{we2} = 555.55$

$f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.00305417$

$c = \text{confinement factor} = 1.10542$   
 $y1 = 0.00152175$   
 $sh1 = 0.0048696$   
 $ft1 = 479.7871$   
 $fy1 = 399.8226$   
 $su1 = 0.0066488$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 $\text{Shear\_factor} = 1.00$   
 $lo/lou,min = lb/ld = 0.33981258$   
 $su1 = 0.4 * esu1\_nominal ((5.5), \text{TBDY}) = 0.032$   
 From table 5A.1, TBDY:  $esu1\_nominal = 0.08$ ,  
 For calculation of  $esu1\_nominal$  and  $y1, sh1, ft1, fy1$ , it is considered  
 characteristic value  $fsy1 = fs1/1.2$ , from table 5.1, TBDY.  
 $y1, sh1, ft1, fy1$ , are also multiplied by  $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with  $fs1 = (fs,jacket * Asl,ten,jacket + fs,core * Asl,ten,core) / Asl,ten = 399.8226$   
 with  $Es1 = (Es,jacket * Asl,ten,jacket + Es,core * Asl,ten,core) / Asl,ten = 200000.00$   
 $y2 = 0.00152175$   
 $sh2 = 0.0048696$   
 $ft2 = 479.7871$   
 $fy2 = 399.8226$   
 $su2 = 0.0066488$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 $\text{Shear\_factor} = 1.00$   
 $lo/lou,min = lb/lb,min = 0.33981258$   
 $su2 = 0.4 * esu2\_nominal ((5.5), \text{TBDY}) = 0.032$   
 From table 5A.1, TBDY:  $esu2\_nominal = 0.08$ ,  
 For calculation of  $esu2\_nominal$  and  $y2, sh2, ft2, fy2$ , it is considered  
 characteristic value  $fsy2 = fs2/1.2$ , from table 5.1, TBDY.  
 $y1, sh1, ft1, fy1$ , are also multiplied by  $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with  $fs2 = (fs,jacket * Asl,com,jacket + fs,core * Asl,com,core) / Asl,com = 399.8226$   
 with  $Es2 = (Es,jacket * Asl,com,jacket + Es,core * Asl,com,core) / Asl,com = 200000.00$   
 $yv = 0.00152175$   
 $shv = 0.0048696$   
 $ftv = 507.2537$   
 $fyv = 422.7114$   
 $suv = 0.0066488$   
 using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 $\text{Shear\_factor} = 1.00$   
 $lo/lou,min = lb/ld = 0.33981258$   
 $suv = 0.4 * esuv\_nominal ((5.5), \text{TBDY}) = 0.032$   
 From table 5A.1, TBDY:  $esuv\_nominal = 0.08$ ,  
 considering characteristic value  $fsyv = fsv/1.2$ , from table 5.1, TBDY  
 For calculation of  $esuv\_nominal$  and  $yv, shv, ftv, fyv$ , it is considered  
 characteristic value  $fsyv = fsv/1.2$ , from table 5.1, TBDY.  
 $y1, sh1, ft1, fy1$ , are also multiplied by  $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.  
 with  $fsv = (fs,jacket * Asl,mid,jacket + fs,mid * Asl,mid,core) / Asl,mid = 422.7114$   
 with  $Es_v = (Es,jacket * Asl,mid,jacket + Es,mid * Asl,mid,core) / Asl,mid = 200000.00$   
 $1 = Asl,ten / (b * d) * (fs1 / fc) = 0.0752324$   
 $2 = Asl,com / (b * d) * (fs2 / fc) = 0.0752324$   
 $v = Asl,mid / (b * d) * (fsv / fc) = 0.02812438$   
 and confined core properties:  
 $b = 390.00$   
 $d = 377.00$   
 $d' = 13.00$   
 $fcc (5A.2, \text{TBDY}) = 36.47874$   
 $cc (5A.5, \text{TBDY}) = 0.00305417$   
 $c = \text{confinement factor} = 1.10542$   
 $1 = Asl,ten / (b * d) * (fs1 / fc) = 0.09371431$   
 $2 = Asl,com / (b * d) * (fs2 / fc) = 0.09371431$   
 $v = Asl,mid / (b * d) * (fsv / fc) = 0.03503353$   
 Case/Assumption: Unconfined full section - Steel rupture  
 ' satisfies Eq. (4.3)  
 --->  
 $v < vs,y2$  - LHS eq.(4.5) is satisfied

--->

su (4.9) = 0.16791801  
Mu = MRc (4.14) = 2.2193E+008  
u = su (4.1) = 1.9632832E-005

-----  
Calculation of ratio lb/l<sub>d</sub>

-----  
Lap Length: lb/l<sub>d</sub> = 0.33981258

lb = 300.00

l<sub>d</sub> = 882.8396

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

= 1

db = 16.66667

Mean strength value of all re-bars: fy = 655.558

Mean concrete strength: fc' = (fc'\_jacket\*Area\_jacket + fc'\_core\*Area\_core)/Area\_section = 28.98765, 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 = 2.86234

Atr = Min(Atr\_x,Atr\_y) = 257.6106

where Atr\_x, Atr\_y are the sum of the area of all stirrup legs along X and Y loxal axis

s = Max(s\_external,s\_internal) = 300.00

n = 12.00

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

-----  
Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

u = 1.9632832E-005

Mu = 2.2193E+008

-----  
with full section properties:

b = 450.00

d = 407.00

d' = 43.00

v = 0.00124204

N = 7506.808

fc = 33.00

co (5A.5, TBDY) = 0.002

Final value of cu: cu\* = shear\_factor \* Max( cu, cc) = 0.01393923

The Shear\_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: cu = 0.01393923

we ((5.4c), TBDY) = ase\* sh,min\*fywe/fce+Min( fx, fy) = 0.06811101

where f = af\*pf\*ffe/fce is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

-----  
fx = 0.06628267

af = 0.54930041

b = 450.00

h = 450.00

From EC8 A.4.4.3(6), pf = 2tf/bw = 0.00451556

bw = 450.00

effective stress from (A.35), ff,e = 881.8461

-----  
fy = 0.06628267

af = 0.54930041

b = 450.00

h = 450.00

From EC8 A.4.4.3(6), pf = 2tf/bw = 0.00451556

bw = 450.00

effective stress from (A.35), ff,e = 881.8461

$R = 40.00$   
 Effective FRP thickness,  $t_f = NL * t * \cos(b_1) = 1.016$   
 $f_{u,f} = 1055.00$   
 $E_f = 64828.00$   
 $u_{,f} = 0.015$   
 $ase((5.4d), TBDY) = (ase_1 * A_{ext} + ase_2 * A_{int}) / A_{sec} = 0.14546167$   
 $ase_1 = 0.12623274$   
 $bo_1 = 390.00$   
 $ho_1 = 390.00$   
 $bi_2_1 = 608400.00$   
 $ase_2 = \text{Max}(ase_1, ase_2) = 0.18853448$   
 $bo_2 = 242.00$   
 $ho_2 = 242.00$   
 $bi_2_2 = 234256.00$

$psh_{,min} * F_{ywe} = \text{Min}(psh_{,x} * F_{ywe}, psh_{,y} * F_{ywe}) = 1.38262$   
 Expression ((5.4d), TBDY) for  $psh_{,min} * F_{ywe}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$psh_{,x} * F_{ywe} = psh_1 * F_{ywe1} + ps_2 * F_{ywe2} = 1.38262$   
 $ps_1 \text{ (external)} = (A_{sh1} * h_1 / s_1) / A_{sec} = 0.00116355$   
 $A_{sh1} = A_{stir_1} * ns_1 = 157.0796$   
 No stirrups,  $ns_1 = 2.00$   
 $h_1 = 450.00$   
 $ps_2 \text{ (internal)} = (A_{sh2} * h_2 / s_2) / A_{sec} = 0.00103427$   
 $A_{sh2} = A_{stir_2} * ns_2 = 100.531$   
 No stirrups,  $ns_2 = 2.00$   
 $h_2 = 250.00$

$psh_{,y} * F_{ywe} = psh_1 * F_{ywe1} + ps_2 * F_{ywe2} = 1.38262$   
 $ps_1 \text{ (external)} = (A_{sh1} * h_1 / s_1) / A_{sec} = 0.00116355$   
 $A_{sh1} = A_{stir_1} * ns_1 = 157.0796$   
 No stirrups,  $ns_1 = 2.00$   
 $h_1 = 450.00$   
 $ps_2 \text{ (internal)} = (A_{sh2} * h_2 / s_2) / A_{sec} = 0.00103427$   
 $A_{sh2} = A_{stir_2} * ns_2 = 100.531$   
 No stirrups,  $ns_2 = 2.00$   
 $h_2 = 250.00$

$A_{sec} = 202500.00$   
 $s_1 = 300.00$   
 $s_2 = 120.00$   
 $f_{ywe1} = 694.45$   
 $f_{ywe2} = 555.55$   
 $f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY:  $cc = 0.00305417$   
 $c = \text{confinement factor} = 1.10542$

$y_1 = 0.00152175$   
 $sh_1 = 0.0048696$   
 $ft_1 = 479.7871$   
 $fy_1 = 399.8226$   
 $su_1 = 0.0066488$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
 and also multiplied by the shear\_factor according to 15.7.1.4, with  
 $\text{Shear\_factor} = 1.00$

$lo/lo_{,min} = lb/ld = 0.33981258$   
 $su_1 = 0.4 * esu_1_{nominal}((5.5), TBDY) = 0.032$

From table 5A.1, TBDY:  $esu_1_{nominal} = 0.08$ ,

For calculation of  $esu_1_{nominal}$  and  $y_1, sh_1, ft_1, fy_1$ , it is considered  
 characteristic value  $fsy_1 = fs_1 / 1.2$ , from table 5.1, TBDY.

$y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$ , from 10.3.5, ASCE 41-17.

with  $fs_1 = (f_{s,jacket} * A_{sl,ten,jacket} + f_{s,core} * A_{sl,ten,core}) / A_{sl,ten} = 399.8226$

with  $Es_1 = (E_{s,jacket} * A_{sl,ten,jacket} + E_{s,core} * A_{sl,ten,core}) / A_{sl,ten} = 200000.00$

$y_2 = 0.00152175$   
 $sh_2 = 0.0048696$   
 $ft_2 = 479.7871$   
 $fy_2 = 399.8226$   
 $su_2 = 0.0066488$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

$$l_o/l_{o,min} = l_b/l_{b,min} = 0.33981258$$

$$s_u2 = 0.4 * e_{su2,nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY:  $e_{su2,nominal} = 0.08$ ,

For calculation of  $e_{su2,nominal}$  and  $y_2, sh_2, ft_2, fy_2$ , it is considered  
characteristic value  $f_{sy2} = f_{s2}/1.2$ , from table 5.1, TBDY.

$y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.

$$\text{with } f_{s2} = (f_{s,jacket} * A_{s1,com,jacket} + f_{s,core} * A_{s1,com,core}) / A_{s1,com} = 399.8226$$

$$\text{with } E_{s2} = (E_{s,jacket} * A_{s1,com,jacket} + E_{s,core} * A_{s1,com,core}) / A_{s1,com} = 200000.00$$

$$y_v = 0.00152175$$

$$sh_v = 0.0048696$$

$$ft_v = 507.2537$$

$$fy_v = 422.7114$$

$$s_{uv} = 0.0066488$$

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

$$l_o/l_{o,min} = l_b/l_d = 0.33981258$$

$$s_{uv} = 0.4 * e_{suv,nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY:  $e_{suv,nominal} = 0.08$ ,

considering characteristic value  $f_{sv} = f_{sv}/1.2$ , from table 5.1, TBDY

For calculation of  $e_{suv,nominal}$  and  $y_v, sh_v, ft_v, fy_v$ , it is considered  
characteristic value  $f_{sv} = f_{sv}/1.2$ , from table 5.1, TBDY.

$y_1, sh_1, ft_1, fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.

$$\text{with } f_{sv} = (f_{s,jacket} * A_{s,mid,jacket} + f_{s,mid} * A_{s,mid,core}) / A_{s,mid} = 422.7114$$

$$\text{with } E_{sv} = (E_{s,jacket} * A_{s,mid,jacket} + E_{s,mid} * A_{s,mid,core}) / A_{s,mid} = 200000.00$$

$$1 = A_{s,ten} / (b * d) * (f_{s1} / f_c) = 0.0752324$$

$$2 = A_{s,com} / (b * d) * (f_{s2} / f_c) = 0.0752324$$

$$v = A_{s,mid} / (b * d) * (f_{sv} / f_c) = 0.02812438$$

and confined core properties:

$$b = 390.00$$

$$d = 377.00$$

$$d' = 13.00$$

$$f_{cc} (5A.2, TBDY) = 36.47874$$

$$c_c (5A.5, TBDY) = 0.00305417$$

$$c = \text{confinement factor} = 1.10542$$

$$1 = A_{s,ten} / (b * d) * (f_{s1} / f_c) = 0.09371431$$

$$2 = A_{s,com} / (b * d) * (f_{s2} / f_c) = 0.09371431$$

$$v = A_{s,mid} / (b * d) * (f_{sv} / f_c) = 0.03503353$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < v_{s,y2}$  - LHS eq.(4.5) is satisfied

--->

$$s_u (4.9) = 0.16791801$$

$$\mu = M R_c (4.14) = 2.2193E+008$$

$$u = s_u (4.1) = 1.9632832E-005$$

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

Lap Length:  $l_b/l_d = 0.33981258$

$$l_b = 300.00$$

$$l_d = 882.8396$$

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

$$= 1$$

$$d_b = 16.66667$$

Mean strength value of all re-bars:  $f_y = 655.558$

Mean concrete strength:  $f'_c = (f'_{c,jacket} * Area_{jacket} + f'_{c,core} * Area_{core}) / Area_{section} = 28.98765$ , but  $f_c^{0.5} < =$   
8.3 MPa (22.5.3.1, ACI 318-14)

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 25.00$$

$$K_{tr} = 2.86234$$

$$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 257.6106$$

where  $A_{tr_x}$ ,  $A_{tr_y}$  are the sum of the area of all stirrup legs along X and Y local axis

$$s = \text{Max}(s_{\text{external}}, s_{\text{internal}}) = 300.00$$

$$n = 12.00$$

-----  
-----  
-----  
Calculation of  $\mu_2$ -

-----  
-----  
Calculation of ultimate curvature  $\mu$  according to 4.1, Biskinis/Fardis 2013:

$$\mu = 1.9632832E-005$$

$$\mu_2 = 2.2193E+008$$

-----  
with full section properties:

$$b = 450.00$$

$$d = 407.00$$

$$d' = 43.00$$

$$v = 0.00124204$$

$$N = 7506.808$$

$$f_c = 33.00$$

$$\omega (5A.5, \text{TBDY}) = 0.002$$

$$\text{Final value of } \mu_c: \mu_c^* = \text{shear\_factor} * \text{Max}(\mu_c, \mu_{cc}) = 0.01393923$$

The Shear\_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \mu_c = 0.01393923$$

$$\mu_{we} ((5.4c), \text{TBDY}) = a_{se} * \text{sh}_{\text{min}} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.06811101$$

where  $f = a_f * p_f * f_{fe} / f_{ce}$  is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.06628267$$

$$a_f = 0.54930041$$

$$b = 450.00$$

$$h = 450.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.00451556$$

$$b_w = 450.00$$

$$\text{effective stress from (A.35), } f_{fe} = 881.8461$$

$$f_y = 0.06628267$$

$$a_f = 0.54930041$$

$$b = 450.00$$

$$h = 450.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.00451556$$

$$b_w = 450.00$$

$$\text{effective stress from (A.35), } f_{fe} = 881.8461$$

$$R = 40.00$$

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

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$a_{se} ((5.4d), \text{TBDY}) = (a_{se1} * A_{ext} + a_{se2} * A_{int}) / A_{sec} = 0.14546167$$

$$a_{se1} = 0.12623274$$

$$b_{o,1} = 390.00$$

$$h_{o,1} = 390.00$$

$$b_{i,1} = 608400.00$$

$$a_{se2} = \text{Max}(a_{se1}, a_{se2}) = 0.18853448$$

$$b_{o,2} = 242.00$$

$$h_{o,2} = 242.00$$

$$b_{i,2} = 234256.00$$

$$p_{sh, \text{min}} * f_{ywe} = \text{Min}(p_{sh,x} * f_{ywe}, p_{sh,y} * f_{ywe}) = 1.38262$$

Expression ((5.4d), TBDY) for  $p_{sh, \text{min}} * f_{ywe}$  has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$$p_{sh_x} * f_{ywe} = p_{sh1} * f_{ywe1} + p_{sh2} * f_{ywe2} = 1.38262$$

$$p_{s1} (\text{external}) = (A_{sh1} * h_1 / s_1) / A_{sec} = 0.00116355$$

$$A_{sh1} = A_{stir_1} * n_{s_1} = 157.0796$$

$$\text{No stirrups, } n_{s_1} = 2.00$$

h1 = 450.00  
ps2 (internal) = (Ash2\*h2/s2)/Asec = 0.00103427  
Ash2 = Astir\_2\*ns\_2 = 100.531  
No stirups, ns\_2 = 2.00  
h2 = 250.00

-----  
psh\_y\*Fywe = psh1\*Fywe1+ps2\*Fywe2 = 1.38262  
ps1 (external) = (Ash1\*h1/s1)/Asec = 0.00116355  
Ash1 = Astir\_1\*ns\_1 = 157.0796  
No stirups, ns\_1 = 2.00  
h1 = 450.00  
ps2 (internal) = (Ash2\*h2/s2)/Asec = 0.00103427  
Ash2 = Astir\_2\*ns\_2 = 100.531  
No stirups, ns\_2 = 2.00  
h2 = 250.00

-----  
Asec = 202500.00  
s1 = 300.00  
s2 = 120.00  
fywe1 = 694.45  
fywe2 = 555.55  
fce = 33.00

From ((5.A5), TBDY), TBDY: cc = 0.00305417  
c = confinement factor = 1.10542

y1 = 0.00152175  
sh1 = 0.0048696  
ft1 = 479.7871  
fy1 = 399.8226  
su1 = 0.0066488

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

lo/lou,min = lb/d = 0.33981258

su1 = 0.4\*esu1\_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu1\_nominal = 0.08,

For calculation of esu1\_nominal and y1, sh1,ft1,fy1, it is considered  
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25\*(lb/d)^ 2/3), from 10.3.5, ASCE 41-17.

with fs1 = (fs,jacket\*Asl,ten,jacket + fs,core\*Asl,ten,core)/Asl,ten = 399.8226

with Es1 = (Es,jacket\*Asl,ten,jacket + Es,core\*Asl,ten,core)/Asl,ten = 200000.00

y2 = 0.00152175  
sh2 = 0.0048696  
ft2 = 479.7871  
fy2 = 399.8226  
su2 = 0.0066488

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

lo/lou,min = lb/lb,min = 0.33981258

su2 = 0.4\*esu2\_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu2\_nominal = 0.08,

For calculation of esu2\_nominal and y2, sh2,ft2,fy2, it is considered  
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25\*(lb/d)^ 2/3), from 10.3.5, ASCE 41-17.

with fs2 = (fs,jacket\*Asl,com,jacket + fs,core\*Asl,com,core)/Asl,com = 399.8226

with Es2 = (Es,jacket\*Asl,com,jacket + Es,core\*Asl,com,core)/Asl,com = 200000.00

yv = 0.00152175  
shv = 0.0048696  
ftv = 507.2537  
fyv = 422.7114  
suv = 0.0066488

using (30) in Biskinis/Fardis (2013) multiplied with shear\_factor  
and also multiplied by the shear\_factor according to 15.7.1.4, with  
Shear\_factor = 1.00

lo/lou,min = lb/d = 0.33981258

suv = 0.4\*esuv\_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esuv\_nominal = 0.08,

considering characteristic value  $f_{sv} = f_{sv}/1.2$ , from table 5.1, TBDY  
For calculation of  $e_{suv\_nominal}$  and  $y_v$ ,  $sh_v$ ,  $ft_v$ ,  $fy_v$ , it is considered characteristic value  $f_{sv} = f_{sv}/1.2$ , from table 5.1, TBDY.

$y_1$ ,  $sh_1$ ,  $ft_1$ ,  $fy_1$ , are also multiplied by  $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$ , from 10.3.5, ASCE 41-17.

with  $f_{sv} = (f_{s,jacket} \cdot A_{s,mid,jacket} + f_{s,mid} \cdot A_{s,mid,core}) / A_{s,mid} = 422.7114$

with  $E_{sv} = (E_{s,jacket} \cdot A_{s,mid,jacket} + E_{s,mid} \cdot A_{s,mid,core}) / A_{s,mid} = 200000.00$

$1 = A_{s,ten} / (b \cdot d) \cdot (f_{s1} / f_c) = 0.0752324$

$2 = A_{s,com} / (b \cdot d) \cdot (f_{s2} / f_c) = 0.0752324$

$v = A_{s,mid} / (b \cdot d) \cdot (f_{sv} / f_c) = 0.02812438$

and confined core properties:

$b = 390.00$

$d = 377.00$

$d' = 13.00$

$f_{cc}$  (5A.2, TBDY) = 36.47874

$cc$  (5A.5, TBDY) = 0.00305417

$c$  = confinement factor = 1.10542

$1 = A_{s,ten} / (b \cdot d) \cdot (f_{s1} / f_c) = 0.09371431$

$2 = A_{s,com} / (b \cdot d) \cdot (f_{s2} / f_c) = 0.09371431$

$v = A_{s,mid} / (b \cdot d) \cdot (f_{sv} / f_c) = 0.03503353$

Case/Assumption: Unconfined full section - Steel rupture  
' satisfies Eq. (4.3)

--->

$v < v_{s,y2}$  - LHS eq.(4.5) is satisfied

--->

$su$  (4.9) = 0.16791801

$Mu = MRc$  (4.14) = 2.2193E+008

$u = su$  (4.1) = 1.9632832E-005

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

Lap Length:  $l_b/l_d = 0.33981258$

$l_b = 300.00$

$l_d = 882.8396$

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

= 1

$db = 16.66667$

Mean strength value of all re-bars:  $fy = 655.558$

Mean concrete strength:  $f'_c = (f'_{c,jacket} \cdot Area_{jacket} + f'_{c,core} \cdot Area_{core}) / Area_{section} = 28.98765$ , but  $f_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 2.86234$

$A_{tr} = \text{Min}(A_{tr,x}, A_{tr,y}) = 257.6106$

where  $A_{tr,x}$ ,  $A_{tr,y}$  are the sum of the area of all stirrup legs along X and Y loxal axis

$s = \text{Max}(s_{external}, s_{internal}) = 300.00$

$n = 12.00$

-----  
Calculation of Shear Strength  $V_r = \text{Min}(V_{r1}, V_{r2}) = 567563.724$

-----  
Calculation of Shear Strength at edge 1,  $V_{r1} = 567563.724$

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

$V_{Col0} = 567563.724$

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

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

= 1 (normal-weight concrete)

Mean concrete strength:  $f'_c = (f'_{c,jacket} \cdot Area_{jacket} + f'_{c,core} \cdot Area_{core}) / Area_{section} = 28.98765$ , but  $f_c^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$\mu_u = 1.0463738E-012$   
 $V_u = 2.7162834E-031$   
 $d = 0.8 \cdot h = 360.00$   
 $N_u = 7506.808$   
 $A_g = 202500.00$   
 From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 144280.365$   
 where:  
 $V_{s1} = 69813.729$  is calculated for jacket, with:  
 $d = 360.00$   
 $A_v = 157079.633$   
 $f_y = 555.56$   
 $s = 300.00$   
 $V_{s1}$  is multiplied by  $Col1 = 0.66666667$   
 $s/d = 0.83333333$   
 $V_{s2} = 74466.637$  is calculated for core, with:  
 $d = 200.00$   
 $A_v = 100530.965$   
 $f_y = 444.44$   
 $s = 120.00$   
 $V_{s2}$  is multiplied by  $Col2 = 1.00$   
 $s/d = 0.60$   
 $V_f$  ((11-3)-(11.4), ACI 440) = 214457.247  
 $f = 0.95$ , for fully-wrapped sections  
 $w_f/s_f = 1$  (FRP strips adjacent to one another).  
 In (11.3)  $\sin + \cos$  is replaced with  $(\cot + \cot a) \sin a$  which is more a generalised expression,  
 where  $a$  is the angle of the crack direction (see KANEPE).  
 This later relation, considered as a function  $V_f(\theta)$ , is implemented for every different fiber orientation  $a_i$ ,  
 as well as for 2 crack directions,  $\theta = 45^\circ$  and  $\theta = -45^\circ$  to take into consideration the cyclic seismic loading.  
 orientation 1:  $\theta = b_1 + 90^\circ = 90.00$   
 $V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, \theta)|)$ , with:  
 total thickness per orientation,  $t_{f1} = N_L \cdot t / N_{oDir} = 1.016$   
 $d_{fv} = d$  (figure 11.2, ACI 440) = 407.00  
 $f_{fe}$  ((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:  $V_s + V_f \leq 579413.096$   
 $b_w = 450.00$

Calculation of Shear Strength at edge 2,  $V_{r2} = 567563.724$   
 $V_{r2} = V_{Col}$  ((10.3), ASCE 41-17) =  $k_{nl} \cdot V_{Col0}$   
 $V_{Col0} = 567563.724$   
 $k_{nl} = 1$  (zero step-static loading)

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

$\mu = 1$  (normal-weight concrete)  
 Mean concrete strength:  $f_c' = (f_c'_{jacket} \cdot Area_{jacket} + f_c'_{core} \cdot Area_{core}) / Area_{section} = 28.98765$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)  
 $M/Vd = 2.00$   
 $\mu_u = 1.0463738E-012$   
 $V_u = 2.7162834E-031$   
 $d = 0.8 \cdot h = 360.00$   
 $N_u = 7506.808$   
 $A_g = 202500.00$   
 From (11.5.4.8), ACI 318-14:  $V_s = V_{s1} + V_{s2} = 144280.365$   
 where:  
 $V_{s1} = 69813.729$  is calculated for jacket, with:  
 $d = 360.00$   
 $A_v = 157079.633$   
 $f_y = 555.56$   
 $s = 300.00$   
 $V_{s1}$  is multiplied by  $Col1 = 0.66666667$   
 $s/d = 0.83333333$   
 $V_{s2} = 74466.637$  is calculated for core, with:

$d = 200.00$   
 $A_v = 100530.965$   
 $f_y = 444.44$   
 $s = 120.00$   
 Vs2 is multiplied by Col2 = 1.00  
 $s/d = 0.60$   
 $V_f((11-3)-(11.4), \text{ACI 440}) = 214457.247$   
 $f = 0.95$ , for fully-wrapped sections  
 $w_f/s_f = 1$  (FRP strips adjacent to one another).  
 In (11.3)  $\sin + \cos$  is replaced with  $(\cot + \cot a)\sin a$  which is more a generalised expression,  
 where  $a$  is the angle of the crack direction (see KANEPE).  
 This later relation, considered as a function  $V_f(\theta)$ , is implemented for every different fiber orientation  $a_i$ ,  
 as well as for 2 crack directions,  $\theta = 45^\circ$  and  $\theta = -45^\circ$  to take into consideration the cyclic seismic loading.  
 orientation 1:  $\theta_1 = \theta_1 + 90^\circ = 90.00$   
 $V_f = \text{Min}(|V_f(45, \theta_1)|, |V_f(-45, a_1)|)$ , with:  
 total thickness per orientation,  $t_{f1} = N_L * t / \text{NoDir} = 1.016$   
 $d_{fv} = d$  (figure 11.2, ACI 440) = 407.00  
 $f_{fe}((11-5), \text{ACI 440}) = 259.312$   
 $E_f = 64828.00$   
 $f_e = 0.004$ , from (11.6a), ACI 440  
 with  $f_u = 0.01$   
 From (11-11), ACI 440:  $V_s + V_f \leq 579413.096$   
 $b_w = 450.00$

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 End Of Calculation of Shear Capacity ratio for element: column JC1 of floor 1  
 At local axis: 2

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 Start Of Calculation of Chord Rotation Capacity for element: column JC1 of floor 1  
 At local axis: 3

Integration Section: (b)  
 Section Type: rcjrs

Constant Properties

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 Knowledge Factor,  $\lambda = 0.85$   
 Chord Rotation is generally considered as Deformation-Controlled Action according to Table C7-1, ASCE 41-17.  
 Mean strengths are used for Deformation-Controlled Actions according to 7.5.1.3, ASCE 41-17  
 Consequently:  
 Jacket  
 New material of Primary Member: Concrete Strength,  $f_c = f_{cm} = 33.00$   
 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,  $E_s = 200000.00$   
 External Height,  $H = 450.00$   
 External Width,  $W = 450.00$   
 Internal Height,  $H = 250.00$   
 Internal Width,  $W = 250.00$   
 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,  $M = 0.09202348$   
Shear Force,  $V_2 = 11781.223$   
Shear Force,  $V_3 = -2.6378276E-013$   
Axial Force,  $F = -7502.094$   
Longitudinal Reinforcement Area Distribution (in 2 divisions)  
-Tension:  $As_t = 0.00$   
-Compression:  $As_c = 2676.637$   
Longitudinal Reinforcement Area Distribution (in 3 divisions)  
-Tension:  $As_{ten} = 1137.257$   
-Compression:  $As_{com} = 1137.257$   
-Middle:  $As_{mid} = 402.1239$   
Longitudinal External Reinforcement Area Distribution (in 3 divisions)  
-Tension:  $As_{ten,jacket} = 829.3805$   
-Compression:  $As_{com,jacket} = 829.3805$   
-Middle:  $As_{mid,jacket} = 402.1239$   
Longitudinal Internal Reinforcement Area Distribution (in 3 divisions)  
-Tension:  $As_{ten,core} = 307.8761$   
-Compression:  $As_{com,core} = 307.8761$   
-Middle:  $As_{mid,core} = 0.00$   
Mean Diameter of Tension Reinforcement,  $Db_L = 16.80$

Existing component: From table 7-7, ASCE 41\_17: Final chord rotation Capacity  $u_{R} = u = 0.03337626$   
 $u = y + p = 0.03926619$

- Calculation of  $y$  -

$y = (M_y * L_s / 3) / E_{eff} = 0.00065005$  ((4.29), Biskinis Phd))  
 $M_y = 1.7613E+008$   
 $L_s = M/V$  (with  $L_s > 0.1 * L$  and  $L_s < 2 * L$ ) = 300.00  
From table 10.5, ASCE 41\_17:  $E_{eff} = factor * E_c * I_g = 2.7095E+013$   
factor = 0.30  
 $A_g = 202500.00$   
Mean concrete strength:  $f'_c = (f'_{c,jacket} * Area_{jacket} + f'_{c,core} * Area_{core}) / Area_{section} = 28.98765$   
 $N = 7502.094$   
 $E_c * I_g = E_{c,jacket} * I_{g,jacket} + E_{c,core} * I_{g,core} = 9.0315E+013$

Calculation of Yielding Moment  $M_y$

Calculation of  $y$  and  $M_y$  according to Annex 7 -

$y = \text{Min}(y_{ten}, y_{com})$   
 $y_{ten} = 6.1806717E-006$   
with ((10.1), ASCE 41-17)  $f_y = \text{Min}(f_y, 1.25 * f_y * ((l_b / d)^{2/3})) = 374.3546$   
 $d = 407.00$   
 $y = 0.25591399$   
 $A = 0.01472387$   
 $B = 0.00818866$   
with  $pt = 0.00430549$   
 $pc = 0.00620943$

$p_v = 0.0021956$   
 $N = 7502.094$   
 $b = 450.00$   
 $\rho = 0.10565111$   
 $y_{comp} = 2.2127287E-005$   
 with  $f_c^*$  (12.3, (ACI 440)) = 34.40847  
 $f_c = 33.00$   
 $f_l = 0.82797802$   
 $b = 450.00$   
 $h = 450.00$   
 $A_g = 202500.00$   
 From (12.9), ACI 440:  $k_a = 0.54261599$   
 $g = p_t + p_c + p_v = 0.01461445$   
 $r_c = 40.00$   
 $A_e/A_c = 0.54261599$   
 Effective FRP thickness,  $t_f = N L^* t \cos(b_1) = 1.016$   
 effective strain from (12.5) and (12.12),  $\epsilon_{fe} = 0.004$   
 $f_u = 0.01$   
 $E_f = 64828.00$   
 $E_c = 26999.444$   
 $y = 0.25471852$   
 $A = 0.01452517$   
 $B = 0.00807924$   
 with  $E_s = 200000.00$

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

Lap Length:  $l_d/l_{d,min} = 0.42476573$

$l_b = 300.00$

$l_d = 706.2717$

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

$= 1$

$d_b = 16.66667$

Mean strength value of all re-bars:  $f_y = 524.4464$

Mean concrete strength:  $f_c' = (f_c'_{jacket} \cdot Area_{jacket} + f_c'_{core} \cdot Area_{core}) / Area_{section} = 28.98765$ , but  $f_c'^{0.5} \leq 8.3$  MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 2.86234$

$A_{tr} = \min(A_{tr_x}, A_{tr_y}) = 257.6106$

where  $A_{tr_x}$ ,  $A_{tr_y}$  are the sum of the area of all stirrup legs along X and Y local axis

$s = \max(s_{external}, s_{internal}) = 300.00$

$n = 12.00$

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 - Calculation of  $\rho_p$  -  
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From table 10-8:  $\rho_p = 0.03861614$

with:

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

shear control ratio  $V_y E / V_{col} O E = 0.26068017$

$d = d_{external} = 407.00$

$s = s_{external} = 0.00$

$t = s_1 + s_2 + 2 \cdot t_f / b_w \cdot (f_{fe} / f_s) = 0.00430549$

jacket:  $s_1 = A_{v1} \cdot h_1 / (s_1 \cdot A_g) = 0.00116355$

$A_{v1} = 157.0796$ , is the total area of all stirrups parallel to loading (shear) direction

$h_1 = 450.00$

$s_1 = 300.00$

core:  $s_2 = A_{v2} \cdot h_2 / (s_2 \cdot A_g) = 0.00103427$

$A_{v2} = 100.531$ , is the total area of all stirrups parallel to loading (shear) direction

$h_2 = 250.00$

$s_2 = 120.00$

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.

$$N_{UD} = 7502.094$$

$$A_g = 202500.00$$

$$f_{cE} = (f_{c\_jacket} \cdot Area\_jacket + f_{c\_core} \cdot Area\_core) / section\_area = 28.98765$$

$$f_{yIE} = (f_{y\_ext\_Long\_Reinf} \cdot Area\_ext\_Long\_Reinf + f_{y\_int\_Long\_Reinf} \cdot Area\_int\_Long\_Reinf) / Area\_Tot\_Long\_Rein = 529.9972$$

$$f_{yIE} = (f_{y\_ext\_Trans\_Reinf} \cdot s_1 + f_{y\_int\_Trans\_Reinf} \cdot s_2) / (s_1 + s_2) = 503.2682$$

$$p_l = Area\_Tot\_Long\_Rein / (b \cdot d) = 0.01461445$$

$$b = 450.00$$

$$d = 407.00$$

$$f_{cE} = 28.98765$$

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End Of Calculation of Chord Rotation Capacity for element: column JC1 of floor 1

At local axis: 3

Integration Section: (b)

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