

Detailed Member Calculations

Units: N&mm

Regulation: ASCE 41-17

Calculation No. 1

column C1, Floor 1

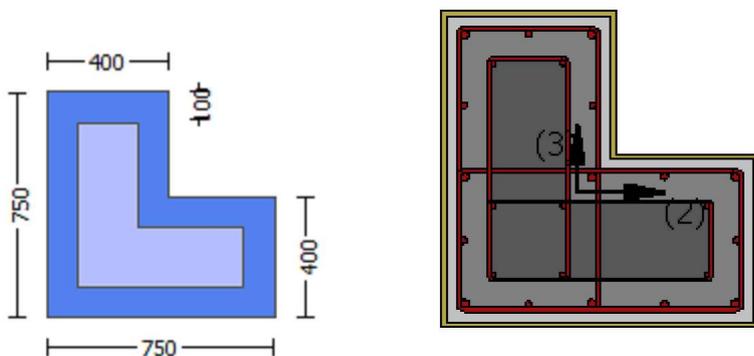
Limit State: Operational Level (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Shear capacity V_{Rd}

Edge: Start

Local Axis: (2)



Start Of Calculation of Shear Capacity for element: column JLC1 of floor 1

At local axis: 2

Integration Section: (a)

Section Type: rcjlc

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 Secondary Member: Concrete Strength, $f_c = f_{c_lower_bound} = 25.00$

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

Concrete Elasticity, $E_c = 26999.444$
 Steel Elasticity, $E_s = 200000.00$
 Existing Column
 Existing material of Secondary Member: Concrete Strength, $f_c = f_{c_lower_bound} = 16.00$
 Existing material of Secondary Member: Steel Strength, $f_s = f_{s_lower_bound} = 400.00$
 Concrete Elasticity, $E_c = 21019.039$
 Steel Elasticity, $E_s = 200000.00$
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 Note: Especially for the calculation of γ for displacement ductility demand,
 the expected (mean value) strengths are used (7.5.1.3, ASCE 41-17) because bending is considered as
 Deformation-Controlled Action (Table C7-1, ASCE 41-17).
 Jacket
 New material: Concrete Strength, $f_c = f_{cm} = 33.00$
 New material: Steel Strength, $f_s = f_{sm} = 555.5556$
 Existing Column
 Existing material: Concrete Strength, $f_c = f_{cm} = 20.00$
 Existing material: Steel Strength, $f_s = f_{sm} = 444.4444$
 #####
 Max Height, $H_{max} = 750.00$
 Min Height, $H_{min} = 400.00$
 Max Width, $W_{max} = 750.00$
 Min Width, $W_{min} = 400.00$
 Jacket Thickness, $t_j = 100.00$
 Cover Thickness, $c = 25.00$
 Element Length, $L = 3000.00$
 Secondary Member
 Ribbed Bars
 Ductile Steel
 Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
 Longitudinal Bars With Ends Lapped Starting at the End Sections
 Lap Length $l_o = l_b = 300.00$
 FRP Wrapping Data
 Type: Carbon
 Cured laminate properties (design values)
 Thickness, $t = 1.016$
 Tensile Strength, $f_{fu} = 1055.00$
 Tensile Modulus, $E_f = 64828.00$
 Elongation, $e_{fu} = 0.01$
 Number of directions, $NoDir = 1$
 Fiber orientations, $bi: 0.00^\circ$
 Number of layers, $NL = 1$
 Radius of rounding corners, $R = 40.00$

 Stepwise Properties

EDGE -A-
 Bending Moment, $M_a = -2.3777E+007$
 Shear Force, $V_a = -7895.087$
 EDGE -B-
 Bending Moment, $M_b = 86052.274$
 Shear Force, $V_b = 7895.087$
 BOTH EDGES
 Axial Force, $F = -17072.715$
 Longitudinal Reinforcement Area Distribution (in 2 divisions)
 -Tension: $As_t = 0.00$
 -Compression: $As_c = 5353.274$
 Longitudinal Reinforcement Area Distribution (in 3 divisions)
 -Tension: $As_{l,ten} = 1137.257$
 -Compression: $As_{l,com} = 2208.54$
 -Middle: $As_{l,mid} = 2007.478$
 Mean Diameter of Tension Reinforcement, $Db_{L,ten} = 16.80$

Existing component: From table 7-7, ASCE 41_17: Final Shear Capacity $VR = *V_n = 744888.396$

$$V_n \text{ ((10.3), ASCE 41-17)} = k_n \cdot V_{CoI} = 876339.289$$

$$V_{CoI} = 876339.289$$

$$k_n = 1.00$$

$$\text{displacement_ductility_demand} = 0.03309229$$

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

= 1 (normal-weight concrete)

Mean concrete strength: $f'_c = (f'_{c_jacket} \cdot \text{Area}_{jacket} + f'_{c_core} \cdot \text{Area}_{core}) / \text{Area}_{section} = 21.31818$, but $f'_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$$M/Vd = 4.00$$

$$\mu_u = 2.3777E+007$$

$$V_u = 7895.087$$

$$d = 0.8 \cdot h = 600.00$$

$$N_u = 17072.715$$

$$A_g = 300000.00$$

$$\text{From (11.5.4.8), ACI 318-14: } V_s = V_{s,jacket} + V_{s,core} = 793340.11$$

where:

$$V_{s,jacket} = V_{s,j1} + V_{s,j2} = 722566.31$$

$V_{s,j1} = 251327.412$ is calculated for section web jacket, with:

$$d = 320.00$$

$$A_v = 157079.633$$

$$f_y = 500.00$$

$$s = 100.00$$

$V_{s,j1}$ is multiplied by $Col,j1 = 1.00$

$$s/d = 0.3125$$

$V_{s,j2} = 471238.898$ is calculated for section flange jacket, with:

$$d = 600.00$$

$$A_v = 157079.633$$

$$f_y = 500.00$$

$$s = 100.00$$

$V_{s,j2}$ is multiplied by $Col,j2 = 1.00$

$$s/d = 0.16666667$$

$$V_{s,core} = V_{s,c1} + V_{s,c2} = 70773.799$$

$V_{s,c1} = 0.00$ is calculated for section web core, with:

$$d = 160.00$$

$$A_v = 100530.965$$

$$f_y = 400.00$$

$$s = 250.00$$

$V_{s,c1}$ is multiplied by $Col,c1 = 0.00$

$$s/d = 1.5625$$

$V_{s,c2} = 70773.799$ is calculated for section flange core, with:

$$d = 440.00$$

$$A_v = 100530.965$$

$$f_y = 400.00$$

$$s = 250.00$$

$V_{s,c2}$ is multiplied by $Col,c2 = 1.00$

$$s/d = 0.56818182$$

$$V_f \text{ ((11-3)-(11.4), ACI 440)} = 372533.843$$

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

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

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

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

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

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

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

$$d_{fv} = d \text{ (figure 11.2, ACI 440)} = 707.00$$

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

$$E_f = 64828.00$$

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

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

$$\text{From (11-11), ACI 440: } V_s + V_f \leq 736127.561$$

$$b_w = 400.00$$

displacement_ductility_demand is calculated as δ / y

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

From analysis, chord rotation = $9.6518539E-005$
 $y = (M_y * L_s / 3) / E_{eff} = 0.00291665$ ((4.29), Biskinis Phd))
 $M_y = 4.2101E+008$
 $L_s = M/V$ (with $L_s > 0.1 * L$ and $L_s < 2 * L$) = 3011.649
From table 10.5, ASCE 41_17: $E_{eff} = factor * E_c * I_g = 1.4491E+014$
 $factor = 0.30$
 $A_g = 440000.00$
Mean concrete strength: $f_c' = (f_c'_{jacket} * Area_{jacket} + f_c'_{core} * Area_{core}) / Area_{section} = 27.68182$
 $N = 17072.715$
 $E_c * I_g = E_{c,jacket} * I_{g,jacket} + E_{c,core} * I_{g,core} = 4.8303E+014$

Calculation of Yielding Moment M_y

Calculation of δ / y and M_y according to Annex 7 -

Assuming neutral axis within flange ($y < t/d$, compression zone rectangular) with:
flange width, $b = 750.00$
web width, $b_w = 400.00$
flange thickness, $t = 400.00$

$y = \text{Min}(y_{ten}, y_{com})$
 $y_{ten} = 3.1432128E-006$
with ((10.1), ASCE 41-17) $f_y = \text{Min}(f_y, 1.25 * f_y * (I_b / I_d)^{2/3}) = 358.4764$
 $d = 707.00$
 $y = 0.19343861$
 $A = 0.01018557$
 $B = 0.00449598$
with $p_t = 0.00214476$
 $p_c = 0.00416509$
 $p_v = 0.00378591$
 $N = 17072.715$
 $b = 750.00$
 $\lambda = 0.06082037$
 $y_{comp} = 1.6462519E-005$
with $f_c' (12.3, (ACI 440)) = 33.48734$
 $f_c = 33.00$
 $f_l = 0.49678681$
 $b = b_{max} = 750.00$
 $h = h_{max} = 750.00$
 $A_g = 0.44$
 $g = p_t + p_c + p_v = 0.01009575$
 $rc = 40.00$
 $A_e / A_c = 0.31291181$
Effective FRP thickness, $t_f = N L * t * \text{Cos}(b_1) = 1.016$
effective strain from (12.5) and (12.12), $\epsilon_{fe} = 0.004$
 $f_u = 0.01$
 $E_f = 64828.00$
 $E_c = 26999.444$
 $y = 0.19181501$
 $A = 0.01002364$
 $B = 0.00440616$
with $E_s = 200000.00$
CONFIRMATION: $y = 0.19279145 < t/d$

Calculation of ratio I_b / I_d

Lap Length: $l_d/l_{d,min} = 0.39803249$

$l_b = 300.00$

$l_d = 753.7073$

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: $f_y = 524.4444$

Mean concrete strength: $f_c' = (f_c'_{jacket} \cdot Area_{jacket} + f_c'_{core} \cdot Area_{core}) / Area_{section} = 27.68182$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 1.7174$

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

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

$s = \text{Max}(s_{external}, s_{internal}) = 250.00$

$n = 24.00$

End Of Calculation of Shear Capacity for element: column JLC1 of floor 1

At local axis: 2

Integration Section: (a)

Calculation No. 2

column C1, Floor 1

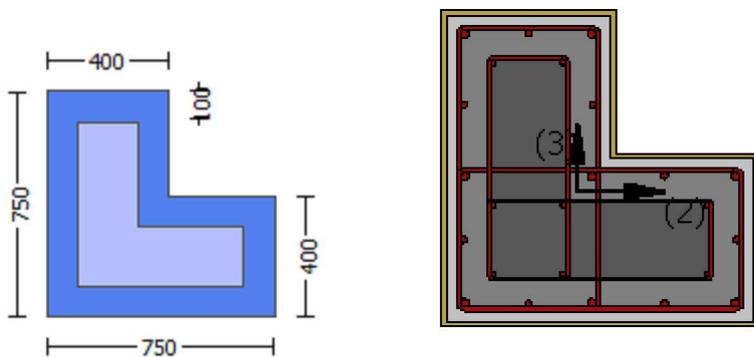
Limit State: Operational Level (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity (θ_r)

Edge: Start

Local Axis: (2)



Start Of Calculation of Shear Capacity ratio for element: column JLC1 of floor 1

At Shear local axis: 3

(Bending local axis: 2)

Section Type: rcjlcs

Constant Properties

Knowledge Factor, $\gamma = 0.85$

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

Consequently:

Jacket

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

New material of Secondary Member: Steel Strength, $f_s = f_{sm} = 555.5556$

Concrete Elasticity, $E_c = 26999.444$

Steel Elasticity, $E_s = 200000.00$

Existing Column

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

Existing material of Secondary Member: Steel Strength, $f_s = f_{sm} = 444.4444$

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, $f_s = 1.25 \cdot f_{sm} = 694.4444$

Existing Column

Existing material: Steel Strength, $f_s = 1.25 \cdot f_{sm} = 555.5556$

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Max Height, $H_{max} = 750.00$

Min Height, $H_{min} = 400.00$

Max Width, $W_{max} = 750.00$

Min Width, $W_{min} = 400.00$

Jacket Thickness, $t_j = 100.00$

Cover Thickness, $c = 25.00$

Mean Confinement Factor overall section = 1.03889

Element Length, $L = 3000.00$

Secondary Member

Ribbed Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

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, $V_a = -0.00051441$

EDGE -B-

Shear Force, $V_b = 0.00051441$

BOTH EDGES

Axial Force, $F = -16273.616$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

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

-Compression: $A_{sl,c} = 5353.274$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

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

-Compression: $A_{sl,com} = 2208.54$

-Middle: $A_{sl,mid} = 2007.478$

Calculation of Shear Capacity ratio , $V_e/V_r = 0.55377356$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 552827.824$

with

$M_{pr1} = \text{Max}(M_{u1+} , M_{u1-}) = 8.2924E+008$

$M_{u1+} = 5.1260E+008$, 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

$M_{u1-} = 8.2924E+008$, 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

$M_{pr2} = \text{Max}(M_{u2+} , M_{u2-}) = 8.2924E+008$

$M_{u2+} = 5.1260E+008$, 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

$M_{u2-} = 8.2924E+008$, 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 ϕ_u according to 4.1, Biskinis/Fardis 2013:

$\phi_u = 9.5578758E-006$

$M_u = 5.1260E+008$

with full section properties:

$b = 750.00$

$d = 707.00$

$d' = 43.00$

$v = 0.00093001$

$N = 16273.616$

$f_c = 33.00$

ω (5A.5, TBDY) = 0.002

Final value of ϕ_u : $\phi_u^* = \text{shear_factor} * \text{Max}(\phi_u, \phi_c) = 0.01288354$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $\phi_u = 0.01288354$

ω_e ((5.4c), TBDY) = $\omega_{se} * \text{sh}_{, \text{min}} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.05503171$

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

$f_x = 0.04286225$

Expression ((15B.6), TBDY) is modified as $\omega_{se} = 1 - (\text{Unconfined area}) / (\text{total area})$

$\omega_{se} = 0.31984848$

with Unconfined area = $((b_{\text{max}} - 2R)^2 + (h_{\text{max}} - 2R)^2) / 3 = 140733.333$

$b_{\text{max}} = 750.00$

$h_{\text{max}} = 750.00$

From EC8 A.4.4.3(6), $\omega_{se} = 2t_f / b_w = 0.00508$

$b_w = 400.00$

effective stress from (A.35), $f_{fe} = 870.5244$

$f_y = 0.04286225$

Expression ((15B.6), TBDY) is modified as $\omega_{se} = 1 - (\text{Unconfined area}) / (\text{total area})$

$\omega_{se} = 0.31984848$

with Unconfined area = $((b_{\text{max}} - 2R)^2 + (h_{\text{max}} - 2R)^2) / 3 = 140733.333$

$b_{\text{max}} = 750.00$

$h_{\text{max}} = 750.00$

From EC8 A.4.4.3(6), $\omega_{se} = 2t_f / b_w = 0.00508$

$b_w = 400.00$

effective stress from (A.35), $f_{fe} = 870.5244$

$R = 40.00$

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

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{,f} = 0.015$

ω_{se} ((5.4d), TBDY) = $(\omega_{se1} * A_{\text{ext}} + \omega_{se2} * A_{\text{int}}) / A_{\text{sec}} = 0.45746528$

$$ase1 = \text{Max}(((A_{conf,max1} - A_{noConf1}) / A_{conf,max1}) * (A_{conf,min1} / A_{conf,max1}), 0) = 0.45746528$$

The definitions of A_{noConf} , $A_{conf,min}$ and $A_{conf,max}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988) "Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max1} = 353600.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{conf,min1} = 293525.00$ is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area $A_{conf,max1}$ by a length equal to half the clear spacing between external hoops.

$A_{noConf1} = 158733.333$ is the unconfined external core area which is equal to $b_i^2/6$ as defined at (A.2).

$$ase2 (>= ase1) = \text{Max}(((A_{conf,max2} - A_{noConf2}) / A_{conf,max2}) * (A_{conf,min2} / A_{conf,max2}), 0) = 0.45746528$$

The definitions of A_{noConf} , $A_{conf,min}$ and $A_{conf,max}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988) "Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max2} = 171264.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

$A_{conf,min2} = 54741.00$ is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area $A_{conf,max2}$ by a length equal to half the clear spacing between internal hoops.

$A_{noConf2} = 106242.667$ is the unconfined internal core area which is equal to $b_i^2/6$ as defined at (A.2).

$$psh_{min} * F_{ywe} = \text{Min}(psh_x * F_{ywe}, psh_y * F_{ywe}) = 2.92621$$

Expression (5.4d) 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)

$$psh_x * F_{ywe} = psh1 * F_{ywe1} + ps2 * F_{ywe2} = 2.92621$$

$$psh1 \text{ ((5.4d), TBDY)} = L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00367709$$

$$L_{stir1} \text{ (Length of stirrups along Y)} = 2060.00$$

$$A_{stir1} \text{ (stirrups area)} = 78.53982$$

$$psh2 \text{ (5.4d)} = L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00067082$$

$$L_{stir2} \text{ (Length of stirrups along Y)} = 1468.00$$

$$A_{stir2} \text{ (stirrups area)} = 50.26548$$

$$psh_y * F_{ywe} = psh1 * F_{ywe1} + ps2 * F_{ywe2} = 2.92621$$

$$psh1 \text{ ((5.4d), TBDY)} = L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00367709$$

$$L_{stir1} \text{ (Length of stirrups along X)} = 2060.00$$

$$A_{stir1} \text{ (stirrups area)} = 78.53982$$

$$psh2 \text{ ((5.4d), TBDY)} = L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00067082$$

$$L_{stir2} \text{ (Length of stirrups along X)} = 1468.00$$

$$A_{stir2} \text{ (stirrups area)} = 50.26548$$

$$A_{sec} = 440000.00$$

$$s1 = 100.00$$

$$s2 = 250.00$$

$$fywe1 = 694.4444$$

$$fywe2 = 555.5556$$

$$f_{ce} = 33.00$$

$$\text{From ((5.A5), TBDY), TBDY: } cc = 0.00238888$$

$$c = \text{confinement factor} = 1.03889$$

$$y1 = 0.00145721$$

$$sh1 = 0.00466307$$

$$ft1 = 459.4373$$

$$fy1 = 382.8645$$

$$su1 = 0.00582756$$

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

$$l_o / l_{ou,min} = l_b / l_d = 0.318426$$

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

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 $\text{Min}(1, 1.25 * (l_b / l_d)^{2/3})$, from 10.3.5, ASCE 41-17.

$$\text{with } fs1 = (fs_{jacket} * A_{sl,ten,jacket} + fs_{core} * A_{sl,ten,core}) / A_{sl,ten} = 382.8645$$

with $E_{s1} = (E_{s,jacket} \cdot A_{s,ten,jacket} + E_{s,core} \cdot A_{s,ten,core}) / A_{s,ten} = 200000.00$
 $y_2 = 0.00145721$
 $sh_2 = 0.00466307$
 $ft_2 = 465.423$
 $fy_2 = 387.8525$
 $su_2 = 0.00582756$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 $Shear_factor = 1.00$
 $l_0/l_{ou,min} = l_b/l_{b,min} = 0.318426$
 $su_2 = 0.4 \cdot esu_{2,nominal} ((5.5), TBDY) = 0.032$
 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 $fs_2 = fs_2/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $Min(1, 1.25 \cdot (l_b/l_d)^{2/3})$, from 10.3.5, ASCE 41-17.
 with $fs_2 = (fs_{jacket} \cdot A_{s,com,jacket} + fs_{core} \cdot A_{s,com,core}) / A_{s,com} = 387.8525$
 with $E_{s2} = (E_{s,jacket} \cdot A_{s,com,jacket} + E_{s,core} \cdot A_{s,com,core}) / A_{s,com} = 200000.00$
 $y_v = 0.00145721$
 $sh_v = 0.00466307$
 $ft_v = 463.3885$
 $fy_v = 386.157$
 $suv = 0.00582756$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 $Shear_factor = 1.00$
 $l_0/l_{ou,min} = l_b/l_d = 0.318426$
 $suv = 0.4 \cdot esuv_{nominal} ((5.5), TBDY) = 0.032$
 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 $Min(1, 1.25 \cdot (l_b/l_d)^{2/3})$, from 10.3.5, ASCE 41-17.
 with $fs_v = (fs_{jacket} \cdot A_{s,mid,jacket} + fs_{mid} \cdot A_{s,mid,core}) / A_{s,mid} = 386.157$
 with $E_{sv} = (E_{s,jacket} \cdot A_{s,mid,jacket} + E_{s,mid} \cdot A_{s,mid,core}) / A_{s,mid} = 200000.00$
 $1 = A_{s,ten} / (b \cdot d) \cdot (fs_1 / fc) = 0.02488335$
 $2 = A_{s,com} / (b \cdot d) \cdot (fs_2 / fc) = 0.04895276$
 $v = A_{s,mid} / (b \cdot d) \cdot (fs_v / fc) = 0.04430167$

and confined core properties:

$b = 690.00$
 $d = 677.00$
 $d' = 13.00$
 $f_{cc} (5A.2, TBDY) = 34.2833$
 $cc (5A.5, TBDY) = 0.00238888$
 $c = \text{confinement factor} = 1.03889$
 $1 = A_{s,ten} / (b \cdot d) \cdot (fs_1 / fc) = 0.02824566$
 $2 = A_{s,com} / (b \cdot d) \cdot (fs_2 / fc) = 0.05556741$
 $v = A_{s,mid} / (b \cdot d) \cdot (fs_v / fc) = 0.05028784$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

---->

$v < v_s, y_2$ - LHS eq.(4.5) is satisfied

---->

$su (4.9) = 0.13760581$
 $M_u = MR_c (4.14) = 5.1260E+008$
 $u = su (4.1) = 9.5578758E-006$

 Calculation of ratio l_b/l_d

 Lap Length: $l_b/l_d = 0.318426$

$l_b = 300.00$

$l_d = 942.1341$

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: $fy = 655.5556$

Mean concrete strength: $fc' = (fc'_{jacket} \cdot Area_{jacket} + fc'_{core} \cdot Area_{core}) / Area_{section} = 27.68182$, but $fc'^{0.5} < =$

8.3 MPa (22.5.3.1, ACI 318-14)

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$cb = 25.00$$

$$K_{tr} = 1.7174$$

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

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

$$s = \text{Max}(s_{\text{external}}, s_{\text{internal}}) = 250.00$$

$$n = 24.00$$

Calculation of μ_1 -

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

$$\mu = 1.0408734E-005$$

$$\mu = 8.2924E+008$$

with full section properties:

$$b = 400.00$$

$$d = 707.00$$

$$d' = 43.00$$

$$v = 0.00174378$$

$$N = 16273.616$$

$$f_c = 33.00$$

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

$$\text{Final value of } \mu: \mu^* = \text{shear_factor} * \text{Max}(\mu, \alpha) = 0.01288354$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \mu = 0.01288354$$

$$\text{where } \mu = \alpha * \text{sh}_{\text{min}} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.05503171$$

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

$$f_x = 0.04286225$$

Expression ((15B.6), TBDY) is modified as $\alpha_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$\alpha_f = 0.31984848$$

$$\text{with Unconfined area} = ((b_{\text{max}} - 2R)^2 + (h_{\text{max}} - 2R)^2) / 3 = 140733.333$$

$$b_{\text{max}} = 750.00$$

$$h_{\text{max}} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } \rho_f = 2t_f / b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{fe} = 870.5244$$

$$f_y = 0.04286225$$

Expression ((15B.6), TBDY) is modified as $\alpha_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$\alpha_f = 0.31984848$$

$$\text{with Unconfined area} = ((b_{\text{max}} - 2R)^2 + (h_{\text{max}} - 2R)^2) / 3 = 140733.333$$

$$b_{\text{max}} = 750.00$$

$$h_{\text{max}} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } \rho_f = 2t_f / b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{fe} = 870.5244$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L * t * \text{Cos}(\beta_1) = 1.016$$

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

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$\text{ase ((5.4d), TBDY) = } (\text{ase}_1 * A_{\text{ext}} + \text{ase}_2 * A_{\text{int}}) / A_{\text{sec}} = 0.45746528$$

$$\text{ase}_1 = \text{Max}(((A_{\text{conf,max1}} - A_{\text{noConf1}}) / A_{\text{conf,max1}}) * (A_{\text{conf,min1}} / A_{\text{conf,max1}}), 0) = 0.45746528$$

The definitions of A_{noConf} , $A_{\text{conf,min}}$ and $A_{\text{conf,max}}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

Aconf,max1 = 353600.00 is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

Aconf,min1 = 293525.00 is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area Aconf,max1 by a length equal to half the clear spacing between external hoops.

AnoConf1 = 158733.333 is the unconfined external core area which is equal to $b_i^2/6$ as defined at (A.2).
ase2 (>=ase1) = $\text{Max}(((Aconf,max2 - AnoConf2)/Aconf,max2) * (Aconf,min2/Aconf,max2), 0) = 0.45746528$

The definitions of AnoConf, Aconf,min and Aconf,max are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

Aconf,max2 = 171264.00 is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

Aconf,min2 = 54741.00 is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area Aconf,max2 by a length equal to half the clear spacing between internal hoops.

AnoConf2 = 106242.667 is the unconfined internal core area which is equal to $b_i^2/6$ as defined at (A.2).

psh,min*Fywe = $\text{Min}(psh,x*Fywe, psh,y*Fywe) = 2.92621$

Expression (5.4d) 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 = 2.92621

psh1 ((5.4d), TBDY) = $Lstir1 * Astir1 / (Asec * s1) = 0.00367709$

Lstir1 (Length of stirrups along Y) = 2060.00

Astir1 (stirrups area) = 78.53982

psh2 (5.4d) = $Lstir2 * Astir2 / (Asec * s2) = 0.00067082$

Lstir2 (Length of stirrups along Y) = 1468.00

Astir2 (stirrups area) = 50.26548

psh_y*Fywe = psh1*Fywe1 + ps2*Fywe2 = 2.92621

psh1 ((5.4d), TBDY) = $Lstir1 * Astir1 / (Asec * s1) = 0.00367709$

Lstir1 (Length of stirrups along X) = 2060.00

Astir1 (stirrups area) = 78.53982

psh2 ((5.4d), TBDY) = $Lstir2 * Astir2 / (Asec * s2) = 0.00067082$

Lstir2 (Length of stirrups along X) = 1468.00

Astir2 (stirrups area) = 50.26548

Asec = 440000.00

s1 = 100.00

s2 = 250.00

fywe1 = 694.4444

fywe2 = 555.5556

fce = 33.00

From ((5.A5), TBDY), TBDY: cc = 0.00238888

c = confinement factor = 1.03889

y1 = 0.00145721

sh1 = 0.00466307

ft1 = 465.423

fy1 = 387.8525

su1 = 0.00582756

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 = 0.318426

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 = $(fs_jacket * Asl_ten_jacket + fs_core * Asl_ten_core) / Asl_ten = 387.8525$

with Es1 = $(Es_jacket * Asl_ten_jacket + Es_core * Asl_ten_core) / Asl_ten = 200000.00$

y2 = 0.00145721

sh2 = 0.00466307

ft2 = 459.4373

fy2 = 382.8645

su2 = 0.00582756

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 = 0.318426

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 = 382.8645

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

yv = 0.00145721

shv = 0.00466307

ftv = 463.3885

fyv = 386.157

suv = 0.00582756

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 = 0.318426

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 = 386.157

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

1 = Asl,ten/(b*d)*(fs1/fc) = 0.09178643

2 = Asl,com/(b*d)*(fs2/fc) = 0.04665628

v = Asl,mid/(b*d)*(fsv/fc) = 0.08306563

and confined core properties:

b = 340.00

d = 677.00

d' = 13.00

fcc (5A.2, TBDY) = 34.2833

cc (5A.5, TBDY) = 0.00238888

c = confinement factor = 1.03889

1 = Asl,ten/(b*d)*(fs1/fc) = 0.11276915

2 = Asl,com/(b*d)*(fs2/fc) = 0.05732208

v = Asl,mid/(b*d)*(fsv/fc) = 0.10205474

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

v < vs,y2 - LHS eq.(4.5) is satisfied

--->

su (4.9) = 0.20810191

Mu = MRc (4.14) = 8.2924E+008

u = su (4.1) = 1.0408734E-005

Calculation of ratio lb/ld

Lap Length: lb/ld = 0.318426

lb = 300.00

ld = 942.1341

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 = 655.5556

Mean concrete strength: fc' = (fc'_jacket*Area_jacket + fc'_core*Area_core)/Area_section = 27.68182, but $fc'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

t = 1.00

s = 0.80

e = 1.00

cb = 25.00

Ktr = 1.7174

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

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

$$s = \text{Max}(s_{\text{external}}, s_{\text{internal}}) = 250.00$$

$$n = 24.00$$

Calculation of μ_{2+}

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

$$\mu = 9.5578758E-006$$

$$\mu_{2+} = 5.1260E+008$$

with full section properties:

$$b = 750.00$$

$$d = 707.00$$

$$d' = 43.00$$

$$v = 0.00093001$$

$$N = 16273.616$$

$$f_c = 33.00$$

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

$$\text{Final value of } c_{\text{cu}}: c_{\text{cu}}^* = \text{shear_factor} * \text{Max}(c_{\text{cu}}, c_{\text{cc}}) = 0.01288354$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } c_{\text{cu}} = 0.01288354$$

$$w_e \text{ ((5.4c), TBDY) } = a_{\text{se}} * s_{h,\text{min}} * f_{y,w_e} / f_{c,e} + \text{Min}(f_x, f_y) = 0.05503171$$

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

$$f_x = 0.04286225$$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.31984848$$

$$\text{with Unconfined area} = ((b_{\text{max}} - 2R)^2 + (h_{\text{max}} - 2R)^2) / 3 = 140733.333$$

$$b_{\text{max}} = 750.00$$

$$h_{\text{max}} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 870.5244$$

$$f_y = 0.04286225$$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.31984848$$

$$\text{with Unconfined area} = ((b_{\text{max}} - 2R)^2 + (h_{\text{max}} - 2R)^2) / 3 = 140733.333$$

$$b_{\text{max}} = 750.00$$

$$h_{\text{max}} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 870.5244$$

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$a_{\text{se}} \text{ ((5.4d), TBDY) } = (a_{\text{se1}} * A_{\text{ext}} + a_{\text{se2}} * A_{\text{int}}) / A_{\text{sec}} = 0.45746528$$

$$a_{\text{se1}} = \text{Max}(((A_{\text{conf,max1}} - A_{\text{noConf1}}) / A_{\text{conf,max1}}) * (A_{\text{conf,min1}} / A_{\text{conf,max1}}), 0) = 0.45746528$$

The definitions of A_{noConf} , $A_{\text{conf,min}}$ and $A_{\text{conf,max}}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{\text{conf,max1}} = 353600.00$ is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{\text{conf,min1}} = 293525.00$ is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area $A_{\text{conf,max1}}$ by a length

equal to half the clear spacing between external hoops.

$A_{\text{noConf1}} = 158733.333$ is the unconfined external core area which is equal to $b_i^2/6$ as defined at (A.2).

$$ase2 (>= ase1) = \text{Max}(((Aconf,max2 - AnoConf2)/Aconf,max2) * (Aconf,min2/Aconf,max2), 0) = 0.45746528$$

The definitions of AnoConf, Aconf,min and Aconf,max are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988) "Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

Aconf,max2 = 171264.00 is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

Aconf,min2 = 54741.00 is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area Aconf,max2 by a length equal to half the clear spacing between internal hoops.

AnoConf2 = 106242.667 is the unconfined internal core area which is equal to $b_i^2/6$ as defined at (A.2).

$$psh,min * Fywe = \text{Min}(psh,x * Fywe, psh,y * Fywe) = 2.92621$$

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

$$psh,x * Fywe = psh1 * Fywe1 + ps2 * Fywe2 = 2.92621$$

$$psh1 \text{ ((5.4d), TBDY)} = Lstir1 * Astir1 / (Asec * s1) = 0.00367709$$

$$Lstir1 \text{ (Length of stirrups along Y)} = 2060.00$$

$$Astir1 \text{ (stirrups area)} = 78.53982$$

$$psh2 \text{ (5.4d)} = Lstir2 * Astir2 / (Asec * s2) = 0.00067082$$

$$Lstir2 \text{ (Length of stirrups along Y)} = 1468.00$$

$$Astir2 \text{ (stirrups area)} = 50.26548$$

$$psh,y * Fywe = psh1 * Fywe1 + ps2 * Fywe2 = 2.92621$$

$$psh1 \text{ ((5.4d), TBDY)} = Lstir1 * Astir1 / (Asec * s1) = 0.00367709$$

$$Lstir1 \text{ (Length of stirrups along X)} = 2060.00$$

$$Astir1 \text{ (stirrups area)} = 78.53982$$

$$psh2 \text{ ((5.4d), TBDY)} = Lstir2 * Astir2 / (Asec * s2) = 0.00067082$$

$$Lstir2 \text{ (Length of stirrups along X)} = 1468.00$$

$$Astir2 \text{ (stirrups area)} = 50.26548$$

$$Asec = 440000.00$$

$$s1 = 100.00$$

$$s2 = 250.00$$

$$fywe1 = 694.4444$$

$$fywe2 = 555.5556$$

$$fce = 33.00$$

$$\text{From ((5.A5), TBDY), TBDY: } cc = 0.00238888$$

$$c = \text{confinement factor} = 1.03889$$

$$y1 = 0.00145721$$

$$sh1 = 0.00466307$$

$$ft1 = 459.4373$$

$$fy1 = 382.8645$$

$$su1 = 0.00582756$$

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

$$lo/lou,min = lb/l_d = 0.318426$$

$$su1 = 0.4 * esu1_nominal \text{ ((5.5), TBDY)} = 0.032$$

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 $\text{Min}(1, 1.25 * (lb/l_d)^{2/3})$, from 10.3.5, ASCE 41-17.

$$\text{with } fs1 = (fs_jacket * Asl,ten,jacket + fs_core * Asl,ten,core) / Asl,ten = 382.8645$$

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

$$y2 = 0.00145721$$

$$sh2 = 0.00466307$$

$$ft2 = 465.423$$

$$fy2 = 387.8525$$

$$su2 = 0.00582756$$

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

$$lo/lou,min = lb/l_b,min = 0.318426$$

$$su2 = 0.4 * esu2_nominal \text{ ((5.5), TBDY)} = 0.032$$

From table 5A.1, TBDY: esu2_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_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 $fs_2 = (fs_{jacket} \cdot Asl_{com,jacket} + fs_{core} \cdot Asl_{com,core}) / Asl_{com} = 387.8525$

with $Es_2 = (Es_{jacket} \cdot Asl_{com,jacket} + Es_{core} \cdot Asl_{com,core}) / Asl_{com} = 200000.00$

$y_v = 0.00145721$

$sh_v = 0.00466307$

$ft_v = 463.3885$

$fy_v = 386.157$

$s_{uv} = 0.00582756$

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

$lo/lo_{u,min} = lb/ld = 0.318426$

$s_{uv} = 0.4 \cdot es_{uv_nominal} ((5,5), TBDY) = 0.032$

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 $f_{sv} = (f_{s,jacket} \cdot Asl_{mid,jacket} + f_{s,mid} \cdot Asl_{mid,core}) / Asl_{mid} = 386.157$

with $Es_v = (Es_{jacket} \cdot Asl_{mid,jacket} + Es_{mid} \cdot Asl_{mid,core}) / Asl_{mid} = 200000.00$

$1 = Asl_{ten} / (b \cdot d) \cdot (f_{s1} / f_c) = 0.02488335$

$2 = Asl_{com} / (b \cdot d) \cdot (f_{s2} / f_c) = 0.04895276$

$v = Asl_{mid} / (b \cdot d) \cdot (f_{sv} / f_c) = 0.04430167$

and confined core properties:

$b = 690.00$

$d = 677.00$

$d' = 13.00$

$f_{cc} (5A.2, TBDY) = 34.2833$

$cc (5A.5, TBDY) = 0.00238888$

$c = \text{confinement factor} = 1.03889$

$1 = Asl_{ten} / (b \cdot d) \cdot (f_{s1} / f_c) = 0.02824566$

$2 = Asl_{com} / (b \cdot d) \cdot (f_{s2} / f_c) = 0.05556741$

$v = Asl_{mid} / (b \cdot d) \cdot (f_{sv} / f_c) = 0.05028784$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

$su (4.9) = 0.13760581$

$Mu = MRc (4.14) = 5.1260E+008$

$u = su (4.1) = 9.5578758E-006$

Calculation of ratio lb/ld

Lap Length: $lb/ld = 0.318426$

$lb = 300.00$

$ld = 942.1341$

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: $fy = 655.5556$

Mean concrete strength: $f_c' = (f_c'_{jacket} \cdot Area_{jacket} + f_c'_{core} \cdot Area_{core}) / Area_{section} = 27.68182$, but $f_c'^{0.5} < = 8.3$ MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 1.7174$

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

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

$s = \text{Max}(s_{external}, s_{internal}) = 250.00$

$n = 24.00$

Calculation of Mu2-

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

$$\mu = 1.0408734E-005$$

$$Mu = 8.2924E+008$$

with full section properties:

$$b = 400.00$$

$$d = 707.00$$

$$d' = 43.00$$

$$v = 0.00174378$$

$$N = 16273.616$$

$$f_c = 33.00$$

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

$$\text{Final value of } \mu: \mu = \text{shear_factor} * \text{Max}(\mu_c, \mu_c) = 0.01288354$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \mu = 0.01288354$$

$$\mu_c \text{ ((5.4c), TBDY) } = a_{se} * \text{sh}_{, \min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.05503171$$

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

$$f_x = 0.04286225$$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.31984848$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 140733.333$$

$$b_{\max} = 750.00$$

$$h_{\max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 870.5244$$

$$f_y = 0.04286225$$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.31984848$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 140733.333$$

$$b_{\max} = 750.00$$

$$h_{\max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 870.5244$$

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$a_{se} \text{ ((5.4d), TBDY) } = (a_{se1} * A_{ext} + a_{se2} * A_{int}) / A_{sec} = 0.45746528$$

$$a_{se1} = \text{Max}(((A_{\text{conf,max1}} - A_{\text{noConf1}}) / A_{\text{conf,max1}}) * (A_{\text{conf,min1}} / A_{\text{conf,max1}}), 0) = 0.45746528$$

The definitions of A_{noConf} , $A_{\text{conf,min}}$ and $A_{\text{conf,max}}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{\text{conf,max1}} = 353600.00$ is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{\text{conf,min1}} = 293525.00$ is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area $A_{\text{conf,max1}}$ by a length

equal to half the clear spacing between external hoops.

$A_{\text{noConf1}} = 158733.333$ is the unconfined external core area which is equal to $b_i^2/6$ as defined at (A.2).

$$a_{se2} (>= a_{se1}) = \text{Max}(((A_{\text{conf,max2}} - A_{\text{noConf2}}) / A_{\text{conf,max2}}) * (A_{\text{conf,min2}} / A_{\text{conf,max2}}), 0) = 0.45746528$$

The definitions of A_{noConf} , $A_{\text{conf,min}}$ and $A_{\text{conf,max}}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

Aconf,max2 = 171264.00 is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

Aconf,min2 = 54741.00 is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area Aconf,max2 by a length equal to half the clear spacing between internal hoops.

AnoConf2 = 106242.667 is the unconfined internal core area which is equal to $b_i^2/6$ as defined at (A.2).

$$psh_{min} \cdot F_{ywe} = \text{Min}(psh_x \cdot F_{ywe}, psh_y \cdot F_{ywe}) = 2.92621$$

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

$$psh_x \cdot F_{ywe} = psh1 \cdot F_{ywe1} + ps2 \cdot F_{ywe2} = 2.92621$$
$$psh1 \text{ ((5.4d), TBDY)} = L_{stir1} \cdot A_{stir1} / (A_{sec} \cdot s1) = 0.00367709$$

Lstir1 (Length of stirrups along Y) = 2060.00
Astir1 (stirrups area) = 78.53982

$$psh2 \text{ (5.4d)} = L_{stir2} \cdot A_{stir2} / (A_{sec} \cdot s2) = 0.00067082$$

Lstir2 (Length of stirrups along Y) = 1468.00
Astir2 (stirrups area) = 50.26548

$$psh_y \cdot F_{ywe} = psh1 \cdot F_{ywe1} + ps2 \cdot F_{ywe2} = 2.92621$$
$$psh1 \text{ ((5.4d), TBDY)} = L_{stir1} \cdot A_{stir1} / (A_{sec} \cdot s1) = 0.00367709$$

Lstir1 (Length of stirrups along X) = 2060.00
Astir1 (stirrups area) = 78.53982

$$psh2 \text{ ((5.4d), TBDY)} = L_{stir2} \cdot A_{stir2} / (A_{sec} \cdot s2) = 0.00067082$$

Lstir2 (Length of stirrups along X) = 1468.00
Astir2 (stirrups area) = 50.26548

$$A_{sec} = 440000.00$$

$$s1 = 100.00$$

$$s2 = 250.00$$

$$fy_{we1} = 694.4444$$

$$fy_{we2} = 555.5556$$

$$f_{ce} = 33.00$$

$$\text{From ((5.A5), TBDY), TBDY: } cc = 0.00238888$$

$$c = \text{confinement factor} = 1.03889$$

$$y1 = 0.00145721$$

$$sh1 = 0.00466307$$

$$ft1 = 465.423$$

$$fy1 = 387.8525$$

$$su1 = 0.00582756$$

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

$$l_o/l_{ou,min} = l_b/l_d = 0.318426$$

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

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

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

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

$$\text{with } fs1 = (f_{s,jacket} \cdot A_{sl,ten,jacket} + f_{s,core} \cdot A_{sl,ten,core}) / A_{sl,ten} = 387.8525$$

$$\text{with } Es1 = (E_{s,jacket} \cdot A_{sl,ten,jacket} + E_{s,core} \cdot A_{sl,ten,core}) / A_{sl,ten} = 200000.00$$

$$y2 = 0.00145721$$

$$sh2 = 0.00466307$$

$$ft2 = 459.4373$$

$$fy2 = 382.8645$$

$$su2 = 0.00582756$$

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

$$l_o/l_{ou,min} = l_b/l_{b,min} = 0.318426$$

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

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

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

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

$$\text{with } fs2 = (f_{s,jacket} \cdot A_{sl,com,jacket} + f_{s,core} \cdot A_{sl,com,core}) / A_{sl,com} = 382.8645$$

$$\text{with } Es2 = (E_{s,jacket} \cdot A_{sl,com,jacket} + E_{s,core} \cdot A_{sl,com,core}) / A_{sl,com} = 200000.00$$

$$y_v = 0.00145721$$

$shv = 0.00466307$
 $ftv = 463.3885$
 $fyv = 386.157$
 $suv = 0.00582756$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 $Shear_factor = 1.00$
 $lo/lou,min = lb/ld = 0.318426$
 $suv = 0.4 * esuv_nominal ((5.5), TBDY) = 0.032$
 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 $Min(1,1.25*(lb/ld)^{2/3})$, from 10.3.5, ASCE 41-17.
 with $fsv = (fs,jacket*Asl,mid,jacket + fs,mid*Asl,mid,core)/Asl,mid = 386.157$
 with $Esv = (Es,jacket*Asl,mid,jacket + Es,mid*Asl,mid,core)/Asl,mid = 200000.00$
 $1 = Asl,ten/(b*d)*(fs1/fc) = 0.09178643$
 $2 = Asl,com/(b*d)*(fs2/fc) = 0.04665628$
 $v = Asl,mid/(b*d)*(fsv/fc) = 0.08306563$
 and confined core properties:
 $b = 340.00$
 $d = 677.00$
 $d' = 13.00$
 $fcc (5A.2, TBDY) = 34.2833$
 $cc (5A.5, TBDY) = 0.00238888$
 $c = confinement\ factor = 1.03889$
 $1 = Asl,ten/(b*d)*(fs1/fc) = 0.11276915$
 $2 = Asl,com/(b*d)*(fs2/fc) = 0.05732208$
 $v = Asl,mid/(b*d)*(fsv/fc) = 0.10205474$
 Case/Assumption: Unconfined full section - Steel rupture
 ' satisfies Eq. (4.3)
 --->
 $v < vs,y2$ - LHS eq.(4.5) is satisfied
 --->
 $su (4.9) = 0.20810191$
 $Mu = MRc (4.14) = 8.2924E+008$
 $u = su (4.1) = 1.0408734E-005$

 Calculation of ratio lb/ld

Lap Length: $lb/ld = 0.318426$
 $lb = 300.00$
 $ld = 942.1341$
 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: $fy = 655.5556$
 Mean concrete strength: $fc' = (fc'_jacket*Area_jacket + fc'_core*Area_core)/Area_section = 27.68182$, but $fc'^{0.5} <=$
 $8.3\ MPa$ (22.5.3.1, ACI 318-14)
 $t = 1.00$
 $s = 0.80$
 $e = 1.00$
 $cb = 25.00$
 $Ktr = 1.7174$
 $Atr = Min(Atr_x,Atr_y) = 257.6106$
 where Atr_x, Atr_y are the sum of the area of all stirrup legs along X and Y loxal axis
 $s = Max(s_external,s_internal) = 250.00$
 $n = 24.00$

 Calculation of Shear Strength $Vr = Min(Vr1,Vr2) = 998292.205$

Calculation of Shear Strength at edge 1, $Vr1 = 998292.205$
 $Vr1 = VCol ((10.3), ASCE 41-17) = knl*VCol0$

VCoI0 = 998292.205

knl = 1 (zero step-static loading)

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

= 1 (normal-weight concrete)

Mean concrete strength: $f_c' = (f_c'_{\text{jacket}} \cdot \text{Area}_{\text{jacket}} + f_c'_{\text{core}} \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 27.68182$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 4.00$

$\mu_u = 11.77537$

$V_u = 0.00051441$

$d = 0.8 \cdot h = 600.00$

$N_u = 16273.616$

$A_g = 300000.00$

From (11.5.4.8), ACI 318-14: $V_s = V_{s,\text{jacket}} + V_{s,\text{core}} = 881489.011$

where:

$V_{s,\text{jacket}} = V_{s,j1} + V_{s,j2} = 802851.456$

$V_{s,j1} = 523598.776$ is calculated for section web jacket, with:

$d = 600.00$

$A_v = 157079.633$

$f_y = 555.5556$

$s = 100.00$

$V_{s,j1}$ is multiplied by $\text{Col},j1 = 1.00$

$s/d = 0.16666667$

$V_{s,j2} = 279252.68$ is calculated for section flange jacket, with:

$d = 320.00$

$A_v = 157079.633$

$f_y = 555.5556$

$s = 100.00$

$V_{s,j2}$ is multiplied by $\text{Col},j2 = 1.00$

$s/d = 0.3125$

$V_{s,\text{core}} = V_{s,c1} + V_{s,c2} = 78637.555$

$V_{s,c1} = 78637.555$ is calculated for section web core, with:

$d = 440.00$

$A_v = 100530.965$

$f_y = 444.4444$

$s = 250.00$

$V_{s,c1}$ is multiplied by $\text{Col},c1 = 1.00$

$s/d = 0.56818182$

$V_{s,c2} = 0.00$ is calculated for section flange core, with:

$d = 160.00$

$A_v = 100530.965$

$f_y = 444.4444$

$s = 250.00$

$V_{s,c2}$ is multiplied by $\text{Col},c2 = 0.00$

$s/d = 1.5625$

V_f ((11-3)-(11.4), ACI 440) = 372533.843

$f = 0.95$, for fully-wrapped sections

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

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

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

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

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

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

$d_{fv} = d$ (figure 11.2, ACI 440) = 707.00

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: $V_s + V_f \leq 838832.606$

$b_w = 400.00$

Calculation of Shear Strength at edge 2, $V_{r2} = 998292.205$

$Vr2 = VCol \text{ ((10.3), ASCE 41-17)} = knl * VCol0$

$VCol0 = 998292.205$

$kn1 = 1$ (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: $fc' = (fc'_{jacket} * Area_{jacket} + fc'_{core} * Area_{core}) / Area_{section} = 27.68182$, but $fc'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M / Vd = 4.00$

$Mu = 11.77482$

$Vu = 0.00051441$

$d = 0.8 * h = 600.00$

$Nu = 16273.616$

$Ag = 300000.00$

From (11.5.4.8), ACI 318-14: $Vs = Vs_{jacket} + Vs_{core} = 881489.011$

where:

$Vs_{jacket} = Vs_{j1} + Vs_{j2} = 802851.456$

$Vs_{j1} = 523598.776$ is calculated for section web jacket, with:

$d = 600.00$

$Av = 157079.633$

$fy = 555.5556$

$s = 100.00$

Vs_{j1} is multiplied by $Col_{j1} = 1.00$

$s/d = 0.16666667$

$Vs_{j2} = 279252.68$ is calculated for section flange jacket, with:

$d = 320.00$

$Av = 157079.633$

$fy = 555.5556$

$s = 100.00$

Vs_{j2} is multiplied by $Col_{j2} = 1.00$

$s/d = 0.3125$

$Vs_{core} = Vs_{c1} + Vs_{c2} = 78637.555$

$Vs_{c1} = 78637.555$ is calculated for section web core, with:

$d = 440.00$

$Av = 100530.965$

$fy = 444.4444$

$s = 250.00$

Vs_{c1} is multiplied by $Col_{c1} = 1.00$

$s/d = 0.56818182$

$Vs_{c2} = 0.00$ is calculated for section flange core, with:

$d = 160.00$

$Av = 100530.965$

$fy = 444.4444$

$s = 250.00$

Vs_{c2} is multiplied by $Col_{c2} = 0.00$

$s/d = 1.5625$

$Vf \text{ ((11-3)-(11.4), ACI 440)} = 372533.843$

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

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

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

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

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

$dfv = d$ (figure 11.2, ACI 440) = 707.00

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

$Ef = 64828.00$

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

with $fu = 0.01$

From (11-11), ACI 440: $Vs + Vf \leq 838832.606$

$bw = 400.00$

End Of Calculation of Shear Capacity ratio for element: column JLC1 of floor 1
At local axis: 3

Start Of Calculation of Shear Capacity ratio for element: column JLC1 of floor 1
At Shear local axis: 2
(Bending local axis: 3)
Section Type: rcjlc3

Constant Properties

Knowledge Factor, $\gamma = 0.85$
Mean strength values are used for both shear and moment calculations.
Consequently:
Jacket
New material of Secondary Member: Concrete Strength, $f_c = f_{cm} = 33.00$
New material of Secondary Member: Steel Strength, $f_s = f_{sm} = 555.5556$
Concrete Elasticity, $E_c = 26999.444$
Steel Elasticity, $E_s = 200000.00$

Existing Column
Existing material of Secondary Member: Concrete Strength, $f_c = f_{cm} = 20.00$
Existing material of Secondary Member: Steel Strength, $f_s = f_{sm} = 444.4444$
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, $f_s = 1.25 \cdot f_{sm} = 694.4444$
Existing Column
Existing material: Steel Strength, $f_s = 1.25 \cdot f_{sm} = 555.5556$

Max Height, $H_{max} = 750.00$
Min Height, $H_{min} = 400.00$
Max Width, $W_{max} = 750.00$
Min Width, $W_{min} = 400.00$
Jacket Thickness, $t_j = 100.00$
Cover Thickness, $c = 25.00$
Mean Confinement Factor overall section = 1.03889

Element Length, $L = 3000.00$
Secondary Member
Ribbed Bars
Ductile Steel
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
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, $V_a = -0.00051441$
EDGE -B-

Shear Force, $V_b = 0.00051441$

BOTH EDGES

Axial Force, $F = -16273.616$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: $A_{st} = 0.00$

-Compression: $A_{sc} = 5353.274$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

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

-Compression: $A_{sc,com} = 2208.54$

-Middle: $A_{sc,mid} = 2007.478$

Calculation of Shear Capacity ratio, $V_e/V_r = 0.55377356$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 552827.824$

with

$M_{pr1} = \text{Max}(M_{u1+}, M_{u1-}) = 8.2924E+008$

$M_{u1+} = 5.1260E+008$, 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

$M_{u1-} = 8.2924E+008$, 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

$M_{pr2} = \text{Max}(M_{u2+}, M_{u2-}) = 8.2924E+008$

$M_{u2+} = 5.1260E+008$, 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

$M_{u2-} = 8.2924E+008$, 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 ϕ_u according to 4.1, Biskinis/Fardis 2013:

$\phi_u = 9.5578758E-006$

$M_u = 5.1260E+008$

with full section properties:

$b = 750.00$

$d = 707.00$

$d' = 43.00$

$v = 0.00093001$

$N = 16273.616$

$f_c = 33.00$

α_{co} (5A.5, TBDY) = 0.002

Final value of ϕ_u : $\phi_u^* = \text{shear_factor} * \text{Max}(\phi_u, \phi_c) = 0.01288354$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $\phi_u = 0.01288354$

where ϕ_u ((5.4c), TBDY) = $\alpha_{se} * \text{sh}_{min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.05503171$

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

$f_x = 0.04286225$

Expression ((15B.6), TBDY) is modified as $\alpha_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$\alpha_f = 0.31984848$

with Unconfined area = $((b_{max} - 2R)^2 + (h_{max} - 2R)^2) / 3 = 140733.333$

$b_{max} = 750.00$

$h_{max} = 750.00$

From EC8 A.4.4.3(6), $\rho_f = 2t_f / b_w = 0.00508$

$b_w = 400.00$

effective stress from (A.35), $f_{f,e} = 870.5244$

$f_y = 0.04286225$

Expression ((15B.6), TBDY) is modified as $\alpha_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$\alpha_f = 0.31984848$

with Unconfined area = $((b_{max} - 2R)^2 + (h_{max} - 2R)^2) / 3 = 140733.333$

$b_{max} = 750.00$

hmax = 750.00
From EC8 A.4.4.3(6), $pf = 2tf/bw = 0.00508$
bw = 400.00
effective stress from (A.35), $ff,e = 870.5244$

R = 40.00
Effective FRP thickness, $tf = NL*t*\text{Cos}(b1) = 1.016$
 $f_{u,f} = 1055.00$
 $E_f = 64828.00$
 $u_{,f} = 0.015$

$ase((5.4d), \text{TBDY}) = (ase1*A_{ext} + ase2*A_{int})/A_{sec} = 0.45746528$

$ase1 = \text{Max}(((A_{conf,max1} - A_{noConf1})/A_{conf,max1}) * (A_{conf,min1}/A_{conf,max1}), 0) = 0.45746528$

The definitions of A_{noConf} , $A_{conf,min}$ and $A_{conf,max}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988) "Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max1} = 353600.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{conf,min1} = 293525.00$ is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area $A_{conf,max1}$ by a length equal to half the clear spacing between external hoops.

$A_{noConf1} = 158733.333$ is the unconfined external core area which is equal to $b_i^2/6$ as defined at (A.2).

$ase2 (>= ase1) = \text{Max}(((A_{conf,max2} - A_{noConf2})/A_{conf,max2}) * (A_{conf,min2}/A_{conf,max2}), 0) = 0.45746528$

The definitions of A_{noConf} , $A_{conf,min}$ and $A_{conf,max}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988) "Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max2} = 171264.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

$A_{conf,min2} = 54741.00$ is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area $A_{conf,max2}$ by a length equal to half the clear spacing between internal hoops.

$A_{noConf2} = 106242.667$ is the unconfined internal core area which is equal to $b_i^2/6$ as defined at (A.2).

$p_{sh,min} * F_{ywe} = \text{Min}(p_{sh,x} * F_{ywe}, p_{sh,y} * F_{ywe}) = 2.92621$

Expression (5.4d) 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)

$p_{sh,x} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{sh2} * F_{ywe2} = 2.92621$

$p_{sh1}((5.4d), \text{TBDY}) = L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00367709$

L_{stir1} (Length of stirrups along Y) = 2060.00

A_{stir1} (stirrups area) = 78.53982

$p_{sh2}((5.4d)) = L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00067082$

L_{stir2} (Length of stirrups along Y) = 1468.00

A_{stir2} (stirrups area) = 50.26548

$p_{sh,y} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{sh2} * F_{ywe2} = 2.92621$

$p_{sh1}((5.4d), \text{TBDY}) = L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00367709$

L_{stir1} (Length of stirrups along X) = 2060.00

A_{stir1} (stirrups area) = 78.53982

$p_{sh2}((5.4d), \text{TBDY}) = L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00067082$

L_{stir2} (Length of stirrups along X) = 1468.00

A_{stir2} (stirrups area) = 50.26548

$A_{sec} = 440000.00$

$s1 = 100.00$

$s2 = 250.00$

$f_{ywe1} = 694.4444$

$f_{ywe2} = 555.5556$

$f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY: $cc = 0.00238888$

$c =$ confinement factor = 1.03889

$y1 = 0.00145721$

$sh1 = 0.00466307$

$ft1 = 459.4373$

$fy1 = 382.8645$

$$su1 = 0.00582756$$

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

$$lo/lou,min = lb/ld = 0.318426$$

$$su1 = 0.4*esu1_nominal ((5.5), TBDY) = 0.032$$

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.

$$\text{with } fs1 = (fs,jacket*Asl,ten,jacket + fs,core*Asl,ten,core)/Asl,ten = 382.8645$$

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

$$y2 = 0.00145721$$

$$sh2 = 0.00466307$$

$$ft2 = 465.423$$

$$fy2 = 387.8525$$

$$su2 = 0.00582756$$

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

$$lo/lou,min = lb/lb,min = 0.318426$$

$$su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032$$

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.

$$\text{with } fs2 = (fs,jacket*Asl,com,jacket + fs,core*Asl,com,core)/Asl,com = 387.8525$$

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

$$yv = 0.00145721$$

$$shv = 0.00466307$$

$$ftv = 463.3885$$

$$fyv = 386.157$$

$$suv = 0.00582756$$

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

$$lo/lou,min = lb/ld = 0.318426$$

$$suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032$$

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.

$$\text{with } fsv = (fs,jacket*Asl,mid,jacket + fs,mid*Asl,mid,core)/Asl,mid = 386.157$$

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

$$1 = Asl,ten/(b*d)*(fs1/fc) = 0.02488335$$

$$2 = Asl,com/(b*d)*(fs2/fc) = 0.04895276$$

$$v = Asl,mid/(b*d)*(fsv/fc) = 0.04430167$$

and confined core properties:

$$b = 690.00$$

$$d = 677.00$$

$$d' = 13.00$$

$$fcc (5A.2, TBDY) = 34.2833$$

$$cc (5A.5, TBDY) = 0.00238888$$

$$c = \text{confinement factor} = 1.03889$$

$$1 = Asl,ten/(b*d)*(fs1/fc) = 0.02824566$$

$$2 = Asl,com/(b*d)*(fs2/fc) = 0.05556741$$

$$v = Asl,mid/(b*d)*(fsv/fc) = 0.05028784$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

v < vs,y2 - LHS eq.(4.5) is satisfied

--->

$$su (4.9) = 0.13760581$$

$$\mu_u = MRc (4.14) = 5.1260E+008$$

$$u = su (4.1) = 9.5578758E-006$$

Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.318426$

$l_b = 300.00$

$l_d = 942.1341$

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: $f_y = 655.5556$

Mean concrete strength: $f_c' = (f_c'_{\text{jacket}} \cdot \text{Area}_{\text{jacket}} + f_c'_{\text{core}} \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 27.68182$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$c_b = 25.00$

$K_{tr} = 1.7174$

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

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

$s = \text{Max}(s_{\text{external}}, s_{\text{internal}}) = 250.00$

$n = 24.00$

Calculation of μ_1

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

$\mu = 1.0408734E-005$

$\mu_u = 8.2924E+008$

with full section properties:

$b = 400.00$

$d = 707.00$

$d' = 43.00$

$v = 0.00174378$

$N = 16273.616$

$f_c = 33.00$

c_o (5A.5, TBDY) = 0.002

Final value of c_u : $c_u^* = \text{shear_factor} \cdot \text{Max}(c_u, c_o) = 0.01288354$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $c_u = 0.01288354$

where c_u ((5.4c), TBDY) = $a_{se} \cdot s_{h, \min} \cdot f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.05503171$

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)

$f_x = 0.04286225$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$a_f = 0.31984848$

with Unconfined area = $((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 140733.333$

$b_{\max} = 750.00$

$h_{\max} = 750.00$

From EC8 A.4.4.3(6), $p_f = 2t_f / b_w = 0.00508$

$b_w = 400.00$

effective stress from (A.35), $f_{fe} = 870.5244$

$f_y = 0.04286225$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$a_f = 0.31984848$

with Unconfined area = $((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 140733.333$

$b_{\max} = 750.00$

$h_{\max} = 750.00$

From EC8 A.4.4.3(6), $p_f = 2t_f / b_w = 0.00508$

$b_w = 400.00$

effective stress from (A.35), $f_{fe} = 870.5244$

$R = 40.00$

Effective FRP thickness, $t_f = NL \cdot t \cdot \cos(b_1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{,f} = 0.015$

$ase((5.4d), TBDY) = (ase_1 \cdot A_{ext} + ase_2 \cdot A_{int}) / A_{sec} = 0.45746528$

$ase_1 = \text{Max}(((A_{conf,max1} - A_{noConf1}) / A_{conf,max1}) \cdot (A_{conf,min1} / A_{conf,max1}), 0) = 0.45746528$

The definitions of A_{noConf} , $A_{conf,min}$ and $A_{conf,max}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max1} = 353600.00$ is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{conf,min1} = 293525.00$ is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area $A_{conf,max1}$ by a length equal to half the clear spacing between external hoops.

$A_{noConf1} = 158733.333$ is the unconfined external core area which is equal to $b_i^2/6$ as defined at (A.2).

$ase_2 (>= ase_1) = \text{Max}(((A_{conf,max2} - A_{noConf2}) / A_{conf,max2}) \cdot (A_{conf,min2} / A_{conf,max2}), 0) = 0.45746528$

The definitions of A_{noConf} , $A_{conf,min}$ and $A_{conf,max}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max2} = 171264.00$ is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

$A_{conf,min2} = 54741.00$ is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area $A_{conf,max2}$ by a length equal to half the clear spacing between internal hoops.

$A_{noConf2} = 106242.667$ is the unconfined internal core area which is equal to $b_i^2/6$ as defined at (A.2).

$p_{sh,min} \cdot F_{ywe} = \text{Min}(p_{sh,x} \cdot F_{ywe}, p_{sh,y} \cdot F_{ywe}) = 2.92621$

Expression (5.4d) 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)

 $p_{sh,x} \cdot F_{ywe} = p_{sh1} \cdot F_{ywe1} + p_{sh2} \cdot F_{ywe2} = 2.92621$

$p_{sh1}((5.4d), TBDY) = L_{stir1} \cdot A_{stir1} / (A_{sec} \cdot s_1) = 0.00367709$

L_{stir1} (Length of stirrups along Y) = 2060.00

A_{stir1} (stirrups area) = 78.53982

$p_{sh2}((5.4d)) = L_{stir2} \cdot A_{stir2} / (A_{sec} \cdot s_2) = 0.00067082$

L_{stir2} (Length of stirrups along Y) = 1468.00

A_{stir2} (stirrups area) = 50.26548

 $p_{sh,y} \cdot F_{ywe} = p_{sh1} \cdot F_{ywe1} + p_{sh2} \cdot F_{ywe2} = 2.92621$

$p_{sh1}((5.4d), TBDY) = L_{stir1} \cdot A_{stir1} / (A_{sec} \cdot s_1) = 0.00367709$

L_{stir1} (Length of stirrups along X) = 2060.00

A_{stir1} (stirrups area) = 78.53982

$p_{sh2}((5.4d), TBDY) = L_{stir2} \cdot A_{stir2} / (A_{sec} \cdot s_2) = 0.00067082$

L_{stir2} (Length of stirrups along X) = 1468.00

A_{stir2} (stirrups area) = 50.26548

 $A_{sec} = 440000.00$

$s_1 = 100.00$

$s_2 = 250.00$

$f_{ywe1} = 694.4444$

$f_{ywe2} = 555.5556$

$f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY: $cc = 0.00238888$

c = confinement factor = 1.03889

$y_1 = 0.00145721$

$sh_1 = 0.00466307$

$ft_1 = 465.423$

$fy_1 = 387.8525$

$su_1 = 0.00582756$

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

$l_o/l_{ou,min} = l_b/l_d = 0.318426$

$su_1 = 0.4 \cdot e_{su1_nominal}((5.5), TBDY) = 0.032$

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 $fs1 = (fs_jacket \cdot Asl,ten,jacket + fs_core \cdot Asl,ten,core) / Asl,ten = 387.8525$

with $Es1 = (Es_jacket \cdot Asl,ten,jacket + Es_core \cdot Asl,ten,core) / Asl,ten = 200000.00$

$y2 = 0.00145721$

$sh2 = 0.00466307$

$ft2 = 459.4373$

$fy2 = 382.8645$

$su2 = 0.00582756$

using (30) in Biskinis/Fardis (2013) multiplied with $shear_factor$

and also multiplied by the $shear_factor$ according to 15.7.1.4, with

$Shear_factor = 1.00$

$lo/lou,min = lb/lb,min = 0.318426$

$su2 = 0.4 \cdot esu2_nominal ((5.5), TBDY) = 0.032$

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 $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$, from 10.3.5, ASCE 41-17.

with $fs2 = (fs_jacket \cdot Asl,com,jacket + fs_core \cdot Asl,com,core) / Asl,com = 382.8645$

with $Es2 = (Es_jacket \cdot Asl,com,jacket + Es_core \cdot Asl,com,core) / Asl,com = 200000.00$

$yv = 0.00145721$

$shv = 0.00466307$

$ftv = 463.3885$

$fyv = 386.157$

$suv = 0.00582756$

using (30) in Biskinis/Fardis (2013) multiplied with $shear_factor$

and also multiplied by the $shear_factor$ according to 15.7.1.4, with

$Shear_factor = 1.00$

$lo/lou,min = lb/ld = 0.318426$

$suv = 0.4 \cdot esuv_nominal ((5.5), TBDY) = 0.032$

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 $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$, from 10.3.5, ASCE 41-17.

with $fsv = (fs_jacket \cdot Asl,mid,jacket + fs_mid \cdot Asl,mid,core) / Asl,mid = 386.157$

with $Esv = (Es_jacket \cdot Asl,mid,jacket + Es_mid \cdot Asl,mid,core) / Asl,mid = 200000.00$

$1 = Asl,ten / (b \cdot d) \cdot (fs1 / fc) = 0.09178643$

$2 = Asl,com / (b \cdot d) \cdot (fs2 / fc) = 0.04665628$

$v = Asl,mid / (b \cdot d) \cdot (fsv / fc) = 0.08306563$

and confined core properties:

$b = 340.00$

$d = 677.00$

$d' = 13.00$

$fcc (5A.2, TBDY) = 34.2833$

$cc (5A.5, TBDY) = 0.00238888$

$c = \text{confinement factor} = 1.03889$

$1 = Asl,ten / (b \cdot d) \cdot (fs1 / fc) = 0.11276915$

$2 = Asl,com / (b \cdot d) \cdot (fs2 / fc) = 0.05732208$

$v = Asl,mid / (b \cdot d) \cdot (fsv / fc) = 0.10205474$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < vs,y2$ - LHS eq.(4.5) is satisfied

--->

$su (4.9) = 0.20810191$

$Mu = MRc (4.14) = 8.2924E+008$

$u = su (4.1) = 1.0408734E-005$

Calculation of ratio lb/ld

Lap Length: $lb/ld = 0.318426$

$lb = 300.00$

$ld = 942.1341$

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: $f_y = 655.5556$

Mean concrete strength: $f_c' = (f_c'_{jacket} \cdot Area_{jacket} + f_c'_{core} \cdot Area_{core}) / Area_{section} = 27.68182$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 25.00$$

$$K_{tr} = 1.7174$$

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

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

$$s = \text{Max}(s_{external}, s_{internal}) = 250.00$$

$$n = 24.00$$

Calculation of μ_{2+}

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

$$\mu = 9.5578758E-006$$

$$\mu_{2+} = 5.1260E+008$$

with full section properties:

$$b = 750.00$$

$$d = 707.00$$

$$d' = 43.00$$

$$v = 0.00093001$$

$$N = 16273.616$$

$$f_c = 33.00$$

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

Final value of μ_c : $\mu_c^* = \text{shear_factor} \cdot \text{Max}(\mu_c, \mu_{cc}) = 0.01288354$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $\mu_c = 0.01288354$

$$\mu_e \text{ ((5.4c), TBDY)} = a_{se} \cdot \text{sh}_{min} \cdot f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.05503171$$

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)

$$f_x = 0.04286225$$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.31984848$$

with Unconfined area = $((b_{max} - 2R)^2 + (h_{max} - 2R)^2) / 3 = 140733.333$

$$b_{max} = 750.00$$

$$h_{max} = 750.00$$

From EC8 A.4.4.3(6), $p_f = 2t_f / b_w = 0.00508$

$$b_w = 400.00$$

effective stress from (A.35), $f_{f,e} = 870.5244$

$$f_y = 0.04286225$$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.31984848$$

with Unconfined area = $((b_{max} - 2R)^2 + (h_{max} - 2R)^2) / 3 = 140733.333$

$$b_{max} = 750.00$$

$$h_{max} = 750.00$$

From EC8 A.4.4.3(6), $p_f = 2t_f / b_w = 0.00508$

$$b_w = 400.00$$

effective stress from (A.35), $f_{f,e} = 870.5244$

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

a_{se} ((5.4d), TBDY) = $(a_{se1} \cdot A_{ext} + a_{se2} \cdot A_{int}) / A_{sec} = 0.45746528$

$$a_{se1} = \text{Max}(((A_{conf,max1} - A_{noConf1}) / A_{conf,max1}) \cdot (A_{conf,min1} / A_{conf,max1}), 0) = 0.45746528$$

The definitions of A_{noConf} , $A_{conf,min}$ and $A_{conf,max}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max1} = 353600.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{conf,min1} = 293525.00$ is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area $A_{conf,max1}$ by a length equal to half the clear spacing between external hoops.

$A_{noConf1} = 158733.333$ is the unconfined external core area which is equal to $b_i^2/6$ as defined at (A.2).
 $ase2 (>= ase1) = \text{Max}(((A_{conf,max2} - A_{noConf2})/A_{conf,max2}) * (A_{conf,min2}/A_{conf,max2}), 0) = 0.45746528$

The definitions of A_{noConf} , $A_{conf,min}$ and $A_{conf,max}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max2} = 171264.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

$A_{conf,min2} = 54741.00$ is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area $A_{conf,max2}$ by a length equal to half the clear spacing between internal hoops.

$A_{noConf2} = 106242.667$ is the unconfined internal core area which is equal to $b_i^2/6$ as defined at (A.2).

$psh_{min} * F_{ywe} = \text{Min}(psh_x * F_{ywe}, psh_y * F_{ywe}) = 2.92621$

Expression (5.4d) 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)

 $psh_x * F_{ywe} = psh1 * F_{ywe1} + ps2 * F_{ywe2} = 2.92621$

$psh1$ ((5.4d), TBDY) = $L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00367709$

L_{stir1} (Length of stirrups along Y) = 2060.00

A_{stir1} (stirrups area) = 78.53982

$psh2$ (5.4d) = $L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00067082$

L_{stir2} (Length of stirrups along Y) = 1468.00

A_{stir2} (stirrups area) = 50.26548

 $psh_y * F_{ywe} = psh1 * F_{ywe1} + ps2 * F_{ywe2} = 2.92621$

$psh1$ ((5.4d), TBDY) = $L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00367709$

L_{stir1} (Length of stirrups along X) = 2060.00

A_{stir1} (stirrups area) = 78.53982

$psh2$ ((5.4d), TBDY) = $L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00067082$

L_{stir2} (Length of stirrups along X) = 1468.00

A_{stir2} (stirrups area) = 50.26548

 $A_{sec} = 440000.00$

$s1 = 100.00$

$s2 = 250.00$

$f_{ywe1} = 694.4444$

$f_{ywe2} = 555.5556$

$f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY: $cc = 0.00238888$

c = confinement factor = 1.03889

$y1 = 0.00145721$

$sh1 = 0.00466307$

$ft1 = 459.4373$

$fy1 = 382.8645$

$su1 = 0.00582756$

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

$lo/lou_{min} = lb/ld = 0.318426$

$su1 = 0.4 * esu1_{nominal}$ ((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 $fs1 = (fs_{jacket} * A_{sl,ten,jacket} + fs_{core} * A_{sl,ten,core}) / A_{sl,ten} = 382.8645$

with $Es1 = (Es_{jacket} * A_{sl,ten,jacket} + Es_{core} * A_{sl,ten,core}) / A_{sl,ten} = 200000.00$

$y_2 = 0.00145721$
 $sh_2 = 0.00466307$
 $ft_2 = 465.423$
 $fy_2 = 387.8525$
 $su_2 = 0.00582756$
 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
 $lo/lo_{min} = lb/lb_{min} = 0.318426$
 $su_2 = 0.4 * esu_{2,nominal} ((5.5), TBDY) = 0.032$
 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 $fs_2 = (fs_{jacket} * Asl_{com,jacket} + fs_{core} * Asl_{com,core}) / Asl_{com} = 387.8525$
 with $Es_2 = (Es_{jacket} * Asl_{com,jacket} + Es_{core} * Asl_{com,core}) / Asl_{com} = 200000.00$

$y_v = 0.00145721$
 $sh_v = 0.00466307$
 $ft_v = 463.3885$
 $fy_v = 386.157$
 $suv = 0.00582756$
 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
 $lo/lo_{min} = lb/ld = 0.318426$
 $suv = 0.4 * esuv_{nominal} ((5.5), TBDY) = 0.032$
 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 $Min(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE 41-17.
 with $fsv = (fs_{jacket} * Asl_{mid,jacket} + fs_{mid} * Asl_{mid,core}) / Asl_{mid} = 386.157$
 with $Es_v = (Es_{jacket} * Asl_{mid,jacket} + Es_{mid} * Asl_{mid,core}) / Asl_{mid} = 200000.00$
 $1 = Asl_{ten} / (b * d) * (fs_1 / fc) = 0.02488335$
 $2 = Asl_{com} / (b * d) * (fs_2 / fc) = 0.04895276$
 $v = Asl_{mid} / (b * d) * (fsv / fc) = 0.04430167$

and confined core properties:

$b = 690.00$
 $d = 677.00$
 $d' = 13.00$
 $fcc (5A.2, TBDY) = 34.2833$
 $cc (5A.5, TBDY) = 0.00238888$
 $c = \text{confinement factor} = 1.03889$
 $1 = Asl_{ten} / (b * d) * (fs_1 / fc) = 0.02824566$
 $2 = Asl_{com} / (b * d) * (fs_2 / fc) = 0.05556741$
 $v = Asl_{mid} / (b * d) * (fsv / fc) = 0.05028784$

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

--->
 $v < v_s, y_2$ - LHS eq.(4.5) is satisfied
 --->
 $su (4.9) = 0.13760581$
 $Mu = MRc (4.14) = 5.1260E+008$
 $u = su (4.1) = 9.5578758E-006$

Calculation of ratio lb/ld

Lap Length: $lb/ld = 0.318426$
 $lb = 300.00$
 $ld = 942.1341$

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: $fy = 655.5556$
 Mean concrete strength: $fc' = (fc'_{jacket} * Area_{jacket} + fc'_{core} * Area_{core}) / Area_{section} = 27.68182$, but $fc'^{0.5} <= 8.3$ MPa (22.5.3.1, ACI 318-14)

$t = 1.00$
 $s = 0.80$
 $e = 1.00$
 $cb = 25.00$
 $K_{tr} = 1.7174$
 $A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 257.6106$
 where A_{tr_x} , A_{tr_y} are the sum of the area of all stirrup legs along X and Y local axis
 $s = \text{Max}(s_{\text{external}}, s_{\text{internal}}) = 250.00$
 $n = 24.00$

 Calculation of μ_2 -

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

$\mu = 1.0408734E-005$
 $M_u = 8.2924E+008$

 with full section properties:

$b = 400.00$
 $d = 707.00$
 $d' = 43.00$
 $v = 0.00174378$
 $N = 16273.616$
 $f_c = 33.00$
 $\alpha_1(5A.5, \text{TBDY}) = 0.002$
 Final value of μ_c : $\mu_c^* = \text{shear_factor} * \text{Max}(\mu_c, \mu_{cc}) = 0.01288354$
 The Shear_factor is considered equal to 1 (pure moment strength)
 From (5.4b), TBDY: $\mu_c = 0.01288354$
 μ_{cc} ((5.4c), TBDY) = $\alpha_1 \text{se} * \text{sh}_{\text{min}} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.05503171$
 where $f = \alpha_1 * \rho_f * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

 $f_x = 0.04286225$

Expression ((15B.6), TBDY) is modified as $\alpha_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$\alpha_f = 0.31984848$

with Unconfined area = $((b_{\text{max}} - 2R)^2 + (h_{\text{max}} - 2R)^2) / 3 = 140733.333$

$b_{\text{max}} = 750.00$

$h_{\text{max}} = 750.00$

From EC8 A.4.4.3(6), $\rho_f = 2t_f / b_w = 0.00508$

$b_w = 400.00$

effective stress from (A.35), $f_{fe} = 870.5244$

 $f_y = 0.04286225$

Expression ((15B.6), TBDY) is modified as $\alpha_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$\alpha_f = 0.31984848$

with Unconfined area = $((b_{\text{max}} - 2R)^2 + (h_{\text{max}} - 2R)^2) / 3 = 140733.333$

$b_{\text{max}} = 750.00$

$h_{\text{max}} = 750.00$

From EC8 A.4.4.3(6), $\rho_f = 2t_f / b_w = 0.00508$

$b_w = 400.00$

effective stress from (A.35), $f_{fe} = 870.5244$

 $R = 40.00$

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

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{f} = 0.015$

α_{se} ((5.4d), TBDY) = $(\alpha_{se1} * A_{\text{ext}} + \alpha_{se2} * A_{\text{int}}) / A_{\text{sec}} = 0.45746528$

$\alpha_{se1} = \text{Max}(((A_{\text{conf,max1}} - A_{\text{noConf1}}) / A_{\text{conf,max1}}) * (A_{\text{conf,min1}} / A_{\text{conf,max1}}), 0) = 0.45746528$

The definitions of A_{noConf} , $A_{\text{conf,min}}$ and $A_{\text{conf,max}}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{\text{conf,max1}} = 353600.00$ is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{conf,min1} = 293525.00$ is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area $A_{conf,max1}$ by a length equal to half the clear spacing between external hoops.

$A_{noConf1} = 158733.333$ is the unconfined external core area which is equal to $b_i^2/6$ as defined at (A.2).
 $ase_2 (>= ase_1) = \text{Max}(((A_{conf,max2} - A_{noConf2})/A_{conf,max2}) * (A_{conf,min2}/A_{conf,max2}), 0) = 0.45746528$

The definitions of A_{noConf} , $A_{conf,min}$ and $A_{conf,max}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max2} = 171264.00$ is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

$A_{conf,min2} = 54741.00$ is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area $A_{conf,max2}$ by a length equal to half the clear spacing between internal hoops.

$A_{noConf2} = 106242.667$ is the unconfined internal core area which is equal to $b_i^2/6$ as defined at (A.2).

$p_{sh,min} * F_{ywe} = \text{Min}(p_{sh,x} * F_{ywe}, p_{sh,y} * F_{ywe}) = 2.92621$

Expression (5.4d) 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)

 $p_{sh,x} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{s2} * F_{ywe2} = 2.92621$

$p_{sh1} ((5.4d), \text{TBDY}) = L_{stir1} * A_{stir1} / (A_{sec} * s_1) = 0.00367709$

L_{stir1} (Length of stirrups along Y) = 2060.00

A_{stir1} (stirrups area) = 78.53982

$p_{sh2} (5.4d) = L_{stir2} * A_{stir2} / (A_{sec} * s_2) = 0.00067082$

L_{stir2} (Length of stirrups along Y) = 1468.00

A_{stir2} (stirrups area) = 50.26548

 $p_{sh,y} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{s2} * F_{ywe2} = 2.92621$

$p_{sh1} ((5.4d), \text{TBDY}) = L_{stir1} * A_{stir1} / (A_{sec} * s_1) = 0.00367709$

L_{stir1} (Length of stirrups along X) = 2060.00

A_{stir1} (stirrups area) = 78.53982

$p_{sh2} ((5.4d), \text{TBDY}) = L_{stir2} * A_{stir2} / (A_{sec} * s_2) = 0.00067082$

L_{stir2} (Length of stirrups along X) = 1468.00

A_{stir2} (stirrups area) = 50.26548

 $A_{sec} = 440000.00$

$s_1 = 100.00$

$s_2 = 250.00$

$f_{ywe1} = 694.4444$

$f_{ywe2} = 555.5556$

$f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY: $cc = 0.00238888$

$c = \text{confinement factor} = 1.03889$

$y_1 = 0.00145721$

$sh_1 = 0.00466307$

$ft_1 = 465.423$

$fy_1 = 387.8525$

$su_1 = 0.00582756$

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

$l_0/l_{ou,min} = l_b/l_d = 0.318426$

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

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 $fs_1 = (f_{s,jacket} * A_{sl,ten,jacket} + f_{s,core} * A_{sl,ten,core}) / A_{sl,ten} = 387.8525$

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

$y_2 = 0.00145721$

$sh_2 = 0.00466307$

$ft_2 = 459.4373$

$fy_2 = 382.8645$

$su_2 = 0.00582756$

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 = 0.318426

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 = 382.8645

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

yv = 0.00145721

shv = 0.00466307

ftv = 463.3885

fyv = 386.157

suv = 0.00582756

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 = 0.318426

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 = 386.157

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

1 = Asl,ten/(b*d)*(fs1/fc) = 0.09178643

2 = Asl,com/(b*d)*(fs2/fc) = 0.04665628

v = Asl,mid/(b*d)*(fsv/fc) = 0.08306563

and confined core properties:

b = 340.00

d = 677.00

d' = 13.00

fcc (5A.2, TBDY) = 34.2833

cc (5A.5, TBDY) = 0.00238888

c = confinement factor = 1.03889

1 = Asl,ten/(b*d)*(fs1/fc) = 0.11276915

2 = Asl,com/(b*d)*(fs2/fc) = 0.05732208

v = Asl,mid/(b*d)*(fsv/fc) = 0.10205474

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

v < vs,y2 - LHS eq.(4.5) is satisfied

--->

su (4.9) = 0.20810191

Mu = MRc (4.14) = 8.2924E+008

u = su (4.1) = 1.0408734E-005

Calculation of ratio lb/ld

Lap Length: lb/ld = 0.318426

lb = 300.00

ld = 942.1341

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 = 655.5556

Mean concrete strength: fc' = (fc',jacket*Area_jacket + fc',core*Area_core)/Area_section = 27.68182, but $fc'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

t = 1.00

s = 0.80

e = 1.00

cb = 25.00

Ktr = 1.7174

Atr = Min(Atr_x,Atr_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
 $s = \text{Max}(s_{\text{external}}, s_{\text{internal}}) = 250.00$
 $n = 24.00$

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 998292.205$

Calculation of Shear Strength at edge 1, $V_{r1} = 998292.205$

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

$V_{\text{Col}0} = 998292.205$

$k_{nl} = 1$ (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: $f_c' = (f_c'_{\text{jacket}} * \text{Area}_{\text{jacket}} + f_c'_{\text{core}} * \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 27.68182$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 4.00$

$\mu_u = 11.78089$

$V_u = 0.00051441$

$d = 0.8 * h = 600.00$

$N_u = 16273.616$

$A_g = 300000.00$

From (11.5.4.8), ACI 318-14: $V_s = V_{s,\text{jacket}} + V_{s,\text{core}} = 881489.011$

where:

$V_{s,\text{jacket}} = V_{s,j1} + V_{s,j2} = 802851.456$

$V_{s,j1} = 279252.68$ is calculated for section web jacket, with:

$d = 320.00$

$A_v = 157079.633$

$f_y = 555.5556$

$s = 100.00$

$V_{s,j1}$ is multiplied by $\text{Col},j1 = 1.00$

$s/d = 0.3125$

$V_{s,j2} = 523598.776$ is calculated for section flange jacket, with:

$d = 600.00$

$A_v = 157079.633$

$f_y = 555.5556$

$s = 100.00$

$V_{s,j2}$ is multiplied by $\text{Col},j2 = 1.00$

$s/d = 0.16666667$

$V_{s,\text{core}} = V_{s,c1} + V_{s,c2} = 78637.555$

$V_{s,c1} = 0.00$ is calculated for section web core, with:

$d = 160.00$

$A_v = 100530.965$

$f_y = 444.4444$

$s = 250.00$

$V_{s,c1}$ is multiplied by $\text{Col},c1 = 0.00$

$s/d = 1.5625$

$V_{s,c2} = 78637.555$ is calculated for section flange core, with:

$d = 440.00$

$A_v = 100530.965$

$f_y = 444.4444$

$s = 250.00$

$V_{s,c2}$ is multiplied by $\text{Col},c2 = 1.00$

$s/d = 0.56818182$

$V_f ((11-3)-(11.4), \text{ACI 440}) = 372533.843$

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

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

total thickness per orientation, $t_{f1} = NL \cdot t / \text{NoDir} = 1.016$
 $d_{fv} = d$ (figure 11.2, ACI 440) = 707.00
 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: $V_s + V_f \leq 838832.606$
 $b_w = 400.00$

Calculation of Shear Strength at edge 2, $V_{r2} = 998292.205$
 $V_{r2} = V_{Col}$ ((10.3), ASCE 41-17) = $k_{nl} \cdot V_{Col0}$
 $V_{Col0} = 998292.205$
 $k_{nl} = 1$ (zero step-static loading)

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

= 1 (normal-weight concrete)
Mean concrete strength: $f'_c = (f'_{c,jacket} \cdot \text{Area}_{jacket} + f'_{c,core} \cdot \text{Area}_{core}) / \text{Area}_{section} = 27.68182$, but $f_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 4.00$

$\mu_u = 11.78144$

$\nu_u = 0.00051441$

$d = 0.8 \cdot h = 600.00$

$N_u = 16273.616$

$A_g = 300000.00$

From (11.5.4.8), ACI 318-14: $V_s = V_{s,jacket} + V_{s,core} = 881489.011$

where:

$V_{s,jacket} = V_{sj1} + V_{sj2} = 802851.456$

$V_{sj1} = 279252.68$ is calculated for section web jacket, with:

$d = 320.00$

$A_v = 157079.633$

$f_y = 555.5556$

$s = 100.00$

V_{sj1} is multiplied by $Col_{j1} = 1.00$

$s/d = 0.3125$

$V_{sj2} = 523598.776$ is calculated for section flange jacket, with:

$d = 600.00$

$A_v = 157079.633$

$f_y = 555.5556$

$s = 100.00$

V_{sj2} is multiplied by $Col_{j2} = 1.00$

$s/d = 0.16666667$

$V_{s,core} = V_{sc1} + V_{sc2} = 78637.555$

$V_{sc1} = 0.00$ is calculated for section web core, with:

$d = 160.00$

$A_v = 100530.965$

$f_y = 444.4444$

$s = 250.00$

V_{sc1} is multiplied by $Col_{c1} = 0.00$

$s/d = 1.5625$

$V_{sc2} = 78637.555$ is calculated for section flange core, with:

$d = 440.00$

$A_v = 100530.965$

$f_y = 444.4444$

$s = 250.00$

V_{sc2} is multiplied by $Col_{c2} = 1.00$

$s/d = 0.56818182$

V_f ((11-3)-(11.4), ACI 440) = 372533.843

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

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) = 707.00
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 <= 838832.606
bw = 400.00

End Of Calculation of Shear Capacity ratio for element: column JLC1 of floor 1
At local axis: 2

Start Of Calculation of Chord Rotation Capacity for element: column JLC1 of floor 1
At local axis: 2
Integration Section: (a)
Section Type: rcjcs

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 Secondary Member: Concrete Strength, $f_c = f_{cm} = 33.00$
New material of Secondary Member: Steel Strength, $f_s = f_{sm} = 555.5556$
Concrete Elasticity, $E_c = 26999.444$
Steel Elasticity, $E_s = 200000.00$
Existing Column
Existing material of Secondary Member: Concrete Strength, $f_c = f_{cm} = 20.00$
Existing material of Secondary Member: Steel Strength, $f_s = f_{sm} = 444.4444$
Concrete Elasticity, $E_c = 21019.039$
Steel Elasticity, $E_s = 200000.00$
Max Height, $H_{max} = 750.00$
Min Height, $H_{min} = 400.00$
Max Width, $W_{max} = 750.00$
Min Width, $W_{min} = 400.00$
Jacket Thickness, $t_j = 100.00$
Cover Thickness, $c = 25.00$
Element Length, $L = 3000.00$
Secondary Member
Ribbed Bars
Ductile Steel
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
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 = -303215.389

Shear Force, $V_2 = -7895.087$
 Shear Force, $V_3 = 147.9094$
 Axial Force, $F = -17072.715$
 Longitudinal Reinforcement Area Distribution (in 2 divisions)
 -Tension: $As_t = 0.00$
 -Compression: $As_c = 5353.274$
 Longitudinal Reinforcement Area Distribution (in 3 divisions)
 -Tension: $As_{t,ten} = 1137.257$
 -Compression: $As_{c,com} = 2208.54$
 -Middle: $As_{c,mid} = 2007.478$
 Longitudinal External Reinforcement Area Distribution (in 3 divisions)
 -Tension: $As_{t,ten,jacket} = 829.3805$
 -Compression: $As_{c,com,jacket} = 1746.726$
 -Middle: $As_{c,mid,jacket} = 1545.664$
 Longitudinal Internal Reinforcement Area Distribution (in 3 divisions)
 -Tension: $As_{t,ten,core} = 307.8761$
 -Compression: $As_{c,com,core} = 461.8141$
 -Middle: $As_{c,mid,core} = 461.8141$
 Mean Diameter of Tension Reinforcement, $Db_L = 16.80$

Existing component: From table 7-7, ASCE 41_17: Final chord rotation Capacity $u_{R,y} = u_{R,p} = 0.00168754$
 $u_{R,y} = u_{R,p} = 0.00198534$

- Calculation of y -

$y = (M_y * L_s / 3) / E_{eff} = 0.00198534$ ((4.29), Biskinis Phd)
 $M_y = 4.2101E+008$
 $L_s = M/V$ (with $L_s > 0.1 * L$ and $L_s < 2 * L$) = 2050.007
 From table 10.5, ASCE 41_17: $E_{eff} = factor * E_c * I_g = 1.4491E+014$
 $factor = 0.30$
 $A_g = 440000.00$
 Mean concrete strength: $fc' = (fc'_{jacket} * Area_{jacket} + fc'_{core} * Area_{core}) / Area_{section} = 27.68182$
 $N = 17072.715$
 $E_c * I_g = E_{c,jacket} * I_{g,jacket} + E_{c,core} * I_{g,core} = 4.8303E+014$

Calculation of Yielding Moment M_y

Calculation of y and M_y according to Annex 7 -

Assuming neutral axis within flange ($y < t/d$, compression zone rectangular) with:

flange width, $b = 750.00$
 web width, $b_w = 400.00$
 flange thickness, $t = 400.00$

$y = \text{Min}(y_{ten}, y_{com})$
 $y_{ten} = 3.1432128E-006$
 with ((10.1), ASCE 41-17) $f_y = \text{Min}(f_y, 1.25 * f_y * (I_b / I_d)^{2/3}) = 358.4764$
 $d = 707.00$
 $y = 0.19343861$
 $A = 0.01018557$
 $B = 0.00449598$
 with $pt = 0.00671906$
 $pc = 0.00416509$
 $pv = 0.00378591$
 $N = 17072.715$
 $b = 750.00$
 $\alpha = 0.06082037$
 $y_{comp} = 1.6462519E-005$
 with $fc' (12.3, (ACI 440)) = 33.48734$
 $fc = 33.00$
 $fl = 0.49678681$

$b = b_{max} = 750.00$
 $h = h_{max} = 750.00$
 $Ag = 0.44$
 $g = p_t + p_c + p_v = 0.01009575$
 $rc = 40.00$
 $Ae/Ac = 0.31291181$
 Effective FRP thickness, $t_f = NL \cdot t \cdot \cos(b_1) = 1.016$
 effective strain from (12.5) and (12.12), $\epsilon_{fe} = 0.004$
 $f_u = 0.01$
 $E_f = 64828.00$
 $E_c = 26999.444$
 $y = 0.19181501$
 $A = 0.01002364$
 $B = 0.00440616$
 with $E_s = 200000.00$
 CONFIRMATION: $y = 0.19279145 < t/d$

 Calculation of ratio l_b/l_d

Lap Length: $l_d/l_{d,min} = 0.39803249$

$l_b = 300.00$

$l_d = 753.7073$

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: $f_y = 524.4444$

Mean concrete strength: $f'_c = (f'_{c,jacket} \cdot Area_{jacket} + f'_{c,core} \cdot Area_{core}) / Area_{section} = 27.68182$, but $f_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 1.7174$

$A_{tr} = \min(A_{tr,x}, A_{tr,y}) = 257.6106$

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

$s = \max(s_{external}, s_{internal}) = 250.00$

$n = 24.00$

 - Calculation of ρ -

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 $V_y E / V_{CoI} E = 0.55377356$

$d = d_{external} = 707.00$

$s = s_{external} = 0.00$

- $t = s_1 + s_2 + 2 \cdot t_f / b_w \cdot (f_{fe} / f_s) = 0.00671906$

jacket: $s_1 = A_{v1} \cdot L_{stir1} / (s_1 \cdot A_g) = 0.00367709$

$A_{v1} = 78.53982$, is the area of every stirrup parallel to loading (shear) direction

$L_{stir1} = 2060.00$, is the total Length of all stirrups parallel to loading (shear) direction

$s_1 = 100.00$

core: $s_2 = A_{v2} \cdot L_{stir2} / (s_2 \cdot A_g) = 0.00067082$

$A_{v2} = 50.26548$, is the area of every stirrup parallel to loading (shear) direction

$L_{stir2} = 1468.00$, is the total Length of all stirrups parallel to loading (shear) direction

$s_2 = 250.00$

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

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

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

For the normalisation f_s of jacket is used.

$NUD = 17072.715$

$Ag = 440000.00$

$f_{cE} = (f_{c,jacket} \cdot Area_{jacket} + f_{c,core} \cdot Area_{core}) / section_area = 27.68182$

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

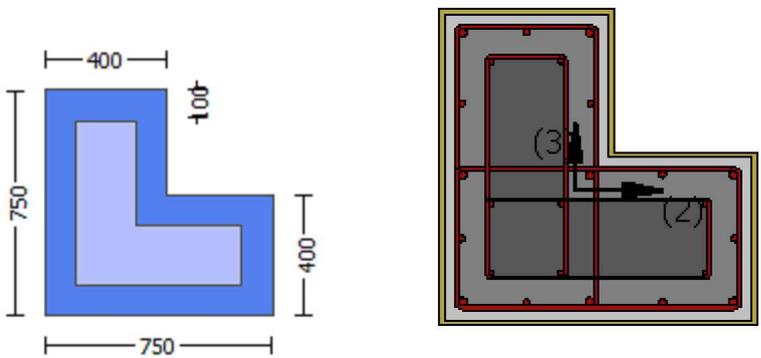
529.9948

$f_{tE} = (f_{y_ext_Trans_Reinf} \cdot s_1 + f_{y_int_Trans_Reinf} \cdot s_2) / (s_1 + s_2) = 538.4128$
 $\rho_l = Area_Tot_Long_Rein / (b \cdot d) = 0.01009575$
 $b = 750.00$
 $d = 707.00$
 $f_{cE} = 27.68182$

 End Of Calculation of Chord Rotation Capacity for element: column JLC1 of floor 1
 At local axis: 2
 Integration Section: (a)

Calculation No. 3

column C1, Floor 1
 Limit State: Operational Level (data interpolation between analysis steps 1 and 2)
 Analysis: Uniform +X
 Check: Shear capacity VRd
 Edge: Start
 Local Axis: (3)



Start Of Calculation of Shear Capacity for element: column JLC1 of floor 1
 At local axis: 3
 Integration Section: (a)
 Section Type: rcjlc

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 Secondary Member: Concrete Strength, $f_c = f_{c_lower_bound} = 25.00$
 New material of Secondary Member: Steel Strength, $f_s = f_{s_lower_bound} = 500.00$
 Concrete Elasticity, $E_c = 26999.444$

Steel Elasticity, $E_s = 200000.00$
Existing Column
Existing material of Secondary Member: Concrete Strength, $f_c = f_{c_lower_bound} = 16.00$
Existing material of Secondary Member: Steel Strength, $f_s = f_{s_lower_bound} = 400.00$
Concrete Elasticity, $E_c = 21019.039$
Steel Elasticity, $E_s = 200000.00$

Note: Especially for the calculation of γ for displacement ductility demand,
the expected (mean value) strengths are used (7.5.1.3, ASCE 41-17) because bending is considered as
Deformation-Controlled Action (Table C7-1, ASCE 41-17).
Jacket
New material: Concrete Strength, $f_c = f_{cm} = 33.00$
New material: Steel Strength, $f_s = f_{sm} = 555.5556$
Existing Column
Existing material: Concrete Strength, $f_c = f_{cm} = 20.00$
Existing material: Steel Strength, $f_s = f_{sm} = 444.4444$

Max Height, $H_{max} = 750.00$
Min Height, $H_{min} = 400.00$
Max Width, $W_{max} = 750.00$
Min Width, $W_{min} = 400.00$
Jacket Thickness, $t_j = 100.00$
Cover Thickness, $c = 25.00$
Element Length, $L = 3000.00$
Secondary Member
Ribbed Bars
Ductile Steel
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
Lap Length $l_o = l_b = 300.00$
FRP Wrapping Data
Type: Carbon
Cured laminate properties (design values)
Thickness, $t = 1.016$
Tensile Strength, $f_{fu} = 1055.00$
Tensile Modulus, $E_f = 64828.00$
Elongation, $e_{fu} = 0.01$
Number of directions, $NoDir = 1$
Fiber orientations, $bi: 0.00^\circ$
Number of layers, $NL = 1$
Radius of rounding corners, $R = 40.00$

Stepwise Properties

EDGE -A-
Bending Moment, $M_a = -303215.389$
Shear Force, $V_a = 147.9094$
EDGE -B-
Bending Moment, $M_b = -138295.135$
Shear Force, $V_b = -147.9094$
BOTH EDGES
Axial Force, $F = -17072.715$
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: $As_t = 0.00$
-Compression: $As_c = 5353.274$
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension: $As_{l,ten} = 1137.257$
-Compression: $As_{l,com} = 2208.54$
-Middle: $As_{l,mid} = 2007.478$
Mean Diameter of Tension Reinforcement, $Db_{L,ten} = 16.80$

Existing component: From table 7-7, ASCE 41_17: Final Shear Capacity $V_R = *V_n = 765235.719$
 $V_n ((10.3), ASCE 41-17) = knl*V_{CoIO} = 900277.316$

$$V_{Col} = 900277.316$$

$$k_{nl} = 1.00$$

$$\text{displacement_ductility_demand} = 0.01904204$$

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

= 1 (normal-weight concrete)

Mean concrete strength: $f_c' = (f_c'_{\text{jacket}} \cdot \text{Area}_{\text{jacket}} + f_c'_{\text{core}} \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 21.31818$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$$M/Vd = 3.41668$$

$$M_u = 303215.389$$

$$V_u = 147.9094$$

$$d = 0.8 \cdot h = 600.00$$

$$N_u = 17072.715$$

$$A_g = 300000.00$$

$$\text{From (11.5.4.8), ACI 318-14: } V_s = V_{s,\text{jacket}} + V_{s,\text{core}} = 793340.11$$

where:

$$V_{s,\text{jacket}} = V_{s,j1} + V_{s,j2} = 722566.31$$

$V_{s,j1} = 471238.898$ is calculated for section web jacket, with:

$$d = 600.00$$

$$A_v = 157079.633$$

$$f_y = 500.00$$

$$s = 100.00$$

$V_{s,j1}$ is multiplied by $Col,j1 = 1.00$

$$s/d = 0.16666667$$

$V_{s,j2} = 251327.412$ is calculated for section flange jacket, with:

$$d = 320.00$$

$$A_v = 157079.633$$

$$f_y = 500.00$$

$$s = 100.00$$

$V_{s,j2}$ is multiplied by $Col,j2 = 1.00$

$$s/d = 0.3125$$

$$V_{s,\text{core}} = V_{s,c1} + V_{s,c2} = 70773.799$$

$V_{s,c1} = 70773.799$ is calculated for section web core, with:

$$d = 440.00$$

$$A_v = 100530.965$$

$$f_y = 400.00$$

$$s = 250.00$$

$V_{s,c1}$ is multiplied by $Col,c1 = 1.00$

$$s/d = 0.56818182$$

$V_{s,c2} = 0.00$ is calculated for section flange core, with:

$$d = 160.00$$

$$A_v = 100530.965$$

$$f_y = 400.00$$

$$s = 250.00$$

$V_{s,c2}$ is multiplied by $Col,c2 = 0.00$

$$s/d = 1.5625$$

$$V_f \text{ ((11-3)-(11.4), ACI 440)} = 372533.843$$

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

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

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

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

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

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

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

$$d_{fv} = d \text{ (figure 11.2, ACI 440)} = 707.00$$

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

$$E_f = 64828.00$$

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

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

$$\text{From (11-11), ACI 440: } V_s + V_f \leq 736127.561$$

$$b_w = 400.00$$

displacement_ductility_demand is calculated as δ / y

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

From analysis, chord rotation = $3.7804921E-005$

$y = (M_y * L_s / 3) / E_{eff} = 0.00198534$ ((4.29), Biskinis Phd)

$M_y = 4.2101E+008$

$L_s = M/V$ (with $L_s > 0.1 * L$ and $L_s < 2 * L$) = 2050.007

From table 10.5, ASCE 41_17: $E_{eff} = factor * E_c * I_g = 1.4491E+014$

factor = 0.30

$A_g = 440000.00$

Mean concrete strength: $f'_c = (f'_c_{jacket} * Area_{jacket} + f'_c_{core} * Area_{core}) / Area_{section} = 27.68182$

$N = 17072.715$

$E_c * I_g = E_{c,jacket} * I_{g,jacket} + E_{c,core} * I_{g,core} = 4.8303E+014$

Calculation of Yielding Moment M_y

Calculation of δ / y and M_y according to Annex 7 -

Assuming neutral axis within flange ($y < t/d$, compression zone rectangular) with:

flange width, $b = 750.00$

web width, $b_w = 400.00$

flange thickness, $t = 400.00$

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

$y_{ten} = 3.1432128E-006$

with ((10.1), ASCE 41-17) $f_y = \text{Min}(f_y, 1.25 * f_y * (I_b / I_d)^{2/3}) = 358.4764$

$d = 707.00$

$y = 0.19343861$

$A = 0.01018557$

$B = 0.00449598$

with $p_t = 0.00214476$

$p_c = 0.00416509$

$p_v = 0.00378591$

$N = 17072.715$

$b = 750.00$

" = 0.06082037

$y_{comp} = 1.6462519E-005$

with f'_c (12.3, (ACI 440)) = 33.48734

$f_c = 33.00$

$f_l = 0.49678681$

$b = b_{max} = 750.00$

$h = h_{max} = 750.00$

$A_g = 0.44$

$g = p_t + p_c + p_v = 0.01009575$

$r_c = 40.00$

$A_e / A_c = 0.31291181$

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

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

$f_u = 0.01$

$E_f = 64828.00$

$E_c = 26999.444$

$y = 0.19181501$

$A = 0.01002364$

$B = 0.00440616$

with $E_s = 200000.00$

CONFIRMATION: $y = 0.19279145 < t/d$

Calculation of ratio I_b / I_d

Lap Length: $I_d / I_{d,min} = 0.39803249$

lb = 300.00

ld = 753.7073

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: $f_y = 524.4444$

Mean concrete strength: $f_c' = (f_c'_{jacket} \cdot Area_{jacket} + f_c'_{core} \cdot Area_{core}) / Area_{section} = 27.68182$, 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 = 1.7174

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

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

s = $\text{Max}(s_{external}, s_{internal}) = 250.00$

n = 24.00

End Of Calculation of Shear Capacity for element: column JLC1 of floor 1

At local axis: 3

Integration Section: (a)

Calculation No. 4

column C1, Floor 1

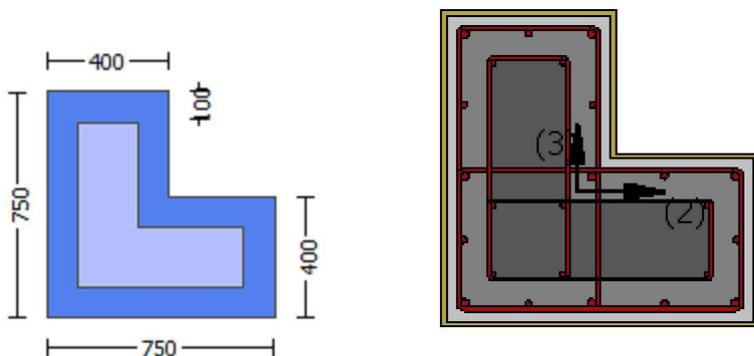
Limit State: Operational Level (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity (ϕ_r)

Edge: Start

Local Axis: (3)



Start Of Calculation of Shear Capacity ratio for element: column JLC1 of floor 1

At Shear local axis: 3

(Bending local axis: 2)

Section Type: rcjlc

Constant Properties

Knowledge Factor, $\phi = 0.85$
Mean strength values are used for both shear and moment calculations.
Consequently:
Jacket
New material of Secondary Member: Concrete Strength, $f_c = f_{cm} = 33.00$
New material of Secondary Member: Steel Strength, $f_s = f_{sm} = 555.5556$
Concrete Elasticity, $E_c = 26999.444$
Steel Elasticity, $E_s = 200000.00$
Existing Column
Existing material of Secondary Member: Concrete Strength, $f_c = f_{cm} = 20.00$
Existing material of Secondary Member: Steel Strength, $f_s = f_{sm} = 444.4444$
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, $f_s = 1.25 * f_{sm} = 694.4444$
Existing Column
Existing material: Steel Strength, $f_s = 1.25 * f_{sm} = 555.5556$

Max Height, $H_{max} = 750.00$
Min Height, $H_{min} = 400.00$
Max Width, $W_{max} = 750.00$
Min Width, $W_{min} = 400.00$
Jacket Thickness, $t_j = 100.00$
Cover Thickness, $c = 25.00$
Mean Confinement Factor overall section = 1.03889
Element Length, $L = 3000.00$
Secondary Member
Ribbed Bars
Ductile Steel
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
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, $V_a = -0.00051441$
EDGE -B-
Shear Force, $V_b = 0.00051441$
BOTH EDGES
Axial Force, $F = -16273.616$
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: $As_t = 0.00$
-Compression: $As_c = 5353.274$
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension: $As_{t,ten} = 1137.257$
-Compression: $As_{l,com} = 2208.54$
-Middle: $As_{l,mid} = 2007.478$

Calculation of Shear Capacity ratio , $V_e/V_r = 0.55377356$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 552827.824$

with

$M_{pr1} = \text{Max}(M_{u1+}, M_{u1-}) = 8.2924E+008$

$M_{u1+} = 5.1260E+008$, 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

$M_{u1-} = 8.2924E+008$, 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

$M_{pr2} = \text{Max}(M_{u2+}, M_{u2-}) = 8.2924E+008$

$M_{u2+} = 5.1260E+008$, 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

$M_{u2-} = 8.2924E+008$, 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 ϕ_u according to 4.1, Biskinis/Fardis 2013:

$\phi_u = 9.5578758E-006$

$M_u = 5.1260E+008$

with full section properties:

$b = 750.00$

$d = 707.00$

$d' = 43.00$

$v = 0.00093001$

$N = 16273.616$

$f_c = 33.00$

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

Final value of ϕ_u : $\phi_u^* = \text{shear_factor} * \text{Max}(\phi_u, \phi_c) = 0.01288354$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $\phi_u = 0.01288354$

we ((5.4c), TBDY) = $\text{ase} * \text{sh}_{\min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.05503171$

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

 $f_x = 0.04286225$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$a_f = 0.31984848$

with Unconfined area = $((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 140733.333$

$b_{\max} = 750.00$

$h_{\max} = 750.00$

From EC8 A.4.4.3(6), $p_f = 2t_f / b_w = 0.00508$

$b_w = 400.00$

effective stress from (A.35), $f_{f,e} = 870.5244$

 $f_y = 0.04286225$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$a_f = 0.31984848$

with Unconfined area = $((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 140733.333$

$b_{\max} = 750.00$

$h_{\max} = 750.00$

From EC8 A.4.4.3(6), $p_f = 2t_f / b_w = 0.00508$

$b_w = 400.00$

effective stress from (A.35), $f_{f,e} = 870.5244$

 $R = 40.00$

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

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{,f} = 0.015$

ase ((5.4d), TBDY) = $(\text{ase}_1 * A_{\text{ext}} + \text{ase}_2 * A_{\text{int}}) / A_{\text{sec}} = 0.45746528$

$\text{ase}_1 = \text{Max}(((A_{\text{conf,max1}} - A_{\text{noConf1}}) / A_{\text{conf,max1}}) * (A_{\text{conf,min1}} / A_{\text{conf,max1}}), 0) = 0.45746528$

The definitions of AnoConf, Aconf,min and Aconf,max are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

Aconf,max1 = 353600.00 is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

Aconf,min1 = 293525.00 is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area Aconf,max1 by a length equal to half the clear spacing between external hoops.

AnoConf1 = 158733.333 is the unconfined external core area which is equal to $b_i^2/6$ as defined at (A.2).
ase2 (\geq ase1) = $\text{Max}(((A_{\text{conf,max2}} - A_{\text{noConf2}})/A_{\text{conf,max2}}) * (A_{\text{conf,min2}}/A_{\text{conf,max2}}), 0) = 0.45746528$

The definitions of AnoConf, Aconf,min and Aconf,max are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

Aconf,max2 = 171264.00 is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

Aconf,min2 = 54741.00 is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area Aconf,max2 by a length equal to half the clear spacing between internal hoops.

AnoConf2 = 106242.667 is the unconfined internal core area which is equal to $b_i^2/6$ as defined at (A.2).
psh,min*Fywe = $\text{Min}(psh_x * Fywe, psh_y * Fywe) = 2.92621$

Expression (5.4d) 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 = 2.92621

psh1 ((5.4d), TBDY) = $L_{\text{stir1}} * A_{\text{stir1}} / (A_{\text{sec}} * s_1) = 0.00367709$

Lstir1 (Length of stirrups along Y) = 2060.00

Astir1 (stirrups area) = 78.53982

psh2 (5.4d) = $L_{\text{stir2}} * A_{\text{stir2}} / (A_{\text{sec}} * s_2) = 0.00067082$

Lstir2 (Length of stirrups along Y) = 1468.00

Astir2 (stirrups area) = 50.26548

psh_y*Fywe = psh1*Fywe1 + ps2*Fywe2 = 2.92621

psh1 ((5.4d), TBDY) = $L_{\text{stir1}} * A_{\text{stir1}} / (A_{\text{sec}} * s_1) = 0.00367709$

Lstir1 (Length of stirrups along X) = 2060.00

Astir1 (stirrups area) = 78.53982

psh2 ((5.4d), TBDY) = $L_{\text{stir2}} * A_{\text{stir2}} / (A_{\text{sec}} * s_2) = 0.00067082$

Lstir2 (Length of stirrups along X) = 1468.00

Astir2 (stirrups area) = 50.26548

Asec = 440000.00

s1 = 100.00

s2 = 250.00

fywe1 = 694.4444

fywe2 = 555.5556

fce = 33.00

From ((5.A5), TBDY), TBDY: cc = 0.00238888

c = confinement factor = 1.03889

y1 = 0.00145721

sh1 = 0.00466307

ft1 = 459.4373

fy1 = 382.8645

su1 = 0.00582756

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 = 0.318426

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

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 $\text{Min}(1, 1.25 * (lb/l_d)^{2/3})$, from 10.3.5, ASCE 41-17.

with fs1 = $(f_{s,jacket} * A_{s,ten,jacket} + f_{s,core} * A_{s,ten,core}) / A_{s,ten} = 382.8645$

with Es1 = $(E_{s,jacket} * A_{s,ten,jacket} + E_{s,core} * A_{s,ten,core}) / A_{s,ten} = 200000.00$

y2 = 0.00145721
sh2 = 0.00466307
ft2 = 465.423
fy2 = 387.8525
su2 = 0.00582756

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 = 0.318426

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 = 387.8525

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

yv = 0.00145721
shv = 0.00466307

ftv = 463.3885

fyv = 386.157

suv = 0.00582756

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 = 0.318426

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 = 386.157

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

1 = Asl,ten/(b*d)*(fs1/fc) = 0.02488335

2 = Asl,com/(b*d)*(fs2/fc) = 0.04895276

v = Asl,mid/(b*d)*(fsv/fc) = 0.04430167

and confined core properties:

b = 690.00

d = 677.00

d' = 13.00

fcc (5A.2, TBDY) = 34.2833

cc (5A.5, TBDY) = 0.00238888

c = confinement factor = 1.03889

1 = Asl,ten/(b*d)*(fs1/fc) = 0.02824566

2 = Asl,com/(b*d)*(fs2/fc) = 0.05556741

v = Asl,mid/(b*d)*(fsv/fc) = 0.05028784

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

v < vs,y2 - LHS eq.(4.5) is satisfied

--->

su (4.9) = 0.13760581

Mu = MRc (4.14) = 5.1260E+008

u = su (4.1) = 9.5578758E-006

Calculation of ratio lb/ld

Lap Length: lb/ld = 0.318426

lb = 300.00

ld = 942.1341

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 = 655.5556

Mean concrete strength: fc' = (fc',jacket*Area_jacket + fc',core*Area_core)/Area_section = 27.68182, but $fc'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$t = 1.00$
 $s = 0.80$
 $e = 1.00$
 $cb = 25.00$
 $K_{tr} = 1.7174$
 $A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 257.6106$
 where A_{tr_x} , A_{tr_y} are the sum of the area of all stirrup legs along X and Y local axis
 $s = \text{Max}(s_{\text{external}}, s_{\text{internal}}) = 250.00$
 $n = 24.00$

 Calculation of μ_1 -

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

$u = 1.0408734E-005$
 $\mu = 8.2924E+008$

 with full section properties:

$b = 400.00$
 $d = 707.00$
 $d' = 43.00$
 $v = 0.00174378$
 $N = 16273.616$

$f_c = 33.00$
 $\alpha (5A.5, \text{TBDY}) = 0.002$

Final value of μ : $\mu^* = \text{shear_factor} * \text{Max}(\mu, \alpha) = 0.01288354$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $\mu = 0.01288354$

where (5.4c), TBDY) = $\alpha * \text{sh}_{\text{min}} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.05503171$

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

 $f_x = 0.04286225$

Expression ((15B.6), TBDY) is modified as $\alpha_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$\alpha_f = 0.31984848$

with Unconfined area = $((b_{\text{max}} - 2R)^2 + (h_{\text{max}} - 2R)^2) / 3 = 140733.333$

$b_{\text{max}} = 750.00$

$h_{\text{max}} = 750.00$

From EC8 A.4.4.3(6), $\rho_f = 2t_f / b_w = 0.00508$

$b_w = 400.00$

effective stress from (A.35), $f_{fe} = 870.5244$

 $f_y = 0.04286225$

Expression ((15B.6), TBDY) is modified as $\alpha_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$\alpha_f = 0.31984848$

with Unconfined area = $((b_{\text{max}} - 2R)^2 + (h_{\text{max}} - 2R)^2) / 3 = 140733.333$

$b_{\text{max}} = 750.00$

$h_{\text{max}} = 750.00$

From EC8 A.4.4.3(6), $\rho_f = 2t_f / b_w = 0.00508$

$b_w = 400.00$

effective stress from (A.35), $f_{fe} = 870.5244$

 $R = 40.00$

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

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{f} = 0.015$

α_{se} ((5.4d), TBDY) = $(\alpha_{se1} * A_{\text{ext}} + \alpha_{se2} * A_{\text{int}}) / A_{\text{sec}} = 0.45746528$

$\alpha_{se1} = \text{Max}(((A_{\text{conf,max1}} - A_{\text{noConf1}}) / A_{\text{conf,max1}}) * (A_{\text{conf,min1}} / A_{\text{conf,max1}}), 0) = 0.45746528$

The definitions of A_{noConf} , $A_{\text{conf,min}}$ and $A_{\text{conf,max}}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{\text{conf,max1}} = 353600.00$ is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{conf,min1} = 293525.00$ is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area $A_{conf,max1}$ by a length equal to half the clear spacing between external hoops.

$A_{noConf1} = 158733.333$ is the unconfined external core area which is equal to $b_i^2/6$ as defined at (A.2).
 $ase_2 (>= ase_1) = \text{Max}(((A_{conf,max2} - A_{noConf2})/A_{conf,max2}) * (A_{conf,min2}/A_{conf,max2}), 0) = 0.45746528$

The definitions of A_{noConf} , $A_{conf,min}$ and $A_{conf,max}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max2} = 171264.00$ is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

$A_{conf,min2} = 54741.00$ is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area $A_{conf,max2}$ by a length equal to half the clear spacing between internal hoops.

$A_{noConf2} = 106242.667$ is the unconfined internal core area which is equal to $b_i^2/6$ as defined at (A.2).

$p_{sh,min} * F_{ywe} = \text{Min}(p_{sh,x} * F_{ywe}, p_{sh,y} * F_{ywe}) = 2.92621$

Expression (5.4d) 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)

 $p_{sh,x} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{s2} * F_{ywe2} = 2.92621$

p_{sh1} ((5.4d), TBDY) = $L_{stir1} * A_{stir1} / (A_{sec} * s_1) = 0.00367709$

L_{stir1} (Length of stirrups along Y) = 2060.00

A_{stir1} (stirrups area) = 78.53982

p_{sh2} (5.4d) = $L_{stir2} * A_{stir2} / (A_{sec} * s_2) = 0.00067082$

L_{stir2} (Length of stirrups along Y) = 1468.00

A_{stir2} (stirrups area) = 50.26548

 $p_{sh,y} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{s2} * F_{ywe2} = 2.92621$

p_{sh1} ((5.4d), TBDY) = $L_{stir1} * A_{stir1} / (A_{sec} * s_1) = 0.00367709$

L_{stir1} (Length of stirrups along X) = 2060.00

A_{stir1} (stirrups area) = 78.53982

p_{sh2} ((5.4d), TBDY) = $L_{stir2} * A_{stir2} / (A_{sec} * s_2) = 0.00067082$

L_{stir2} (Length of stirrups along X) = 1468.00

A_{stir2} (stirrups area) = 50.26548

 $A_{sec} = 440000.00$

$s_1 = 100.00$

$s_2 = 250.00$

$f_{ywe1} = 694.4444$

$f_{ywe2} = 555.5556$

$f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY: $cc = 0.00238888$

c = confinement factor = 1.03889

$y_1 = 0.00145721$

$sh_1 = 0.00466307$

$ft_1 = 465.423$

$fy_1 = 387.8525$

$su_1 = 0.00582756$

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

$l_0/l_{ou,min} = l_b/l_d = 0.318426$

$su_1 = 0.4 * esu_{1,nominal}$ ((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 $fs_1 = (f_{s,jacket} * A_{sl,ten,jacket} + f_{s,core} * A_{sl,ten,core}) / A_{sl,ten} = 387.8525$

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

$y_2 = 0.00145721$

$sh_2 = 0.00466307$

$ft_2 = 459.4373$

$fy_2 = 382.8645$

$su_2 = 0.00582756$

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 = 0.318426

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 = 382.8645

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

yv = 0.00145721

shv = 0.00466307

ftv = 463.3885

fyv = 386.157

suv = 0.00582756

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 = 0.318426

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 = 386.157

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

1 = Asl,ten/(b*d)*(fs1/fc) = 0.09178643

2 = Asl,com/(b*d)*(fs2/fc) = 0.04665628

v = Asl,mid/(b*d)*(fsv/fc) = 0.08306563

and confined core properties:

b = 340.00

d = 677.00

d' = 13.00

fcc (5A.2, TBDY) = 34.2833

cc (5A.5, TBDY) = 0.00238888

c = confinement factor = 1.03889

1 = Asl,ten/(b*d)*(fs1/fc) = 0.11276915

2 = Asl,com/(b*d)*(fs2/fc) = 0.05732208

v = Asl,mid/(b*d)*(fsv/fc) = 0.10205474

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

v < vs,y2 - LHS eq.(4.5) is satisfied

--->

su (4.9) = 0.20810191

Mu = MRc (4.14) = 8.2924E+008

u = su (4.1) = 1.0408734E-005

Calculation of ratio lb/ld

Lap Length: lb/ld = 0.318426

lb = 300.00

ld = 942.1341

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 = 655.5556

Mean concrete strength: fc' = (fc',jacket*Area_jacket + fc',core*Area_core)/Area_section = 27.68182, but $fc'^{0.5} <=$ 8.3 MPa (22.5.3.1, ACI 318-14)

t = 1.00

s = 0.80

e = 1.00

cb = 25.00

Ktr = 1.7174

Atr = Min(Atr_x,Atr_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
 $s = \text{Max}(s_{\text{external}}, s_{\text{internal}}) = 250.00$
 $n = 24.00$

Calculation of μ_{2+}

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

$$u = 9.5578758E-006$$

$$\mu = 5.1260E+008$$

with full section properties:

$$b = 750.00$$

$$d = 707.00$$

$$d' = 43.00$$

$$v = 0.00093001$$

$$N = 16273.616$$

$$f_c = 33.00$$

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

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.01288354$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } c_u = 0.01288354$$

$$w_e \text{ ((5.4c), TBDY)} = a_{se} * s_{h, \min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.05503171$$

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

$$f_x = 0.04286225$$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.31984848$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 140733.333$$

$$b_{\max} = 750.00$$

$$h_{\max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 870.5244$$

$$f_y = 0.04286225$$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.31984848$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 140733.333$$

$$b_{\max} = 750.00$$

$$h_{\max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 870.5244$$

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u_{f} = 0.015$$

$$a_{se} \text{ ((5.4d), TBDY)} = (a_{se1} * A_{ext} + a_{se2} * A_{int}) / A_{sec} = 0.45746528$$

$$a_{se1} = \text{Max}(((A_{\text{conf,max1}} - A_{\text{noConf1}}) / A_{\text{conf,max1}}) * (A_{\text{conf,min1}} / A_{\text{conf,max1}}), 0) = 0.45746528$$

The definitions of A_{noConf} , $A_{\text{conf,min}}$ and $A_{\text{conf,max}}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{\text{conf,max1}} = 353600.00$ is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{\text{conf,min1}} = 293525.00$ is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area $A_{\text{conf,max1}}$ by a length

equal to half the clear spacing between external hoops.

$A_{\text{noConf1}} = 158733.333$ is the unconfined external core area which is equal to $b_i^2/6$ as defined at (A.2).

$$a_{se2} (>= a_{se1}) = \text{Max}(((A_{\text{conf,max2}} - A_{\text{noConf2}}) / A_{\text{conf,max2}}) * (A_{\text{conf,min2}} / A_{\text{conf,max2}}), 0) = 0.45746528$$

The definitions of A_{noConf} , $A_{conf,min}$ and $A_{conf,max}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max2} = 171264.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

$A_{conf,min2} = 54741.00$ is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area $A_{conf,max2}$ by a length equal to half the clear spacing between internal hoops.

$A_{noConf2} = 106242.667$ is the unconfined internal core area which is equal to $b_i^2/6$ as defined at (A.2).

$$psh_{,min} * F_{ywe} = \text{Min}(psh_{,x} * F_{ywe}, psh_{,y} * F_{ywe}) = 2.92621$$

Expression (5.4d) 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)

$$psh_{,x} * F_{ywe} = psh1 * F_{ywe1} + ps2 * F_{ywe2} = 2.92621$$

$$psh1 \text{ ((5.4d), TBDY)} = L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00367709$$

$$L_{stir1} \text{ (Length of stirrups along Y)} = 2060.00$$

$$A_{stir1} \text{ (stirrups area)} = 78.53982$$

$$psh2 \text{ (5.4d)} = L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00067082$$

$$L_{stir2} \text{ (Length of stirrups along Y)} = 1468.00$$

$$A_{stir2} \text{ (stirrups area)} = 50.26548$$

$$psh_{,y} * F_{ywe} = psh1 * F_{ywe1} + ps2 * F_{ywe2} = 2.92621$$

$$psh1 \text{ ((5.4d), TBDY)} = L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00367709$$

$$L_{stir1} \text{ (Length of stirrups along X)} = 2060.00$$

$$A_{stir1} \text{ (stirrups area)} = 78.53982$$

$$psh2 \text{ ((5.4d), TBDY)} = L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00067082$$

$$L_{stir2} \text{ (Length of stirrups along X)} = 1468.00$$

$$A_{stir2} \text{ (stirrups area)} = 50.26548$$

$$A_{sec} = 440000.00$$

$$s1 = 100.00$$

$$s2 = 250.00$$

$$f_{ywe1} = 694.4444$$

$$f_{ywe2} = 555.5556$$

$$f_{ce} = 33.00$$

$$\text{From ((5.A5), TBDY), TBDY: } cc = 0.00238888$$

$$c = \text{confinement factor} = 1.03889$$

$$y1 = 0.00145721$$

$$sh1 = 0.00466307$$

$$ft1 = 459.4373$$

$$fy1 = 382.8645$$

$$su1 = 0.00582756$$

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

$$l_o/l_{ou,min} = l_b/l_d = 0.318426$$

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

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

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

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

$$\text{with } fs1 = (f_{s,jacket} * A_{s,ten,jacket} + f_{s,core} * A_{s,ten,core}) / A_{s,ten} = 382.8645$$

$$\text{with } Es1 = (E_{s,jacket} * A_{s,ten,jacket} + E_{s,core} * A_{s,ten,core}) / A_{s,ten} = 200000.00$$

$$y2 = 0.00145721$$

$$sh2 = 0.00466307$$

$$ft2 = 465.423$$

$$fy2 = 387.8525$$

$$su2 = 0.00582756$$

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

$$l_o/l_{ou,min} = l_b/l_{b,min} = 0.318426$$

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

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

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 $f_{s2} = (f_{s,jacket} \cdot A_{s,com,jacket} + f_{s,core} \cdot A_{s,com,core})/A_{s,com} = 387.8525$

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

$y_v = 0.00145721$

$sh_v = 0.00466307$

$ft_v = 463.3885$

$f_{y_v} = 386.157$

$s_{u_v} = 0.00582756$

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

$l_o/l_{o,min} = l_b/l_d = 0.318426$

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

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 $f_{s_{y_v}} = (f_{s,jacket} \cdot A_{s,mid,jacket} + f_{s,mid} \cdot A_{s,mid,core})/A_{s,mid} = 386.157$

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

$1 = A_{s,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.02488335$

$2 = A_{s,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.04895276$

$v = A_{s,mid}/(b \cdot d) \cdot (f_{s_{y_v}}/f_c) = 0.04430167$

and confined core properties:

$b = 690.00$

$d = 677.00$

$d' = 13.00$

$f_{cc} (5A.2, TBDY) = 34.2833$

$cc (5A.5, TBDY) = 0.00238888$

$c = \text{confinement factor} = 1.03889$

$1 = A_{s,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.02824566$

$2 = A_{s,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.05556741$

$v = A_{s,mid}/(b \cdot d) \cdot (f_{s_{y_v}}/f_c) = 0.05028784$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

$s_u (4.9) = 0.13760581$

$\mu_u = M_{Rc} (4.14) = 5.1260E+008$

$u = s_u (4.1) = 9.5578758E-006$

Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.318426$

$l_b = 300.00$

$l_d = 942.1341$

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: $f_y = 655.5556$

Mean concrete strength: $f'_c = (f'_{c,jacket} \cdot \text{Area}_{jacket} + f'_{c,core} \cdot \text{Area}_{core})/\text{Area}_{section} = 27.68182$, but $f_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 1.7174$

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

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

$s = \text{Max}(s_{external}, s_{internal}) = 250.00$

$n = 24.00$

Calculation of Mu2-

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

$$\mu = 1.0408734E-005$$

$$Mu = 8.2924E+008$$

with full section properties:

$$b = 400.00$$

$$d = 707.00$$

$$d' = 43.00$$

$$v = 0.00174378$$

$$N = 16273.616$$

$$f_c = 33.00$$

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

$$\text{Final value of } \mu: \mu^* = \text{shear_factor} * \text{Max}(\mu, c_o) = 0.01288354$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \mu = 0.01288354$$

$$\mu_e ((5.4c), TBDY) = a_{se} * \text{sh}_{, \min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.05503171$$

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

$$f_x = 0.04286225$$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.31984848$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 140733.333$$

$$b_{\max} = 750.00$$

$$h_{\max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 870.5244$$

$$f_y = 0.04286225$$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.31984848$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 140733.333$$

$$b_{\max} = 750.00$$

$$h_{\max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 870.5244$$

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$a_{se} ((5.4d), TBDY) = (a_{se1} * A_{ext} + a_{se2} * A_{int}) / A_{sec} = 0.45746528$$

$$a_{se1} = \text{Max}(((A_{\text{conf,max1}} - A_{\text{noConf1}}) / A_{\text{conf,max1}}) * (A_{\text{conf,min1}} / A_{\text{conf,max1}}), 0) = 0.45746528$$

The definitions of A_{noConf} , $A_{\text{conf,min}}$ and $A_{\text{conf,max}}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{\text{conf,max1}} = 353600.00$ is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{\text{conf,min1}} = 293525.00$ is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area $A_{\text{conf,max1}}$ by a length

equal to half the clear spacing between external hoops.

$A_{\text{noConf1}} = 158733.333$ is the unconfined external core area which is equal to $b_i^2/6$ as defined at (A.2).

$$a_{se2} (>= a_{se1}) = \text{Max}(((A_{\text{conf,max2}} - A_{\text{noConf2}}) / A_{\text{conf,max2}}) * (A_{\text{conf,min2}} / A_{\text{conf,max2}}), 0) = 0.45746528$$

The definitions of A_{noConf} , $A_{\text{conf,min}}$ and $A_{\text{conf,max}}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{\text{conf,max2}} = 171264.00$ is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

$A_{conf,min2} = 54741.00$ is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area $A_{conf,max2}$ by a length equal to half the clear spacing between internal hoops.

$A_{noConf2} = 106242.667$ is the unconfined internal core area which is equal to $b_i^2/6$ as defined at (A.2).

$p_{sh,min} * F_{ywe} = \text{Min}(p_{sh,x} * F_{ywe}, p_{sh,y} * F_{ywe}) = 2.92621$

Expression (5.4d) 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)

 $p_{sh,x} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{s2} * F_{ywe2} = 2.92621$

p_{sh1} ((5.4d), TBDY) = $L_{stir1} * A_{stir1} / (A_{sec} * s_1) = 0.00367709$

L_{stir1} (Length of stirrups along Y) = 2060.00

A_{stir1} (stirrups area) = 78.53982

p_{sh2} (5.4d) = $L_{stir2} * A_{stir2} / (A_{sec} * s_2) = 0.00067082$

L_{stir2} (Length of stirrups along Y) = 1468.00

A_{stir2} (stirrups area) = 50.26548

$p_{sh,y} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{s2} * F_{ywe2} = 2.92621$

p_{sh1} ((5.4d), TBDY) = $L_{stir1} * A_{stir1} / (A_{sec} * s_1) = 0.00367709$

L_{stir1} (Length of stirrups along X) = 2060.00

A_{stir1} (stirrups area) = 78.53982

p_{sh2} ((5.4d), TBDY) = $L_{stir2} * A_{stir2} / (A_{sec} * s_2) = 0.00067082$

L_{stir2} (Length of stirrups along X) = 1468.00

A_{stir2} (stirrups area) = 50.26548

$A_{sec} = 440000.00$

$s_1 = 100.00$

$s_2 = 250.00$

$f_{ywe1} = 694.4444$

$f_{ywe2} = 555.5556$

$f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY: $cc = 0.00238888$

$c = \text{confinement factor} = 1.03889$

$y_1 = 0.00145721$

$sh_1 = 0.00466307$

$ft_1 = 465.423$

$fy_1 = 387.8525$

$su_1 = 0.00582756$

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

$l_o/l_{ou,min} = l_b/l_d = 0.318426$

$su_1 = 0.4 * esu1_{nominal}$ ((5.5), TBDY) = 0.032

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

For calculation of $esu1_{nominal}$ 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 $fs_1 = (f_{s,jacket} * A_{sl,ten,jacket} + f_{s,core} * A_{sl,ten,core}) / A_{sl,ten} = 387.8525$

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

$y_2 = 0.00145721$

$sh_2 = 0.00466307$

$ft_2 = 459.4373$

$fy_2 = 382.8645$

$su_2 = 0.00582756$

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

$l_o/l_{ou,min} = l_b/l_{b,min} = 0.318426$

$su_2 = 0.4 * esu2_{nominal}$ ((5.5), TBDY) = 0.032

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

For calculation of $esu2_{nominal}$ 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 $fs_2 = (f_{s,jacket} * A_{sl,com,jacket} + f_{s,core} * A_{sl,com,core}) / A_{sl,com} = 382.8645$

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

$y_v = 0.00145721$

$sh_v = 0.00466307$

$$ftv = 463.3885$$

$$fyv = 386.157$$

$$suv = 0.00582756$$

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

$$lo/lo_{u,min} = lb/ld = 0.318426$$

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

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

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

For calculation of $esuv_{nominal}$ and yv , shv , ftv , fyv , it is considered
characteristic value $fsv = fsv/1.2$, 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.

$$\text{with } fsv = (fs_{jacket} * Asl_{mid,jacket} + fs_{mid} * Asl_{mid,core}) / Asl_{mid} = 386.157$$

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

$$1 = Asl_{ten} / (b * d) * (fs1 / fc) = 0.09178643$$

$$2 = Asl_{com} / (b * d) * (fs2 / fc) = 0.04665628$$

$$v = Asl_{mid} / (b * d) * (fsv / fc) = 0.08306563$$

and confined core properties:

$$b = 340.00$$

$$d = 677.00$$

$$d' = 13.00$$

$$fcc (5A.2, TBDY) = 34.2833$$

$$cc (5A.5, TBDY) = 0.00238888$$

$$c = \text{confinement factor} = 1.03889$$

$$1 = Asl_{ten} / (b * d) * (fs1 / fc) = 0.11276915$$

$$2 = Asl_{com} / (b * d) * (fs2 / fc) = 0.05732208$$

$$v = Asl_{mid} / (b * d) * (fsv / fc) = 0.10205474$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < vs_{y2}$ - LHS eq.(4.5) is satisfied

--->

$$su (4.9) = 0.20810191$$

$$Mu = MRc (4.14) = 8.2924E+008$$

$$u = su (4.1) = 1.0408734E-005$$

Calculation of ratio lb/ld

Lap Length: $lb/ld = 0.318426$

$$lb = 300.00$$

$$ld = 942.1341$$

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: $fy = 655.5556$

Mean concrete strength: $fc' = (fc'_{jacket} * Area_{jacket} + fc'_{core} * Area_{core}) / Area_{section} = 27.68182$, but $fc'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$cb = 25.00$$

$$K_{tr} = 1.7174$$

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

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

$$s = \text{Max}(s_{external}, s_{internal}) = 250.00$$

$$n = 24.00$$

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 998292.205$

Calculation of Shear Strength at edge 1, $V_{r1} = 998292.205$

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

$$V_{Col0} = 998292.205$$

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

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

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

Mean concrete strength: $f'_c = (f'_{c,jacket} \cdot Area_{jacket} + f'_{c,core} \cdot Area_{core}) / Area_{section} = 27.68182$, but $f_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 4.00$

$\mu_u = 11.77537$

$V_u = 0.00051441$

$d = 0.8 \cdot h = 600.00$

$N_u = 16273.616$

$A_g = 300000.00$

From (11.5.4.8), ACI 318-14: $V_s = V_{s,jacket} + V_{s,core} = 881489.011$

where:

$V_{s,jacket} = V_{s,j1} + V_{s,j2} = 802851.456$

$V_{s,j1} = 523598.776$ is calculated for section web jacket, with:

$d = 600.00$

$A_v = 157079.633$

$f_y = 555.5556$

$s = 100.00$

$V_{s,j1}$ is multiplied by $Col_{j1} = 1.00$

$s/d = 0.16666667$

$V_{s,j2} = 279252.68$ is calculated for section flange jacket, with:

$d = 320.00$

$A_v = 157079.633$

$f_y = 555.5556$

$s = 100.00$

$V_{s,j2}$ is multiplied by $Col_{j2} = 1.00$

$s/d = 0.3125$

$V_{s,core} = V_{s,c1} + V_{s,c2} = 78637.555$

$V_{s,c1} = 78637.555$ is calculated for section web core, with:

$d = 440.00$

$A_v = 100530.965$

$f_y = 444.4444$

$s = 250.00$

$V_{s,c1}$ is multiplied by $Col_{c1} = 1.00$

$s/d = 0.56818182$

$V_{s,c2} = 0.00$ is calculated for section flange core, with:

$d = 160.00$

$A_v = 100530.965$

$f_y = 444.4444$

$s = 250.00$

$V_{s,c2}$ is multiplied by $Col_{c2} = 0.00$

$s/d = 1.5625$

V_f ((11-3)-(11.4), ACI 440) = 372533.843

$f = 0.95$, for fully-wrapped sections

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

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

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

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

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

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

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

$d_{fv} = d$ (figure 11.2, ACI 440) = 707.00

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: $V_s + V_f \leq 838832.606$

$b_w = 400.00$

Calculation of Shear Strength at edge 2, $V_{r2} = 998292.205$

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

VColO = 998292.205

knl = 1 (zero step-static loading)

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

= 1 (normal-weight concrete)

Mean concrete strength: $f_c' = (f_c'_{\text{jacket}} \cdot \text{Area}_{\text{jacket}} + f_c'_{\text{core}} \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 27.68182$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 4.00$

$\mu_u = 11.77482$

$V_u = 0.00051441$

$d = 0.8 \cdot h = 600.00$

$N_u = 16273.616$

$A_g = 300000.00$

From (11.5.4.8), ACI 318-14: $V_s = V_{s,\text{jacket}} + V_{s,\text{core}} = 881489.011$

where:

$V_{s,\text{jacket}} = V_{s,j1} + V_{s,j2} = 802851.456$

$V_{s,j1} = 523598.776$ is calculated for section web jacket, with:

$d = 600.00$

$A_v = 157079.633$

$f_y = 555.5556$

$s = 100.00$

$V_{s,j1}$ is multiplied by $\text{Col},j1 = 1.00$

$s/d = 0.16666667$

$V_{s,j2} = 279252.68$ is calculated for section flange jacket, with:

$d = 320.00$

$A_v = 157079.633$

$f_y = 555.5556$

$s = 100.00$

$V_{s,j2}$ is multiplied by $\text{Col},j2 = 1.00$

$s/d = 0.3125$

$V_{s,\text{core}} = V_{s,c1} + V_{s,c2} = 78637.555$

$V_{s,c1} = 78637.555$ is calculated for section web core, with:

$d = 440.00$

$A_v = 100530.965$

$f_y = 444.4444$

$s = 250.00$

$V_{s,c1}$ is multiplied by $\text{Col},c1 = 1.00$

$s/d = 0.56818182$

$V_{s,c2} = 0.00$ is calculated for section flange core, with:

$d = 160.00$

$A_v = 100530.965$

$f_y = 444.4444$

$s = 250.00$

$V_{s,c2}$ is multiplied by $\text{Col},c2 = 0.00$

$s/d = 1.5625$

V_f ((11-3)-(11.4), ACI 440) = 372533.843

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

$d_{fv} = d$ (figure 11.2, ACI 440) = 707.00

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: $V_s + V_f \leq 838832.606$

$b_w = 400.00$

End Of Calculation of Shear Capacity ratio for element: column JLC1 of floor 1

At local axis: 3

Start Of Calculation of Shear Capacity ratio for element: column JLC1 of floor 1

At Shear local axis: 2

(Bending local axis: 3)

Section Type: rcjlc

Constant Properties

Knowledge Factor, $\gamma = 0.85$

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

Consequently:

Jacket

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

New material of Secondary Member: Steel Strength, $f_s = f_{sm} = 555.5556$

Concrete Elasticity, $E_c = 26999.444$

Steel Elasticity, $E_s = 200000.00$

Existing Column

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

Existing material of Secondary Member: Steel Strength, $f_s = f_{sm} = 444.4444$

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, $f_s = 1.25 \cdot f_{sm} = 694.4444$

Existing Column

Existing material: Steel Strength, $f_s = 1.25 \cdot f_{sm} = 555.5556$

#####

Max Height, $H_{max} = 750.00$

Min Height, $H_{min} = 400.00$

Max Width, $W_{max} = 750.00$

Min Width, $W_{min} = 400.00$

Jacket Thickness, $t_j = 100.00$

Cover Thickness, $c = 25.00$

Mean Confinement Factor overall section = 1.03889

Element Length, $L = 3000.00$

Secondary Member

Ribbed Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

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, $V_a = -0.00051441$

EDGE -B-

Shear Force, $V_b = 0.00051441$

BOTH EDGES

Axial Force, $F = -16273.616$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: $As_t = 0.00$

-Compression: $As_c = 5353.274$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension: $As_{ten} = 1137.257$

-Compression: $As_{com} = 2208.54$

-Middle: $As_{mid} = 2007.478$

Calculation of Shear Capacity ratio, $V_e/V_r = 0.55377356$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 552827.824$

with

$M_{pr1} = \text{Max}(Mu_{1+}, Mu_{1-}) = 8.2924E+008$

$Mu_{1+} = 5.1260E+008$, 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

$Mu_{1-} = 8.2924E+008$, 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

$M_{pr2} = \text{Max}(Mu_{2+}, Mu_{2-}) = 8.2924E+008$

$Mu_{2+} = 5.1260E+008$, 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

$Mu_{2-} = 8.2924E+008$, 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 ϕ_u according to 4.1, Biskinis/Fardis 2013:

$\phi_u = 9.5578758E-006$

$M_u = 5.1260E+008$

with full section properties:

$b = 750.00$

$d = 707.00$

$d' = 43.00$

$v = 0.00093001$

$N = 16273.616$

$f_c = 33.00$

$\omega (5A.5, \text{TB DY}) = 0.002$

Final value of ϕ_u : $\phi_u^* = \text{shear_factor} * \text{Max}(\phi_u, \phi_c) = 0.01288354$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TB DY: $\phi_u = 0.01288354$

where $\phi_u (5.4c, \text{TB DY}) = a_s e^* \phi_{u, \text{min}} * f_{y, \text{FRP}} / f_{c, \text{FRP}} + \text{Min}(\phi_x, \phi_y) = 0.05503171$

where $\phi_x = a_s^* \phi_{f, \text{FRP}} / f_{c, \text{FRP}}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$\phi_x = 0.04286225$

Expression ((15B.6), TB DY) is modified as $a_s = 1 - (\text{Unconfined area})/(\text{total area})$

$a_s = 0.31984848$

with Unconfined area = $((b_{\text{max}} - 2R)^2 + (h_{\text{max}} - 2R)^2)/3 = 140733.333$

$b_{\text{max}} = 750.00$

$h_{\text{max}} = 750.00$

From EC8 A.4.4.3(6), $\phi_f = 2t_f/b_w = 0.00508$

$b_w = 400.00$

effective stress from (A.35), $f_{f, \text{FRP}} = 870.5244$

$\phi_y = 0.04286225$

Expression ((15B.6), TB DY) is modified as $a_s = 1 - (\text{Unconfined area})/(\text{total area})$

$a_s = 0.31984848$

with Unconfined area = $((b_{\text{max}} - 2R)^2 + (h_{\text{max}} - 2R)^2)/3 = 140733.333$

$b_{\text{max}} = 750.00$

$h_{\text{max}} = 750.00$

From EC8 A4.4.3(6), $pf = 2tf/bw = 0.00508$
 $bw = 400.00$
effective stress from (A.35), $ff,e = 870.5244$

R = 40.00

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

$f_u,f = 1055.00$

$E_f = 64828.00$

$u,f = 0.015$

$ase((5.4d), \text{TBDY}) = (ase1*A_{ext} + ase2*A_{int})/A_{sec} = 0.45746528$

$ase1 = \text{Max}(((A_{conf,max1} - A_{noConf1})/A_{conf,max1}) * (A_{conf,min1}/A_{conf,max1}), 0) = 0.45746528$

The definitions of A_{noConf} , $A_{conf,min}$ and $A_{conf,max}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max1} = 353600.00$ is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{conf,min1} = 293525.00$ is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area $A_{conf,max1}$ by a length equal to half the clear spacing between external hoops.

$A_{noConf1} = 158733.333$ is the unconfined external core area which is equal to $b_i^2/6$ as defined at (A.2).

$ase2 (>= ase1) = \text{Max}(((A_{conf,max2} - A_{noConf2})/A_{conf,max2}) * (A_{conf,min2}/A_{conf,max2}), 0) = 0.45746528$

The definitions of A_{noConf} , $A_{conf,min}$ and $A_{conf,max}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max2} = 171264.00$ is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

$A_{conf,min2} = 54741.00$ is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area $A_{conf,max2}$ by a length equal to half the clear spacing between internal hoops.

$A_{noConf2} = 106242.667$ is the unconfined internal core area which is equal to $b_i^2/6$ as defined at (A.2).

$p_{sh,min} * F_{ywe} = \text{Min}(p_{sh,x} * F_{ywe}, p_{sh,y} * F_{ywe}) = 2.92621$

Expression (5.4d) 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)

$p_{sh,x} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{sh2} * F_{ywe2} = 2.92621$

$p_{sh1}((5.4d), \text{TBDY}) = L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00367709$

L_{stir1} (Length of stirrups along Y) = 2060.00

A_{stir1} (stirrups area) = 78.53982

$p_{sh2}((5.4d)) = L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00067082$

L_{stir2} (Length of stirrups along Y) = 1468.00

A_{stir2} (stirrups area) = 50.26548

$p_{sh,y} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{sh2} * F_{ywe2} = 2.92621$

$p_{sh1}((5.4d), \text{TBDY}) = L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00367709$

L_{stir1} (Length of stirrups along X) = 2060.00

A_{stir1} (stirrups area) = 78.53982

$p_{sh2}((5.4d), \text{TBDY}) = L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00067082$

L_{stir2} (Length of stirrups along X) = 1468.00

A_{stir2} (stirrups area) = 50.26548

$A_{sec} = 440000.00$

$s1 = 100.00$

$s2 = 250.00$

$f_{ywe1} = 694.4444$

$f_{ywe2} = 555.5556$

$f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY: $cc = 0.00238888$

c = confinement factor = 1.03889

$y1 = 0.00145721$

$sh1 = 0.00466307$

$ft1 = 459.4373$

$fy1 = 382.8645$

$su1 = 0.00582756$

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

$$l_0/l_{ou,min} = l_b/l_d = 0.318426$$

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

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.

$$\text{with } f_{s1} = (f_{s,jacket} * A_{s,ten,jacket} + f_{s,core} * A_{s,ten,core}) / A_{s,ten} = 382.8645$$

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

$$y_2 = 0.00145721$$

$$sh_2 = 0.00466307$$

$$ft_2 = 465.423$$

$$fy_2 = 387.8525$$

$$s_u2 = 0.00582756$$

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

$$l_0/l_{ou,min} = l_b/l_{b,min} = 0.318426$$

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

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.

$$\text{with } f_{s2} = (f_{s,jacket} * A_{s,com,jacket} + f_{s,core} * A_{s,com,core}) / A_{s,com} = 387.8525$$

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

$$y_v = 0.00145721$$

$$sh_v = 0.00466307$$

$$ft_v = 463.3885$$

$$fy_v = 386.157$$

$$s_uv = 0.00582756$$

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

$$l_0/l_{ou,min} = l_b/l_d = 0.318426$$

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

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.

$$\text{with } f_{sv} = (f_{s,jacket} * A_{s,mid,jacket} + f_{s,mid} * A_{s,mid,core}) / A_{s,mid} = 386.157$$

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

$$1 = A_{s,ten} / (b * d) * (f_{s1} / f_c) = 0.02488335$$

$$2 = A_{s,com} / (b * d) * (f_{s2} / f_c) = 0.04895276$$

$$v = A_{s,mid} / (b * d) * (f_{sv} / f_c) = 0.04430167$$

and confined core properties:

$$b = 690.00$$

$$d = 677.00$$

$$d' = 13.00$$

$$f_{cc} (5A.2, TBDY) = 34.2833$$

$$c_c (5A.5, TBDY) = 0.00238888$$

$$c = \text{confinement factor} = 1.03889$$

$$1 = A_{s,ten} / (b * d) * (f_{s1} / f_c) = 0.02824566$$

$$2 = A_{s,com} / (b * d) * (f_{s2} / f_c) = 0.05556741$$

$$v = A_{s,mid} / (b * d) * (f_{sv} / f_c) = 0.05028784$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

---->

$$s_u (4.9) = 0.13760581$$

$$\mu_u = M_{Rc} (4.14) = 5.1260E+008$$

$$u = s_u (4.1) = 9.5578758E-006$$

Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.318426$

$l_b = 300.00$

$l_d = 942.1341$

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: $f_y = 655.5556$

Mean concrete strength: $f_c' = (f_c'_{\text{jacket}} \cdot \text{Area}_{\text{jacket}} + f_c'_{\text{core}} \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 27.68182$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$c_b = 25.00$

$K_{tr} = 1.7174$

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

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

$s = \text{Max}(s_{\text{external}}, s_{\text{internal}}) = 250.00$

$n = 24.00$

Calculation of μ_{u1}

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

$\mu = 1.0408734E-005$

$\mu_u = 8.2924E+008$

with full section properties:

$b = 400.00$

$d = 707.00$

$d' = 43.00$

$v = 0.00174378$

$N = 16273.616$

$f_c = 33.00$

α_{co} (5A.5, TBDY) = 0.002

Final value of α_{cu} : $\alpha_{cu} = \text{shear_factor} \cdot \text{Max}(\alpha_{cu}, \alpha_{cc}) = 0.01288354$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $\alpha_{cu} = 0.01288354$

where $\alpha_{cu} = \alpha_{se} \cdot \text{sh}_{\min} \cdot f_{ywe} / f_{ce} + \text{Min}(\alpha_{fx}, \alpha_{fy}) = 0.05503171$

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

$\alpha_{fx} = 0.04286225$

Expression ((15B.6), TBDY) is modified as $\alpha_{se} = 1 - (\text{Unconfined area}) / (\text{total area})$

$\alpha_{se} = 0.31984848$

with Unconfined area = $((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 140733.333$

$b_{\max} = 750.00$

$h_{\max} = 750.00$

From EC8 A.4.4.3(6), $\text{pf} = 2t_f / b_w = 0.00508$

$b_w = 400.00$

effective stress from (A.35), $f_{fe} = 870.5244$

$\alpha_{fy} = 0.04286225$

Expression ((15B.6), TBDY) is modified as $\alpha_{se} = 1 - (\text{Unconfined area}) / (\text{total area})$

$\alpha_{se} = 0.31984848$

with Unconfined area = $((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 140733.333$

$b_{\max} = 750.00$

$h_{\max} = 750.00$

From EC8 A.4.4.3(6), $\text{pf} = 2t_f / b_w = 0.00508$

$b_w = 400.00$

effective stress from (A.35), $f_{fe} = 870.5244$

$R = 40.00$

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

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

$$E_f = 64828.00$$

$$u,f = 0.015$$

$$ase \text{ ((5.4d), TBDY)} = (ase1 * A_{ext} + ase2 * A_{int}) / A_{sec} = 0.45746528$$

$$ase1 = \text{Max}(((A_{conf,max1} - A_{noConf1}) / A_{conf,max1}) * (A_{conf,min1} / A_{conf,max1}), 0) = 0.45746528$$

The definitions of A_{noConf} , $A_{conf,min}$ and $A_{conf,max}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max1} = 353600.00$ is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{conf,min1} = 293525.00$ is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area $A_{conf,max1}$ by a length

equal to half the clear spacing between external hoops.

$A_{noConf1} = 158733.333$ is the unconfined external core area which is equal to $b_i^2/6$ as defined at (A.2).

$$ase2 \text{ (>=ase1)} = \text{Max}(((A_{conf,max2} - A_{noConf2}) / A_{conf,max2}) * (A_{conf,min2} / A_{conf,max2}), 0) = 0.45746528$$

The definitions of A_{noConf} , $A_{conf,min}$ and $A_{conf,max}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max2} = 171264.00$ is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

$A_{conf,min2} = 54741.00$ is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area $A_{conf,max2}$ by a length

equal to half the clear spacing between internal hoops.

$A_{noConf2} = 106242.667$ is the unconfined internal core area which is equal to $b_i^2/6$ as defined at (A.2).

$$p_{sh,min} * F_{ywe} = \text{Min}(p_{sh,x} * F_{ywe}, p_{sh,y} * F_{ywe}) = 2.92621$$

Expression (5.4d) 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)

$$p_{sh,x} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{sh2} * F_{ywe2} = 2.92621$$

$$p_{sh1} \text{ ((5.4d), TBDY)} = L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00367709$$

$$L_{stir1} \text{ (Length of stirrups along Y)} = 2060.00$$

$$A_{stir1} \text{ (stirrups area)} = 78.53982$$

$$p_{sh2} \text{ (5.4d)} = L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00067082$$

$$L_{stir2} \text{ (Length of stirrups along Y)} = 1468.00$$

$$A_{stir2} \text{ (stirrups area)} = 50.26548$$

$$p_{sh,y} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{sh2} * F_{ywe2} = 2.92621$$

$$p_{sh1} \text{ ((5.4d), TBDY)} = L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00367709$$

$$L_{stir1} \text{ (Length of stirrups along X)} = 2060.00$$

$$A_{stir1} \text{ (stirrups area)} = 78.53982$$

$$p_{sh2} \text{ ((5.4d), TBDY)} = L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00067082$$

$$L_{stir2} \text{ (Length of stirrups along X)} = 1468.00$$

$$A_{stir2} \text{ (stirrups area)} = 50.26548$$

$$A_{sec} = 440000.00$$

$$s1 = 100.00$$

$$s2 = 250.00$$

$$f_{ywe1} = 694.4444$$

$$f_{ywe2} = 555.5556$$

$$f_{ce} = 33.00$$

$$\text{From ((5.A5), TBDY), TBDY: } c_c = 0.00238888$$

$$c = \text{confinement factor} = 1.03889$$

$$y1 = 0.00145721$$

$$sh1 = 0.00466307$$

$$ft1 = 465.423$$

$$fy1 = 387.8525$$

$$su1 = 0.00582756$$

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

$$l_o / l_{ou,min} = l_b / d = 0.318426$$

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

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 $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$, from 10.3.5, ASCE 41-17.

with $fs1 = (fs_{jacket} \cdot Asl_{ten,jacket} + fs_{core} \cdot Asl_{ten,core}) / Asl_{ten} = 387.8525$

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

$y2 = 0.00145721$

$sh2 = 0.00466307$

$ft2 = 459.4373$

$fy2 = 382.8645$

$su2 = 0.00582756$

using (30) in Biskinis/Fardis (2013) multiplied with $shear_factor$ and also multiplied by the $shear_factor$ according to 15.7.1.4, with $Shear_factor = 1.00$

$lo/lo_{ou,min} = lb/lb_{,min} = 0.318426$

$su2 = 0.4 \cdot esu2_nominal ((5.5), TBDY) = 0.032$

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 $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$, from 10.3.5, ASCE 41-17.

with $fs2 = (fs_{jacket} \cdot Asl_{com,jacket} + fs_{core} \cdot Asl_{com,core}) / Asl_{com} = 382.8645$

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

$yv = 0.00145721$

$shv = 0.00466307$

$ftv = 463.3885$

$fyv = 386.157$

$suv = 0.00582756$

using (30) in Biskinis/Fardis (2013) multiplied with $shear_factor$ and also multiplied by the $shear_factor$ according to 15.7.1.4, with $Shear_factor = 1.00$

$lo/lo_{ou,min} = lb/ld = 0.318426$

$suv = 0.4 \cdot esuv_nominal ((5.5), TBDY) = 0.032$

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 $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$, from 10.3.5, ASCE 41-17.

with $fsv = (fs_{jacket} \cdot Asl_{mid,jacket} + fs_{mid} \cdot Asl_{mid,core}) / Asl_{mid} = 386.157$

with $Es_v = (Es_{jacket} \cdot Asl_{mid,jacket} + Es_{mid} \cdot Asl_{mid,core}) / Asl_{mid} = 200000.00$

$1 = Asl_{ten} / (b \cdot d) \cdot (fs1 / fc) = 0.09178643$

$2 = Asl_{com} / (b \cdot d) \cdot (fs2 / fc) = 0.04665628$

$v = Asl_{mid} / (b \cdot d) \cdot (fsv / fc) = 0.08306563$

and confined core properties:

$b = 340.00$

$d = 677.00$

$d' = 13.00$

$fcc (5A.2, TBDY) = 34.2833$

$cc (5A.5, TBDY) = 0.00238888$

$c = \text{confinement factor} = 1.03889$

$1 = Asl_{ten} / (b \cdot d) \cdot (fs1 / fc) = 0.11276915$

$2 = Asl_{com} / (b \cdot d) \cdot (fs2 / fc) = 0.05732208$

$v = Asl_{mid} / (b \cdot d) \cdot (fsv / fc) = 0.10205474$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < vs_{y2}$ - LHS eq.(4.5) is satisfied

--->

$su (4.9) = 0.20810191$

$Mu = MRc (4.14) = 8.2924E+008$

$u = su (4.1) = 1.0408734E-005$

Calculation of ratio lb/ld

Lap Length: $lb/ld = 0.318426$

$lb = 300.00$

$ld = 942.1341$

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: $f_y = 655.5556$

Mean concrete strength: $f_c' = (f_c'_{\text{jacket}} \cdot \text{Area}_{\text{jacket}} + f_c'_{\text{core}} \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 27.68182$, 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 = 1.7174

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

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

s = $\text{Max}(s_{\text{external}}, s_{\text{internal}}) = 250.00$

n = 24.00

Calculation of μ_{2+}

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

$\mu = 9.5578758E-006$

$\mu_{2+} = 5.1260E+008$

with full section properties:

b = 750.00

d = 707.00

d' = 43.00

v = 0.00093001

N = 16273.616

$f_c = 33.00$

α (5A.5, TBDY) = 0.002

Final value of μ_{cu} : $\mu_{cu}^* = \text{shear_factor} \cdot \text{Max}(\mu_{cu}, \mu_{cc}) = 0.01288354$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $\mu_{cu} = 0.01288354$

we ((5.4c), TBDY) = $\alpha \cdot s \cdot \text{sh}_{\text{min}} \cdot f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.05503171$

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

 $f_x = 0.04286225$

Expression ((15B.6), TBDY) is modified as $\alpha_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$\alpha_f = 0.31984848$

with Unconfined area = $((b_{\text{max}} - 2R)^2 + (h_{\text{max}} - 2R)^2) / 3 = 140733.333$

$b_{\text{max}} = 750.00$

$h_{\text{max}} = 750.00$

From EC8 A.4.4.3(6), $p_f = 2t_f / b_w = 0.00508$

$b_w = 400.00$

effective stress from (A.35), $f_{f,e} = 870.5244$

$f_y = 0.04286225$

Expression ((15B.6), TBDY) is modified as $\alpha_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$\alpha_f = 0.31984848$

with Unconfined area = $((b_{\text{max}} - 2R)^2 + (h_{\text{max}} - 2R)^2) / 3 = 140733.333$

$b_{\text{max}} = 750.00$

$h_{\text{max}} = 750.00$

From EC8 A.4.4.3(6), $p_f = 2t_f / b_w = 0.00508$

$b_w = 400.00$

effective stress from (A.35), $f_{f,e} = 870.5244$

R = 40.00

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

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{f,e} = 0.015$

α_{se} ((5.4d), TBDY) = $(\alpha_{se1} \cdot A_{\text{ext}} + \alpha_{se2} \cdot A_{\text{int}}) / A_{\text{sec}} = 0.45746528$

$\alpha_{se1} = \text{Max}(((A_{\text{conf,max1}} - A_{\text{noConf1}}) / A_{\text{conf,max1}}) \cdot (A_{\text{conf,min1}} / A_{\text{conf,max1}}), 0) = 0.45746528$

The definitions of A_{noConf} , $A_{\text{conf,min}}$ and $A_{\text{conf,max}}$ are derived from generalization

of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max1} = 353600.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the external perimeter hoops.
 $A_{conf,min1} = 293525.00$ is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area $A_{conf,max1}$ by a length equal to half the clear spacing between external hoops.

$A_{noConf1} = 158733.333$ is the unconfined external core area which is equal to $b_i^2/6$ as defined at (A.2).
 $ase2 (>= ase1) = \text{Max}(((A_{conf,max2} - A_{noConf2})/A_{conf,max2}) * (A_{conf,min2}/A_{conf,max2}), 0) = 0.45746528$

The definitions of A_{noConf} , $A_{conf,min}$ and $A_{conf,max}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max2} = 171264.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.
 $A_{conf,min2} = 54741.00$ is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area $A_{conf,max2}$ by a length equal to half the clear spacing between internal hoops.

$A_{noConf2} = 106242.667$ is the unconfined internal core area which is equal to $b_i^2/6$ as defined at (A.2).
 $psh_{min} * F_{ywe} = \text{Min}(psh_x * F_{ywe}, psh_y * F_{ywe}) = 2.92621$

Expression (5.4d) 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)

 $psh_x * F_{ywe} = psh1 * F_{ywe1} + ps2 * F_{ywe2} = 2.92621$
 $psh1$ ((5.4d), TBDY) = $L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00367709$
 L_{stir1} (Length of stirrups along Y) = 2060.00
 A_{stir1} (stirrups area) = 78.53982
 $psh2$ (5.4d) = $L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00067082$
 L_{stir2} (Length of stirrups along Y) = 1468.00
 A_{stir2} (stirrups area) = 50.26548

 $psh_y * F_{ywe} = psh1 * F_{ywe1} + ps2 * F_{ywe2} = 2.92621$
 $psh1$ ((5.4d), TBDY) = $L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00367709$
 L_{stir1} (Length of stirrups along X) = 2060.00
 A_{stir1} (stirrups area) = 78.53982
 $psh2$ ((5.4d), TBDY) = $L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00067082$
 L_{stir2} (Length of stirrups along X) = 1468.00
 A_{stir2} (stirrups area) = 50.26548

 $A_{sec} = 440000.00$

$s1 = 100.00$

$s2 = 250.00$

$f_{ywe1} = 694.4444$

$f_{ywe2} = 555.5556$

$f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY: $cc = 0.00238888$

$c = \text{confinement factor} = 1.03889$

$y1 = 0.00145721$

$sh1 = 0.00466307$

$ft1 = 459.4373$

$fy1 = 382.8645$

$su1 = 0.00582756$

using (30) in Biskinis/Fardis (2013) multiplied with $shear_factor$ and also multiplied by the $shear_factor$ according to 15.7.1.4, with $Shear_factor = 1.00$

$lo/lo_{u,min} = lb/ld = 0.318426$

$su1 = 0.4 * esu1_nominal$ ((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 $fs1 = (fs_{jacket} * A_{sl,ten,jacket} + fs_{core} * A_{sl,ten,core}) / A_{sl,ten} = 382.8645$

with $Es1 = (Es_{jacket} * A_{sl,ten,jacket} + Es_{core} * A_{sl,ten,core}) / A_{sl,ten} = 200000.00$

$y2 = 0.00145721$

$sh_2 = 0.00466307$
 $ft_2 = 465.423$
 $fy_2 = 387.8525$
 $su_2 = 0.00582756$
 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
 $lo/lo_{u,min} = lb/lb_{u,min} = 0.318426$
 $su_2 = 0.4 * esu_{2,nominal} ((5.5), TBDY) = 0.032$
 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 $fs_2 = (fs_{jacket} * Asl_{com,jacket} + fs_{core} * Asl_{com,core}) / Asl_{com} = 387.8525$
 with $Es_2 = (Es_{jacket} * Asl_{com,jacket} + Es_{core} * Asl_{com,core}) / Asl_{com} = 200000.00$
 $yv = 0.00145721$
 $shv = 0.00466307$
 $ftv = 463.3885$
 $fyv = 386.157$
 $suv = 0.00582756$
 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
 $lo/lo_{u,min} = lb/ld = 0.318426$
 $suv = 0.4 * esuv_{nominal} ((5.5), TBDY) = 0.032$
 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 $fsv = (fs_{jacket} * Asl_{mid,jacket} + fs_{mid} * Asl_{mid,core}) / Asl_{mid} = 386.157$
 with $Es_v = (Es_{jacket} * Asl_{mid,jacket} + Es_{mid} * Asl_{mid,core}) / Asl_{mid} = 200000.00$
 $1 = Asl_{ten} / (b * d) * (fs_1 / fc) = 0.02488335$
 $2 = Asl_{com} / (b * d) * (fs_2 / fc) = 0.04895276$
 $v = Asl_{mid} / (b * d) * (fsv / fc) = 0.04430167$

and confined core properties:

$b = 690.00$
 $d = 677.00$
 $d' = 13.00$
 $fcc (5A.2, TBDY) = 34.2833$
 $cc (5A.5, TBDY) = 0.00238888$
 $c = \text{confinement factor} = 1.03889$
 $1 = Asl_{ten} / (b * d) * (fs_1 / fc) = 0.02824566$
 $2 = Asl_{com} / (b * d) * (fs_2 / fc) = 0.05556741$
 $v = Asl_{mid} / (b * d) * (fsv / fc) = 0.05028784$

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

--->
 $v < v_{s,y_2}$ - LHS eq.(4.5) is satisfied
 --->
 $su (4.9) = 0.13760581$
 $Mu = MRc (4.14) = 5.1260E+008$
 $u = su (4.1) = 9.5578758E-006$

 Calculation of ratio lb/ld

 Lap Length: $lb/ld = 0.318426$
 $lb = 300.00$
 $ld = 942.1341$
 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: $fy = 655.5556$
 Mean concrete strength: $fc' = (fc'_{jacket} * Area_{jacket} + fc'_{core} * Area_{core}) / Area_{section} = 27.68182$, but $fc'^{0.5} <=$
 $8.3 \text{ MPa} (22.5.3.1, ACI 318-14)$
 $t = 1.00$

$s = 0.80$
 $e = 1.00$
 $cb = 25.00$
 $K_{tr} = 1.7174$
 $A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 257.6106$
 where A_{tr_x} , A_{tr_y} are the sum of the area of all stirrup legs along X and Y local axis
 $s = \text{Max}(s_{\text{external}}, s_{\text{internal}}) = 250.00$
 $n = 24.00$

 Calculation of μ_2 -

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

$u = 1.0408734E-005$
 $\mu = 8.2924E+008$

 with full section properties:

$b = 400.00$
 $d = 707.00$
 $d' = 43.00$
 $v = 0.00174378$
 $N = 16273.616$

$f_c = 33.00$
 $\alpha_{co} (5A.5, \text{TBDY}) = 0.002$

Final value of μ : $\mu^* = \text{shear_factor} * \text{Max}(\mu_c, \mu_s) = 0.01288354$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $\mu_c = 0.01288354$

where $\mu_s ((5.4c), \text{TBDY}) = \alpha_{se} * \text{sh}_{\text{min}} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.05503171$

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

 $f_x = 0.04286225$

Expression ((15B.6), TBDY) is modified as $\alpha_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$\alpha_f = 0.31984848$

with Unconfined area = $((b_{\text{max}} - 2R)^2 + (h_{\text{max}} - 2R)^2) / 3 = 140733.333$

$b_{\text{max}} = 750.00$

$h_{\text{max}} = 750.00$

From EC8 A.4.4.3(6), $p_f = 2t_f / b_w = 0.00508$

$b_w = 400.00$

effective stress from (A.35), $f_{fe} = 870.5244$

 $f_y = 0.04286225$

Expression ((15B.6), TBDY) is modified as $\alpha_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$\alpha_f = 0.31984848$

with Unconfined area = $((b_{\text{max}} - 2R)^2 + (h_{\text{max}} - 2R)^2) / 3 = 140733.333$

$b_{\text{max}} = 750.00$

$h_{\text{max}} = 750.00$

From EC8 A.4.4.3(6), $p_f = 2t_f / b_w = 0.00508$

$b_w = 400.00$

effective stress from (A.35), $f_{fe} = 870.5244$

 $R = 40.00$

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

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{,f} = 0.015$

$\alpha_{se} ((5.4d), \text{TBDY}) = (\alpha_{se1} * A_{\text{ext}} + \alpha_{se2} * A_{\text{int}}) / A_{\text{sec}} = 0.45746528$

$\alpha_{se1} = \text{Max}(((A_{\text{conf,max1}} - A_{\text{noConf1}}) / A_{\text{conf,max1}}) * (A_{\text{conf,min1}} / A_{\text{conf,max1}}), 0) = 0.45746528$

The definitions of A_{noConf} , $A_{\text{conf,min}}$ and $A_{\text{conf,max}}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{\text{conf,max1}} = 353600.00$ is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

Aconf,min1 = 293525.00 is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area Aconf,max1 by a length equal to half the clear spacing between external hoops.

AnoConf1 = 158733.333 is the unconfined external core area which is equal to $bi^2/6$ as defined at (A.2).
ase2 (\geq ase1) = $\text{Max}(((Aconf,max2 - AnoConf2)/Aconf,max2) * (Aconf,min2/Aconf,max2), 0) = 0.45746528$

The definitions of AnoConf, Aconf,min and Aconf,max are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

Aconf,max2 = 171264.00 is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

Aconf,min2 = 54741.00 is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area Aconf,max2 by a length equal to half the clear spacing between internal hoops.

AnoConf2 = 106242.667 is the unconfined internal core area which is equal to $bi^2/6$ as defined at (A.2).
psh,min*Fywe = $\text{Min}(psh,x*Fywe, psh,y*Fywe) = 2.92621$

Expression (5.4d) 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 = 2.92621
psh1 ((5.4d), TBDY) = $Lstir1 * Astir1 / (Asec * s1) = 0.00367709$

Lstir1 (Length of stirrups along Y) = 2060.00

Astir1 (stirrups area) = 78.53982

psh2 (5.4d) = $Lstir2 * Astir2 / (Asec * s2) = 0.00067082$

Lstir2 (Length of stirrups along Y) = 1468.00

Astir2 (stirrups area) = 50.26548

psh_y*Fywe = psh1*Fywe1 + ps2*Fywe2 = 2.92621
psh1 ((5.4d), TBDY) = $Lstir1 * Astir1 / (Asec * s1) = 0.00367709$

Lstir1 (Length of stirrups along X) = 2060.00

Astir1 (stirrups area) = 78.53982

psh2 ((5.4d), TBDY) = $Lstir2 * Astir2 / (Asec * s2) = 0.00067082$

Lstir2 (Length of stirrups along X) = 1468.00

Astir2 (stirrups area) = 50.26548

Asec = 440000.00

s1 = 100.00

s2 = 250.00

fywe1 = 694.4444

fywe2 = 555.5556

fce = 33.00

From ((5.A5), TBDY), TBDY: cc = 0.00238888

c = confinement factor = 1.03889

y1 = 0.00145721

sh1 = 0.00466307

ft1 = 465.423

fy1 = 387.8525

su1 = 0.00582756

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 = 0.318426

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 = $(fs_jacket * Asl,ten,jacket + fs_core * Asl,ten,core) / Asl,ten = 387.8525$

with Es1 = $(Es_jacket * Asl,ten,jacket + Es_core * Asl,ten,core) / Asl,ten = 200000.00$

y2 = 0.00145721

sh2 = 0.00466307

ft2 = 459.4373

fy2 = 382.8645

su2 = 0.00582756

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 = 0.318426

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 = 382.8645

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

yv = 0.00145721

shv = 0.00466307

ftv = 463.3885

fyv = 386.157

suv = 0.00582756

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 = 0.318426

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 = 386.157

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

1 = Asl,ten/(b*d)*(fs1/fc) = 0.09178643

2 = Asl,com/(b*d)*(fs2/fc) = 0.04665628

v = Asl,mid/(b*d)*(fsv/fc) = 0.08306563

and confined core properties:

b = 340.00

d = 677.00

d' = 13.00

fcc (5A.2, TBDY) = 34.2833

cc (5A.5, TBDY) = 0.00238888

c = confinement factor = 1.03889

1 = Asl,ten/(b*d)*(fs1/fc) = 0.11276915

2 = Asl,com/(b*d)*(fs2/fc) = 0.05732208

v = Asl,mid/(b*d)*(fsv/fc) = 0.10205474

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

v < vs,y2 - LHS eq.(4.5) is satisfied

--->

su (4.9) = 0.20810191

Mu = MRc (4.14) = 8.2924E+008

u = su (4.1) = 1.0408734E-005

Calculation of ratio lb/ld

Lap Length: lb/ld = 0.318426

lb = 300.00

ld = 942.1341

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 = 655.5556

Mean concrete strength: fc' = (fc',jacket*Area_jacket + fc',core*Area_core)/Area_section = 27.68182, but $fc'^{0.5} <=$ 8.3 MPa (22.5.3.1, ACI 318-14)

t = 1.00

s = 0.80

e = 1.00

cb = 25.00

Ktr = 1.7174

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

$$s = \text{Max}(s_{\text{external}}, s_{\text{internal}}) = 250.00$$

$$n = 24.00$$

$$\text{Calculation of Shear Strength } V_r = \text{Min}(V_{r1}, V_{r2}) = 998292.205$$

$$\text{Calculation of Shear Strength at edge 1, } V_{r1} = 998292.205$$

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

$$V_{\text{Col}0} = 998292.205$$

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

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

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

$$\text{Mean concrete strength: } f_c' = (f_c'_{\text{jacket}} * \text{Area}_{\text{jacket}} + f_c'_{\text{core}} * \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 27.68182, \text{ but } f_c'^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

$$M/Vd = 4.00$$

$$\mu_u = 11.78089$$

$$V_u = 0.00051441$$

$$d = 0.8 * h = 600.00$$

$$N_u = 16273.616$$

$$A_g = 300000.00$$

$$\text{From (11.5.4.8), ACI 318-14: } V_s = V_{s,\text{jacket}} + V_{s,\text{core}} = 881489.011$$

where:

$$V_{s,\text{jacket}} = V_{s,j1} + V_{s,j2} = 802851.456$$

$$V_{s,j1} = 279252.68 \text{ is calculated for section web jacket, with:}$$

$$d = 320.00$$

$$A_v = 157079.633$$

$$f_y = 555.5556$$

$$s = 100.00$$

$$V_{s,j1} \text{ is multiplied by } \text{Col},j1 = 1.00$$

$$s/d = 0.3125$$

$$V_{s,j2} = 523598.776 \text{ is calculated for section flange jacket, with:}$$

$$d = 600.00$$

$$A_v = 157079.633$$

$$f_y = 555.5556$$

$$s = 100.00$$

$$V_{s,j2} \text{ is multiplied by } \text{Col},j2 = 1.00$$

$$s/d = 0.16666667$$

$$V_{s,\text{core}} = V_{s,c1} + V_{s,c2} = 78637.555$$

$$V_{s,c1} = 0.00 \text{ is calculated for section web core, with:}$$

$$d = 160.00$$

$$A_v = 100530.965$$

$$f_y = 444.4444$$

$$s = 250.00$$

$$V_{s,c1} \text{ is multiplied by } \text{Col},c1 = 0.00$$

$$s/d = 1.5625$$

$$V_{s,c2} = 78637.555 \text{ is calculated for section flange core, with:}$$

$$d = 440.00$$

$$A_v = 100530.965$$

$$f_y = 444.4444$$

$$s = 250.00$$

$$V_{s,c2} \text{ is multiplied by } \text{Col},c2 = 1.00$$

$$s/d = 0.56818182$$

$$V_f \text{ ((11-3)-(11.4), ACI 440)} = 372533.843$$

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

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

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

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

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

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

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

$dfv = d$ (figure 11.2, ACI 440) = 707.00
 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: $Vs + Vf \leq 838832.606$
 $bw = 400.00$

Calculation of Shear Strength at edge 2, $Vr2 = 998292.205$
 $Vr2 = VCol$ ((10.3), ASCE 41-17) = $knl * VCol0$
 $VCol0 = 998292.205$
 $knl = 1$ (zero step-static loading)

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

= 1 (normal-weight concrete)
Mean concrete strength: $fc' = (fc'_{jacket} * Area_{jacket} + fc'_{core} * Area_{core}) / Area_{section} = 27.68182$, but $fc'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 4.00$

$Mu = 11.78144$

$Vu = 0.00051441$

$d = 0.8 * h = 600.00$

$Nu = 16273.616$

$Ag = 300000.00$

From (11.5.4.8), ACI 318-14: $Vs = Vs_{jacket} + Vs_{core} = 881489.011$

where:

$Vs_{jacket} = Vs_{j1} + Vs_{j2} = 802851.456$

$Vs_{j1} = 279252.68$ is calculated for section web jacket, with:

$d = 320.00$

$Av = 157079.633$

$fy = 555.5556$

$s = 100.00$

Vs_{j1} is multiplied by $Col_{j1} = 1.00$

$s/d = 0.3125$

$Vs_{j2} = 523598.776$ is calculated for section flange jacket, with:

$d = 600.00$

$Av = 157079.633$

$fy = 555.5556$

$s = 100.00$

Vs_{j2} is multiplied by $Col_{j2} = 1.00$

$s/d = 0.16666667$

$Vs_{core} = Vs_{c1} + Vs_{c2} = 78637.555$

$Vs_{c1} = 0.00$ is calculated for section web core, with:

$d = 160.00$

$Av = 100530.965$

$fy = 444.4444$

$s = 250.00$

Vs_{c1} is multiplied by $Col_{c1} = 0.00$

$s/d = 1.5625$

$Vs_{c2} = 78637.555$ is calculated for section flange core, with:

$d = 440.00$

$Av = 100530.965$

$fy = 444.4444$

$s = 250.00$

Vs_{c2} is multiplied by $Col_{c2} = 1.00$

$s/d = 0.56818182$

Vf ((11-3)-(11.4), ACI 440) = 372533.843

$f = 0.95$, for fully-wrapped sections

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

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

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

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

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

total thickness per orientation, $t_{f1} = NL \cdot t / \text{NoDir} = 1.016$
 $d_{fv} = d$ (figure 11.2, ACI 440) = 707.00
 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: $V_s + V_f \leq 838832.606$
 $b_w = 400.00$

End Of Calculation of Shear Capacity ratio for element: column JLC1 of floor 1
At local axis: 2

Start Of Calculation of Chord Rotation Capacity for element: column JLC1 of floor 1
At local axis: 3

Integration Section: (a)
Section Type: rcjlcs

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 Secondary Member: Concrete Strength, $f_c = f_{cm} = 33.00$
New material of Secondary Member: Steel Strength, $f_s = f_{sm} = 555.5556$
Concrete Elasticity, $E_c = 26999.444$
Steel Elasticity, $E_s = 200000.00$
Existing Column
Existing material of Secondary Member: Concrete Strength, $f_c = f_{cm} = 20.00$
Existing material of Secondary Member: Steel Strength, $f_s = f_{sm} = 444.4444$
Concrete Elasticity, $E_c = 21019.039$
Steel Elasticity, $E_s = 200000.00$
Max Height, $H_{max} = 750.00$
Min Height, $H_{min} = 400.00$
Max Width, $W_{max} = 750.00$
Min Width, $W_{min} = 400.00$
Jacket Thickness, $t_j = 100.00$
Cover Thickness, $c = 25.00$
Element Length, $L = 3000.00$
Secondary Member
Ribbed Bars
Ductile Steel
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
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, $\text{NoDir} = 1$
Fiber orientations, $b_i = 0.00^\circ$
Number of layers, $NL = 1$
Radius of rounding corners, $R = 40.00$

Stepwise Properties

Bending Moment, $M = -2.3777E+007$
Shear Force, $V_2 = -7895.087$

Shear Force, $V_3 = 147.9094$
 Axial Force, $F = -17072.715$
 Longitudinal Reinforcement Area Distribution (in 2 divisions)
 -Tension: $As_t = 0.00$
 -Compression: $As_c = 5353.274$
 Longitudinal Reinforcement Area Distribution (in 3 divisions)
 -Tension: $As_{,ten} = 1137.257$
 -Compression: $As_{,com} = 2208.54$
 -Middle: $As_{,mid} = 2007.478$
 Longitudinal External Reinforcement Area Distribution (in 3 divisions)
 -Tension: $As_{,ten,jacket} = 829.3805$
 -Compression: $As_{,com,jacket} = 1746.726$
 -Middle: $As_{,mid,jacket} = 1545.664$
 Longitudinal Internal Reinforcement Area Distribution (in 3 divisions)
 -Tension: $As_{,ten,core} = 307.8761$
 -Compression: $As_{,com,core} = 461.8141$
 -Middle: $As_{,mid,core} = 461.8141$
 Mean Diameter of Tension Reinforcement, $Db_L = 16.80$

Existing component: From table 7-7, ASCE 41_17: Final chord rotation Capacity $u_{,R} = u = 0.00247915$
 $u = y + p = 0.00291665$

- Calculation of y -

$y = (M_y * L_s / 3) / E_{eff} = 0.00291665$ ((4.29), Biskinis Phd)
 $M_y = 4.2101E+008$
 $L_s = M/V$ (with $L_s > 0.1 * L$ and $L_s < 2 * L$) = 3011.649
 From table 10.5, ASCE 41_17: $E_{eff} = factor * E_c * I_g = 1.4491E+014$
 $factor = 0.30$
 $A_g = 440000.00$
 Mean concrete strength: $fc' = (fc'_{jacket} * Area_{jacket} + fc'_{core} * Area_{core}) / Area_{section} = 27.68182$
 $N = 17072.715$
 $E_c * I_g = E_{c,jacket} * I_{g,jacket} + E_{c,core} * I_{g,core} = 4.8303E+014$

Calculation of Yielding Moment M_y

Calculation of y and M_y according to Annex 7 -

Assuming neutral axis within flange ($y < t/d$, compression zone rectangular) with:

flange width, $b = 750.00$
 web width, $b_w = 400.00$
 flange thickness, $t = 400.00$

$y = \text{Min}(y_{ten}, y_{com})$
 $y_{ten} = 3.1432128E-006$
 with ((10.1), ASCE 41-17) $f_y = \text{Min}(f_y, 1.25 * f_y * (I_b / I_d)^{2/3}) = 358.4764$
 $d = 707.00$
 $y = 0.19343861$
 $A = 0.01018557$
 $B = 0.00449598$
 with $pt = 0.00671906$
 $pc = 0.00416509$
 $pv = 0.00378591$
 $N = 17072.715$
 $b = 750.00$
 $" = 0.06082037$
 $y_{comp} = 1.6462519E-005$
 with $fc' (12.3, (ACI 440)) = 33.48734$
 $fc = 33.00$
 $fl = 0.49678681$
 $b = b_{max} = 750.00$

$h = h_{max} = 750.00$
 $A_g = 0.44$
 $g = p_t + p_c + p_v = 0.01009575$
 $rc = 40.00$
 $A_e/A_c = 0.31291181$
 Effective FRP thickness, $t_f = NL \cdot t \cdot \cos(b_1) = 1.016$
 effective strain from (12.5) and (12.12), $\epsilon_{fe} = 0.004$
 $f_u = 0.01$
 $E_f = 64828.00$
 $E_c = 26999.444$
 $y = 0.19181501$
 $A = 0.01002364$
 $B = 0.00440616$
 with $E_s = 200000.00$

CONFIRMATION: $y = 0.19279145 < t/d$

Calculation of ratio l_b/l_d

Lap Length: $l_d/l_{d,min} = 0.39803249$

$l_b = 300.00$

$l_d = 753.7073$

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: $f_y = 524.4444$

Mean concrete strength: $f'_c = (f'_{c,jacket} \cdot Area_{jacket} + f'_{c,core} \cdot Area_{core}) / Area_{section} = 27.68182$, but $f_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 1.7174$

$A_{tr} = \min(A_{tr,x}, A_{tr,y}) = 257.6106$

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

$s = \max(s_{external}, s_{internal}) = 250.00$

$n = 24.00$

- Calculation of ρ -

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 $V_y E / V_{CoI} E = 0.55377356$

$d = d_{external} = 707.00$

$s = s_{external} = 0.00$

- $t = s_1 + s_2 + 2 \cdot t_f / bw \cdot (f_{fe} / f_s) = 0.00671906$

jacket: $s_1 = A_{v1} \cdot L_{stir1} / (s_1 \cdot A_g) = 0.00367709$

$A_{v1} = 78.53982$, is the area of every stirrup parallel to loading (shear) direction

$L_{stir1} = 2060.00$, is the total Length of all stirrups parallel to loading (shear) direction

$s_1 = 100.00$

core: $s_2 = A_{v2} \cdot L_{stir2} / (s_2 \cdot A_g) = 0.00067082$

$A_{v2} = 50.26548$, is the area of every stirrup parallel to loading (shear) direction

$L_{stir2} = 1468.00$, is the total Length of all stirrups parallel to loading (shear) direction

$s_2 = 250.00$

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

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

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

For the normalisation f_s of jacket is used.

$NUD = 17072.715$

$A_g = 440000.00$

$f'_c E = (f'_{c,jacket} \cdot Area_{jacket} + f'_{c,core} \cdot Area_{core}) / section_area = 27.68182$

$f_y E = (f_{y,ext_Long_Reinf} \cdot Area_{ext_Long_Reinf} + f_{y,int_Long_Reinf} \cdot Area_{int_Long_Reinf}) / Area_{Tot_Long_Rein} = 529.9948$

$f_y E = (f_{y,ext_Trans_Reinf} \cdot s_1 + f_{y,int_Trans_Reinf} \cdot s_2) / (s_1 + s_2) = 538.4128$

$$p_l = \text{Area_Tot_Long_Rein}/(b*d) = 0.01009575$$

$$b = 750.00$$

$$d = 707.00$$

$$f_{cE} = 27.68182$$

End Of Calculation of Chord Rotation Capacity for element: column JLC1 of floor 1

At local axis: 3

Integration Section: (a)

Calculation No. 5

column C1, Floor 1

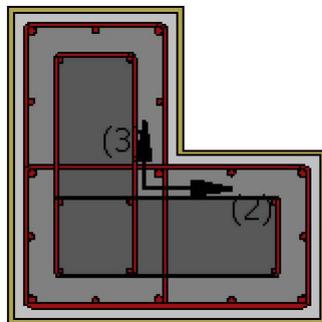
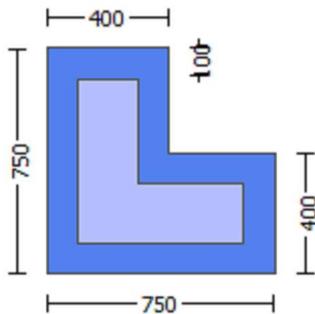
Limit State: Operational Level (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Shear capacity VRd

Edge: End

Local Axis: (2)



Start Of Calculation of Shear Capacity for element: column JLC1 of floor 1

At local axis: 2

Integration Section: (b)

Section Type: rcjls

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 Secondary Member: Concrete Strength, $f_c = f_{c_lower_bound} = 25.00$

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

Concrete Elasticity, $E_c = 26999.444$

Steel Elasticity, $E_s = 200000.00$

```

Existing Column
Existing material of Secondary Member: Concrete Strength, fc = fc_lower_bound = 16.00
Existing material of Secondary Member: Steel Strength, fs = fs_lower_bound = 400.00
Concrete Elasticity, Ec = 21019.039
Steel Elasticity, Es = 200000.00
#####
Note: Especially for the calculation of  $\gamma$  for displacement ductility demand,
the expected (mean value) strengths are used (7.5.1.3, ASCE 41-17) because bending is considered as
Deformation-Controlled Action (Table C7-1, ASCE 41-17).
Jacket
New material: Concrete Strength, fc = fcm = 33.00
New material: Steel Strength, fs = fsm = 555.5556
Existing Column
Existing material: Concrete Strength, fc = fcm = 20.00
Existing material: Steel Strength, fs = fsm = 444.4444
#####
Max Height, Hmax = 750.00
Min Height, Hmin = 400.00
Max Width, Wmax = 750.00
Min Width, Wmin = 400.00
Jacket Thickness, tj = 100.00
Cover Thickness, c = 25.00
Element Length, L = 3000.00
Secondary Member
Ribbed Bars
Ductile Steel
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
Lap Length lo = lb = 300.00
FRP Wrapping Data
Type: Carbon
Cured laminate properties (design values)
Thickness, t = 1.016
Tensile Strength, ffu = 1055.00
Tensile Modulus, Ef = 64828.00
Elongation, efu = 0.01
Number of directions, NoDir = 1
Fiber orientations, bi: 0.00°
Number of layers, NL = 1
Radius of rounding corners, R = 40.00
-----

Stepwise Properties
-----
EDGE -A-
Bending Moment, Ma = -2.3777E+007
Shear Force, Va = -7895.087
EDGE -B-
Bending Moment, Mb = 86052.274
Shear Force, Vb = 7895.087
BOTH EDGES
Axial Force, F = -17072.715
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: Aslt = 0.00
-Compression: Aslc = 5353.274
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension: Asl,ten = 1137.257
-Compression: Asl,com = 2208.54
-Middle: Asl,mid = 2007.478
Mean Diameter of Tension Reinforcement, DbL,ten = 16.80
-----
-----

Existing component: From table 7-7, ASCE 41_17: Final Shear Capacity VR =  $\phi V_n = 864068.364$ 
Vn ((10.3), ASCE 41-17) = knl*VColO = 1.0166E+006
VCol = 1.0166E+006

```

knl = 1.00
displacement_ductility_demand = 0.08537299

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

= 1 (normal-weight concrete)

Mean concrete strength: $f_c' = (f_c'_{\text{jacket}} \cdot \text{Area}_{\text{jacket}} + f_c'_{\text{core}} \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 21.31818$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$M_u = 86052.274$

$V_u = 7895.087$

$d = 0.8 \cdot h = 600.00$

$N_u = 17072.715$

$A_g = 300000.00$

From (11.5.4.8), ACI 318-14: $V_s = V_{s,\text{jacket}} + V_{s,\text{core}} = 793340.11$

where:

$V_{s,\text{jacket}} = V_{s,j1} + V_{s,j2} = 722566.31$

$V_{s,j1} = 251327.412$ is calculated for section web jacket, with:

$d = 320.00$

$A_v = 157079.633$

$f_y = 500.00$

$s = 100.00$

$V_{s,j1}$ is multiplied by $\text{Col},j1 = 1.00$

$s/d = 0.3125$

$V_{s,j2} = 471238.898$ is calculated for section flange jacket, with:

$d = 600.00$

$A_v = 157079.633$

$f_y = 500.00$

$s = 100.00$

$V_{s,j2}$ is multiplied by $\text{Col},j2 = 1.00$

$s/d = 0.16666667$

$V_{s,\text{core}} = V_{s,c1} + V_{s,c2} = 70773.799$

$V_{s,c1} = 0.00$ is calculated for section web core, with:

$d = 160.00$

$A_v = 100530.965$

$f_y = 400.00$

$s = 250.00$

$V_{s,c1}$ is multiplied by $\text{Col},c1 = 0.00$

$s/d = 1.5625$

$V_{s,c2} = 70773.799$ is calculated for section flange core, with:

$d = 440.00$

$A_v = 100530.965$

$f_y = 400.00$

$s = 250.00$

$V_{s,c2}$ is multiplied by $\text{Col},c2 = 1.00$

$s/d = 0.56818182$

V_f ((11-3)-(11.4), ACI 440) = 372533.843

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

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

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

$d_{fv} = d$ (figure 11.2, ACI 440) = 707.00

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: $V_s + V_f \leq 736127.561$

$b_w = 400.00$

displacement_ductility_demand is calculated as δ / y

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

From analysis, chord rotation = $2.4803976E-005$

$y = (M_y * L_s / 3) / E_{eff} = 0.00029054$ ((4.29), Biskinis Phd)

$M_y = 4.2101E+008$

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

From table 10.5, ASCE 41_17: $E_{eff} = factor * E_c * I_g = 1.4491E+014$

factor = 0.30

$A_g = 440000.00$

Mean concrete strength: $f'_c = (f'_{c_jacket} * Area_{jacket} + f'_{c_core} * Area_{core}) / Area_{section} = 27.68182$

$N = 17072.715$

$E_c * I_g = E_{c_jacket} * I_{g_jacket} + E_{c_core} * I_{g_core} = 4.8303E+014$

Calculation of Yielding Moment M_y

Calculation of δ / y and M_y according to Annex 7 -

Assuming neutral axis within flange ($y < t/d$, compression zone rectangular) with:

flange width, $b = 750.00$

web width, $b_w = 400.00$

flange thickness, $t = 400.00$

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

$y_{ten} = 3.1432128E-006$

with ((10.1), ASCE 41-17) $f_y = \text{Min}(f_y, 1.25 * f_y * (I_b / I_d)^{2/3}) = 358.4764$

$d = 707.00$

$y = 0.19343861$

$A = 0.01018557$

$B = 0.00449598$

with $p_t = 0.00214476$

$p_c = 0.00416509$

$p_v = 0.00378591$

$N = 17072.715$

$b = 750.00$

" = 0.06082037

$y_{comp} = 1.6462519E-005$

with f'_c (12.3, (ACI 440)) = 33.48734

$f_c = 33.00$

$f_l = 0.49678681$

$b = b_{max} = 750.00$

$h = h_{max} = 750.00$

$A_g = 0.44$

$g = p_t + p_c + p_v = 0.01009575$

$r_c = 40.00$

$A_e / A_c = 0.31291181$

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

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

$f_u = 0.01$

$E_f = 64828.00$

$E_c = 26999.444$

$y = 0.19181501$

$A = 0.01002364$

$B = 0.00440616$

with $E_s = 200000.00$

CONFIRMATION: $y = 0.19279145 < t/d$

Calculation of ratio I_b / I_d

Lap Length: $I_d / I_{d,min} = 0.39803249$

$I_b = 300.00$

ld = 753.7073

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 = 524.4444

Mean concrete strength: fc' = (fc'_jacket*Area_jacket + fc'_core*Area_core)/Area_section = 27.68182, but fc'^0.5 <= 8.3 MPa (22.5.3.1, ACI 318-14)

t = 1.00

s = 0.80

e = 1.00

cb = 25.00

Ktr = 1.7174

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) = 250.00

n = 24.00

End Of Calculation of Shear Capacity for element: column JLC1 of floor 1

At local axis: 2

Integration Section: (b)

Calculation No. 6

column C1, Floor 1

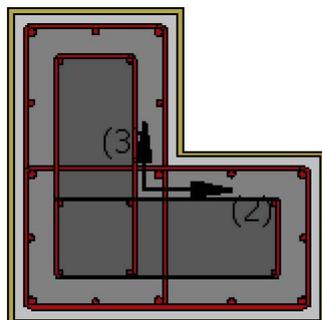
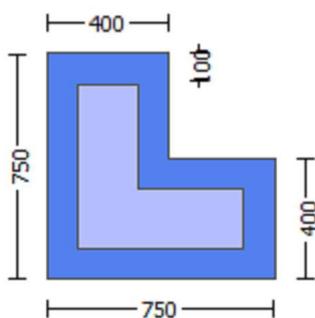
Limit State: Operational Level (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity (u)

Edge: End

Local Axis: (2)



Start Of Calculation of Shear Capacity ratio for element: column JLC1 of floor 1

At Shear local axis: 3

(Bending local axis: 2)

Section Type: rcjlc

Constant Properties

Knowledge Factor, $\phi = 0.85$
Mean strength values are used for both shear and moment calculations.
Consequently:
Jacket
New material of Secondary Member: Concrete Strength, $f_c = f_{cm} = 33.00$
New material of Secondary Member: Steel Strength, $f_s = f_{sm} = 555.5556$
Concrete Elasticity, $E_c = 26999.444$
Steel Elasticity, $E_s = 200000.00$
Existing Column
Existing material of Secondary Member: Concrete Strength, $f_c = f_{cm} = 20.00$
Existing material of Secondary Member: Steel Strength, $f_s = f_{sm} = 444.4444$
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, $f_s = 1.25 * f_{sm} = 694.4444$
Existing Column
Existing material: Steel Strength, $f_s = 1.25 * f_{sm} = 555.5556$

Max Height, $H_{max} = 750.00$
Min Height, $H_{min} = 400.00$
Max Width, $W_{max} = 750.00$
Min Width, $W_{min} = 400.00$
Jacket Thickness, $t_j = 100.00$
Cover Thickness, $c = 25.00$
Mean Confinement Factor overall section = 1.03889
Element Length, $L = 3000.00$
Secondary Member
Ribbed Bars
Ductile Steel
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
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, $V_a = -0.00051441$
EDGE -B-
Shear Force, $V_b = 0.00051441$
BOTH EDGES
Axial Force, $F = -16273.616$
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: $As_t = 0.00$
-Compression: $As_c = 5353.274$
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension: $As_{t,ten} = 1137.257$
-Compression: $As_{l,com} = 2208.54$
-Middle: $As_{l,mid} = 2007.478$

Calculation of Shear Capacity ratio , $V_e/V_r = 0.55377356$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 552827.824$
with

$M_{pr1} = \text{Max}(M_{u1+} , M_{u1-}) = 8.2924E+008$

$M_{u1+} = 5.1260E+008$, 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

$M_{u1-} = 8.2924E+008$, 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

$M_{pr2} = \text{Max}(M_{u2+} , M_{u2-}) = 8.2924E+008$

$M_{u2+} = 5.1260E+008$, 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

$M_{u2-} = 8.2924E+008$, 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 ϕ_u according to 4.1, Biskinis/Fardis 2013:

$\phi_u = 9.5578758E-006$

$M_u = 5.1260E+008$

with full section properties:

$b = 750.00$

$d = 707.00$

$d' = 43.00$

$v = 0.00093001$

$N = 16273.616$

$f_c = 33.00$

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

Final value of ϕ_u : $\phi_u^* = \text{shear_factor} * \text{Max}(\phi_u, \phi_c) = 0.01288354$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $\phi_u = 0.01288354$

ω_e ((5.4c), TBDY) = $\alpha \text{se} * \text{sh}_{\min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.05503171$

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

 $f_x = 0.04286225$

Expression ((15B.6), TBDY) is modified as $\alpha_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$\alpha_f = 0.31984848$

with Unconfined area = $((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 140733.333$

$b_{\max} = 750.00$

$h_{\max} = 750.00$

From EC8 A.4.4.3(6), $p_f = 2t_f / b_w = 0.00508$

$b_w = 400.00$

effective stress from (A.35), $f_{f,e} = 870.5244$

$f_y = 0.04286225$

Expression ((15B.6), TBDY) is modified as $\alpha_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$\alpha_f = 0.31984848$

with Unconfined area = $((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 140733.333$

$b_{\max} = 750.00$

$h_{\max} = 750.00$

From EC8 A.4.4.3(6), $p_f = 2t_f / b_w = 0.00508$

$b_w = 400.00$

effective stress from (A.35), $f_{f,e} = 870.5244$

$R = 40.00$

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

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{f} = 0.015$

α_{se} ((5.4d), TBDY) = $(\alpha_{se1} * A_{ext} + \alpha_{se2} * A_{int}) / A_{sec} = 0.45746528$

$\alpha_{se1} = \text{Max}(((A_{conf,max1} - A_{noConf1}) / A_{conf,max1}) * (A_{conf,min1} / A_{conf,max1}), 0) = 0.45746528$

The definitions of A_{noConf} , $A_{conf,min}$ and $A_{conf,max}$ are derived from generalization

of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max1} = 353600.00$ is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{conf,min1} = 293525.00$ is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area $A_{conf,max1}$ by a length equal to half the clear spacing between external hoops.

$A_{noConf1} = 158733.333$ is the unconfined external core area which is equal to $b_i^2/6$ as defined at (A.2).

$ase2 (>= ase1) = \text{Max}(((A_{conf,max2} - A_{noConf2})/A_{conf,max2}) * (A_{conf,min2}/A_{conf,max2}), 0) = 0.45746528$

The definitions of A_{noConf} , $A_{conf,min}$ and $A_{conf,max}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max2} = 171264.00$ is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

$A_{conf,min2} = 54741.00$ is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area $A_{conf,max2}$ by a length equal to half the clear spacing between internal hoops.

$A_{noConf2} = 106242.667$ is the unconfined internal core area which is equal to $b_i^2/6$ as defined at (A.2).

$p_{sh,min} * F_{ywe} = \text{Min}(p_{sh,x} * F_{ywe}, p_{sh,y} * F_{ywe}) = 2.92621$

Expression (5.4d) 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)

 $p_{sh,x} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{s2} * F_{ywe2} = 2.92621$

p_{sh1} ((5.4d), TBDY) = $L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00367709$

L_{stir1} (Length of stirrups along Y) = 2060.00

A_{stir1} (stirrups area) = 78.53982

p_{sh2} (5.4d) = $L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00067082$

L_{stir2} (Length of stirrups along Y) = 1468.00

A_{stir2} (stirrups area) = 50.26548

 $p_{sh,y} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{s2} * F_{ywe2} = 2.92621$

p_{sh1} ((5.4d), TBDY) = $L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00367709$

L_{stir1} (Length of stirrups along X) = 2060.00

A_{stir1} (stirrups area) = 78.53982

p_{sh2} ((5.4d), TBDY) = $L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00067082$

L_{stir2} (Length of stirrups along X) = 1468.00

A_{stir2} (stirrups area) = 50.26548

 $A_{sec} = 440000.00$

$s1 = 100.00$

$s2 = 250.00$

$f_{ywe1} = 694.4444$

$f_{ywe2} = 555.5556$

$f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY: $cc = 0.00238888$

$c = \text{confinement factor} = 1.03889$

$y1 = 0.00145721$

$sh1 = 0.00466307$

$ft1 = 459.4373$

$fy1 = 382.8645$

$su1 = 0.00582756$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor

and also multiplied by the shear_factor according to 15.7.1.4, with

$\text{Shear_factor} = 1.00$

$l_o/l_{o,min} = l_b/l_d = 0.318426$

$su1 = 0.4 * esu1_{nominal}$ ((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 $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE 41-17.

with $fs1 = (f_{s,jacket} * A_{sl,ten,jacket} + f_{s,core} * A_{sl,ten,core}) / A_{sl,ten} = 382.8645$

with $Es1 = (E_{s,jacket} * A_{sl,ten,jacket} + E_{s,core} * A_{sl,ten,core}) / A_{sl,ten} = 200000.00$

$y2 = 0.00145721$

$sh_2 = 0.00466307$
 $ft_2 = 465.423$
 $fy_2 = 387.8525$
 $su_2 = 0.00582756$
 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
 $lo/lo_{u,min} = lb/lb_{u,min} = 0.318426$
 $su_2 = 0.4 * esu_{2,nominal} ((5.5), TBDY) = 0.032$
 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 $fs_2 = (fs_{jacket} * Asl_{com,jacket} + fs_{core} * Asl_{com,core}) / Asl_{com} = 387.8525$
 with $Es_2 = (Es_{jacket} * Asl_{com,jacket} + Es_{core} * Asl_{com,core}) / Asl_{com} = 200000.00$
 $yv = 0.00145721$
 $shv = 0.00466307$
 $ftv = 463.3885$
 $fyv = 386.157$
 $suv = 0.00582756$
 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
 $lo/lo_{u,min} = lb/ld = 0.318426$
 $suv = 0.4 * esuv_{nominal} ((5.5), TBDY) = 0.032$
 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 $fsv = (fs_{jacket} * Asl_{mid,jacket} + fs_{mid} * Asl_{mid,core}) / Asl_{mid} = 386.157$
 with $Es_v = (Es_{jacket} * Asl_{mid,jacket} + Es_{mid} * Asl_{mid,core}) / Asl_{mid} = 200000.00$
 $1 = Asl_{ten} / (b * d) * (fs_1 / fc) = 0.02488335$
 $2 = Asl_{com} / (b * d) * (fs_2 / fc) = 0.04895276$
 $v = Asl_{mid} / (b * d) * (fsv / fc) = 0.04430167$

and confined core properties:

$b = 690.00$
 $d = 677.00$
 $d' = 13.00$
 $fcc (5A.2, TBDY) = 34.2833$
 $cc (5A.5, TBDY) = 0.00238888$
 $c = \text{confinement factor} = 1.03889$
 $1 = Asl_{ten} / (b * d) * (fs_1 / fc) = 0.02824566$
 $2 = Asl_{com} / (b * d) * (fs_2 / fc) = 0.05556741$
 $v = Asl_{mid} / (b * d) * (fsv / fc) = 0.05028784$

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

--->
 $v < v_{s,y_2}$ - LHS eq.(4.5) is satisfied
 --->
 $su (4.9) = 0.13760581$
 $Mu = MRc (4.14) = 5.1260E+008$
 $u = su (4.1) = 9.5578758E-006$

 Calculation of ratio lb/ld

 Lap Length: $lb/ld = 0.318426$
 $lb = 300.00$
 $ld = 942.1341$
 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: $fy = 655.5556$
 Mean concrete strength: $fc' = (fc'_{jacket} * Area_{jacket} + fc'_{core} * Area_{core}) / Area_{section} = 27.68182$, but $fc'^{0.5} <=$
 8.3 MPa (22.5.3.1, ACI 318-14)
 $t = 1.00$

$s = 0.80$
 $e = 1.00$
 $cb = 25.00$
 $K_{tr} = 1.7174$
 $A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 257.6106$
 where A_{tr_x} , A_{tr_y} are the sum of the area of all stirrup legs along X and Y local axis
 $s = \text{Max}(s_{\text{external}}, s_{\text{internal}}) = 250.00$
 $n = 24.00$

 Calculation of μ_1 -

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

$u = 1.0408734E-005$
 $\mu = 8.2924E+008$

 with full section properties:

$b = 400.00$
 $d = 707.00$
 $d' = 43.00$
 $v = 0.00174378$
 $N = 16273.616$

$f_c = 33.00$
 $\alpha_{co} (5A.5, \text{TBDY}) = 0.002$

Final value of μ : $\mu^* = \text{shear_factor} * \text{Max}(\mu_c, \mu_s) = 0.01288354$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $\mu_c = 0.01288354$

where μ_s ((5.4c), TBDY) = $\alpha_{se} * \text{sh}_{\text{min}} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.05503171$

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

 $f_x = 0.04286225$

Expression ((15B.6), TBDY) is modified as $\alpha_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$\alpha_f = 0.31984848$

with Unconfined area = $((b_{\text{max}} - 2R)^2 + (h_{\text{max}} - 2R)^2) / 3 = 140733.333$

$b_{\text{max}} = 750.00$

$h_{\text{max}} = 750.00$

From EC8 A.4.4.3(6), $p_f = 2t_f / b_w = 0.00508$

$b_w = 400.00$

effective stress from (A.35), $f_{fe} = 870.5244$

 $f_y = 0.04286225$

Expression ((15B.6), TBDY) is modified as $\alpha_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$\alpha_f = 0.31984848$

with Unconfined area = $((b_{\text{max}} - 2R)^2 + (h_{\text{max}} - 2R)^2) / 3 = 140733.333$

$b_{\text{max}} = 750.00$

$h_{\text{max}} = 750.00$

From EC8 A.4.4.3(6), $p_f = 2t_f / b_w = 0.00508$

$b_w = 400.00$

effective stress from (A.35), $f_{fe} = 870.5244$

 $R = 40.00$

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

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{,f} = 0.015$

α_{se} ((5.4d), TBDY) = $(\alpha_{se1} * A_{\text{ext}} + \alpha_{se2} * A_{\text{int}}) / A_{\text{sec}} = 0.45746528$

$\alpha_{se1} = \text{Max}(((A_{\text{conf,max1}} - A_{\text{noConf1}}) / A_{\text{conf,max1}}) * (A_{\text{conf,min1}} / A_{\text{conf,max1}}), 0) = 0.45746528$

The definitions of A_{noConf} , $A_{\text{conf,min}}$ and $A_{\text{conf,max}}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{\text{conf,max1}} = 353600.00$ is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

Aconf,min1 = 293525.00 is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area Aconf,max1 by a length equal to half the clear spacing between external hoops.

AnoConf1 = 158733.333 is the unconfined external core area which is equal to $bi^2/6$ as defined at (A.2).
ase2 (\geq ase1) = $\text{Max}(((Aconf,max2 - AnoConf2)/Aconf,max2) * (Aconf,min2/Aconf,max2), 0) = 0.45746528$

The definitions of AnoConf, Aconf,min and Aconf,max are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

Aconf,max2 = 171264.00 is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

Aconf,min2 = 54741.00 is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area Aconf,max2 by a length equal to half the clear spacing between internal hoops.

AnoConf2 = 106242.667 is the unconfined internal core area which is equal to $bi^2/6$ as defined at (A.2).
psh,min*Fywe = $\text{Min}(psh,x*Fywe, psh,y*Fywe) = 2.92621$

Expression (5.4d) 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 = 2.92621
psh1 ((5.4d), TBDY) = $Lstir1 * Astir1 / (Asec * s1) = 0.00367709$

Lstir1 (Length of stirrups along Y) = 2060.00

Astir1 (stirrups area) = 78.53982

psh2 (5.4d) = $Lstir2 * Astir2 / (Asec * s2) = 0.00067082$

Lstir2 (Length of stirrups along Y) = 1468.00

Astir2 (stirrups area) = 50.26548

psh_y*Fywe = psh1*Fywe1 + ps2*Fywe2 = 2.92621
psh1 ((5.4d), TBDY) = $Lstir1 * Astir1 / (Asec * s1) = 0.00367709$

Lstir1 (Length of stirrups along X) = 2060.00

Astir1 (stirrups area) = 78.53982

psh2 ((5.4d), TBDY) = $Lstir2 * Astir2 / (Asec * s2) = 0.00067082$

Lstir2 (Length of stirrups along X) = 1468.00

Astir2 (stirrups area) = 50.26548

Asec = 440000.00

s1 = 100.00

s2 = 250.00

fywe1 = 694.4444

fywe2 = 555.5556

fce = 33.00

From ((5.A5), TBDY), TBDY: cc = 0.00238888

c = confinement factor = 1.03889

y1 = 0.00145721

sh1 = 0.00466307

ft1 = 465.423

fy1 = 387.8525

su1 = 0.00582756

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 = 0.318426

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 = $(fs_jacket * Asl,ten,jacket + fs_core * Asl,ten,core) / Asl,ten = 387.8525$

with Es1 = $(Es_jacket * Asl,ten,jacket + Es_core * Asl,ten,core) / Asl,ten = 200000.00$

y2 = 0.00145721

sh2 = 0.00466307

ft2 = 459.4373

fy2 = 382.8645

su2 = 0.00582756

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 = 0.318426

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 = 382.8645

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

yv = 0.00145721

shv = 0.00466307

ftv = 463.3885

fyv = 386.157

suv = 0.00582756

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 = 0.318426

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 = 386.157

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

1 = Asl,ten/(b*d)*(fs1/fc) = 0.09178643

2 = Asl,com/(b*d)*(fs2/fc) = 0.04665628

v = Asl,mid/(b*d)*(fsv/fc) = 0.08306563

and confined core properties:

b = 340.00

d = 677.00

d' = 13.00

fcc (5A.2, TBDY) = 34.2833

cc (5A.5, TBDY) = 0.00238888

c = confinement factor = 1.03889

1 = Asl,ten/(b*d)*(fs1/fc) = 0.11276915

2 = Asl,com/(b*d)*(fs2/fc) = 0.05732208

v = Asl,mid/(b*d)*(fsv/fc) = 0.10205474

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

v < vs,y2 - LHS eq.(4.5) is satisfied

--->

su (4.9) = 0.20810191

Mu = MRc (4.14) = 8.2924E+008

u = su (4.1) = 1.0408734E-005

Calculation of ratio lb/ld

Lap Length: lb/ld = 0.318426

lb = 300.00

ld = 942.1341

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 = 655.5556

Mean concrete strength: fc' = (fc',jacket*Area_jacket + fc',core*Area_core)/Area_section = 27.68182, but $fc'^{0.5} < =$
8.3 MPa (22.5.3.1, ACI 318-14)

t = 1.00

s = 0.80

e = 1.00

cb = 25.00

Ktr = 1.7174

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

$$s = \text{Max}(s_{\text{external}}, s_{\text{internal}}) = 250.00$$
$$n = 24.00$$

Calculation of μ_{2+}

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

$$u = 9.5578758E-006$$

$$\mu = 5.1260E+008$$

with full section properties:

$$b = 750.00$$

$$d = 707.00$$

$$d' = 43.00$$

$$v = 0.00093001$$

$$N = 16273.616$$

$$f_c = 33.00$$

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

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.01288354$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } c_u = 0.01288354$$

$$w_e \text{ ((5.4c), TBDY)} = a_{se} * s_{h,\text{min}} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.05503171$$

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

$$f_x = 0.04286225$$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.31984848$$

$$\text{with Unconfined area} = ((b_{\text{max}} - 2R)^2 + (h_{\text{max}} - 2R)^2) / 3 = 140733.333$$

$$b_{\text{max}} = 750.00$$

$$h_{\text{max}} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 870.5244$$

$$f_y = 0.04286225$$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.31984848$$

$$\text{with Unconfined area} = ((b_{\text{max}} - 2R)^2 + (h_{\text{max}} - 2R)^2) / 3 = 140733.333$$

$$b_{\text{max}} = 750.00$$

$$h_{\text{max}} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 870.5244$$

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u_{f} = 0.015$$

$$a_{se} \text{ ((5.4d), TBDY)} = (a_{se1} * A_{\text{ext}} + a_{se2} * A_{\text{int}}) / A_{\text{sec}} = 0.45746528$$

$$a_{se1} = \text{Max}(((A_{\text{conf,max1}} - A_{\text{noConf1}}) / A_{\text{conf,max1}}) * (A_{\text{conf,min1}} / A_{\text{conf,max1}}), 0) = 0.45746528$$

The definitions of A_{noConf} , $A_{\text{conf,min}}$ and $A_{\text{conf,max}}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{\text{conf,max1}} = 353600.00$ is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{\text{conf,min1}} = 293525.00$ is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area $A_{\text{conf,max1}}$ by a length equal to half the clear spacing between external hoops.

$A_{\text{noConf1}} = 158733.333$ is the unconfined external core area which is equal to $b_i^2/6$ as defined at (A.2).

$$a_{se2} (> a_{se1}) = \text{Max}(((A_{\text{conf,max2}} - A_{\text{noConf2}}) / A_{\text{conf,max2}}) * (A_{\text{conf,min2}} / A_{\text{conf,max2}}), 0) = 0.45746528$$

The definitions of A_{noConf} , $A_{\text{conf,min}}$ and $A_{\text{conf,max}}$ are derived from generalization

of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max2} = 171264.00$ is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

$A_{conf,min2} = 54741.00$ is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area $A_{conf,max2}$ by a length equal to half the clear spacing between internal hoops.

$A_{noConf2} = 106242.667$ is the unconfined internal core area which is equal to $b_i^2/6$ as defined at (A.2).

$p_{sh,min} * F_{ywe} = \text{Min}(p_{sh,x} * F_{ywe}, p_{sh,y} * F_{ywe}) = 2.92621$

Expression (5.4d) 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)

 $p_{sh,x} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{s2} * F_{ywe2} = 2.92621$

p_{sh1} ((5.4d), TBDY) = $L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00367709$

L_{stir1} (Length of stirrups along Y) = 2060.00

A_{stir1} (stirrups area) = 78.53982

p_{sh2} (5.4d) = $L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00067082$

L_{stir2} (Length of stirrups along Y) = 1468.00

A_{stir2} (stirrups area) = 50.26548

 $p_{sh,y} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{s2} * F_{ywe2} = 2.92621$

p_{sh1} ((5.4d), TBDY) = $L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00367709$

L_{stir1} (Length of stirrups along X) = 2060.00

A_{stir1} (stirrups area) = 78.53982

p_{sh2} ((5.4d), TBDY) = $L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00067082$

L_{stir2} (Length of stirrups along X) = 1468.00

A_{stir2} (stirrups area) = 50.26548

 $A_{sec} = 440000.00$

$s1 = 100.00$

$s2 = 250.00$

$f_{ywe1} = 694.4444$

$f_{ywe2} = 555.5556$

$f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY: $cc = 0.00238888$

$c = \text{confinement factor} = 1.03889$

$y1 = 0.00145721$

$sh1 = 0.00466307$

$ft1 = 459.4373$

$fy1 = 382.8645$

$su1 = 0.00582756$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor

and also multiplied by the shear_factor according to 15.7.1.4, with

$\text{Shear_factor} = 1.00$

$l_o/l_{o,min} = l_b/l_d = 0.318426$

$su1 = 0.4 * esu1_{nominal}$ ((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 $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE 41-17.

with $fs1 = (f_{s,jacket} * A_{sl,ten,jacket} + f_{s,core} * A_{sl,ten,core}) / A_{sl,ten} = 382.8645$

with $Es1 = (E_{s,jacket} * A_{sl,ten,jacket} + E_{s,core} * A_{sl,ten,core}) / A_{sl,ten} = 200000.00$

$y2 = 0.00145721$

$sh2 = 0.00466307$

$ft2 = 465.423$

$fy2 = 387.8525$

$su2 = 0.00582756$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor

and also multiplied by the shear_factor according to 15.7.1.4, with

$\text{Shear_factor} = 1.00$

$l_o/l_{o,min} = l_b/l_{b,min} = 0.318426$

$su2 = 0.4 * esu2_{nominal}$ ((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.

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

with $fs_2 = (fs_{jacket} \cdot A_{sl,com,jacket} + fs_{core} \cdot A_{sl,com,core}) / A_{sl,com} = 387.8525$

with $Es_2 = (Es_{jacket} \cdot A_{sl,com,jacket} + Es_{core} \cdot A_{sl,com,core}) / A_{sl,com} = 200000.00$

$y_v = 0.00145721$

$sh_v = 0.00466307$

$ft_v = 463.3885$

$fy_v = 386.157$

$suv = 0.00582756$

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

$lo/lou, min = lb/d = 0.318426$

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

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 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 $\text{Min}(1, 1.25 \cdot (lb/d)^{2/3})$, from 10.3.5, ASCE 41-17.

with $fsv = (fs_{jacket} \cdot A_{sl,mid,jacket} + fs_{mid} \cdot A_{sl,mid,core}) / A_{sl,mid} = 386.157$

with $Es_v = (Es_{jacket} \cdot A_{sl,mid,jacket} + Es_{mid} \cdot A_{sl,mid,core}) / A_{sl,mid} = 200000.00$

$1 = A_{sl,ten} / (b \cdot d) \cdot (fs_1 / fc) = 0.02488335$

$2 = A_{sl,com} / (b \cdot d) \cdot (fs_2 / fc) = 0.04895276$

$v = A_{sl,mid} / (b \cdot d) \cdot (fsv / fc) = 0.04430167$

and confined core properties:

$b = 690.00$

$d = 677.00$

$d' = 13.00$

$fcc (5A.2, TBDY) = 34.2833$

$cc (5A.5, TBDY) = 0.00238888$

$c =$ confinement factor = 1.03889

$1 = A_{sl,ten} / (b \cdot d) \cdot (fs_1 / fc) = 0.02824566$

$2 = A_{sl,com} / (b \cdot d) \cdot (fs_2 / fc) = 0.05556741$

$v = A_{sl,mid} / (b \cdot d) \cdot (fsv / fc) = 0.05028784$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

$su (4.9) = 0.13760581$

$Mu = MRc (4.14) = 5.1260E+008$

$u = su (4.1) = 9.5578758E-006$

Calculation of ratio lb/d

Lap Length: $lb/d = 0.318426$

$lb = 300.00$

$ld = 942.1341$

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: $fy = 655.5556$

Mean concrete strength: $fc' = (fc'_{jacket} \cdot Area_{jacket} + fc'_{core} \cdot Area_{core}) / Area_{section} = 27.68182$, but $fc'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 1.7174$

$A_{tr} = \text{Min}(A_{tr,x}, A_{tr,y}) = 257.6106$

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

$s = \text{Max}(s_{external}, s_{internal}) = 250.00$

$n = 24.00$

Calculation of Mu_2 -

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

$$\mu = 1.0408734E-005$$

$$\mu_u = 8.2924E+008$$

with full section properties:

$$b = 400.00$$

$$d = 707.00$$

$$d' = 43.00$$

$$v = 0.00174378$$

$$N = 16273.616$$

$$f_c = 33.00$$

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

$$\text{Final value of } \mu_u: \mu_u = \text{shear_factor} * \text{Max}(\mu_c, \mu_c) = 0.01288354$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \mu_u = 0.01288354$$

$$\mu_w ((5.4c), TBDY) = a_{se} * \text{sh}_{, \min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.05503171$$

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

$$f_x = 0.04286225$$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.31984848$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 140733.333$$

$$b_{\max} = 750.00$$

$$h_{\max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 870.5244$$

$$f_y = 0.04286225$$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.31984848$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 140733.333$$

$$b_{\max} = 750.00$$

$$h_{\max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 870.5244$$

$$R = 40.00$$

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

$$f_u, f = 1055.00$$

$$E_f = 64828.00$$

$$u, f = 0.015$$

$$a_{se} ((5.4d), TBDY) = (a_{se1} * A_{ext} + a_{se2} * A_{int}) / A_{sec} = 0.45746528$$

$$a_{se1} = \text{Max}(((A_{\text{conf}, \max 1} - A_{\text{noConf1}}) / A_{\text{conf}, \max 1}) * (A_{\text{conf}, \min 1} / A_{\text{conf}, \max 1}), 0) = 0.45746528$$

The definitions of A_{noConf} , $A_{\text{conf}, \min}$ and $A_{\text{conf}, \max}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{\text{conf}, \max 1} = 353600.00$ is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{\text{conf}, \min 1} = 293525.00$ is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area $A_{\text{conf}, \max 1}$ by a length equal to half the clear spacing between external hoops.

$A_{\text{noConf1}} = 158733.333$ is the unconfined external core area which is equal to $b_i^2 / 6$ as defined at (A.2).

$$a_{se2} (>= a_{se1}) = \text{Max}(((A_{\text{conf}, \max 2} - A_{\text{noConf2}}) / A_{\text{conf}, \max 2}) * (A_{\text{conf}, \min 2} / A_{\text{conf}, \max 2}), 0) = 0.45746528$$

The definitions of A_{noConf} , $A_{\text{conf}, \min}$ and $A_{\text{conf}, \max}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{\text{conf}, \max 2} = 171264.00$ is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

Aconf,min2 = 54741.00 is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area Aconf,max2 by a length equal to half the clear spacing between internal hoops.

AnoConf2 = 106242.667 is the unconfined internal core area which is equal to $bi^2/6$ as defined at (A.2).
 $psh,min*Fywe = \text{Min}(psh,x*Fywe, psh,y*Fywe) = 2.92621$

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

 $psh_x*Fywe = psh1*Fywe1 + ps2*Fywe2 = 2.92621$
 $psh1 \text{ ((5.4d), TBDY)} = Lstir1*Astir1/(Asec*s1) = 0.00367709$
Lstir1 (Length of stirrups along Y) = 2060.00
Astir1 (stirrups area) = 78.53982
 $psh2 \text{ (5.4d)} = Lstir2*Astir2/(Asec*s2) = 0.00067082$
Lstir2 (Length of stirrups along Y) = 1468.00
Astir2 (stirrups area) = 50.26548

 $psh_y*Fywe = psh1*Fywe1 + ps2*Fywe2 = 2.92621$
 $psh1 \text{ ((5.4d), TBDY)} = Lstir1*Astir1/(Asec*s1) = 0.00367709$
Lstir1 (Length of stirrups along X) = 2060.00
Astir1 (stirrups area) = 78.53982
 $psh2 \text{ ((5.4d), TBDY)} = Lstir2*Astir2/(Asec*s2) = 0.00067082$
Lstir2 (Length of stirrups along X) = 1468.00
Astir2 (stirrups area) = 50.26548

Asec = 440000.00
s1 = 100.00
s2 = 250.00
fywe1 = 694.4444
fywe2 = 555.5556
fce = 33.00

From ((5.A5), TBDY), TBDY: cc = 0.00238888
c = confinement factor = 1.03889

y1 = 0.00145721
sh1 = 0.00466307
ft1 = 465.423
fy1 = 387.8525
su1 = 0.00582756

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 = 0.318426
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 $\text{Min}(1, 1.25*(lb/lb)^{2/3})$, from 10.3.5, ASCE 41-17.

with $fs1 = (fs,jacket*Asl,ten,jacket + fs,core*Asl,ten,core)/Asl,ten = 387.8525$

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

y2 = 0.00145721
sh2 = 0.00466307
ft2 = 459.4373
fy2 = 382.8645
su2 = 0.00582756

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 = 0.318426
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 $\text{Min}(1, 1.25*(lb/lb)^{2/3})$, from 10.3.5, ASCE 41-17.

with $fs2 = (fs,jacket*Asl,com,jacket + fs,core*Asl,com,core)/Asl,com = 382.8645$

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

yv = 0.00145721
shv = 0.00466307
ftv = 463.3885

$f_{yv} = 386.157$
 $s_{uv} = 0.00582756$
 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
 $l_o/l_{ou,min} = l_b/l_d = 0.318426$
 $s_{uv} = 0.4 * e_{suv_nominal} ((5,5), TBDY) = 0.032$
 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 , 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 $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE 41-17.
 with $f_{sv} = (f_{s,jacket} * A_{s,mid,jacket} + f_{s,mid} * A_{s,mid,core}) / A_{s,mid} = 386.157$
 with $E_{sv} = (E_{s,jacket} * A_{s,mid,jacket} + E_{s,mid} * A_{s,mid,core}) / A_{s,mid} = 200000.00$
 $1 = A_{s,ten} / (b * d) * (f_{s1} / f_c) = 0.09178643$
 $2 = A_{s,com} / (b * d) * (f_{s2} / f_c) = 0.04665628$
 $v = A_{s,mid} / (b * d) * (f_{sv} / f_c) = 0.08306563$

and confined core properties:

$b = 340.00$
 $d = 677.00$
 $d' = 13.00$
 $f_{cc} (5A.2, TBDY) = 34.2833$
 $c_c (5A.5, TBDY) = 0.00238888$
 $c = \text{confinement factor} = 1.03889$
 $1 = A_{s,ten} / (b * d) * (f_{s1} / f_c) = 0.11276915$
 $2 = A_{s,com} / (b * d) * (f_{s2} / f_c) = 0.05732208$
 $v = A_{s,mid} / (b * d) * (f_{sv} / f_c) = 0.10205474$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

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

$s_u (4.9) = 0.20810191$
 $M_u = M_{Rc} (4.14) = 8.2924E+008$
 $u = s_u (4.1) = 1.0408734E-005$

 Calculation of ratio l_b/l_d

 Lap Length: $l_b/l_d = 0.318426$

$l_b = 300.00$

$l_d = 942.1341$

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: $f_y = 655.5556$

Mean concrete strength: $f'_c = (f'_{c,jacket} * Area_{jacket} + f'_{c,core} * Area_{core}) / Area_{section} = 27.68182$, but $f_c^{0.5} <= 8.3$ MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 1.7174$

$A_{tr} = \text{Min}(A_{tr,x}, A_{tr,y}) = 257.6106$

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

$s = \text{Max}(s_{external}, s_{internal}) = 250.00$

$n = 24.00$

 Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 998292.205$

 Calculation of Shear Strength at edge 1, $V_{r1} = 998292.205$

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

$V_{CoI0} = 998292.205$

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

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

= 1 (normal-weight concrete)

Mean concrete strength: $f_c' = (f_c'_{\text{jacket}} \cdot \text{Area}_{\text{jacket}} + f_c'_{\text{core}} \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 27.68182$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 4.00$

$\mu_u = 11.77537$

$V_u = 0.00051441$

$d = 0.8 \cdot h = 600.00$

$N_u = 16273.616$

$A_g = 300000.00$

From (11.5.4.8), ACI 318-14: $V_s = V_{s,\text{jacket}} + V_{s,\text{core}} = 881489.011$

where:

$V_{s,\text{jacket}} = V_{s,j1} + V_{s,j2} = 802851.456$

$V_{s,j1} = 523598.776$ is calculated for section web jacket, with:

$d = 600.00$

$A_v = 157079.633$

$f_y = 555.5556$

$s = 100.00$

$V_{s,j1}$ is multiplied by $\text{Col},j1 = 1.00$

$s/d = 0.16666667$

$V_{s,j2} = 279252.68$ is calculated for section flange jacket, with:

$d = 320.00$

$A_v = 157079.633$

$f_y = 555.5556$

$s = 100.00$

$V_{s,j2}$ is multiplied by $\text{Col},j2 = 1.00$

$s/d = 0.3125$

$V_{s,\text{core}} = V_{s,c1} + V_{s,c2} = 78637.555$

$V_{s,c1} = 78637.555$ is calculated for section web core, with:

$d = 440.00$

$A_v = 100530.965$

$f_y = 444.4444$

$s = 250.00$

$V_{s,c1}$ is multiplied by $\text{Col},c1 = 1.00$

$s/d = 0.56818182$

$V_{s,c2} = 0.00$ is calculated for section flange core, with:

$d = 160.00$

$A_v = 100530.965$

$f_y = 444.4444$

$s = 250.00$

$V_{s,c2}$ is multiplied by $\text{Col},c2 = 0.00$

$s/d = 1.5625$

V_f ((11-3)-(11.4), ACI 440) = 372533.843

$f = 0.95$, for fully-wrapped sections

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

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

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

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

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

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

$d_{fv} = d$ (figure 11.2, ACI 440) = 707.00

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: $V_s + V_f \leq 838832.606$

$b_w = 400.00$

Calculation of Shear Strength at edge 2, $V_{r2} = 998292.205$

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

$V_{\text{Col}0} = 998292.205$

knl = 1 (zero step-static loading)

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

= 1 (normal-weight concrete)

Mean concrete strength: $f_c' = (f_c'_{\text{jacket}} \cdot \text{Area}_{\text{jacket}} + f_c'_{\text{core}} \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 27.68182$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 4.00$

$\mu_u = 11.77482$

$V_u = 0.00051441$

$d = 0.8 \cdot h = 600.00$

$N_u = 16273.616$

$A_g = 300000.00$

From (11.5.4.8), ACI 318-14: $V_s = V_{s,\text{jacket}} + V_{s,\text{core}} = 881489.011$

where:

$V_{s,\text{jacket}} = V_{s,j1} + V_{s,j2} = 802851.456$

$V_{s,j1} = 523598.776$ is calculated for section web jacket, with:

$d = 600.00$

$A_v = 157079.633$

$f_y = 555.5556$

$s = 100.00$

$V_{s,j1}$ is multiplied by $\text{Col},j1 = 1.00$

$s/d = 0.16666667$

$V_{s,j2} = 279252.68$ is calculated for section flange jacket, with:

$d = 320.00$

$A_v = 157079.633$

$f_y = 555.5556$

$s = 100.00$

$V_{s,j2}$ is multiplied by $\text{Col},j2 = 1.00$

$s/d = 0.3125$

$V_{s,\text{core}} = V_{s,c1} + V_{s,c2} = 78637.555$

$V_{s,c1} = 78637.555$ is calculated for section web core, with:

$d = 440.00$

$A_v = 100530.965$

$f_y = 444.4444$

$s = 250.00$

$V_{s,c1}$ is multiplied by $\text{Col},c1 = 1.00$

$s/d = 0.56818182$

$V_{s,c2} = 0.00$ is calculated for section flange core, with:

$d = 160.00$

$A_v = 100530.965$

$f_y = 444.4444$

$s = 250.00$

$V_{s,c2}$ is multiplied by $\text{Col},c2 = 0.00$

$s/d = 1.5625$

V_f ((11-3)-(11.4), ACI 440) = 372533.843

$f = 0.95$, for fully-wrapped sections

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

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

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

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

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

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

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

$d_{fv} = d$ (figure 11.2, ACI 440) = 707.00

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: $V_s + V_f \leq 838832.606$

$b_w = 400.00$

End Of Calculation of Shear Capacity ratio for element: column JLC1 of floor 1

At local axis: 3

Start Of Calculation of Shear Capacity ratio for element: column JLC1 of floor 1

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

Constant Properties

Knowledge Factor, $\gamma = 0.85$
Mean strength values are used for both shear and moment calculations.
Consequently:

Jacket
New material of Secondary Member: Concrete Strength, $f_c = f_{cm} = 33.00$
New material of Secondary Member: Steel Strength, $f_s = f_{sm} = 555.5556$
Concrete Elasticity, $E_c = 26999.444$
Steel Elasticity, $E_s = 200000.00$

Existing Column
Existing material of Secondary Member: Concrete Strength, $f_c = f_{cm} = 20.00$
Existing material of Secondary Member: Steel Strength, $f_s = f_{sm} = 444.4444$
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, $f_s = 1.25 * f_{sm} = 694.4444$
Existing Column
Existing material: Steel Strength, $f_s = 1.25 * f_{sm} = 555.5556$
#####

Max Height, $H_{max} = 750.00$
Min Height, $H_{min} = 400.00$
Max Width, $W_{max} = 750.00$
Min Width, $W_{min} = 400.00$
Jacket Thickness, $t_j = 100.00$
Cover Thickness, $c = 25.00$
Mean Confinement Factor overall section = 1.03889

Element Length, $L = 3000.00$
Secondary Member
Ribbed Bars
Ductile Steel
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)

Longitudinal Bars With Ends Lapped Starting at the End Sections
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, $V_a = -0.00051441$
EDGE -B-
Shear Force, $V_b = 0.00051441$
BOTH EDGES

Axial Force, $F = -16273.616$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: $As_t = 0.00$

-Compression: $As_c = 5353.274$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension: $As_{ten} = 1137.257$

-Compression: $As_{com} = 2208.54$

-Middle: $As_{mid} = 2007.478$

Calculation of Shear Capacity ratio, $V_e/V_r = 0.55377356$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 552827.824$

with

$M_{pr1} = \text{Max}(Mu_{1+}, Mu_{1-}) = 8.2924E+008$

$Mu_{1+} = 5.1260E+008$, 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

$Mu_{1-} = 8.2924E+008$, 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

$M_{pr2} = \text{Max}(Mu_{2+}, Mu_{2-}) = 8.2924E+008$

$Mu_{2+} = 5.1260E+008$, 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

$Mu_{2-} = 8.2924E+008$, is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the static loading combination

Calculation of Mu_{1+}

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

$\phi_u = 9.5578758E-006$

$M_u = 5.1260E+008$

with full section properties:

$b = 750.00$

$d = 707.00$

$d' = 43.00$

$v = 0.00093001$

$N = 16273.616$

$f_c = 33.00$

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

Final value of ϕ_u : $\phi_u^* = \text{shear_factor} * \text{Max}(\phi_u, \phi_c) = 0.01288354$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $\phi_u = 0.01288354$

where $\phi_u = a_s e * \text{sh}_{\min} * f_{ywe} / f_{ce} + \text{Min}(\phi_x, \phi_y) = 0.05503171$

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

$\phi_x = 0.04286225$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$a_f = 0.31984848$

with Unconfined area = $((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 140733.333$

$b_{\max} = 750.00$

$h_{\max} = 750.00$

From EC8 A.4.4.3(6), $p_f = 2t_f / b_w = 0.00508$

$b_w = 400.00$

effective stress from (A.35), $f_{fe} = 870.5244$

$\phi_y = 0.04286225$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$a_f = 0.31984848$

with Unconfined area = $((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 140733.333$

$b_{\max} = 750.00$

$h_{\max} = 750.00$

From EC8 A.4.4.3(6), $p_f = 2t_f / b_w = 0.00508$

bw = 400.00
effective stress from (A.35), $f_{f,e} = 870.5244$

R = 40.00
Effective FRP thickness, $t_f = NL * t * \cos(b_1) = 1.016$
 $f_{u,f} = 1055.00$
 $E_f = 64828.00$
 $u_{,f} = 0.015$

$ase((5.4d), TBDY) = (ase_1 * A_{ext} + ase_2 * A_{int}) / A_{sec} = 0.45746528$

$ase_1 = \text{Max}(((A_{conf,max1} - A_{noConf1}) / A_{conf,max1}) * (A_{conf,min1} / A_{conf,max1}), 0) = 0.45746528$

The definitions of A_{noConf} , $A_{conf,min}$ and $A_{conf,max}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max1} = 353600.00$ is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{conf,min1} = 293525.00$ is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area $A_{conf,max1}$ by a length equal to half the clear spacing between external hoops.

$A_{noConf1} = 158733.333$ is the unconfined external core area which is equal to $b_i^2/6$ as defined at (A.2).

$ase_2 (>= ase_1) = \text{Max}(((A_{conf,max2} - A_{noConf2}) / A_{conf,max2}) * (A_{conf,min2} / A_{conf,max2}), 0) = 0.45746528$

The definitions of A_{noConf} , $A_{conf,min}$ and $A_{conf,max}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max2} = 171264.00$ is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

$A_{conf,min2} = 54741.00$ is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area $A_{conf,max2}$ by a length equal to half the clear spacing between internal hoops.

$A_{noConf2} = 106242.667$ is the unconfined internal core area which is equal to $b_i^2/6$ as defined at (A.2).

$p_{sh,min} * F_{ywe} = \text{Min}(p_{sh,x} * F_{ywe}, p_{sh,y} * F_{ywe}) = 2.92621$

Expression (5.4d) 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)

$p_{sh,x} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{sh2} * F_{ywe2} = 2.92621$

$p_{sh1}((5.4d), TBDY) = L_{stir1} * A_{stir1} / (A_{sec} * s_1) = 0.00367709$

L_{stir1} (Length of stirrups along Y) = 2060.00

A_{stir1} (stirrups area) = 78.53982

$p_{sh2}((5.4d)) = L_{stir2} * A_{stir2} / (A_{sec} * s_2) = 0.00067082$

L_{stir2} (Length of stirrups along Y) = 1468.00

A_{stir2} (stirrups area) = 50.26548

$p_{sh,y} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{sh2} * F_{ywe2} = 2.92621$

$p_{sh1}((5.4d), TBDY) = L_{stir1} * A_{stir1} / (A_{sec} * s_1) = 0.00367709$

L_{stir1} (Length of stirrups along X) = 2060.00

A_{stir1} (stirrups area) = 78.53982

$p_{sh2}((5.4d), TBDY) = L_{stir2} * A_{stir2} / (A_{sec} * s_2) = 0.00067082$

L_{stir2} (Length of stirrups along X) = 1468.00

A_{stir2} (stirrups area) = 50.26548

$A_{sec} = 440000.00$

$s_1 = 100.00$

$s_2 = 250.00$

$f_{ywe1} = 694.4444$

$f_{ywe2} = 555.5556$

$f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY: $cc = 0.00238888$

c = confinement factor = 1.03889

$y_1 = 0.00145721$

$sh_1 = 0.00466307$

$ft_1 = 459.4373$

$fy_1 = 382.8645$

$su_1 = 0.00582756$

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 = 0.318426

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 = 382.8645

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

y2 = 0.00145721

sh2 = 0.00466307

ft2 = 465.423

fy2 = 387.8525

su2 = 0.00582756

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 = 0.318426

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 = 387.8525

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

yv = 0.00145721

shv = 0.00466307

ftv = 463.3885

fyv = 386.157

suv = 0.00582756

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 = 0.318426

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 = 386.157

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

1 = Asl,ten/(b*d)*(fs1/fc) = 0.02488335

2 = Asl,com/(b*d)*(fs2/fc) = 0.04895276

v = Asl,mid/(b*d)*(fsv/fc) = 0.04430167

and confined core properties:

b = 690.00

d = 677.00

d' = 13.00

fcc (5A.2, TBDY) = 34.2833

cc (5A.5, TBDY) = 0.00238888

c = confinement factor = 1.03889

1 = Asl,ten/(b*d)*(fs1/fc) = 0.02824566

2 = Asl,com/(b*d)*(fs2/fc) = 0.05556741

v = Asl,mid/(b*d)*(fsv/fc) = 0.05028784

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

v < vs,y2 - LHS eq.(4.5) is satisfied

--->

su (4.9) = 0.13760581

Mu = MRc (4.14) = 5.1260E+008

u = su (4.1) = 9.5578758E-006

Calculation of ratio lb/ld

Lap Length: $l_b/l_d = 0.318426$

$l_b = 300.00$

$l_d = 942.1341$

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: $f_y = 655.5556$

Mean concrete strength: $f_c' = (f_c'_{\text{jacket}} \cdot \text{Area}_{\text{jacket}} + f_c'_{\text{core}} \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 27.68182$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 1.7174$

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

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

$s = \text{Max}(s_{\text{external}}, s_{\text{internal}}) = 250.00$

$n = 24.00$

Calculation of μ_1 -

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

$\mu = 1.0408734E-005$

$\mu = 8.2924E+008$

with full section properties:

$b = 400.00$

$d = 707.00$

$d' = 43.00$

$v = 0.00174378$

$N = 16273.616$

$f_c = 33.00$

α (5A.5, TBDY) = 0.002

Final value of μ : $\mu^* = \text{shear_factor} \cdot \text{Max}(\mu, \mu_c) = 0.01288354$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $\mu = 0.01288354$

where ((5.4c), TBDY) = $\alpha \cdot \text{sh}_{\min} \cdot f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.05503171$

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

$f_x = 0.04286225$

Expression ((15B.6), TBDY) is modified as $\alpha f = 1 - (\text{Unconfined area}) / (\text{total area})$

$\alpha f = 0.31984848$

with Unconfined area = $((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 140733.333$

$b_{\max} = 750.00$

$h_{\max} = 750.00$

From EC8 A.4.4.3(6), $\text{pf} = 2t_f / b_w = 0.00508$

$b_w = 400.00$

effective stress from (A.35), $f_{fe} = 870.5244$

$f_y = 0.04286225$

Expression ((15B.6), TBDY) is modified as $\alpha f = 1 - (\text{Unconfined area}) / (\text{total area})$

$\alpha f = 0.31984848$

with Unconfined area = $((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 140733.333$

$b_{\max} = 750.00$

$h_{\max} = 750.00$

From EC8 A.4.4.3(6), $\text{pf} = 2t_f / b_w = 0.00508$

$b_w = 400.00$

effective stress from (A.35), $f_{fe} = 870.5244$

$R = 40.00$

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

$f_{u,f} = 1055.00$

$$E_f = 64828.00$$

$$u, f = 0.015$$

$$ase \text{ ((5.4d), TBDY)} = (ase1 * A_{ext} + ase2 * A_{int}) / A_{sec} = 0.45746528$$

$$ase1 = \text{Max}(((A_{conf,max1} - A_{noConf1}) / A_{conf,max1}) * (A_{conf,min1} / A_{conf,max1}), 0) = 0.45746528$$

The definitions of A_{noConf} , $A_{conf,min}$ and $A_{conf,max}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max1} = 353600.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{conf,min1} = 293525.00$ is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area $A_{conf,max1}$ by a length equal to half the clear spacing between external hoops.

$A_{noConf1} = 158733.333$ is the unconfined external core area which is equal to $b_i^2/6$ as defined at (A.2).

$$ase2 (\geq ase1) = \text{Max}(((A_{conf,max2} - A_{noConf2}) / A_{conf,max2}) * (A_{conf,min2} / A_{conf,max2}), 0) = 0.45746528$$

The definitions of A_{noConf} , $A_{conf,min}$ and $A_{conf,max}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max2} = 171264.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

$A_{conf,min2} = 54741.00$ is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area $A_{conf,max2}$ by a length equal to half the clear spacing between internal hoops.

$A_{noConf2} = 106242.667$ is the unconfined internal core area which is equal to $b_i^2/6$ as defined at (A.2).

$$psh_{min} * F_{ywe} = \text{Min}(psh_x * F_{ywe}, psh_y * F_{ywe}) = 2.92621$$

Expression (5.4d) 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)

$$psh_x * F_{ywe} = psh1 * F_{ywe1} + ps2 * F_{ywe2} = 2.92621$$

$$psh1 \text{ ((5.4d), TBDY)} = L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00367709$$

$$L_{stir1} \text{ (Length of stirrups along Y)} = 2060.00$$

$$A_{stir1} \text{ (stirrups area)} = 78.53982$$

$$psh2 \text{ (5.4d)} = L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00067082$$

$$L_{stir2} \text{ (Length of stirrups along Y)} = 1468.00$$

$$A_{stir2} \text{ (stirrups area)} = 50.26548$$

$$psh_y * F_{ywe} = psh1 * F_{ywe1} + ps2 * F_{ywe2} = 2.92621$$

$$psh1 \text{ ((5.4d), TBDY)} = L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00367709$$

$$L_{stir1} \text{ (Length of stirrups along X)} = 2060.00$$

$$A_{stir1} \text{ (stirrups area)} = 78.53982$$

$$psh2 \text{ ((5.4d), TBDY)} = L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00067082$$

$$L_{stir2} \text{ (Length of stirrups along X)} = 1468.00$$

$$A_{stir2} \text{ (stirrups area)} = 50.26548$$

$$A_{sec} = 440000.00$$

$$s1 = 100.00$$

$$s2 = 250.00$$

$$fywe1 = 694.4444$$

$$fywe2 = 555.5556$$

$$f_{ce} = 33.00$$

$$\text{From ((5.A5), TBDY), TBDY: } cc = 0.00238888$$

$$c = \text{confinement factor} = 1.03889$$

$$y1 = 0.00145721$$

$$sh1 = 0.00466307$$

$$ft1 = 465.423$$

$$fy1 = 387.8525$$

$$su1 = 0.00582756$$

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

$$l_o/l_{ou,min} = l_b/l_d = 0.318426$$

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

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

For calculation of $esu1_{nominal}$ and $y1$, $sh1$, $ft1$, $fy1$, it is considered

characteristic value $f_{sy1} = f_{s1}/1.2$, 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 $f_{s1} = (f_{s,jacket} \cdot A_{s,ten,jacket} + f_{s,core} \cdot A_{s,ten,core})/A_{s,ten} = 387.8525$

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

$y_2 = 0.00145721$

$sh_2 = 0.00466307$

$ft_2 = 459.4373$

$fy_2 = 382.8645$

$su_2 = 0.00582756$

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

$l_o/l_{o,min} = l_b/l_{b,min} = 0.318426$

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

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 $f_{s2} = (f_{s,jacket} \cdot A_{s,com,jacket} + f_{s,core} \cdot A_{s,com,core})/A_{s,com} = 382.8645$

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

$y_v = 0.00145721$

$sh_v = 0.00466307$

$ft_v = 463.3885$

$fy_v = 386.157$

$su_v = 0.00582756$

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

$l_o/l_{o,min} = l_b/l_d = 0.318426$

$su_v = 0.4 \cdot esu_{v,nominal} ((5.5), TBDY) = 0.032$

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 $f_{sv} = (f_{s,jacket} \cdot A_{s,mid,jacket} + f_{s,mid} \cdot A_{s,mid,core})/A_{s,mid} = 386.157$

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

$1 = A_{s,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.09178643$

$2 = A_{s,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.04665628$

$v = A_{s,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.08306563$

and confined core properties:

$b = 340.00$

$d = 677.00$

$d' = 13.00$

$f_{cc} (5A.2, TBDY) = 34.2833$

$cc (5A.5, TBDY) = 0.00238888$

$c = \text{confinement factor} = 1.03889$

$1 = A_{s,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.11276915$

$2 = A_{s,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.05732208$

$v = A_{s,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.10205474$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

---->

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

---->

$su (4.9) = 0.20810191$

$Mu = MRc (4.14) = 8.2924E+008$

$u = su (4.1) = 1.0408734E-005$

Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.318426$

$l_b = 300.00$

$l_d = 942.1341$

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: $f_y = 655.5556$
 Mean concrete strength: $f_c' = (f_c'_{jacket} \cdot Area_{jacket} + f_c'_{core} \cdot Area_{core}) / Area_{section} = 27.68182$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $t = 1.00$
 $s = 0.80$
 $e = 1.00$
 $cb = 25.00$
 $K_{tr} = 1.7174$
 $A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 257.6106$
 where A_{tr_x} , A_{tr_y} are the sum of the area of all stirrup legs along X and Y local axis
 $s = \text{Max}(s_{external}, s_{internal}) = 250.00$
 $n = 24.00$

 Calculation of μ_{2+}

Calculation of ultimate curvature μ according to 4.1, Biskinis/Fardis 2013:
 $\mu = 9.5578758E-006$
 $\mu_u = 5.1260E+008$

 with full section properties:

$b = 750.00$
 $d = 707.00$
 $d' = 43.00$
 $v = 0.00093001$
 $N = 16273.616$
 $f_c = 33.00$
 $\alpha (5A.5, \text{TBDY}) = 0.002$
 Final value of μ_c : $\mu_c^* = \text{shear_factor} \cdot \text{Max}(\mu_c, \mu_{cc}) = 0.01288354$
 The Shear_factor is considered equal to 1 (pure moment strength)
 From (5.4b), TBDY: $\mu_c = 0.01288354$
 $\mu_{ve} ((5.4c), \text{TBDY}) = \alpha_{se} \cdot \text{sh}_{\min} \cdot f_{yve} / f_{ce} + \text{Min}(f_x, f_y) = 0.05503171$
 where $f = \alpha_f \cdot p_f \cdot f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

 $f_x = 0.04286225$

Expression ((15B.6), TBDY) is modified as $\alpha_f = 1 - (\text{Unconfined area}) / (\text{total area})$
 $\alpha_f = 0.31984848$

with Unconfined area = $((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 140733.333$

$b_{\max} = 750.00$

$h_{\max} = 750.00$

From EC8 A.4.4.3(6), $p_f = 2t_f / b_w = 0.00508$

$b_w = 400.00$

effective stress from (A.35), $f_{f,e} = 870.5244$

 $f_y = 0.04286225$

Expression ((15B.6), TBDY) is modified as $\alpha_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$\alpha_f = 0.31984848$

with Unconfined area = $((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 140733.333$

$b_{\max} = 750.00$

$h_{\max} = 750.00$

From EC8 A.4.4.3(6), $p_f = 2t_f / b_w = 0.00508$

$b_w = 400.00$

effective stress from (A.35), $f_{f,e} = 870.5244$

 $R = 40.00$

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

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{,f} = 0.015$

$\alpha_{se} ((5.4d), \text{TBDY}) = (\alpha_{se1} \cdot A_{\text{ext}} + \alpha_{se2} \cdot A_{\text{int}}) / A_{\text{sec}} = 0.45746528$

$\alpha_{se1} = \text{Max}(((A_{\text{conf,max1}} - A_{\text{noConf1}}) / A_{\text{conf,max1}}) \cdot (A_{\text{conf,min1}} / A_{\text{conf,max1}}), 0) = 0.45746528$

The definitions of A_{noConf} , $A_{\text{conf,min}}$ and $A_{\text{conf,max}}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988) "Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max1} = 353600.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{conf,min1} = 293525.00$ is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area $A_{conf,max1}$ by a length equal to half the clear spacing between external hoops.

$A_{noConf1} = 158733.333$ is the unconfined external core area which is equal to $b_i^2/6$ as defined at (A.2).
 $a_{se2} (>= a_{se1}) = \text{Max}(((A_{conf,max2} - A_{noConf2})/A_{conf,max2}) * (A_{conf,min2}/A_{conf,max2}), 0) = 0.45746528$

The definitions of A_{noConf} , $A_{conf,min}$ and $A_{conf,max}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988) "Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max2} = 171264.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

$A_{conf,min2} = 54741.00$ is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area $A_{conf,max2}$ by a length equal to half the clear spacing between internal hoops.

$A_{noConf2} = 106242.667$ is the unconfined internal core area which is equal to $b_i^2/6$ as defined at (A.2).
 $p_{sh,min} * F_{ywe} = \text{Min}(p_{sh,x} * F_{ywe}, p_{sh,y} * F_{ywe}) = 2.92621$

Expression (5.4d) 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)

 $p_{sh,x} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{s2} * F_{ywe2} = 2.92621$
 p_{sh1} ((5.4d), TBDY) = $L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00367709$
 L_{stir1} (Length of stirrups along Y) = 2060.00
 A_{stir1} (stirrups area) = 78.53982
 p_{sh2} (5.4d) = $L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00067082$
 L_{stir2} (Length of stirrups along Y) = 1468.00
 A_{stir2} (stirrups area) = 50.26548

 $p_{sh,y} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{s2} * F_{ywe2} = 2.92621$
 p_{sh1} ((5.4d), TBDY) = $L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00367709$
 L_{stir1} (Length of stirrups along X) = 2060.00
 A_{stir1} (stirrups area) = 78.53982
 p_{sh2} ((5.4d), TBDY) = $L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00067082$
 L_{stir2} (Length of stirrups along X) = 1468.00
 A_{stir2} (stirrups area) = 50.26548

 $A_{sec} = 440000.00$
 $s1 = 100.00$
 $s2 = 250.00$
 $f_{ywe1} = 694.4444$
 $f_{ywe2} = 555.5556$
 $f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY: $cc = 0.00238888$

$c = \text{confinement factor} = 1.03889$

$y1 = 0.00145721$
 $sh1 = 0.00466307$
 $ft1 = 459.4373$
 $fy1 = 382.8645$
 $su1 = 0.00582756$

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

$l_o/l_{ou,min} = l_b/l_d = 0.318426$
 $su1 = 0.4 * esu1_{nominal}$ ((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 $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE 41-17.

with $fs1 = (f_{s,jacket} * A_{sl,ten,jacket} + f_{s,core} * A_{sl,ten,core}) / A_{sl,ten} = 382.8645$

with $Es1 = (E_{s,jacket} * A_{sl,ten,jacket} + E_{s,core} * A_{sl,ten,core}) / A_{sl,ten} = 200000.00$

$y2 = 0.00145721$
 $sh2 = 0.00466307$

$$ft2 = 465.423$$

$$fy2 = 387.8525$$

$$su2 = 0.00582756$$

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

$$lo/lo_{u,min} = lb/lb_{u,min} = 0.318426$$

$$su2 = 0.4 * esu2_{nominal} ((5.5), TBDY) = 0.032$$

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.

$$\text{with } fs2 = (fs_{jacket} * A_{sl,com,jacket} + fs_{core} * A_{sl,com,core}) / A_{sl,com} = 387.8525$$

$$\text{with } Es2 = (Es_{jacket} * A_{sl,com,jacket} + Es_{core} * A_{sl,com,core}) / A_{sl,com} = 200000.00$$

$$yv = 0.00145721$$

$$shv = 0.00466307$$

$$ftv = 463.3885$$

$$fyv = 386.157$$

$$suv = 0.00582756$$

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

$$lo/lo_{u,min} = lb/ld = 0.318426$$

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

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.

$$\text{with } fsv = (fs_{jacket} * A_{sl,mid,jacket} + fs_{mid} * A_{sl,mid,core}) / A_{sl,mid} = 386.157$$

$$\text{with } Esv = (Es_{jacket} * A_{sl,mid,jacket} + Es_{mid} * A_{sl,mid,core}) / A_{sl,mid} = 200000.00$$

$$1 = A_{sl,ten} / (b * d) * (fs1 / fc) = 0.02488335$$

$$2 = A_{sl,com} / (b * d) * (fs2 / fc) = 0.04895276$$

$$v = A_{sl,mid} / (b * d) * (fsv / fc) = 0.04430167$$

and confined core properties:

$$b = 690.00$$

$$d = 677.00$$

$$d' = 13.00$$

$$fcc (5A.2, TBDY) = 34.2833$$

$$cc (5A.5, TBDY) = 0.00238888$$

$$c = \text{confinement factor} = 1.03889$$

$$1 = A_{sl,ten} / (b * d) * (fs1 / fc) = 0.02824566$$

$$2 = A_{sl,com} / (b * d) * (fs2 / fc) = 0.05556741$$

$$v = A_{sl,mid} / (b * d) * (fsv / fc) = 0.05028784$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

---->

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

---->

$$su (4.9) = 0.13760581$$

$$Mu = MRc (4.14) = 5.1260E+008$$

$$u = su (4.1) = 9.5578758E-006$$

Calculation of ratio lb/ld

Lap Length: $lb/ld = 0.318426$

$$lb = 300.00$$

$$ld = 942.1341$$

Calculation of $lb_{u,min}$ 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: $fy = 655.5556$

Mean concrete strength: $fc' = (fc'_{jacket} * Area_{jacket} + fc'_{core} * Area_{core}) / Area_{section} = 27.68182$, but $fc'^{0.5} < =$
8.3 MPa (22.5.3.1, ACI 318-14)

$$t = 1.00$$

$$s = 0.80$$

e = 1.00
cb = 25.00
Ktr = 1.7174
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) = 250.00
n = 24.00

Calculation of Mu2-

Calculation of ultimate curvature ϕ_u according to 4.1, Biskinis/Fardis 2013:
u = 1.0408734E-005
Mu = 8.2924E+008

with full section properties:

b = 400.00
d = 707.00
d' = 43.00
v = 0.00174378
N = 16273.616
fc = 33.00
co (5A.5, TBDY) = 0.002
Final value of ϕ_u : $\phi_u^* = \text{shear_factor} * \text{Max}(\phi_u, \phi_c) = 0.01288354$
The Shear_factor is considered equal to 1 (pure moment strength)
From (5.4b), TBDY: $\phi_u = 0.01288354$
 ϕ_{we} ((5.4c), TBDY) = $\text{ase} * \text{sh_min} * f_{ywe} / f_{ce} + \text{Min}(\phi_x, \phi_y) = 0.05503171$
where $\phi = \text{af} * \text{pf} * \text{ffe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

 $\phi_x = 0.04286225$

Expression ((15B.6), TBDY) is modified as $\text{af} = 1 - (\text{Unconfined area}) / (\text{total area})$
 $\text{af} = 0.31984848$

with Unconfined area = $((b_{\text{max}} - 2R)^2 + (h_{\text{max}} - 2R)^2) / 3 = 140733.333$

$b_{\text{max}} = 750.00$

$h_{\text{max}} = 750.00$

From EC8 A.4.4.3(6), $\text{pf} = 2t_f / b_w = 0.00508$

$b_w = 400.00$

effective stress from (A.35), $\text{ff}_e = 870.5244$

 $\phi_y = 0.04286225$

Expression ((15B.6), TBDY) is modified as $\text{af} = 1 - (\text{Unconfined area}) / (\text{total area})$

$\text{af} = 0.31984848$

with Unconfined area = $((b_{\text{max}} - 2R)^2 + (h_{\text{max}} - 2R)^2) / 3 = 140733.333$

$b_{\text{max}} = 750.00$

$h_{\text{max}} = 750.00$

From EC8 A.4.4.3(6), $\text{pf} = 2t_f / b_w = 0.00508$

$b_w = 400.00$

effective stress from (A.35), $\text{ff}_e = 870.5244$

R = 40.00

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

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{,f} = 0.015$

ase ((5.4d), TBDY) = $(\text{ase}_1 * A_{\text{ext}} + \text{ase}_2 * A_{\text{int}}) / A_{\text{sec}} = 0.45746528$

$\text{ase}_1 = \text{Max}(((A_{\text{conf,max1}} - A_{\text{noConf1}}) / A_{\text{conf,max1}}) * (A_{\text{conf,min1}} / A_{\text{conf,max1}}), 0) = 0.45746528$

The definitions of A_{noConf} , $A_{\text{conf,min}}$ and $A_{\text{conf,max}}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{\text{conf,max1}} = 353600.00$ is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{\text{conf,min1}} = 293525.00$ is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area $A_{conf,max1}$ by a length equal to half the clear spacing between external hoops.

$A_{noConf1} = 158733.333$ is the unconfined external core area which is equal to $b_i^2/6$ as defined at (A.2).
 $ase2 (>= ase1) = \text{Max}(((A_{conf,max2} - A_{noConf2})/A_{conf,max2}) * (A_{conf,min2}/A_{conf,max2}), 0) = 0.45746528$

The definitions of A_{noConf} , $A_{conf,min}$ and $A_{conf,max}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988) "Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max2} = 171264.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

$A_{conf,min2} = 54741.00$ is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area $A_{conf,max2}$ by a length equal to half the clear spacing between internal hoops.

$A_{noConf2} = 106242.667$ is the unconfined internal core area which is equal to $b_i^2/6$ as defined at (A.2).
 $psh_{,min} * F_{ywe} = \text{Min}(psh_{,x} * F_{ywe}, psh_{,y} * F_{ywe}) = 2.92621$

Expression (5.4d) 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)

 $psh_{,x} * F_{ywe} = psh1 * F_{ywe1} + ps2 * F_{ywe2} = 2.92621$
 $psh1$ ((5.4d), TBDY) = $L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00367709$
 L_{stir1} (Length of stirrups along Y) = 2060.00
 A_{stir1} (stirrups area) = 78.53982
 $psh2$ (5.4d) = $L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00067082$
 L_{stir2} (Length of stirrups along Y) = 1468.00
 A_{stir2} (stirrups area) = 50.26548

 $psh_{,y} * F_{ywe} = psh1 * F_{ywe1} + ps2 * F_{ywe2} = 2.92621$
 $psh1$ ((5.4d), TBDY) = $L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00367709$
 L_{stir1} (Length of stirrups along X) = 2060.00
 A_{stir1} (stirrups area) = 78.53982
 $psh2$ ((5.4d), TBDY) = $L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00067082$
 L_{stir2} (Length of stirrups along X) = 1468.00
 A_{stir2} (stirrups area) = 50.26548

 $A_{sec} = 440000.00$

$s1 = 100.00$

$s2 = 250.00$

$f_{ywe1} = 694.4444$

$f_{ywe2} = 555.5556$

$f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY: $cc = 0.00238888$

$c =$ confinement factor = 1.03889

$y1 = 0.00145721$

$sh1 = 0.00466307$

$ft1 = 465.423$

$fy1 = 387.8525$

$su1 = 0.00582756$

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

$l_o/l_{ou,min} = l_b/l_d = 0.318426$

$su1 = 0.4 * esu1_{nominal}$ ((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 $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE 41-17.

with $fs1 = (f_{s,jacket} * A_{s1,ten,jacket} + f_{s,core} * A_{s1,ten,core}) / A_{s1,ten} = 387.8525$

with $Es1 = (E_{s,jacket} * A_{s1,ten,jacket} + E_{s,core} * A_{s1,ten,core}) / A_{s1,ten} = 200000.00$

$y2 = 0.00145721$

$sh2 = 0.00466307$

$ft2 = 459.4373$

$fy2 = 382.8645$

$su2 = 0.00582756$

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

$$l_o/l_{o,min} = l_b/l_{b,min} = 0.318426$$

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

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 $f_{s_y2} = f_{s2}/1.2$, 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.

$$\text{with } f_{s2} = (f_{s,jacket} \cdot A_{s,com,jacket} + f_{s,core} \cdot A_{s,com,core}) / A_{s,com} = 382.8645$$

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

$$y_v = 0.00145721$$

$$sh_v = 0.00466307$$

$$ft_v = 463.3885$$

$$fy_v = 386.157$$

$$s_{uv} = 0.00582756$$

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

$$l_o/l_{o,min} = l_b/l_d = 0.318426$$

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

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

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

For calculation of $e_{s_{uv}, nominal}$ and y_v , sh_v, ft_v, fy_v , it is considered characteristic value $f_{s_{uv}} = f_{sv}/1.2$, 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.

$$\text{with } f_{sv} = (f_{s,jacket} \cdot A_{s,mid,jacket} + f_{s,mid} \cdot A_{s,mid,core}) / A_{s,mid} = 386.157$$

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

$$1 = A_{s,ten} / (b \cdot d) \cdot (f_{s1} / f_c) = 0.09178643$$

$$2 = A_{s,com} / (b \cdot d) \cdot (f_{s2} / f_c) = 0.04665628$$

$$v = A_{s,mid} / (b \cdot d) \cdot (f_{sv} / f_c) = 0.08306563$$

and confined core properties:

$$b = 340.00$$

$$d = 677.00$$

$$d' = 13.00$$

$$f_{cc} (5A.2, TBDY) = 34.2833$$

$$c_c (5A.5, TBDY) = 0.00238888$$

$$c = \text{confinement factor} = 1.03889$$

$$1 = A_{s,ten} / (b \cdot d) \cdot (f_{s1} / f_c) = 0.11276915$$

$$2 = A_{s,com} / (b \cdot d) \cdot (f_{s2} / f_c) = 0.05732208$$

$$v = A_{s,mid} / (b \cdot d) \cdot (f_{sv} / f_c) = 0.10205474$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

---->

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

---->

$$s_u (4.9) = 0.20810191$$

$$\mu_u = M_{Rc} (4.14) = 8.2924E+008$$

$$u = s_u (4.1) = 1.0408734E-005$$

Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.318426$

$$l_b = 300.00$$

$$l_d = 942.1341$$

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: $f_y = 655.5556$

Mean concrete strength: $f'_c = (f'_{c,jacket} \cdot \text{Area}_{jacket} + f'_{c,core} \cdot \text{Area}_{core}) / \text{Area}_{section} = 27.68182$, but $f_c^{0.5} <= 8.3$ MPa (22.5.3.1, ACI 318-14)

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 25.00$$

$$K_{tr} = 1.7174$$

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

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

$$s = \text{Max}(s_{external}, s_{internal}) = 250.00$$

n = 24.00

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 998292.205$

Calculation of Shear Strength at edge 1, $V_{r1} = 998292.205$

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

$V_{Co10} = 998292.205$

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

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

= 1 (normal-weight concrete)

Mean concrete strength: $f_c' = (f_c'_{\text{jacket}} \cdot \text{Area}_{\text{jacket}} + f_c'_{\text{core}} \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 27.68182$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M / Vd = 4.00$

$\mu_u = 11.78089$

$V_u = 0.00051441$

$d = 0.8 \cdot h = 600.00$

$N_u = 16273.616$

$A_g = 300000.00$

From (11.5.4.8), ACI 318-14: $V_s = V_{s,\text{jacket}} + V_{s,\text{core}} = 881489.011$

where:

$V_{s,\text{jacket}} = V_{s,j1} + V_{s,j2} = 802851.456$

$V_{s,j1} = 279252.68$ is calculated for section web jacket, with:

$d = 320.00$

$A_v = 157079.633$

$f_y = 555.5556$

$s = 100.00$

$V_{s,j1}$ is multiplied by $Col_{j1} = 1.00$

$s/d = 0.3125$

$V_{s,j2} = 523598.776$ is calculated for section flange jacket, with:

$d = 600.00$

$A_v = 157079.633$

$f_y = 555.5556$

$s = 100.00$

$V_{s,j2}$ is multiplied by $Col_{j2} = 1.00$

$s/d = 0.16666667$

$V_{s,\text{core}} = V_{s,c1} + V_{s,c2} = 78637.555$

$V_{s,c1} = 0.00$ is calculated for section web core, with:

$d = 160.00$

$A_v = 100530.965$

$f_y = 444.4444$

$s = 250.00$

$V_{s,c1}$ is multiplied by $Col_{c1} = 0.00$

$s/d = 1.5625$

$V_{s,c2} = 78637.555$ is calculated for section flange core, with:

$d = 440.00$

$A_v = 100530.965$

$f_y = 444.4444$

$s = 250.00$

$V_{s,c2}$ is multiplied by $Col_{c2} = 1.00$

$s/d = 0.56818182$

V_f ((11-3)-(11.4), ACI 440) = 372533.843

$f = 0.95$, for fully-wrapped sections

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

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

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

orientation 1: $\theta = 45^\circ$ and $a = 90^\circ$

$V_f = \text{Min}(|V_f(45, 90)|, |V_f(-45, 90)|)$, with:

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

$d_{fv} = d$ (figure 11.2, ACI 440) = 707.00

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: $V_s + V_f \leq 838832.606$
 b_w = 400.00

Calculation of Shear Strength at edge 2, V_{r2} = 998292.205
 $V_{r2} = V_{Col}$ ((10.3), ASCE 41-17) = $k_n l * V_{Col0}$
 V_{Col0} = 998292.205
 $k_n l$ = 1 (zero step-static loading)

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

= 1 (normal-weight concrete)
Mean concrete strength: $f'_c = (f'_{c,jacket} * Area_{jacket} + f'_{c,core} * Area_{core}) / Area_{section} = 27.68182$, but $f_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

M/Vd = 4.00
 μ_u = 11.78144
 V_u = 0.00051441
 d = $0.8 * h$ = 600.00
 N_u = 16273.616
 A_g = 300000.00
From (11.5.4.8), ACI 318-14: $V_s = V_{s,jacket} + V_{s,core} = 881489.011$
where:

$V_{s,jacket} = V_{s,j1} + V_{s,j2} = 802851.456$
 $V_{s,j1} = 279252.68$ is calculated for section web jacket, with:
 d = 320.00
 A_v = 157079.633
 f_y = 555.5556
 s = 100.00

$V_{s,j1}$ is multiplied by $Col_{j1} = 1.00$
 s/d = 0.3125

$V_{s,j2} = 523598.776$ is calculated for section flange jacket, with:
 d = 600.00
 A_v = 157079.633
 f_y = 555.5556
 s = 100.00

$V_{s,j2}$ is multiplied by $Col_{j2} = 1.00$
 s/d = 0.16666667

$V_{s,core} = V_{s,c1} + V_{s,c2} = 78637.555$
 $V_{s,c1} = 0.00$ is calculated for section web core, with:
 d = 160.00
 A_v = 100530.965
 f_y = 444.4444
 s = 250.00

$V_{s,c1}$ is multiplied by $Col_{c1} = 0.00$
 s/d = 1.5625

$V_{s,c2} = 78637.555$ is calculated for section flange core, with:
 d = 440.00
 A_v = 100530.965
 f_y = 444.4444
 s = 250.00

$V_{s,c2}$ is multiplied by $Col_{c2} = 1.00$
 s/d = 0.56818182

V_f ((11-3)-(11.4), ACI 440) = 372533.843
 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: $\theta = b_1 + 90^\circ = 90.00$
 $V_f = \text{Min}(|V_f(45, 1)|, |V_f(-45, a_1)|)$, with:

total thickness per orientation, $tf_1 = NL * t / NoDir = 1.016$

dfv = d (figure 11.2, ACI 440) = 707.00
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 <= 838832.606
bw = 400.00

End Of Calculation of Shear Capacity ratio for element: column JLC1 of floor 1
At local axis: 2

Start Of Calculation of Chord Rotation Capacity for element: column JLC1 of floor 1
At local axis: 2
Integration Section: (b)
Section Type: rcjics

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 Secondary Member: Concrete Strength, $f_c = f_{cm} = 33.00$
New material of Secondary Member: Steel Strength, $f_s = f_{sm} = 555.5556$
Concrete Elasticity, $E_c = 26999.444$
Steel Elasticity, $E_s = 200000.00$
Existing Column
Existing material of Secondary Member: Concrete Strength, $f_c = f_{cm} = 20.00$
Existing material of Secondary Member: Steel Strength, $f_s = f_{sm} = 444.4444$
Concrete Elasticity, $E_c = 21019.039$
Steel Elasticity, $E_s = 200000.00$
Max Height, $H_{max} = 750.00$
Min Height, $H_{min} = 400.00$
Max Width, $W_{max} = 750.00$
Min Width, $W_{min} = 400.00$
Jacket Thickness, $t_j = 100.00$
Cover Thickness, $c = 25.00$
Element Length, $L = 3000.00$
Secondary Member
Ribbed Bars
Ductile Steel
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
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, $M = -138295.135$
Shear Force, $V_2 = 7895.087$
Shear Force, $V_3 = -147.9094$

Axial Force, $F = -17072.715$
 Longitudinal Reinforcement Area Distribution (in 2 divisions)
 -Tension: $As_t = 0.00$
 -Compression: $As_c = 5353.274$
 Longitudinal Reinforcement Area Distribution (in 3 divisions)
 -Tension: $As_{ten} = 1137.257$
 -Compression: $As_{com} = 2208.54$
 -Middle: $As_{mid} = 2007.478$
 Longitudinal External Reinforcement Area Distribution (in 3 divisions)
 -Tension: $As_{ten,jacket} = 829.3805$
 -Compression: $As_{com,jacket} = 1746.726$
 -Middle: $As_{mid,jacket} = 1545.664$
 Longitudinal Internal Reinforcement Area Distribution (in 3 divisions)
 -Tension: $As_{ten,core} = 307.8761$
 -Compression: $As_{com,core} = 461.8141$
 -Middle: $As_{mid,core} = 461.8141$
 Mean Diameter of Tension Reinforcement, $Db_L = 16.80$

Existing component: From table 7-7, ASCE 41_17: Final chord rotation Capacity $u_R = \phi u = 0.00076968$
 $u = y + p = 0.0009055$

- Calculation of y -

$y = (M_y * L_s / 3) / E_{eff} = 0.0009055$ ((4.29), Biskinis Phd)
 $M_y = 4.2101E+008$
 $L_s = M/V$ (with $L_s > 0.1 * L$ and $L_s < 2 * L$) = 934.9987
 From table 10.5, ASCE 41_17: $E_{eff} = factor * E_c * I_g = 1.4491E+014$
 $factor = 0.30$
 $A_g = 440000.00$
 Mean concrete strength: $fc' = (fc'_{jacket} * Area_{jacket} + fc'_{core} * Area_{core}) / Area_{section} = 27.68182$
 $N = 17072.715$
 $E_c * I_g = E_{c,jacket} * I_{g,jacket} + E_{c,core} * I_{g,core} = 4.8303E+014$

Calculation of Yielding Moment M_y

Calculation of y and M_y according to Annex 7 -

Assuming neutral axis within flange ($y < t/d$, compression zone rectangular) with:
 flange width, $b = 750.00$
 web width, $b_w = 400.00$
 flange thickness, $t = 400.00$

$y = \text{Min}(y_{ten}, y_{com})$
 $y_{ten} = 3.1432128E-006$
 with ((10.1), ASCE 41-17) $f_y = \text{Min}(f_y, 1.25 * f_y * (I_b / I_d)^{2/3}) = 358.4764$
 $d = 707.00$
 $y = 0.19343861$
 $A = 0.01018557$
 $B = 0.00449598$
 with $pt = 0.00671906$
 $pc = 0.00416509$
 $pv = 0.00378591$
 $N = 17072.715$
 $b = 750.00$
 $" = 0.06082037$
 $y_{comp} = 1.6462519E-005$
 with $fc' (12.3, (ACI 440)) = 33.48734$
 $fc = 33.00$
 $fl = 0.49678681$
 $b = b_{max} = 750.00$
 $h = h_{max} = 750.00$

$$A_g = 0.44$$

$$g = p_t + p_c + p_v = 0.01009575$$

$$r_c = 40.00$$

$$A_e/A_c = 0.31291181$$

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

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

$$f_u = 0.01$$

$$E_f = 64828.00$$

$$E_c = 26999.444$$

$$y = 0.19181501$$

$$A = 0.01002364$$

$$B = 0.00440616$$

$$\text{with } E_s = 200000.00$$

$$\text{CONFIRMATION: } y = 0.19279145 < t/d$$

Calculation of ratio l_b/l_d

$$\text{Lap Length: } l_d/l_{d,\min} = 0.39803249$$

$$l_b = 300.00$$

$$l_d = 753.7073$$

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

$$= 1$$

$$d_b = 16.66667$$

$$\text{Mean strength value of all re-bars: } f_y = 524.4444$$

$$\text{Mean concrete strength: } f_c' = (f_c'_{\text{jacket}} * \text{Area}_{\text{jacket}} + f_c'_{\text{core}} * \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 27.68182, \text{ but } f_c'^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 25.00$$

$$K_{tr} = 1.7174$$

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

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

$$s = \max(s_{\text{external}}, s_{\text{internal}}) = 250.00$$

$$n = 24.00$$

- Calculation of ρ -

$$\text{From table 10-8: } \rho = 0.00$$

with:

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

$$\text{shear control ratio } V_y E / V_{CoI} E = 0.55377356$$

$$d = d_{\text{external}} = 707.00$$

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

$$t = s_1 + s_2 + 2 * t_f / b_w * (f_{fe} / f_s) = 0.00671906$$

$$\text{jacket: } s_1 = A_{v1} * L_{\text{stir1}} / (s_1 * A_g) = 0.00367709$$

$A_{v1} = 78.53982$, is the area of every stirrup parallel to loading (shear) direction

$L_{\text{stir1}} = 2060.00$, is the total Length of all stirrups parallel to loading (shear) direction

$$s_1 = 100.00$$

$$\text{core: } s_2 = A_{v2} * L_{\text{stir2}} / (s_2 * A_g) = 0.00067082$$

$A_{v2} = 50.26548$, is the area of every stirrup parallel to loading (shear) direction

$L_{\text{stir2}} = 1468.00$, is the total Length of all stirrups parallel to loading (shear) direction

$$s_2 = 250.00$$

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

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

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

For the normalisation f_s of jacket is used.

$$N_{UD} = 17072.715$$

$$A_g = 440000.00$$

$$f_c E = (f_c'_{\text{jacket}} * \text{Area}_{\text{jacket}} + f_c'_{\text{core}} * \text{Area}_{\text{core}}) / \text{section_area} = 27.68182$$

$$f_y E = (f_y_{\text{ext_Long_Reinf}} * \text{Area}_{\text{ext_Long_Reinf}} + f_y_{\text{int_Long_Reinf}} * \text{Area}_{\text{int_Long_Reinf}}) / \text{Area}_{\text{Tot_Long_Rein}} = 529.9948$$

$$f_y t E = (f_y_{\text{ext_Trans_Reinf}} * s_1 + f_y_{\text{int_Trans_Reinf}} * s_2) / (s_1 + s_2) = 538.4128$$

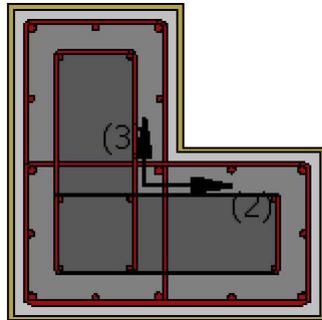
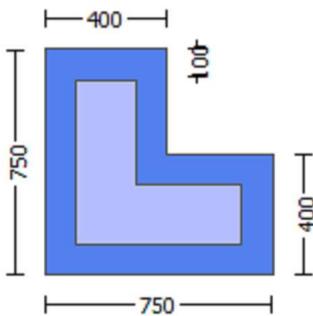
$$\rho_l = \text{Area}_{\text{Tot_Long_Rein}} / (b * d) = 0.01009575$$

b = 750.00
d = 707.00
f_{cE} = 27.68182

End Of Calculation of Chord Rotation Capacity for element: column JLC1 of floor 1
At local axis: 2
Integration Section: (b)

Calculation No. 7

column C1, Floor 1
Limit State: Operational Level (data interpolation between analysis steps 1 and 2)
Analysis: Uniform +X
Check: Shear capacity VRd
Edge: End
Local Axis: (3)



Start Of Calculation of Shear Capacity for element: column JLC1 of floor 1
At local axis: 3
Integration Section: (b)
Section Type: rcjcs

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 Secondary Member: Concrete Strength, $f_c = f_{c_lower_bound} = 25.00$
New material of Secondary Member: Steel Strength, $f_s = f_{s_lower_bound} = 500.00$
Concrete Elasticity, $E_c = 26999.444$
Steel Elasticity, $E_s = 200000.00$
Existing Column

```

Existing material of Secondary Member: Concrete Strength,  $f_c = f_{c\_lower\_bound} = 16.00$ 
Existing material of Secondary 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,  $f_s = f_{sm} = 555.5556$ 
Existing Column
Existing material: Concrete Strength,  $f_c = f_{cm} = 20.00$ 
Existing material: Steel Strength,  $f_s = f_{sm} = 444.4444$ 
#####
Max Height,  $H_{max} = 750.00$ 
Min Height,  $H_{min} = 400.00$ 
Max Width,  $W_{max} = 750.00$ 
Min Width,  $W_{min} = 400.00$ 
Jacket Thickness,  $t_j = 100.00$ 
Cover Thickness,  $c = 25.00$ 
Element Length,  $L = 3000.00$ 
Secondary Member
Ribbed Bars
Ductile Steel
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
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,  $M_a = -303215.389$ 
Shear Force,  $V_a = 147.9094$ 
EDGE -B-
Bending Moment,  $M_b = -138295.135$ 
Shear Force,  $V_b = -147.9094$ 
BOTH EDGES
Axial Force,  $F = -17072.715$ 
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension:  $A_{sl} = 0.00$ 
-Compression:  $A_{slc} = 5353.274$ 
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension:  $A_{sl,ten} = 1137.257$ 
-Compression:  $A_{sl,com} = 2208.54$ 
-Middle:  $A_{sl,mid} = 2007.478$ 
Mean Diameter of Tension Reinforcement,  $Db_{L,ten} = 16.80$ 
-----
-----

Existing component: From table 7-7, ASCE 41_17: Final Shear Capacity  $V_R = *V_n = 864068.364$ 
 $V_n ((10.3), ASCE 41-17) = knl * V_{CoIo} = 1.0166E+006$ 
 $V_{CoI} = 1.0166E+006$ 
 $knl = 1.00$ 

```

displacement_ductility_demand = 3.2359817E-005

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

= 1 (normal-weight concrete)

Mean concrete strength: $f_c' = (f_c'_{\text{jacket}} \cdot \text{Area}_{\text{jacket}} + f_c'_{\text{core}} \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 21.31818$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$\mu_u = 138295.135$

$V_u = 147.9094$

$d = 0.8 \cdot h = 600.00$

$N_u = 17072.715$

$A_g = 300000.00$

From (11.5.4.8), ACI 318-14: $V_s = V_{s,\text{jacket}} + V_{s,\text{core}} = 793340.11$

where:

$V_{s,\text{jacket}} = V_{s,j1} + V_{s,j2} = 722566.31$

$V_{s,j1} = 471238.898$ is calculated for section web jacket, with:

$d = 600.00$

$A_v = 157079.633$

$f_y = 500.00$

$s = 100.00$

$V_{s,j1}$ is multiplied by $\text{Col},j1 = 1.00$

$s/d = 0.16666667$

$V_{s,j2} = 251327.412$ is calculated for section flange jacket, with:

$d = 320.00$

$A_v = 157079.633$

$f_y = 500.00$

$s = 100.00$

$V_{s,j2}$ is multiplied by $\text{Col},j2 = 1.00$

$s/d = 0.3125$

$V_{s,\text{core}} = V_{s,c1} + V_{s,c2} = 70773.799$

$V_{s,c1} = 70773.799$ is calculated for section web core, with:

$d = 440.00$

$A_v = 100530.965$

$f_y = 400.00$

$s = 250.00$

$V_{s,c1}$ is multiplied by $\text{Col},c1 = 1.00$

$s/d = 0.56818182$

$V_{s,c2} = 0.00$ is calculated for section flange core, with:

$d = 160.00$

$A_v = 100530.965$

$f_y = 400.00$

$s = 250.00$

$V_{s,c2}$ is multiplied by $\text{Col},c2 = 0.00$

$s/d = 1.5625$

V_f ((11-3)-(11.4), ACI 440) = 372533.843

$f = 0.95$, 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, $t_{f1} = NL \cdot t / \text{NoDir} = 1.016$

$d_{fv} = d$ (figure 11.2, ACI 440) = 707.00

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: $V_s + V_f \leq 736127.561$

$b_w = 400.00$

displacement_ductility_demand is calculated as δ / y

- Calculation of ϕ_y for END B -
for rotation axis 2 and integ. section (b)

From analysis, chord rotation $\theta = 2.9301958E-008$

$y = (M_y * L_s / 3) / E_{eff} = 0.0009055$ ((4.29), Biskinis Phd))

$M_y = 4.2101E+008$

$L_s = M/V$ (with $L_s > 0.1 * L$ and $L_s < 2 * L$) = 934.9987

From table 10.5, ASCE 41_17: $E_{eff} = factor * E_c * I_g = 1.4491E+014$

factor = 0.30

$A_g = 440000.00$

Mean concrete strength: $f_c' = (f_c'_{jacket} * Area_{jacket} + f_c'_{core} * Area_{core}) / Area_{section} = 27.68182$

$N = 17072.715$

$E_c * I_g = E_c_{jacket} * I_{g,jacket} + E_c_{core} * I_{g,core} = 4.8303E+014$

Calculation of Yielding Moment M_y

Calculation of ϕ_y and M_y according to Annex 7 -

Assuming neutral axis within flange ($y < t/d$, compression zone rectangular) with:

flange width, $b = 750.00$

web width, $b_w = 400.00$

flange thickness, $t = 400.00$

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

$y_{ten} = 3.1432128E-006$

with ((10.1), ASCE 41-17) $f_y = \text{Min}(f_y, 1.25 * f_y * (l_b / d)^{2/3}) = 358.4764$

$d = 707.00$

$y = 0.19343861$

$A = 0.01018557$

$B = 0.00449598$

with $p_t = 0.00214476$

$p_c = 0.00416509$

$p_v = 0.00378591$

$N = 17072.715$

$b = 750.00$

" = 0.06082037

$y_{comp} = 1.6462519E-005$

with $f_c' (12.3, (ACI 440)) = 33.48734$

$f_c = 33.00$

$f_l = 0.49678681$

$b = b_{max} = 750.00$

$h = h_{max} = 750.00$

$A_g = 0.44$

$g = p_t + p_c + p_v = 0.01009575$

$r_c = 40.00$

$A_e / A_c = 0.31291181$

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

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

$f_u = 0.01$

$E_f = 64828.00$

$E_c = 26999.444$

$y = 0.19181501$

$A = 0.01002364$

$B = 0.00440616$

with $E_s = 200000.00$

CONFIRMATION: $y = 0.19279145 < t/d$

Calculation of ratio l_b/d

Lap Length: $l_d / l_{d,min} = 0.39803249$

$l_b = 300.00$

$l_d = 753.7073$

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: $f_y = 524.4444$

Mean concrete strength: $f_c' = (f_c'_{\text{jacket}} \cdot \text{Area}_{\text{jacket}} + f_c'_{\text{core}} \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 27.68182$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$cb = 25.00$$

$$K_{tr} = 1.7174$$

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

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

$$s = \text{Max}(s_{\text{external}}, s_{\text{internal}}) = 250.00$$

$$n = 24.00$$

End Of Calculation of Shear Capacity for element: column JLC1 of floor 1

At local axis: 3

Integration Section: (b)

Calculation No. 8

column C1, Floor 1

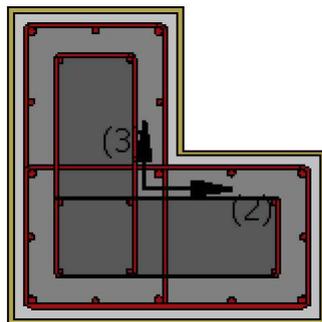
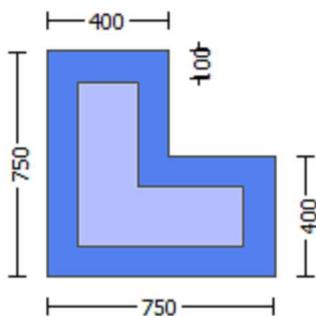
Limit State: Operational Level (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity (u)

Edge: End

Local Axis: (3)



Start Of Calculation of Shear Capacity ratio for element: column JLC1 of floor 1

At Shear local axis: 3

(Bending local axis: 2)

Section Type: rcjlc

Constant Properties

Knowledge Factor, = 0.85

```

Mean strength values are used for both shear and moment calculations.
Consequently:
Jacket
New material of Secondary Member: Concrete Strength, fc = fcm = 33.00
New material of Secondary Member: Steel Strength, fs = fsm = 555.5556
Concrete Elasticity, Ec = 26999.444
Steel Elasticity, Es = 200000.00
Existing Column
Existing material of Secondary Member: Concrete Strength, fc = fcm = 20.00
Existing material of Secondary Member: Steel Strength, fs = fsm = 444.4444
Concrete Elasticity, Ec = 21019.039
Steel Elasticity, Es = 200000.00
#####
Note: Especially for the calculation of moment strengths,
the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14
Jacket
New material: Steel Strength, fs = 1.25*fsm = 694.4444
Existing Column
Existing material: Steel Strength, fs = 1.25*fsm = 555.5556
#####
Max Height, Hmax = 750.00
Min Height, Hmin = 400.00
Max Width, Wmax = 750.00
Min Width, Wmin = 400.00
Jacket Thickness, tj = 100.00
Cover Thickness, c = 25.00
Mean Confinement Factor overall section = 1.03889
Element Length, L = 3000.00
Secondary Member
Ribbed Bars
Ductile Steel
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
Lap Length lo = 300.00
FRP Wrapping Data
Type: Carbon
Cured laminate properties (design values)
Thickness, t = 1.016
Tensile Strength, ffu = 1055.00
Tensile Modulus, Ef = 64828.00
Elongation, efu = 0.01
Number of directions, NoDir = 1
Fiber orientations, bi: 0.00°
Number of layers, NL = 1
Radius of rounding corners, R = 40.00
-----

Stepwise Properties
-----
At local axis: 3
EDGE -A-
Shear Force, Va = -0.00051441
EDGE -B-
Shear Force, Vb = 0.00051441
BOTH EDGES
Axial Force, F = -16273.616
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: Aslt = 0.00
-Compression: Aslc = 5353.274
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension: Asl,ten = 1137.257
-Compression: Asl,com = 2208.54
-Middle: Asl,mid = 2007.478
-----
-----

```

Calculation of Shear Capacity ratio , $V_e/V_r = 0.55377356$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 552827.824$

with
 $M_{pr1} = \text{Max}(M_{u1+} , M_{u1-}) = 8.2924E+008$
 $M_{u1+} = 5.1260E+008$, 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
 $M_{u1-} = 8.2924E+008$, 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
 $M_{pr2} = \text{Max}(M_{u2+} , M_{u2-}) = 8.2924E+008$
 $M_{u2+} = 5.1260E+008$, 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
 $M_{u2-} = 8.2924E+008$, 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 ϕ_u according to 4.1, Biskinis/Fardis 2013:

$\phi_u = 9.5578758E-006$

$M_u = 5.1260E+008$

with full section properties:

$b = 750.00$

$d = 707.00$

$d' = 43.00$

$v = 0.00093001$

$N = 16273.616$

$f_c = 33.00$

α_1 (5A.5, TBDY) = 0.002

Final value of ϕ_u : $\phi_u^* = \text{shear_factor} * \text{Max}(\phi_u, \phi_c) = 0.01288354$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $\phi_u = 0.01288354$

ω_e ((5.4c), TBDY) = $\alpha_1 * \text{sh, min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.05503171$

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

 $f_x = 0.04286225$

Expression ((15B.6), TBDY) is modified as $\alpha_f = 1 - (\text{Unconfined area})/(\text{total area})$

$\alpha_f = 0.31984848$

with Unconfined area = $((b_{\text{max}} - 2R)^2 + (h_{\text{max}} - 2R)^2)/3 = 140733.333$

$b_{\text{max}} = 750.00$

$h_{\text{max}} = 750.00$

From EC8 A.4.4.3(6), $\rho_f = 2t_f/b_w = 0.00508$

$b_w = 400.00$

effective stress from (A.35), $f_{f,e} = 870.5244$

$f_y = 0.04286225$

Expression ((15B.6), TBDY) is modified as $\alpha_f = 1 - (\text{Unconfined area})/(\text{total area})$

$\alpha_f = 0.31984848$

with Unconfined area = $((b_{\text{max}} - 2R)^2 + (h_{\text{max}} - 2R)^2)/3 = 140733.333$

$b_{\text{max}} = 750.00$

$h_{\text{max}} = 750.00$

From EC8 A.4.4.3(6), $\rho_f = 2t_f/b_w = 0.00508$

$b_w = 400.00$

effective stress from (A.35), $f_{f,e} = 870.5244$

$R = 40.00$

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

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{,f} = 0.015$

α_{se} ((5.4d), TBDY) = $(\alpha_{se1} * A_{\text{ext}} + \alpha_{se2} * A_{\text{int}})/A_{\text{sec}} = 0.45746528$

$\alpha_{se1} = \text{Max}(((A_{\text{conf,max1}} - A_{\text{noConf1}})/A_{\text{conf,max1}}) * (A_{\text{conf,min1}}/A_{\text{conf,max1}}), 0) = 0.45746528$

The definitions of A_{noConf} , $A_{\text{conf,min}}$ and $A_{\text{conf,max}}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988) "Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max1} = 353600.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{conf,min1} = 293525.00$ is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area $A_{conf,max1}$ by a length equal to half the clear spacing between external hoops.

$A_{noConf1} = 158733.333$ is the unconfined external core area which is equal to $b_i^2/6$ as defined at (A.2).
 $ase2 (>= ase1) = \text{Max}(((A_{conf,max2} - A_{noConf2})/A_{conf,max2}) * (A_{conf,min2}/A_{conf,max2}), 0) = 0.45746528$

The definitions of A_{noConf} , $A_{conf,min}$ and $A_{conf,max}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988) "Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max2} = 171264.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

$A_{conf,min2} = 54741.00$ is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area $A_{conf,max2}$ by a length equal to half the clear spacing between internal hoops.

$A_{noConf2} = 106242.667$ is the unconfined internal core area which is equal to $b_i^2/6$ as defined at (A.2).
 $psh_{min} * F_{ywe} = \text{Min}(psh_x * F_{ywe}, psh_y * F_{ywe}) = 2.92621$

Expression (5.4d) 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)

 $psh_x * F_{ywe} = psh1 * F_{ywe1} + ps2 * F_{ywe2} = 2.92621$

$psh1$ ((5.4d), TBDY) = $L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00367709$

L_{stir1} (Length of stirrups along Y) = 2060.00

A_{stir1} (stirrups area) = 78.53982

$psh2$ (5.4d) = $L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00067082$

L_{stir2} (Length of stirrups along Y) = 1468.00

A_{stir2} (stirrups area) = 50.26548

 $psh_y * F_{ywe} = psh1 * F_{ywe1} + ps2 * F_{ywe2} = 2.92621$

$psh1$ ((5.4d), TBDY) = $L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00367709$

L_{stir1} (Length of stirrups along X) = 2060.00

A_{stir1} (stirrups area) = 78.53982

$psh2$ ((5.4d), TBDY) = $L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00067082$

L_{stir2} (Length of stirrups along X) = 1468.00

A_{stir2} (stirrups area) = 50.26548

 $A_{sec} = 440000.00$

$s1 = 100.00$

$s2 = 250.00$

$f_{ywe1} = 694.4444$

$f_{ywe2} = 555.5556$

$f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY: $cc = 0.00238888$

$c = \text{confinement factor} = 1.03889$

$y1 = 0.00145721$

$sh1 = 0.00466307$

$ft1 = 459.4373$

$fy1 = 382.8645$

$su1 = 0.00582756$

using (30) in Biskinis/Fardis (2013) multiplied with $shear_factor$ and also multiplied by the $shear_factor$ according to 15.7.1.4, with $Shear_factor = 1.00$

$lo/lo_{u,min} = lb/ld = 0.318426$

$su1 = 0.4 * esu1_{nominal}$ ((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 $fs1 = (f_{s,jacket} * A_{s1,ten,jacket} + f_{s,core} * A_{s1,ten,core}) / A_{s1,ten} = 382.8645$

with $Es1 = (E_{s,jacket} * A_{s1,ten,jacket} + E_{s,core} * A_{s1,ten,core}) / A_{s1,ten} = 200000.00$

$y2 = 0.00145721$

$sh2 = 0.00466307$

$$ft2 = 465.423$$

$$fy2 = 387.8525$$

$$su2 = 0.00582756$$

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

$$lo/lo_{u,min} = lb/lb_{u,min} = 0.318426$$

$$su2 = 0.4 * esu2_{nominal} ((5.5), TBDY) = 0.032$$

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 $Min(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE 41-17.

$$\text{with } fs2 = (fs_{jacket} * Asl_{com,jacket} + fs_{core} * Asl_{com,core}) / Asl_{com} = 387.8525$$

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

$$yv = 0.00145721$$

$$shv = 0.00466307$$

$$ftv = 463.3885$$

$$fyv = 386.157$$

$$suv = 0.00582756$$

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

$$lo/lo_{u,min} = lb/ld = 0.318426$$

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

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 $Min(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE 41-17.

$$\text{with } fsv = (fs_{jacket} * Asl_{mid,jacket} + fs_{mid} * Asl_{mid,core}) / Asl_{mid} = 386.157$$

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

$$1 = Asl_{ten} / (b * d) * (fs1 / fc) = 0.02488335$$

$$2 = Asl_{com} / (b * d) * (fs2 / fc) = 0.04895276$$

$$v = Asl_{mid} / (b * d) * (fsv / fc) = 0.04430167$$

and confined core properties:

$$b = 690.00$$

$$d = 677.00$$

$$d' = 13.00$$

$$fcc (5A.2, TBDY) = 34.2833$$

$$cc (5A.5, TBDY) = 0.00238888$$

$$c = \text{confinement factor} = 1.03889$$

$$1 = Asl_{ten} / (b * d) * (fs1 / fc) = 0.02824566$$

$$2 = Asl_{com} / (b * d) * (fs2 / fc) = 0.05556741$$

$$v = Asl_{mid} / (b * d) * (fsv / fc) = 0.05028784$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

---->

$v < vs, y2$ - LHS eq.(4.5) is satisfied

---->

$$su (4.9) = 0.13760581$$

$$Mu = MRc (4.14) = 5.1260E+008$$

$$u = su (4.1) = 9.5578758E-006$$

Calculation of ratio lb/ld

Lap Length: $lb/ld = 0.318426$

$$lb = 300.00$$

$$ld = 942.1341$$

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: $fy = 655.5556$

Mean concrete strength: $fc' = (fc'_{jacket} * Area_{jacket} + fc'_{core} * Area_{core}) / Area_{section} = 27.68182$, but $fc'^{0.5} < =$
8.3 MPa (22.5.3.1, ACI 318-14)

$$t = 1.00$$

$$s = 0.80$$

e = 1.00
cb = 25.00
Ktr = 1.7174
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) = 250.00
n = 24.00

Calculation of Mu1-

Calculation of ultimate curvature ϕ_u according to 4.1, Biskinis/Fardis 2013:
u = 1.0408734E-005
Mu = 8.2924E+008

with full section properties:

b = 400.00
d = 707.00
d' = 43.00
v = 0.00174378
N = 16273.616
fc = 33.00
co (5A.5, TBDY) = 0.002
Final value of ϕ_u : $\phi_u^* = \text{shear_factor} * \text{Max}(\phi_u, \phi_c) = 0.01288354$
The Shear_factor is considered equal to 1 (pure moment strength)
From (5.4b), TBDY: $\phi_u = 0.01288354$
 ϕ_{we} ((5.4c), TBDY) = $\text{ase} * \text{sh}_{\min} * f_{ywe} / f_{ce} + \text{Min}(\phi_x, \phi_y) = 0.05503171$
where $\phi = \text{af} * \text{pf} * \text{ffe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

 $\phi_x = 0.04286225$

Expression ((15B.6), TBDY) is modified as $\text{af} = 1 - (\text{Unconfined area}) / (\text{total area})$

$\text{af} = 0.31984848$

with Unconfined area = $((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 140733.333$

$b_{\max} = 750.00$

$h_{\max} = 750.00$

From EC8 A.4.4.3(6), $\text{pf} = 2t_f / b_w = 0.00508$

$b_w = 400.00$

effective stress from (A.35), $\text{ff}_e = 870.5244$

 $\phi_y = 0.04286225$

Expression ((15B.6), TBDY) is modified as $\text{af} = 1 - (\text{Unconfined area}) / (\text{total area})$

$\text{af} = 0.31984848$

with Unconfined area = $((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 140733.333$

$b_{\max} = 750.00$

$h_{\max} = 750.00$

From EC8 A.4.4.3(6), $\text{pf} = 2t_f / b_w = 0.00508$

$b_w = 400.00$

effective stress from (A.35), $\text{ff}_e = 870.5244$

R = 40.00

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

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{,f} = 0.015$

ase ((5.4d), TBDY) = $(\text{ase}_1 * A_{\text{ext}} + \text{ase}_2 * A_{\text{int}}) / A_{\text{sec}} = 0.45746528$

$\text{ase}_1 = \text{Max}(((A_{\text{conf,max1}} - A_{\text{noConf1}}) / A_{\text{conf,max1}}) * (A_{\text{conf,min1}} / A_{\text{conf,max1}}), 0) = 0.45746528$

The definitions of A_{noConf} , $A_{\text{conf,min}}$ and $A_{\text{conf,max}}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{\text{conf,max1}} = 353600.00$ is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{\text{conf,min1}} = 293525.00$ is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area $A_{conf,max1}$ by a length equal to half the clear spacing between external hoops.

$A_{noConf1} = 158733.333$ is the unconfined external core area which is equal to $b_i^2/6$ as defined at (A.2).
 $ase2 (>= ase1) = \text{Max}(((A_{conf,max2} - A_{noConf2})/A_{conf,max2}) * (A_{conf,min2}/A_{conf,max2}), 0) = 0.45746528$

The definitions of A_{noConf} , $A_{conf,min}$ and $A_{conf,max}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988) "Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max2} = 171264.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

$A_{conf,min2} = 54741.00$ is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area $A_{conf,max2}$ by a length equal to half the clear spacing between internal hoops.

$A_{noConf2} = 106242.667$ is the unconfined internal core area which is equal to $b_i^2/6$ as defined at (A.2).
 $p_{sh,min} * F_{ywe} = \text{Min}(p_{sh,x} * F_{ywe}, p_{sh,y} * F_{ywe}) = 2.92621$

Expression (5.4d) 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)

 $p_{sh,x} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{s2} * F_{ywe2} = 2.92621$
 p_{sh1} ((5.4d), TBDY) = $L_{stir1} * A_{stir1} / (A_{sec} * s_1) = 0.00367709$
 L_{stir1} (Length of stirrups along Y) = 2060.00
 A_{stir1} (stirrups area) = 78.53982
 p_{sh2} (5.4d) = $L_{stir2} * A_{stir2} / (A_{sec} * s_2) = 0.00067082$
 L_{stir2} (Length of stirrups along Y) = 1468.00
 A_{stir2} (stirrups area) = 50.26548

 $p_{sh,y} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{s2} * F_{ywe2} = 2.92621$
 p_{sh1} ((5.4d), TBDY) = $L_{stir1} * A_{stir1} / (A_{sec} * s_1) = 0.00367709$
 L_{stir1} (Length of stirrups along X) = 2060.00
 A_{stir1} (stirrups area) = 78.53982
 p_{sh2} ((5.4d), TBDY) = $L_{stir2} * A_{stir2} / (A_{sec} * s_2) = 0.00067082$
 L_{stir2} (Length of stirrups along X) = 1468.00
 A_{stir2} (stirrups area) = 50.26548

 $A_{sec} = 440000.00$

$s_1 = 100.00$

$s_2 = 250.00$

$f_{ywe1} = 694.4444$

$f_{ywe2} = 555.5556$

$f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY: $cc = 0.00238888$

$c = \text{confinement factor} = 1.03889$

$y_1 = 0.00145721$

$sh_1 = 0.00466307$

$ft_1 = 465.423$

$fy_1 = 387.8525$

$su_1 = 0.00582756$

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

$l_o/l_{ou,min} = l_b/l_d = 0.318426$

$su_1 = 0.4 * esu1_{nominal}$ ((5.5), TBDY) = 0.032

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

For calculation of $esu1_{nominal}$ 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 $fs_1 = (f_{s,jacket} * A_{s,ten,jacket} + f_{s,core} * A_{s,ten,core}) / A_{s,ten} = 387.8525$

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

$y_2 = 0.00145721$

$sh_2 = 0.00466307$

$ft_2 = 459.4373$

$fy_2 = 382.8645$

$su_2 = 0.00582756$

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

$$l_0/l_{0u,min} = l_b/l_{b,min} = 0.318426$$

$$s_u = 0.4 \cdot e_{su2_nominal} ((5.5), \text{TBDY}) = 0.032$$

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.

$$\text{with } f_{s2} = (f_{s,jacket} \cdot A_{s1,com,jacket} + f_{s,core} \cdot A_{s1,com,core}) / A_{s1,com} = 382.8645$$

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

$$y_v = 0.00145721$$

$$sh_v = 0.00466307$$

$$ft_v = 463.3885$$

$$fy_v = 386.157$$

$$s_{uv} = 0.00582756$$

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

$$l_0/l_{0u,min} = l_b/l_d = 0.318426$$

$$s_{uv} = 0.4 \cdot e_{suv_nominal} ((5.5), \text{TBDY}) = 0.032$$

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.

$$\text{with } f_{sv} = (f_{s,jacket} \cdot A_{s,mid,jacket} + f_{s,mid} \cdot A_{s,mid,core}) / A_{s,mid} = 386.157$$

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

$$1 = A_{s1,ten} / (b \cdot d) \cdot (f_{s1} / f_c) = 0.09178643$$

$$2 = A_{s1,com} / (b \cdot d) \cdot (f_{s2} / f_c) = 0.04665628$$

$$v = A_{s1,mid} / (b \cdot d) \cdot (f_{sv} / f_c) = 0.08306563$$

and confined core properties:

$$b = 340.00$$

$$d = 677.00$$

$$d' = 13.00$$

$$f_{cc} (5A.2, \text{TBDY}) = 34.2833$$

$$c_c (5A.5, \text{TBDY}) = 0.00238888$$

$$c = \text{confinement factor} = 1.03889$$

$$1 = A_{s1,ten} / (b \cdot d) \cdot (f_{s1} / f_c) = 0.11276915$$

$$2 = A_{s1,com} / (b \cdot d) \cdot (f_{s2} / f_c) = 0.05732208$$

$$v = A_{s1,mid} / (b \cdot d) \cdot (f_{sv} / f_c) = 0.10205474$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

---->

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

---->

$$s_u (4.9) = 0.20810191$$

$$M_u = M_{Rc} (4.14) = 8.2924E+008$$

$$u = s_u (4.1) = 1.0408734E-005$$

Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.318426$

$$l_b = 300.00$$

$$l_d = 942.1341$$

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: $f_y = 655.5556$

Mean concrete strength: $f'_c = (f'_{c,jacket} \cdot \text{Area}_{jacket} + f'_{c,core} \cdot \text{Area}_{core}) / \text{Area}_{section} = 27.68182$, but $f_c^{0.5} <= 8.3 \text{ MPa}$ (22.5.3.1, ACI 318-14)

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 25.00$$

$$K_{tr} = 1.7174$$

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

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

$$s = \text{Max}(s_{external}, s_{internal}) = 250.00$$

$$n = 24.00$$

Calculation of μ_{2+}

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

$$\mu = 9.5578758E-006$$

$$\mu_{2+} = 5.1260E+008$$

with full section properties:

$$b = 750.00$$

$$d = 707.00$$

$$d' = 43.00$$

$$v = 0.00093001$$

$$N = 16273.616$$

$$f_c = 33.00$$

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

$$\text{Final value of } \mu_{2+}: \mu_{2+} = \text{shear_factor} * \text{Max}(\mu_c, \mu_{cc}) = 0.01288354$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \mu_c = 0.01288354$$

$$\mu_{cc} \text{ ((5.4c), TBDY)} = a_{se} * s_{h,min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.05503171$$

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

$$f_x = 0.04286225$$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.31984848$$

$$\text{with Unconfined area} = ((b_{max} - 2R)^2 + (h_{max} - 2R)^2) / 3 = 140733.333$$

$$b_{max} = 750.00$$

$$h_{max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{fe} = 870.5244$$

$$f_y = 0.04286225$$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.31984848$$

$$\text{with Unconfined area} = ((b_{max} - 2R)^2 + (h_{max} - 2R)^2) / 3 = 140733.333$$

$$b_{max} = 750.00$$

$$h_{max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{fe} = 870.5244$$

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u_{f} = 0.015$$

$$a_{se} \text{ ((5.4d), TBDY)} = (a_{se1} * A_{ext} + a_{se2} * A_{int}) / A_{sec} = 0.45746528$$

$$a_{se1} = \text{Max}(((A_{conf,max1} - A_{noConf1}) / A_{conf,max1}) * (A_{conf,min1} / A_{conf,max1}), 0) = 0.45746528$$

The definitions of A_{noConf} , $A_{conf,min}$ and $A_{conf,max}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max1} = 353600.00$ is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{conf,min1} = 293525.00$ is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area $A_{conf,max1}$ by a length

equal to half the clear spacing between external hoops.

$A_{noConf1} = 158733.333$ is the unconfined external core area which is equal to $b_i^2/6$ as defined at (A.2).

$$a_{se2} (>= a_{se1}) = \text{Max}(((A_{conf,max2} - A_{noConf2}) / A_{conf,max2}) * (A_{conf,min2} / A_{conf,max2}), 0) = 0.45746528$$

The definitions of A_{noConf} , $A_{conf,min}$ and $A_{conf,max}$ are derived from generalization

of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)
"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max2} = 171264.00$ is the confined core area at levels of member with hoops and
is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

$A_{conf,min2} = 54741.00$ is the confined core area at midway between the levels of hoops and
is calculated by reducing all the dimensions of the area $A_{conf,max2}$ by a length
equal to half the clear spacing between internal hoops.

$A_{noConf2} = 106242.667$ is the unconfined internal core area which is equal to $b_i^2/6$ as defined at (A.2).

$p_{sh,min} * F_{ywe} = \text{Min}(p_{sh,x} * F_{ywe}, p_{sh,y} * F_{ywe}) = 2.92621$

Expression (5.4d) 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)

 $p_{sh,x} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{s2} * F_{ywe2} = 2.92621$

p_{sh1} ((5.4d), TBDY) = $L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00367709$

L_{stir1} (Length of stirrups along Y) = 2060.00

A_{stir1} (stirrups area) = 78.53982

p_{sh2} (5.4d) = $L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00067082$

L_{stir2} (Length of stirrups along Y) = 1468.00

A_{stir2} (stirrups area) = 50.26548

 $p_{sh,y} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{s2} * F_{ywe2} = 2.92621$

p_{sh1} ((5.4d), TBDY) = $L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00367709$

L_{stir1} (Length of stirrups along X) = 2060.00

A_{stir1} (stirrups area) = 78.53982

p_{sh2} ((5.4d), TBDY) = $L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00067082$

L_{stir2} (Length of stirrups along X) = 1468.00

A_{stir2} (stirrups area) = 50.26548

 $A_{sec} = 440000.00$

$s1 = 100.00$

$s2 = 250.00$

$f_{ywe1} = 694.4444$

$f_{ywe2} = 555.5556$

$f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY: $cc = 0.00238888$

$c = \text{confinement factor} = 1.03889$

$y1 = 0.00145721$

$sh1 = 0.00466307$

$ft1 = 459.4373$

$fy1 = 382.8645$

$su1 = 0.00582756$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor

and also multiplied by the shear_factor according to 15.7.1.4, with

$\text{Shear_factor} = 1.00$

$l_o/l_{o,min} = l_b/l_d = 0.318426$

$su1 = 0.4 * esu1_{nominal}$ ((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 $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE 41-17.

with $fs1 = (f_{s,jacket} * A_{s,ten,jacket} + f_{s,core} * A_{s,ten,core}) / A_{s,ten} = 382.8645$

with $Es1 = (E_{s,jacket} * A_{s,ten,jacket} + E_{s,core} * A_{s,ten,core}) / A_{s,ten} = 200000.00$

$y2 = 0.00145721$

$sh2 = 0.00466307$

$ft2 = 465.423$

$fy2 = 387.8525$

$su2 = 0.00582756$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor

and also multiplied by the shear_factor according to 15.7.1.4, with

$\text{Shear_factor} = 1.00$

$l_o/l_{o,min} = l_b/l_{b,min} = 0.318426$

$su2 = 0.4 * esu2_{nominal}$ ((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 $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE 41-17.

with $fs_2 = (fs_{jacket} \cdot Asl_{com,jacket} + fs_{core} \cdot Asl_{com,core}) / Asl_{com} = 387.8525$
 with $Es_2 = (Es_{jacket} \cdot Asl_{com,jacket} + Es_{core} \cdot Asl_{com,core}) / Asl_{com} = 200000.00$
 $yv = 0.00145721$
 $shv = 0.00466307$
 $ftv = 463.3885$
 $fyv = 386.157$
 $suv = 0.00582756$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 $Shear_factor = 1.00$
 $lo/lou,min = lb/ld = 0.318426$
 $suv = 0.4 \cdot esuv_nominal ((5.5), TBDY) = 0.032$
 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 $fsv = (fs_{jacket} \cdot Asl_{mid,jacket} + fs_{mid} \cdot Asl_{mid,core}) / Asl_{mid} = 386.157$
 with $Esv = (Es_{jacket} \cdot Asl_{mid,jacket} + Es_{mid} \cdot Asl_{mid,core}) / Asl_{mid} = 200000.00$
 $1 = Asl_{ten} / (b \cdot d) \cdot (fs_1 / fc) = 0.02488335$
 $2 = Asl_{com} / (b \cdot d) \cdot (fs_2 / fc) = 0.04895276$
 $v = Asl_{mid} / (b \cdot d) \cdot (fsv / fc) = 0.04430167$

and confined core properties:

$b = 690.00$
 $d = 677.00$
 $d' = 13.00$
 $fcc (5A.2, TBDY) = 34.2833$
 $cc (5A.5, TBDY) = 0.00238888$
 $c = \text{confinement factor} = 1.03889$
 $1 = Asl_{ten} / (b \cdot d) \cdot (fs_1 / fc) = 0.02824566$
 $2 = Asl_{com} / (b \cdot d) \cdot (fs_2 / fc) = 0.05556741$
 $v = Asl_{mid} / (b \cdot d) \cdot (fsv / fc) = 0.05028784$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

$v < vs,y_2$ - LHS eq.(4.5) is satisfied

$su (4.9) = 0.13760581$

$Mu = MRc (4.14) = 5.1260E+008$

$u = su (4.1) = 9.5578758E-006$

 Calculation of ratio lb/ld

 Lap Length: $lb/ld = 0.318426$

$lb = 300.00$

$ld = 942.1341$

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: $fy = 655.5556$

Mean concrete strength: $fc' = (fc'_{jacket} \cdot Area_{jacket} + fc'_{core} \cdot Area_{core}) / Area_{section} = 27.68182$, but $fc'^{0.5} <=$

8.3 MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$Ktr = 1.7174$

$Atr = Min(Atr_x, Atr_y) = 257.6106$

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

$s = Max(s_{external}, s_{internal}) = 250.00$

$n = 24.00$

 Calculation of Mu_2 -

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

$$u = 1.0408734E-005$$

$$\mu = 8.2924E+008$$

with full section properties:

$$b = 400.00$$

$$d = 707.00$$

$$d' = 43.00$$

$$v = 0.00174378$$

$$N = 16273.616$$

$$f_c = 33.00$$

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

$$\text{Final value of } \phi_u: \phi_u^* = \text{shear_factor} * \text{Max}(\phi_u, \phi_c) = 0.01288354$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \phi_u = 0.01288354$$

$$\omega (5.4c, \text{TBDY}) = \text{ase} * \text{sh}_{\min} * f_{ywe} / f_{ce} + \text{Min}(\phi_x, \phi_y) = 0.05503171$$

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

$$\phi_x = 0.04286225$$

Expression ((15B.6), TBDY) is modified as $\text{af} = 1 - (\text{Unconfined area}) / (\text{total area})$

$$\text{af} = 0.31984848$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 140733.333$$

$$b_{\max} = 750.00$$

$$h_{\max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), pf} = 2t_f / b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), ff,e} = 870.5244$$

$$\phi_y = 0.04286225$$

Expression ((15B.6), TBDY) is modified as $\text{af} = 1 - (\text{Unconfined area}) / (\text{total area})$

$$\text{af} = 0.31984848$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 140733.333$$

$$b_{\max} = 750.00$$

$$h_{\max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), pf} = 2t_f / b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), ff,e} = 870.5244$$

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$\text{ase} ((5.4d), \text{TBDY}) = (\text{ase}_1 * A_{\text{ext}} + \text{ase}_2 * A_{\text{int}}) / A_{\text{sec}} = 0.45746528$$

$$\text{ase}_1 = \text{Max}(((A_{\text{conf,max1}} - A_{\text{noConf1}}) / A_{\text{conf,max1}}) * (A_{\text{conf,min1}} / A_{\text{conf,max1}}), 0) = 0.45746528$$

The definitions of A_{noConf} , $A_{\text{conf,min}}$ and $A_{\text{conf,max}}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{\text{conf,max1}} = 353600.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{\text{conf,min1}} = 293525.00$ is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area $A_{\text{conf,max1}}$ by a length equal to half the clear spacing between external hoops.

$A_{\text{noConf1}} = 158733.333$ is the unconfined external core area which is equal to $b_i^2/6$ as defined at (A.2).

$$\text{ase}_2 (\geq \text{ase}_1) = \text{Max}(((A_{\text{conf,max2}} - A_{\text{noConf2}}) / A_{\text{conf,max2}}) * (A_{\text{conf,min2}} / A_{\text{conf,max2}}), 0) = 0.45746528$$

The definitions of A_{noConf} , $A_{\text{conf,min}}$ and $A_{\text{conf,max}}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{\text{conf,max2}} = 171264.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

$A_{\text{conf,min2}} = 54741.00$ is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area $A_{conf,max2}$ by a length equal to half the clear spacing between internal hoops.

$AnoConf2 = 106242.667$ is the unconfined internal core area which is equal to $bi^2/6$ as defined at (A.2).

$$psh_{min} * Fywe = \text{Min}(psh_x * Fywe, psh_y * Fywe) = 2.92621$$

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

$$psh_x * Fywe = psh1 * Fywe1 + ps2 * Fywe2 = 2.92621$$
$$psh1 \text{ ((5.4d), TBDY)} = Lstir1 * Astir1 / (Asec * s1) = 0.00367709$$

Lstir1 (Length of stirrups along Y) = 2060.00
Astir1 (stirrups area) = 78.53982

$$psh2 \text{ (5.4d)} = Lstir2 * Astir2 / (Asec * s2) = 0.00067082$$

Lstir2 (Length of stirrups along Y) = 1468.00
Astir2 (stirrups area) = 50.26548

$$psh_y * Fywe = psh1 * Fywe1 + ps2 * Fywe2 = 2.92621$$
$$psh1 \text{ ((5.4d), TBDY)} = Lstir1 * Astir1 / (Asec * s1) = 0.00367709$$

Lstir1 (Length of stirrups along X) = 2060.00
Astir1 (stirrups area) = 78.53982

$$psh2 \text{ ((5.4d), TBDY)} = Lstir2 * Astir2 / (Asec * s2) = 0.00067082$$

Lstir2 (Length of stirrups along X) = 1468.00
Astir2 (stirrups area) = 50.26548

$$Asec = 440000.00$$

$$s1 = 100.00$$

$$s2 = 250.00$$

$$fywe1 = 694.4444$$

$$fywe2 = 555.5556$$

$$fce = 33.00$$

$$\text{From ((5.A.5), TBDY), TBDY: } cc = 0.00238888$$

$$c = \text{confinement factor} = 1.03889$$

$$y1 = 0.00145721$$

$$sh1 = 0.00466307$$

$$ft1 = 465.423$$

$$fy1 = 387.8525$$

$$su1 = 0.00582756$$

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

$$lo/lou_{min} = lb/ld = 0.318426$$

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

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.

$$\text{with } fs1 = (fs_{jacket} * Asl_{ten,jacket} + fs_{core} * Asl_{ten,core}) / Asl_{ten} = 387.8525$$

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

$$y2 = 0.00145721$$

$$sh2 = 0.00466307$$

$$ft2 = 459.4373$$

$$fy2 = 382.8645$$

$$su2 = 0.00582756$$

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

$$lo/lou_{min} = lb/lb_{min} = 0.318426$$

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

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.

$y2, sh2, ft2, fy2$, are also multiplied by $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE 41-17.

$$\text{with } fs2 = (fs_{jacket} * Asl_{com,jacket} + fs_{core} * Asl_{com,core}) / Asl_{com} = 382.8645$$

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

$$yv = 0.00145721$$

$$shv = 0.00466307$$

$$ftv = 463.3885$$

$$fyv = 386.157$$

suv = 0.00582756

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 = 0.318426

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/ld)^ 2/3), from 10.3.5, ASCE 41-17.

with fsv = (fsjacket*Asl,mid,jacket + fs,mid*Asl,mid,core)/Asl,mid = 386.157

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

1 = Asl,ten/(b*d)*(fs1/fc) = 0.09178643

2 = Asl,com/(b*d)*(fs2/fc) = 0.04665628

v = Asl,mid/(b*d)*(fsv/fc) = 0.08306563

and confined core properties:

b = 340.00

d = 677.00

d' = 13.00

fcc (5A.2, TBDY) = 34.2833

cc (5A.5, TBDY) = 0.00238888

c = confinement factor = 1.03889

1 = Asl,ten/(b*d)*(fs1/fc) = 0.11276915

2 = Asl,com/(b*d)*(fs2/fc) = 0.05732208

v = Asl,mid/(b*d)*(fsv/fc) = 0.10205474

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

v < vs,y2 - LHS eq.(4.5) is satisfied

--->

su (4.9) = 0.20810191

Mu = MRc (4.14) = 8.2924E+008

u = su (4.1) = 1.0408734E-005

Calculation of ratio lb/ld

Lap Length: lb/ld = 0.318426

lb = 300.00

ld = 942.1341

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 = 655.5556

Mean concrete strength: fc' = (fc'_jacket*Area_jacket + fc'_core*Area_core)/Area_section = 27.68182, but fc'^0.5 <= 8.3 MPa (22.5.3.1, ACI 318-14)

t = 1.00

s = 0.80

e = 1.00

cb = 25.00

Ktr = 1.7174

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) = 250.00

n = 24.00

Calculation of Shear Strength Vr = Min(Vr1,Vr2) = 998292.205

Calculation of Shear Strength at edge 1, Vr1 = 998292.205

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

VCol0 = 998292.205

knl = 1 (zero step-static loading)

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

= 1 (normal-weight concrete)

Mean concrete strength: $f_c' = (f_c'_{\text{jacket}} \cdot \text{Area}_{\text{jacket}} + f_c'_{\text{core}} \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 27.68182$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 4.00$

$\mu_u = 11.77537$

$V_u = 0.00051441$

$d = 0.8 \cdot h = 600.00$

$N_u = 16273.616$

$A_g = 300000.00$

From (11.5.4.8), ACI 318-14: $V_s = V_{s,\text{jacket}} + V_{s,\text{core}} = 881489.011$

where:

$V_{s,\text{jacket}} = V_{s,j1} + V_{s,j2} = 802851.456$

$V_{s,j1} = 523598.776$ is calculated for section web jacket, with:

$d = 600.00$

$A_v = 157079.633$

$f_y = 555.5556$

$s = 100.00$

$V_{s,j1}$ is multiplied by $\text{Col},j1 = 1.00$

$s/d = 0.16666667$

$V_{s,j2} = 279252.68$ is calculated for section flange jacket, with:

$d = 320.00$

$A_v = 157079.633$

$f_y = 555.5556$

$s = 100.00$

$V_{s,j2}$ is multiplied by $\text{Col},j2 = 1.00$

$s/d = 0.3125$

$V_{s,\text{core}} = V_{s,c1} + V_{s,c2} = 78637.555$

$V_{s,c1} = 78637.555$ is calculated for section web core, with:

$d = 440.00$

$A_v = 100530.965$

$f_y = 444.4444$

$s = 250.00$

$V_{s,c1}$ is multiplied by $\text{Col},c1 = 1.00$

$s/d = 0.56818182$

$V_{s,c2} = 0.00$ is calculated for section flange core, with:

$d = 160.00$

$A_v = 100530.965$

$f_y = 444.4444$

$s = 250.00$

$V_{s,c2}$ is multiplied by $\text{Col},c2 = 0.00$

$s/d = 1.5625$

V_f ((11-3)-(11.4), ACI 440) = 372533.843

$f = 0.95$, for fully-wrapped sections

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

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

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

This later relation, considered as a function $V_f(\theta, a_i)$, 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: $\theta = b1 + 90^\circ = 90.00$

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

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

$d_{fv} = d$ (figure 11.2, ACI 440) = 707.00

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: $V_s + V_f \leq 838832.606$

$b_w = 400.00$

Calculation of Shear Strength at edge 2, $V_{r2} = 998292.205$

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

$V_{\text{Col}0} = 998292.205$

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

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

= 1 (normal-weight concrete)

Mean concrete strength: $f_c' = (f_c'_{\text{jacket}} \cdot \text{Area}_{\text{jacket}} + f_c'_{\text{core}} \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 27.68182$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 4.00$

$\mu_u = 11.77482$

$V_u = 0.00051441$

$d = 0.8 \cdot h = 600.00$

$N_u = 16273.616$

$A_g = 300000.00$

From (11.5.4.8), ACI 318-14: $V_s = V_{s,\text{jacket}} + V_{s,\text{core}} = 881489.011$

where:

$V_{s,\text{jacket}} = V_{s,j1} + V_{s,j2} = 802851.456$

$V_{s,j1} = 523598.776$ is calculated for section web jacket, with:

$d = 600.00$

$A_v = 157079.633$

$f_y = 555.5556$

$s = 100.00$

$V_{s,j1}$ is multiplied by $\text{Col},j1 = 1.00$

$s/d = 0.1666667$

$V_{s,j2} = 279252.68$ is calculated for section flange jacket, with:

$d = 320.00$

$A_v = 157079.633$

$f_y = 555.5556$

$s = 100.00$

$V_{s,j2}$ is multiplied by $\text{Col},j2 = 1.00$

$s/d = 0.3125$

$V_{s,\text{core}} = V_{s,c1} + V_{s,c2} = 78637.555$

$V_{s,c1} = 78637.555$ is calculated for section web core, with:

$d = 440.00$

$A_v = 100530.965$

$f_y = 444.4444$

$s = 250.00$

$V_{s,c1}$ is multiplied by $\text{Col},c1 = 1.00$

$s/d = 0.56818182$

$V_{s,c2} = 0.00$ is calculated for section flange core, with:

$d = 160.00$

$A_v = 100530.965$

$f_y = 444.4444$

$s = 250.00$

$V_{s,c2}$ is multiplied by $\text{Col},c2 = 0.00$

$s/d = 1.5625$

V_f ((11-3)-(11.4), ACI 440) = 372533.843

$f = 0.95$, for fully-wrapped sections

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

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

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

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

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

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

$d_{fv} = d$ (figure 11.2, ACI 440) = 707.00

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: $V_s + V_f \leq 838832.606$

$b_w = 400.00$

End Of Calculation of Shear Capacity ratio for element: column JLC1 of floor 1

At local axis: 3

Start Of Calculation of Shear Capacity ratio for element: column JLC1 of floor 1
At Shear local axis: 2
(Bending local axis: 3)
Section Type: rcjlc

Constant Properties

Knowledge Factor, $\gamma = 0.85$
Mean strength values are used for both shear and moment calculations.
Consequently:
Jacket
New material of Secondary Member: Concrete Strength, $f_c = f_{cm} = 33.00$
New material of Secondary Member: Steel Strength, $f_s = f_{sm} = 555.5556$
Concrete Elasticity, $E_c = 26999.444$
Steel Elasticity, $E_s = 200000.00$
Existing Column
Existing material of Secondary Member: Concrete Strength, $f_c = f_{cm} = 20.00$
Existing material of Secondary Member: Steel Strength, $f_s = f_{sm} = 444.4444$
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, $f_s = 1.25 * f_{sm} = 694.4444$
Existing Column
Existing material: Steel Strength, $f_s = 1.25 * f_{sm} = 555.5556$

Max Height, $H_{max} = 750.00$
Min Height, $H_{min} = 400.00$
Max Width, $W_{max} = 750.00$
Min Width, $W_{min} = 400.00$
Jacket Thickness, $t_j = 100.00$
Cover Thickness, $c = 25.00$
Mean Confinement Factor overall section = 1.03889
Element Length, $L = 3000.00$
Secondary Member
Ribbed Bars
Ductile Steel
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
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, $V_a = -0.00051441$
EDGE -B-
Shear Force, $V_b = 0.00051441$
BOTH EDGES
Axial Force, $F = -16273.616$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: $A_{st} = 0.00$

-Compression: $A_{sc} = 5353.274$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

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

-Compression: $A_{sc,com} = 2208.54$

-Middle: $A_{st,mid} = 2007.478$

Calculation of Shear Capacity ratio, $V_e/V_r = 0.55377356$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 552827.824$

with

$M_{pr1} = \text{Max}(M_{u1+}, M_{u1-}) = 8.2924E+008$

$M_{u1+} = 5.1260E+008$, 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

$M_{u1-} = 8.2924E+008$, 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

$M_{pr2} = \text{Max}(M_{u2+}, M_{u2-}) = 8.2924E+008$

$M_{u2+} = 5.1260E+008$, 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

$M_{u2-} = 8.2924E+008$, 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 ϕ_u according to 4.1, Biskinis/Fardis 2013:

$\phi_u = 9.5578758E-006$

$M_u = 5.1260E+008$

with full section properties:

$b = 750.00$

$d = 707.00$

$d' = 43.00$

$v = 0.00093001$

$N = 16273.616$

$f_c = 33.00$

ϕ_c (5A.5, TBDY) = 0.002

Final value of ϕ_u : $\phi_u^* = \text{shear_factor} * \text{Max}(\phi_u, \phi_c) = 0.01288354$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $\phi_u = 0.01288354$

ϕ_{we} ((5.4c), TBDY) = $a_s e * \text{sh}_{\min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.05503171$

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

$f_x = 0.04286225$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$a_f = 0.31984848$

with Unconfined area = $((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 140733.333$

$b_{\max} = 750.00$

$h_{\max} = 750.00$

From EC8 A.4.4.3(6), $p_f = 2t_f / b_w = 0.00508$

$b_w = 400.00$

effective stress from (A.35), $f_{fe} = 870.5244$

$f_y = 0.04286225$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$a_f = 0.31984848$

with Unconfined area = $((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 140733.333$

$b_{\max} = 750.00$

$h_{\max} = 750.00$

From EC8 A.4.4.3(6), $p_f = 2t_f / b_w = 0.00508$

$b_w = 400.00$

effective stress from (A.35), $f_{f,e} = 870.5244$

$R = 40.00$

Effective FRP thickness, $t_f = NL * t * \cos(b_1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{,f} = 0.015$

$ase((5.4d), TBDY) = (ase_1 * A_{ext} + ase_2 * A_{int}) / A_{sec} = 0.45746528$

$ase_1 = \text{Max}(((A_{conf,max1} - A_{noConf1}) / A_{conf,max1}) * (A_{conf,min1} / A_{conf,max1}), 0) = 0.45746528$

The definitions of $A_{noConf1}$, $A_{conf,min1}$ and $A_{conf,max1}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max1} = 353600.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{conf,min1} = 293525.00$ is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area $A_{conf,max1}$ by a length equal to half the clear spacing between external hoops.

$A_{noConf1} = 158733.333$ is the unconfined external core area which is equal to $b_i^2/6$ as defined at (A.2).

$ase_2 (>= ase_1) = \text{Max}(((A_{conf,max2} - A_{noConf2}) / A_{conf,max2}) * (A_{conf,min2} / A_{conf,max2}), 0) = 0.45746528$

The definitions of A_{noConf} , $A_{conf,min}$ and $A_{conf,max}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max2} = 171264.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

$A_{conf,min2} = 54741.00$ is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area $A_{conf,max2}$ by a length equal to half the clear spacing between internal hoops.

$A_{noConf2} = 106242.667$ is the unconfined internal core area which is equal to $b_i^2/6$ as defined at (A.2).

$p_{sh,min} * F_{ywe} = \text{Min}(p_{sh,x} * F_{ywe}, p_{sh,y} * F_{ywe}) = 2.92621$

Expression (5.4d) 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)

$p_{sh,x} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{sh2} * F_{ywe2} = 2.92621$

$p_{sh1}((5.4d), TBDY) = L_{stir1} * A_{stir1} / (A_{sec} * s_1) = 0.00367709$

L_{stir1} (Length of stirrups along Y) = 2060.00

A_{stir1} (stirrups area) = 78.53982

$p_{sh2}((5.4d)) = L_{stir2} * A_{stir2} / (A_{sec} * s_2) = 0.00067082$

L_{stir2} (Length of stirrups along Y) = 1468.00

A_{stir2} (stirrups area) = 50.26548

$p_{sh,y} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{sh2} * F_{ywe2} = 2.92621$

$p_{sh1}((5.4d), TBDY) = L_{stir1} * A_{stir1} / (A_{sec} * s_1) = 0.00367709$

L_{stir1} (Length of stirrups along X) = 2060.00

A_{stir1} (stirrups area) = 78.53982

$p_{sh2}((5.4d), TBDY) = L_{stir2} * A_{stir2} / (A_{sec} * s_2) = 0.00067082$

L_{stir2} (Length of stirrups along X) = 1468.00

A_{stir2} (stirrups area) = 50.26548

$A_{sec} = 440000.00$

$s_1 = 100.00$

$s_2 = 250.00$

$f_{ywe1} = 694.4444$

$f_{ywe2} = 555.5556$

$f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY: $cc = 0.00238888$

$c =$ confinement factor = 1.03889

$y_1 = 0.00145721$

$sh_1 = 0.00466307$

$ft_1 = 459.4373$

$fy_1 = 382.8645$

$su_1 = 0.00582756$

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 = 0.318426

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 = 382.8645

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

y2 = 0.00145721

sh2 = 0.00466307

ft2 = 465.423

fy2 = 387.8525

su2 = 0.00582756

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 = 0.318426

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 = 387.8525

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

yv = 0.00145721

shv = 0.00466307

ftv = 463.3885

fyv = 386.157

suv = 0.00582756

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 = 0.318426

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 = 386.157

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

1 = Asl,ten/(b*d)*(fs1/fc) = 0.02488335

2 = Asl,com/(b*d)*(fs2/fc) = 0.04895276

v = Asl,mid/(b*d)*(fsv/fc) = 0.04430167

and confined core properties:

b = 690.00

d = 677.00

d' = 13.00

fcc (5A.2, TBDY) = 34.2833

cc (5A.5, TBDY) = 0.00238888

c = confinement factor = 1.03889

1 = Asl,ten/(b*d)*(fs1/fc) = 0.02824566

2 = Asl,com/(b*d)*(fs2/fc) = 0.05556741

v = Asl,mid/(b*d)*(fsv/fc) = 0.05028784

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

v < vs,y2 - LHS eq.(4.5) is satisfied

--->

su (4.9) = 0.13760581

Mu = MRc (4.14) = 5.1260E+008

u = su (4.1) = 9.5578758E-006

Calculation of ratio lb/d

Lap Length: $l_b/l_d = 0.318426$

$l_b = 300.00$

$l_d = 942.1341$

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: $f_y = 655.5556$

Mean concrete strength: $f_c' = (f_c'_{\text{jacket}} \cdot \text{Area}_{\text{jacket}} + f_c'_{\text{core}} \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 27.68182$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$c_b = 25.00$

$K_{tr} = 1.7174$

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

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

$s = \text{Max}(s_{\text{external}}, s_{\text{internal}}) = 250.00$

$n = 24.00$

Calculation of μ_1 -

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

$\mu = 1.0408734E-005$

$\mu = 8.2924E+008$

with full section properties:

$b = 400.00$

$d = 707.00$

$d' = 43.00$

$v = 0.00174378$

$N = 16273.616$

$f_c = 33.00$

α (5A.5, TBDY) = 0.002

Final value of μ : $\mu^* = \text{shear_factor} \cdot \text{Max}(\mu, \mu_c) = 0.01288354$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $\mu = 0.01288354$

where μ_c ((5.4c), TBDY) = $\alpha \cdot s_{h, \min} \cdot f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.05503171$

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

 $f_x = 0.04286225$

Expression ((15B.6), TBDY) is modified as $\alpha_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$\alpha_f = 0.31984848$

with Unconfined area = $((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 140733.333$

$b_{\max} = 750.00$

$h_{\max} = 750.00$

From EC8 A.4.4.3(6), $p_f = 2t_f / b_w = 0.00508$

$b_w = 400.00$

effective stress from (A.35), $f_{fe} = 870.5244$

 $f_y = 0.04286225$

Expression ((15B.6), TBDY) is modified as $\alpha_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$\alpha_f = 0.31984848$

with Unconfined area = $((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 140733.333$

$b_{\max} = 750.00$

$h_{\max} = 750.00$

From EC8 A.4.4.3(6), $p_f = 2t_f / b_w = 0.00508$

$b_w = 400.00$

effective stress from (A.35), $f_{fe} = 870.5244$

 $R = 40.00$

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

$f_{u,f} = 1055.00$

$E_f = 64828.00$

u,f = 0.015

ase ((5.4d), TBDY) = (ase1*Aext+ase2*Aint)/Asec = 0.45746528

ase1 = Max(((Aconf,max1-AnoConf1)/Aconf,max1)*(Aconf,min1/Aconf,max1),0) = 0.45746528

The definitions of AnoConf, Aconf,min and Aconf,max are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

Aconf,max1 = 353600.00 is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

Aconf,min1 = 293525.00 is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area Aconf,max1 by a length equal to half the clear spacing between external hoops.

AnoConf1 = 158733.333 is the unconfined external core area which is equal to $b_i^2/6$ as defined at (A.2).

ase2 (>=ase1) = Max(((Aconf,max2-AnoConf2)/Aconf,max2)*(Aconf,min2/Aconf,max2),0) = 0.45746528

The definitions of AnoConf, Aconf,min and Aconf,max are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

Aconf,max2 = 171264.00 is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

Aconf,min2 = 54741.00 is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area Aconf,max2 by a length equal to half the clear spacing between internal hoops.

AnoConf2 = 106242.667 is the unconfined internal core area which is equal to $b_i^2/6$ as defined at (A.2).

psh,min*Fywe = Min(psh,x*Fywe , psh,y*Fywe) = 2.92621

Expression (5.4d) 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 = 2.92621

psh1 ((5.4d), TBDY) = Lstir1*Astir1/(Asec*s1) = 0.00367709

Lstir1 (Length of stirrups along Y) = 2060.00

Astir1 (stirrups area) = 78.53982

psh2 (5.4d) = Lstir2*Astir2/(Asec*s2) = 0.00067082

Lstir2 (Length of stirrups along Y) = 1468.00

Astir2 (stirrups area) = 50.26548

psh_y*Fywe = psh1*Fywe1+ps2*Fywe2 = 2.92621

psh1 ((5.4d), TBDY) = Lstir1*Astir1/(Asec*s1) = 0.00367709

Lstir1 (Length of stirrups along X) = 2060.00

Astir1 (stirrups area) = 78.53982

psh2 ((5.4d), TBDY) = Lstir2*Astir2/(Asec*s2) = 0.00067082

Lstir2 (Length of stirrups along X) = 1468.00

Astir2 (stirrups area) = 50.26548

Asec = 440000.00

s1 = 100.00

s2 = 250.00

fywe1 = 694.4444

fywe2 = 555.5556

fce = 33.00

From ((5.A5), TBDY), TBDY: cc = 0.00238888

c = confinement factor = 1.03889

y1 = 0.00145721

sh1 = 0.00466307

ft1 = 465.423

fy1 = 387.8525

su1 = 0.00582756

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 = 0.318426

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.

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 $fs_1 = (fs_{jacket} \cdot A_{s,ten,jacket} + fs_{core} \cdot A_{s,ten,core}) / A_{s,ten} = 387.8525$

with $Es_1 = (Es_{jacket} \cdot A_{s,ten,jacket} + Es_{core} \cdot A_{s,ten,core}) / A_{s,ten} = 200000.00$

$y_2 = 0.00145721$

$sh_2 = 0.00466307$

$ft_2 = 459.4373$

$fy_2 = 382.8645$

$su_2 = 0.00582756$

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

$l_o/l_{o,min} = l_b/l_{b,min} = 0.318426$

$su_2 = 0.4 \cdot esu_{2,nominal} ((5.5), \text{TBDY}) = 0.032$

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 $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$, from 10.3.5, ASCE 41-17.

with $fs_2 = (fs_{jacket} \cdot A_{s,com,jacket} + fs_{core} \cdot A_{s,com,core}) / A_{s,com} = 382.8645$

with $Es_2 = (Es_{jacket} \cdot A_{s,com,jacket} + Es_{core} \cdot A_{s,com,core}) / A_{s,com} = 200000.00$

$y_v = 0.00145721$

$sh_v = 0.00466307$

$ft_v = 463.3885$

$fy_v = 386.157$

$su_v = 0.00582756$

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

$l_o/l_{o,min} = l_b/l_d = 0.318426$

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

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

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

For calculation of $esuv_{nominal}$ and y_v, sh_v, ft_v, fy_v , it is considered

characteristic value $fsyv = fs_v/1.2$, from table 5.1, TBDY.

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

with $fs_v = (fs_{jacket} \cdot A_{s,mid,jacket} + fs_{mid} \cdot A_{s,mid,core}) / A_{s,mid} = 386.157$

with $Es_v = (Es_{jacket} \cdot A_{s,mid,jacket} + Es_{mid} \cdot A_{s,mid,core}) / A_{s,mid} = 200000.00$

$1 = A_{s,ten} / (b \cdot d) \cdot (fs_1 / fc) = 0.09178643$

$2 = A_{s,com} / (b \cdot d) \cdot (fs_2 / fc) = 0.04665628$

$v = A_{s,mid} / (b \cdot d) \cdot (fs_v / fc) = 0.08306563$

and confined core properties:

$b = 340.00$

$d = 677.00$

$d' = 13.00$

$f_{cc} (5A.2, \text{TBDY}) = 34.2833$

$cc (5A.5, \text{TBDY}) = 0.00238888$

$c = \text{confinement factor} = 1.03889$

$1 = A_{s,ten} / (b \cdot d) \cdot (fs_1 / fc) = 0.11276915$

$2 = A_{s,com} / (b \cdot d) \cdot (fs_2 / fc) = 0.05732208$

$v = A_{s,mid} / (b \cdot d) \cdot (fs_v / fc) = 0.10205474$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < v_s, y_2$ - LHS eq.(4.5) is satisfied

--->

$su (4.9) = 0.20810191$

$Mu = MRc (4.14) = 8.2924E+008$

$u = su (4.1) = 1.0408734E-005$

Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.318426$

$l_b = 300.00$

$l_d = 942.1341$

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: $f_y = 655.5556$
Mean concrete strength: $f_c' = (f_c'_{\text{jacket}} \cdot \text{Area}_{\text{jacket}} + f_c'_{\text{core}} \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 27.68182$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 1.7174$

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

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

$s = \text{Max}(s_{\text{external}}, s_{\text{internal}}) = 250.00$

$n = 24.00$

Calculation of μ_{2+}

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

$\mu = 9.5578758E-006$

$\mu_{2+} = 5.1260E+008$

with full section properties:

$b = 750.00$

$d = 707.00$

$d' = 43.00$

$v = 0.00093001$

$N = 16273.616$

$f_c = 33.00$

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

Final value of μ_{2+} : $\mu_{2+}^* = \text{shear_factor} \cdot \text{Max}(\mu_{2+}, \mu_{2+}^c) = 0.01288354$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $\mu_{2+}^c = 0.01288354$

where $\mu_{2+}^c = (5.4c, \text{TBDY}) = \alpha \cdot \text{shear_factor} \cdot \text{Min}(f_x, f_y) = 0.05503171$

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

 $f_x = 0.04286225$

Expression ((15B.6), TBDY) is modified as $\alpha f = 1 - (\text{Unconfined area}) / (\text{total area})$

$\alpha f = 0.31984848$

with Unconfined area = $((b_{\text{max}} - 2R)^2 + (h_{\text{max}} - 2R)^2) / 3 = 140733.333$

$b_{\text{max}} = 750.00$

$h_{\text{max}} = 750.00$

From EC8 A.4.4.3(6), $\text{pf} = 2t_f / b_w = 0.00508$

$b_w = 400.00$

effective stress from (A.35), $f_{fe} = 870.5244$

$f_y = 0.04286225$

Expression ((15B.6), TBDY) is modified as $\alpha f = 1 - (\text{Unconfined area}) / (\text{total area})$

$\alpha f = 0.31984848$

with Unconfined area = $((b_{\text{max}} - 2R)^2 + (h_{\text{max}} - 2R)^2) / 3 = 140733.333$

$b_{\text{max}} = 750.00$

$h_{\text{max}} = 750.00$

From EC8 A.4.4.3(6), $\text{pf} = 2t_f / b_w = 0.00508$

$b_w = 400.00$

effective stress from (A.35), $f_{fe} = 870.5244$

$R = 40.00$

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

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{f} = 0.015$

αs_e ((5.4d), TBDY) = $(\alpha s_{e1} \cdot A_{\text{ext}} + \alpha s_{e2} \cdot A_{\text{int}}) / A_{\text{sec}} = 0.45746528$

$\alpha s_{e1} = \text{Max}(((A_{\text{conf,max1}} - A_{\text{noConf1}}) / A_{\text{conf,max1}}) \cdot (A_{\text{conf,min1}} / A_{\text{conf,max1}}), 0) = 0.45746528$

The definitions of A_{noConf} , $A_{\text{conf,min}}$ and $A_{\text{conf,max}}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max1} = 353600.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the external perimeter hoops.
 $A_{conf,min1} = 293525.00$ is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area $A_{conf,max1}$ by a length equal to half the clear spacing between external hoops.

$A_{noConf1} = 158733.333$ is the unconfined external core area which is equal to $b_i^2/6$ as defined at (A.2).
 $a_{se2} (>= a_{se1}) = \text{Max}(((A_{conf,max2} - A_{noConf2})/A_{conf,max2}) * (A_{conf,min2}/A_{conf,max2}), 0) = 0.45746528$

The definitions of A_{noConf} , $A_{conf,min}$ and $A_{conf,max}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max2} = 171264.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

$A_{conf,min2} = 54741.00$ is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area $A_{conf,max2}$ by a length equal to half the clear spacing between internal hoops.

$A_{noConf2} = 106242.667$ is the unconfined internal core area which is equal to $b_i^2/6$ as defined at (A.2).
 $p_{sh,min} * F_{ywe} = \text{Min}(p_{sh,x} * F_{ywe}, p_{sh,y} * F_{ywe}) = 2.92621$

Expression (5.4d) 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)

 $p_{sh,x} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{s2} * F_{ywe2} = 2.92621$
 p_{sh1} ((5.4d), TBDY) = $L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00367709$
 L_{stir1} (Length of stirrups along Y) = 2060.00
 A_{stir1} (stirrups area) = 78.53982
 p_{sh2} (5.4d) = $L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00067082$
 L_{stir2} (Length of stirrups along Y) = 1468.00
 A_{stir2} (stirrups area) = 50.26548

 $p_{sh,y} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{s2} * F_{ywe2} = 2.92621$
 p_{sh1} ((5.4d), TBDY) = $L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00367709$
 L_{stir1} (Length of stirrups along X) = 2060.00
 A_{stir1} (stirrups area) = 78.53982
 p_{sh2} ((5.4d), TBDY) = $L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00067082$
 L_{stir2} (Length of stirrups along X) = 1468.00
 A_{stir2} (stirrups area) = 50.26548

 $A_{sec} = 440000.00$
 $s1 = 100.00$
 $s2 = 250.00$
 $f_{ywe1} = 694.4444$
 $f_{ywe2} = 555.5556$
 $f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY: $cc = 0.00238888$
 $c = \text{confinement factor} = 1.03889$

$y1 = 0.00145721$
 $sh1 = 0.00466307$
 $ft1 = 459.4373$
 $fy1 = 382.8645$
 $su1 = 0.00582756$

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

$l_o/l_{ou,min} = l_b/l_d = 0.318426$
 $su1 = 0.4 * esu1_{nominal}$ ((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 $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE 41-17.

with $fs1 = (f_{s,jacket} * A_{s1,ten,jacket} + f_{s,core} * A_{s1,ten,core}) / A_{s1,ten} = 382.8645$

with $Es1 = (E_{s,jacket} * A_{s1,ten,jacket} + E_{s,core} * A_{s1,ten,core}) / A_{s1,ten} = 200000.00$

$y2 = 0.00145721$
 $sh2 = 0.00466307$
 $ft2 = 465.423$

$$f_y2 = 387.8525$$

$$s_u2 = 0.00582756$$

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

$$l_o/l_{o,min} = l_b/l_{b,min} = 0.318426$$

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

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

For calculation of $e_{su2,nominal}$ and y_2 , sh_2 , ft_2 , f_y2 , it is considered
characteristic value $f_{sy2} = f_{s2}/1.2$, from table 5.1, TBDY.

y_1 , sh_1 , ft_1 , f_y1 , are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE 41-17.

$$\text{with } f_{s2} = (f_{s,jacket} * A_{s1,com,jacket} + f_{s,core} * A_{s1,com,core}) / A_{s1,com} = 387.8525$$

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

$$y_v = 0.00145721$$

$$sh_v = 0.00466307$$

$$f_{tv} = 463.3885$$

$$f_{yv} = 386.157$$

$$s_{uv} = 0.00582756$$

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

$$l_o/l_{o,min} = l_b/l_d = 0.318426$$

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

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 , f_{yv} , it is considered
characteristic value $f_{syv} = f_{sv}/1.2$, from table 5.1, TBDY.

y_1 , sh_1 , ft_1 , f_y1 , are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE 41-17.

$$\text{with } f_{sv} = (f_{s,jacket} * A_{s,mid,jacket} + f_{s,mid} * A_{s,mid,core}) / A_{s,mid} = 386.157$$

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

$$1 = A_{s1,ten} / (b * d) * (f_{s1} / f_c) = 0.02488335$$

$$2 = A_{s1,com} / (b * d) * (f_{s2} / f_c) = 0.04895276$$

$$v = A_{s1,mid} / (b * d) * (f_{sv} / f_c) = 0.04430167$$

and confined core properties:

$$b = 690.00$$

$$d = 677.00$$

$$d' = 13.00$$

$$f_{cc} (5A.2, TBDY) = 34.2833$$

$$c_c (5A.5, TBDY) = 0.00238888$$

$$c = \text{confinement factor} = 1.03889$$

$$1 = A_{s1,ten} / (b * d) * (f_{s1} / f_c) = 0.02824566$$

$$2 = A_{s1,com} / (b * d) * (f_{s2} / f_c) = 0.05556741$$

$$v = A_{s1,mid} / (b * d) * (f_{sv} / f_c) = 0.05028784$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

$$s_u (4.9) = 0.13760581$$

$$M_u = M_{Rc} (4.14) = 5.1260E+008$$

$$u = s_u (4.1) = 9.5578758E-006$$

Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.318426$

$$l_b = 300.00$$

$$l_d = 942.1341$$

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: $f_y = 655.5556$

Mean concrete strength: $f'_c = (f'_{c,jacket} * Area_{jacket} + f'_{c,core} * Area_{core}) / Area_{section} = 27.68182$, 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 = 1.7174

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) = 250.00

n = 24.00

Calculation of Mu2-

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

$\kappa_u = 1.0408734E-005$

Mu = 8.2924E+008

with full section properties:

b = 400.00

d = 707.00

d' = 43.00

v = 0.00174378

N = 16273.616

fc = 33.00

co (5A.5, TBDY) = 0.002

Final value of κ_u : $\kappa_u^* = \text{shear_factor} * \text{Max}(\kappa_u, \kappa_c) = 0.01288354$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $\kappa_u = 0.01288354$

we ((5.4c), TBDY) = $\text{ase} * \text{sh}_{\min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.05503171$

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

 $f_x = 0.04286225$

Expression ((15B.6), TBDY) is modified as $\text{af} = 1 - (\text{Unconfined area}) / (\text{total area})$

$\text{af} = 0.31984848$

with Unconfined area = $((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 140733.333$

$b_{\max} = 750.00$

$h_{\max} = 750.00$

From EC8 A.4.4.3(6), $\text{pf} = 2t_f / b_w = 0.00508$

$b_w = 400.00$

effective stress from (A.35), $f_{f,e} = 870.5244$

 $f_y = 0.04286225$

Expression ((15B.6), TBDY) is modified as $\text{af} = 1 - (\text{Unconfined area}) / (\text{total area})$

$\text{af} = 0.31984848$

with Unconfined area = $((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 140733.333$

$b_{\max} = 750.00$

$h_{\max} = 750.00$

From EC8 A.4.4.3(6), $\text{pf} = 2t_f / b_w = 0.00508$

$b_w = 400.00$

effective stress from (A.35), $f_{f,e} = 870.5244$

R = 40.00

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

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{,f} = 0.015$

$\text{ase} ((5.4d), \text{TBDY}) = (\text{ase}_1 * A_{\text{ext}} + \text{ase}_2 * A_{\text{int}}) / A_{\text{sec}} = 0.45746528$

$\text{ase}_1 = \text{Max}(((A_{\text{conf,max1}} - A_{\text{noConf1}}) / A_{\text{conf,max1}}) * (A_{\text{conf,min1}} / A_{\text{conf,max1}}), 0) = 0.45746528$

The definitions of A_{noConf} , $A_{\text{conf,min}}$ and $A_{\text{conf,max}}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{\text{conf,max1}} = 353600.00$ is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{\text{conf,min1}} = 293525.00$ is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area $A_{\text{conf,max1}}$ by a length

equal to half the clear spacing between external hoops.

AnoConf1 = 158733.333 is the unconfined external core area which is equal to $b_i^2/6$ as defined at (A.2).
ase2 (\geq ase1) = $\text{Max}(((A_{\text{conf,max2}} - \text{AnoConf2}) / A_{\text{conf,max2}}) * (A_{\text{conf,min2}} / A_{\text{conf,max2}}), 0) = 0.45746528$

The definitions of AnoConf, Aconf,min and Aconf,max are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

Aconf,max2 = 171264.00 is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

Aconf,min2 = 54741.00 is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area Aconf,max2 by a length

equal to half the clear spacing between internal hoops.

AnoConf2 = 106242.667 is the unconfined internal core area which is equal to $b_i^2/6$ as defined at (A.2).

psh,min*Fywe = $\text{Min}(psh_x * Fywe, psh_y * Fywe) = 2.92621$

Expression (5.4d) 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 = 2.92621

psh1 ((5.4d), TBDY) = $L_{\text{stir1}} * A_{\text{stir1}} / (A_{\text{sec}} * s1) = 0.00367709$

Lstir1 (Length of stirrups along Y) = 2060.00

Astir1 (stirrups area) = 78.53982

psh2 (5.4d) = $L_{\text{stir2}} * A_{\text{stir2}} / (A_{\text{sec}} * s2) = 0.00067082$

Lstir2 (Length of stirrups along Y) = 1468.00

Astir2 (stirrups area) = 50.26548

psh_y*Fywe = psh1*Fywe1 + ps2*Fywe2 = 2.92621

psh1 ((5.4d), TBDY) = $L_{\text{stir1}} * A_{\text{stir1}} / (A_{\text{sec}} * s1) = 0.00367709$

Lstir1 (Length of stirrups along X) = 2060.00

Astir1 (stirrups area) = 78.53982

psh2 ((5.4d), TBDY) = $L_{\text{stir2}} * A_{\text{stir2}} / (A_{\text{sec}} * s2) = 0.00067082$

Lstir2 (Length of stirrups along X) = 1468.00

Astir2 (stirrups area) = 50.26548

Asec = 440000.00

s1 = 100.00

s2 = 250.00

fywe1 = 694.4444

fywe2 = 555.5556

fce = 33.00

From ((5.A5), TBDY), TBDY: cc = 0.00238888

c = confinement factor = 1.03889

y1 = 0.00145721

sh1 = 0.00466307

ft1 = 465.423

fy1 = 387.8525

su1 = 0.00582756

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 = 0.318426

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

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 $\text{Min}(1, 1.25 * (lb/lb)^{2/3})$, from 10.3.5, ASCE 41-17.

with fs1 = $(f_{s,jacket} * A_{s1,ten,jacket} + f_{s,core} * A_{s1,ten,core}) / A_{s1,ten} = 387.8525$

with Es1 = $(E_{s,jacket} * A_{s1,ten,jacket} + E_{s,core} * A_{s1,ten,core}) / A_{s1,ten} = 200000.00$

y2 = 0.00145721

sh2 = 0.00466307

ft2 = 459.4373

fy2 = 382.8645

su2 = 0.00582756

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 = 0.318426

$su_2 = 0.4 \cdot esu_2_nominal ((5.5), TBDY) = 0.032$
 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 $fs_2 = (fs_jacket \cdot Asl_com_jacket + fs_core \cdot Asl_com_core) / Asl_com = 382.8645$
 with $Es_2 = (Es_jacket \cdot Asl_com_jacket + Es_core \cdot Asl_com_core) / Asl_com = 200000.00$
 $yv = 0.00145721$
 $shv = 0.00466307$
 $ftv = 463.3885$
 $fyv = 386.157$
 $suv = 0.00582756$
 using (30) in Biskinis/Fardis (2013) multiplied with $shear_factor$
 and also multiplied by the $shear_factor$ according to 15.7.1.4, with
 $Shear_factor = 1.00$
 $lo/lo_{u,min} = lb/ld = 0.318426$
 $suv = 0.4 \cdot esuv_nominal ((5.5), TBDY) = 0.032$
 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 $fsv = (fs_jacket \cdot Asl_mid_jacket + fs_mid \cdot Asl_mid_core) / Asl_mid = 386.157$
 with $Es_v = (Es_jacket \cdot Asl_mid_jacket + Es_mid \cdot Asl_mid_core) / Asl_mid = 200000.00$
 $1 = Asl_ten / (b \cdot d) \cdot (fs_1 / fc) = 0.09178643$
 $2 = Asl_com / (b \cdot d) \cdot (fs_2 / fc) = 0.04665628$
 $v = Asl_mid / (b \cdot d) \cdot (fsv / fc) = 0.08306563$
 and confined core properties:
 $b = 340.00$
 $d = 677.00$
 $d' = 13.00$
 $fcc (5A.2, TBDY) = 34.2833$
 $cc (5A.5, TBDY) = 0.00238888$
 $c = \text{confinement factor} = 1.03889$
 $1 = Asl_ten / (b \cdot d) \cdot (fs_1 / fc) = 0.11276915$
 $2 = Asl_com / (b \cdot d) \cdot (fs_2 / fc) = 0.05732208$
 $v = Asl_mid / (b \cdot d) \cdot (fsv / fc) = 0.10205474$
 Case/Assumption: Unconfined full section - Steel rupture
 ' satisfies Eq. (4.3)
 --->
 $v < v_{s,y2}$ - LHS eq.(4.5) is satisfied
 --->
 $su (4.9) = 0.20810191$
 $Mu = MRc (4.14) = 8.2924E+008$
 $u = su (4.1) = 1.0408734E-005$

 Calculation of ratio lb/ld

 Lap Length: $lb/ld = 0.318426$
 $lb = 300.00$
 $ld = 942.1341$
 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: $fy = 655.5556$
 Mean concrete strength: $fc' = (fc'_jacket \cdot Area_jacket + fc'_core \cdot Area_core) / Area_section = 27.68182$, but $fc'^{0.5} < =$
 $8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$
 $t = 1.00$
 $s = 0.80$
 $e = 1.00$
 $cb = 25.00$
 $Ktr = 1.7174$
 $Atr = \text{Min}(Atr_x, Atr_y) = 257.6106$
 where Atr_x, Atr_y are the sum of the area of all stirrup legs along X and Y loxal axis
 $s = \text{Max}(s_external, s_internal) = 250.00$
 $n = 24.00$

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 998292.205$

Calculation of Shear Strength at edge 1, $V_{r1} = 998292.205$

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

$V_{Co10} = 998292.205$

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

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

 $= 1$ (normal-weight concrete)

Mean concrete strength: $f'_c = (f'_{c,jacket} * Area_{jacket} + f'_{c,core} * Area_{core}) / Area_{section} = 27.68182$, but $f_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 4.00$

$\mu_u = 11.78089$

$V_u = 0.00051441$

$d = 0.8 * h = 600.00$

$N_u = 16273.616$

$A_g = 300000.00$

From (11.5.4.8), ACI 318-14: $V_s = V_{s,jacket} + V_{s,core} = 881489.011$

where:

$V_{s,jacket} = V_{s,j1} + V_{s,j2} = 802851.456$

$V_{s,j1} = 279252.68$ is calculated for section web jacket, with:

$d = 320.00$

$A_v = 157079.633$

$f_y = 555.5556$

$s = 100.00$

$V_{s,j1}$ is multiplied by $Col_{j1} = 1.00$

$s/d = 0.3125$

$V_{s,j2} = 523598.776$ is calculated for section flange jacket, with:

$d = 600.00$

$A_v = 157079.633$

$f_y = 555.5556$

$s = 100.00$

$V_{s,j2}$ is multiplied by $Col_{j2} = 1.00$

$s/d = 0.16666667$

$V_{s,core} = V_{s,c1} + V_{s,c2} = 78637.555$

$V_{s,c1} = 0.00$ is calculated for section web core, with:

$d = 160.00$

$A_v = 100530.965$

$f_y = 444.4444$

$s = 250.00$

$V_{s,c1}$ is multiplied by $Col_{c1} = 0.00$

$s/d = 1.5625$

$V_{s,c2} = 78637.555$ is calculated for section flange core, with:

$d = 440.00$

$A_v = 100530.965$

$f_y = 444.4444$

$s = 250.00$

$V_{s,c2}$ is multiplied by $Col_{c2} = 1.00$

$s/d = 0.56818182$

V_f ((11-3)-(11.4), ACI 440) = 372533.843

$f = 0.95$, for fully-wrapped sections

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

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

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

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

orientation 1: $\theta = 45^\circ + 90^\circ = 90.00$

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

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

$d_{fv} = d$ (figure 11.2, ACI 440) = 707.00

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

$$E_f = 64828.00$$

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

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

$$\text{From (11-11), ACI 440: } V_s + V_f \leq 838832.606$$

$$b_w = 400.00$$

Calculation of Shear Strength at edge 2, $V_{r2} = 998292.205$

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

$$V_{CoI0} = 998292.205$$

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

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

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

$$\text{Mean concrete strength: } f'_c = (f'_{c,jacket} * \text{Area}_{jacket} + f'_{c,core} * \text{Area}_{core}) / \text{Area}_{section} = 27.68182, \text{ but } f_c^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

$$M/Vd = 4.00$$

$$\mu_u = 11.78144$$

$$V_u = 0.00051441$$

$$d = 0.8 * h = 600.00$$

$$N_u = 16273.616$$

$$A_g = 300000.00$$

$$\text{From (11.5.4.8), ACI 318-14: } V_s = V_{s,jacket} + V_{s,core} = 881489.011$$

where:

$$V_{s,jacket} = V_{s,j1} + V_{s,j2} = 802851.456$$

$$V_{s,j1} = 279252.68 \text{ is calculated for section web jacket, with:}$$

$$d = 320.00$$

$$A_v = 157079.633$$

$$f_y = 555.5556$$

$$s = 100.00$$

$$V_{s,j1} \text{ is multiplied by } Col_{j1} = 1.00$$

$$s/d = 0.3125$$

$$V_{s,j2} = 523598.776 \text{ is calculated for section flange jacket, with:}$$

$$d = 600.00$$

$$A_v = 157079.633$$

$$f_y = 555.5556$$

$$s = 100.00$$

$$V_{s,j2} \text{ is multiplied by } Col_{j2} = 1.00$$

$$s/d = 0.16666667$$

$$V_{s,core} = V_{s,c1} + V_{s,c2} = 78637.555$$

$$V_{s,c1} = 0.00 \text{ is calculated for section web core, with:}$$

$$d = 160.00$$

$$A_v = 100530.965$$

$$f_y = 444.4444$$

$$s = 250.00$$

$$V_{s,c1} \text{ is multiplied by } Col_{c1} = 0.00$$

$$s/d = 1.5625$$

$$V_{s,c2} = 78637.555 \text{ is calculated for section flange core, with:}$$

$$d = 440.00$$

$$A_v = 100530.965$$

$$f_y = 444.4444$$

$$s = 250.00$$

$$V_{s,c2} \text{ is multiplied by } Col_{c2} = 1.00$$

$$s/d = 0.56818182$$

$$V_f \text{ ((11-3)-(11.4), ACI 440)} = 372533.843$$

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

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

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

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

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

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

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

$$d_{fv} = d \text{ (figure 11.2, ACI 440)} = 707.00$$

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 <= 838832.606
bw = 400.00

End Of Calculation of Shear Capacity ratio for element: column JLC1 of floor 1
At local axis: 2

Start Of Calculation of Chord Rotation Capacity for element: column JLC1 of floor 1
At local axis: 3
Integration Section: (b)
Section Type: rcjics

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 Secondary Member: Concrete Strength, $f_c = f_{cm} = 33.00$
New material of Secondary Member: Steel Strength, $f_s = f_{sm} = 555.5556$
Concrete Elasticity, $E_c = 26999.444$
Steel Elasticity, $E_s = 200000.00$
Existing Column
Existing material of Secondary Member: Concrete Strength, $f_c = f_{cm} = 20.00$
Existing material of Secondary Member: Steel Strength, $f_s = f_{sm} = 444.4444$
Concrete Elasticity, $E_c = 21019.039$
Steel Elasticity, $E_s = 200000.00$
Max Height, $H_{max} = 750.00$
Min Height, $H_{min} = 400.00$
Max Width, $W_{max} = 750.00$
Min Width, $W_{min} = 400.00$
Jacket Thickness, $t_j = 100.00$
Cover Thickness, $c = 25.00$
Element Length, $L = 3000.00$
Secondary Member
Ribbed Bars
Ductile Steel
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
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, $M = 86052.274$
Shear Force, $V_2 = 7895.087$
Shear Force, $V_3 = -147.9094$
Axial Force, $F = -17072.715$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: $As_t = 0.00$

-Compression: $As_c = 5353.274$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

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

-Compression: $As_{,com} = 2208.54$

-Middle: $As_{,mid} = 2007.478$

Longitudinal External Reinforcement Area Distribution (in 3 divisions)

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

-Compression: $As_{,com,jacket} = 1746.726$

-Middle: $As_{,mid,jacket} = 1545.664$

Longitudinal Internal Reinforcement Area Distribution (in 3 divisions)

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

-Compression: $As_{,com,core} = 461.8141$

-Middle: $As_{,mid,core} = 461.8141$

Mean Diameter of Tension Reinforcement, $Db_L = 16.80$

Existing component: From table 7-7, ASCE 41_17: Final chord rotation Capacity $u_{,R} = u = 0.00024696$
 $u = y + p = 0.00029054$

- Calculation of y -

$y = (M_y * L_s / 3) / E_{eff} = 0.00029054$ ((4.29), Biskinis Phd))

$M_y = 4.2101E+008$

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

From table 10.5, ASCE 41_17: $E_{eff} = factor * E_c * I_g = 1.4491E+014$

factor = 0.30

$A_g = 440000.00$

Mean concrete strength: $fc' = (fc'_{jacket} * Area_{jacket} + fc'_{core} * Area_{core}) / Area_{section} = 27.68182$

$N = 17072.715$

$E_c * I_g = E_{c,jacket} * I_{g,jacket} + E_{c,core} * I_{g,core} = 4.8303E+014$

Calculation of Yielding Moment M_y

Calculation of y and M_y according to Annex 7 -

Assuming neutral axis within flange ($y < t/d$, compression zone rectangular) with:

flange width, $b = 750.00$

web width, $b_w = 400.00$

flange thickness, $t = 400.00$

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

$y_{ten} = 3.1432128E-006$

with ((10.1), ASCE 41-17) $f_y = \text{Min}(f_y, 1.25 * f_y * (I_b / I_d)^{2/3}) = 358.4764$

$d = 707.00$

$y = 0.19343861$

$A = 0.01018557$

$B = 0.00449598$

with $pt = 0.00671906$

$pc = 0.00416509$

$pv = 0.00378591$

$N = 17072.715$

$b = 750.00$

$" = 0.06082037$

$y_{comp} = 1.6462519E-005$

with $fc' (12.3, (ACI 440)) = 33.48734$

$fc = 33.00$

$fl = 0.49678681$

$b = b_{max} = 750.00$

$h = h_{max} = 750.00$

$A_g = 0.44$

$g = pt + pc + pv = 0.01009575$
 $rc = 40.00$
 $Ae/Ac = 0.31291181$
 Effective FRP thickness, $tf = NL*t*\text{Cos}(b1) = 1.016$
 effective strain from (12.5) and (12.12), $efe = 0.004$
 $fu = 0.01$
 $Ef = 64828.00$
 $Ec = 26999.444$
 $y = 0.19181501$
 $A = 0.01002364$
 $B = 0.00440616$
 with $Es = 200000.00$
 CONFIRMATION: $y = 0.19279145 < t/d$

 Calculation of ratio lb/ld

Lap Length: $ld/ld,min = 0.39803249$
 $lb = 300.00$
 $ld = 753.7073$

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: $fy = 524.4444$
 Mean concrete strength: $fc' = (fc'_jacket*Area_jacket + fc'_core*Area_core)/Area_section = 27.68182$, but $fc'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $t = 1.00$
 $s = 0.80$
 $e = 1.00$
 $cb = 25.00$
 $Ktr = 1.7174$
 $Atr = \text{Min}(Atr_x, Atr_y) = 257.6106$
 where Atr_x, Atr_y are the sum of the area of all stirrup legs along X and Y local axis
 $s = \text{Max}(s_external, s_internal) = 250.00$
 $n = 24.00$

 - Calculation of p -

From table 10-8: $p = 0.00$

with:

- Columns controlled by inadequate development or splicing along the clear height because $lb/ld < 1$
 shear control ratio $VyE/VCoIE = 0.55377356$

$d = d_external = 707.00$

$s = s_external = 0.00$

- $t = s1 + s2 + 2*tf/bw*(ffe/fs) = 0.00671906$

jacket: $s1 = Av1*Lstir1/(s1*Ag) = 0.00367709$

$Av1 = 78.53982$, is the area of every stirrup parallel to loading (shear) direction

$Lstir1 = 2060.00$, is the total Length of all stirrups parallel to loading (shear) direction

$s1 = 100.00$

core: $s2 = Av2*Lstir2/(s2*Ag) = 0.00067082$

$Av2 = 50.26548$, is the area of every stirrup parallel to loading (shear) direction

$Lstir2 = 1468.00$, is the total Length of all stirrups parallel to loading (shear) direction

$s2 = 250.00$

The term $2*tf/bw*(ffe/fs)$ is implemented to account for FRP contribution
 where $f = 2*tf/bw$ is FRP ratio (EC8 - 3, A.4.4.3(6)) and ffe/fs normalises f to steel strength
 All these variables have already been given in Shear control ratio calculation.

For the normalisation fs of jacket is used.

$NUD = 17072.715$

$Ag = 440000.00$

$fcE = (fc_jacket*Area_jacket + fc_core*Area_core)/section_area = 27.68182$

$fyIE = (fy_ext_Long_Reinf*Area_ext_Long_Reinf + fy_int_Long_Reinf*Area_int_Long_Reinf)/Area_Tot_Long_Rein = 529.9948$

$fytE = (fy_ext_Trans_Reinf*s1 + fy_int_Trans_Reinf*s2)/(s1 + s2) = 538.4128$

$pl = Area_Tot_Long_Rein/(b*d) = 0.01009575$

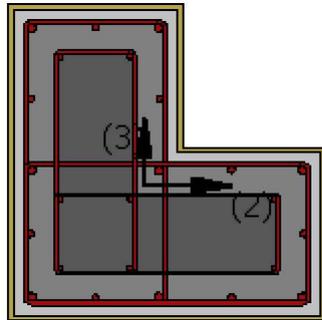
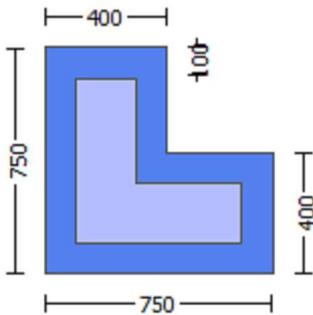
$b = 750.00$

d = 707.00
f_{cE} = 27.68182

End Of Calculation of Chord Rotation Capacity for element: column JLC1 of floor 1
At local axis: 3
Integration Section: (b)

Calculation No. 9

column C1, Floor 1
Limit State: Life Safety (data interpolation between analysis steps 1 and 2)
Analysis: Uniform +X
Check: Shear capacity VRd
Edge: Start
Local Axis: (2)



Start Of Calculation of Shear Capacity for element: column JLC1 of floor 1
At local axis: 2
Integration Section: (a)
Section Type: rcjcs

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 Secondary Member: Concrete Strength, $f_c = f_{c_lower_bound} = 25.00$
New material of Secondary Member: Steel Strength, $f_s = f_{s_lower_bound} = 500.00$
Concrete Elasticity, $E_c = 26999.444$
Steel Elasticity, $E_s = 200000.00$
Existing Column
Existing material of Secondary Member: Concrete Strength, $f_c = f_{c_lower_bound} = 16.00$

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

Note: Especially for the calculation of γ for displacement ductility demand,
the expected (mean value) strengths are used (7.5.1.3, ASCE 41-17) because bending is considered as
Deformation-Controlled Action (Table C7-1, ASCE 41-17).
Jacket
New material: Concrete Strength, $f_c = f_{cm} = 33.00$
New material: Steel Strength, $f_s = f_{sm} = 555.5556$
Existing Column
Existing material: Concrete Strength, $f_c = f_{cm} = 20.00$
Existing material: Steel Strength, $f_s = f_{sm} = 444.4444$

Max Height, $H_{max} = 750.00$
Min Height, $H_{min} = 400.00$
Max Width, $W_{max} = 750.00$
Min Width, $W_{min} = 400.00$
Jacket Thickness, $t_j = 100.00$
Cover Thickness, $c = 25.00$
Element Length, $L = 3000.00$
Secondary Member
Ribbed Bars
Ductile Steel
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
Lap Length $l_o = l_b = 300.00$
FRP Wrapping Data
Type: Carbon
Cured laminate properties (design values)
Thickness, $t = 1.016$
Tensile Strength, $f_{fu} = 1055.00$
Tensile Modulus, $E_f = 64828.00$
Elongation, $e_{fu} = 0.01$
Number of directions, $NoDir = 1$
Fiber orientations, $b_i = 0.00^\circ$
Number of layers, $NL = 1$
Radius of rounding corners, $R = 40.00$

Stepwise Properties

EDGE -A-
Bending Moment, $M_a = -1.9757E+007$
Shear Force, $V_a = -6560.264$
EDGE -B-
Bending Moment, $M_b = 71505.406$
Shear Force, $V_b = 6560.264$
BOTH EDGES
Axial Force, $F = -16937.611$
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: $As_t = 0.00$
-Compression: $As_c = 5353.274$
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension: $As_{l,ten} = 1137.257$
-Compression: $As_{l,com} = 2208.54$
-Middle: $As_{l,mid} = 2007.478$
Mean Diameter of Tension Reinforcement, $Db_{L,ten} = 16.80$

Existing component: From table 7-7, ASCE 41_17: Final Shear Capacity $V_R = \phi V_n = 744877.05$
 V_n ((10.3), ASCE 41-17) = $knI * V_{CoI} = 876325.941$
 $V_{CoI} = 876325.941$
 $knI = 1.00$
displacement_ductility_demand = 0.02749818

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

= 1 (normal-weight concrete)

Mean concrete strength: $f_c' = (f_c'_{\text{jacket}} \cdot \text{Area}_{\text{jacket}} + f_c'_{\text{core}} \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 21.31818$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 4.00$

$\mu_u = 1.9757E+007$

$V_u = 6560.264$

$d = 0.8 \cdot h = 600.00$

$N_u = 16937.611$

$A_g = 300000.00$

From (11.5.4.8), ACI 318-14: $V_s = V_{s,\text{jacket}} + V_{s,\text{core}} = 793340.11$

where:

$V_{s,\text{jacket}} = V_{s,j1} + V_{s,j2} = 722566.31$

$V_{s,j1} = 251327.412$ is calculated for section web jacket, with:

$d = 320.00$

$A_v = 157079.633$

$f_y = 500.00$

$s = 100.00$

$V_{s,j1}$ is multiplied by $\text{Col},j1 = 1.00$

$s/d = 0.3125$

$V_{s,j2} = 471238.898$ is calculated for section flange jacket, with:

$d = 600.00$

$A_v = 157079.633$

$f_y = 500.00$

$s = 100.00$

$V_{s,j2}$ is multiplied by $\text{Col},j2 = 1.00$

$s/d = 0.16666667$

$V_{s,\text{core}} = V_{s,c1} + V_{s,c2} = 70773.799$

$V_{s,c1} = 0.00$ is calculated for section web core, with:

$d = 160.00$

$A_v = 100530.965$

$f_y = 400.00$

$s = 250.00$

$V_{s,c1}$ is multiplied by $\text{Col},c1 = 0.00$

$s/d = 1.5625$

$V_{s,c2} = 70773.799$ is calculated for section flange core, with:

$d = 440.00$

$A_v = 100530.965$

$f_y = 400.00$

$s = 250.00$

$V_{s,c2}$ is multiplied by $\text{Col},c2 = 1.00$

$s/d = 0.56818182$

V_f ((11-3)-(11.4), ACI 440) = 372533.843

$f = 0.95$, for fully-wrapped sections

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

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

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

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

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

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

$d_{fv} = d$ (figure 11.2, ACI 440) = 707.00

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: $V_s + V_f \leq 736127.561$

$b_w = 400.00$

displacement_ductility_demand is calculated as δ / y

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

From analysis, chord rotation = $8.0194801E-005$

$y = (M_y * L_s / 3) / E_{eff} = 0.00291637$ ((4.29), Biskinis Phd))

$M_y = 4.2097E+008$

$L_s = M/V$ (with $L_s > 0.1 * L$ and $L_s < 2 * L$) = 3011.65

From table 10.5, ASCE 41_17: $E_{eff} = factor * E_c * I_g = 1.4491E+014$

factor = 0.30

$A_g = 440000.00$

Mean concrete strength: $f_c' = (f_c'_{jacket} * Area_{jacket} + f_c'_{core} * Area_{core}) / Area_{section} = 27.68182$

$N = 16937.611$

$E_c * I_g = E_c_{jacket} * I_{g,jacket} + E_c_{core} * I_{g,core} = 4.8303E+014$

Calculation of Yielding Moment M_y

Calculation of y and M_y according to Annex 7 -

Assuming neutral axis within flange ($y < t/d$, compression zone rectangular) with:

flange width, $b = 750.00$

web width, $b_w = 400.00$

flange thickness, $t = 400.00$

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

$y_{ten} = 3.1431513E-006$

with ((10.1), ASCE 41-17) $f_y = \text{Min}(f_y, 1.25 * f_y * (l_b / l_d)^{2/3}) = 358.4764$

$d = 707.00$

$y = 0.19342282$

$A = 0.01018486$

$B = 0.00449527$

with $p_t = 0.00214476$

$p_c = 0.00416509$

$p_v = 0.00378591$

$N = 16937.611$

$b = 750.00$

" = 0.06082037

$y_{comp} = 1.6462780E-005$

with f_c^* (12.3, (ACI 440)) = 33.48734

$f_c = 33.00$

$f_l = 0.49678681$

$b = b_{max} = 750.00$

$h = h_{max} = 750.00$

$A_g = 0.44$

$g = p_t + p_c + p_v = 0.01009575$

$r_c = 40.00$

$A_e / A_c = 0.31291181$

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

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

$f_u = 0.01$

$E_f = 64828.00$

$E_c = 26999.444$

$y = 0.19181197$

$A = 0.01002422$

$B = 0.00440616$

with $E_s = 200000.00$

CONFIRMATION: $y = 0.19278073 < t/d$

Calculation of ratio l_b / l_d

Lap Length: $l_d / l_{d,min} = 0.39803249$

$l_b = 300.00$

$l_d = 753.7073$

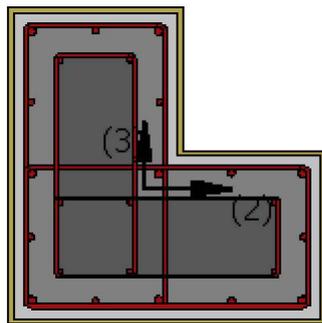
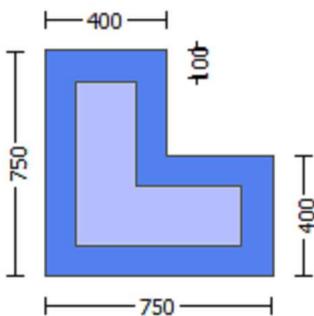
Calculation of l according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

= 1
 db = 16.66667
 Mean strength value of all re-bars: $f_y = 524.4444$
 Mean concrete strength: $f_c' = (f_c'_{jacket} \cdot Area_{jacket} + f_c'_{core} \cdot Area_{core}) / Area_{section} = 27.68182$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $t = 1.00$
 $s = 0.80$
 $e = 1.00$
 $cb = 25.00$
 $K_{tr} = 1.7174$
 $A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 257.6106$
 where A_{tr_x}, A_{tr_y} are the sum of the area of all stirrup legs along X and Y local axis
 $s = \text{Max}(s_{external}, s_{internal}) = 250.00$
 $n = 24.00$

 End Of Calculation of Shear Capacity for element: column JLC1 of floor 1
 At local axis: 2
 Integration Section: (a)

Calculation No. 10

column C1, Floor 1
 Limit State: Life Safety (data interpolation between analysis steps 1 and 2)
 Analysis: Uniform +X
 Check: Chord rotation capacity (θ)
 Edge: Start
 Local Axis: (2)



Start Of Calculation of Shear Capacity ratio for element: column JLC1 of floor 1
 At Shear local axis: 3
 (Bending local axis: 2)
 Section Type: rcjlc

Constant Properties

 Knowledge Factor, $\phi = 0.85$
 Mean strength values are used for both shear and moment calculations.

Consequently:

Jacket

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

New material of Secondary Member: Steel Strength, $f_s = f_{sm} = 555.5556$

Concrete Elasticity, $E_c = 26999.444$

Steel Elasticity, $E_s = 200000.00$

Existing Column

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

Existing material of Secondary Member: Steel Strength, $f_s = f_{sm} = 444.4444$

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, $f_s = 1.25 \cdot f_{sm} = 694.4444$

Existing Column

Existing material: Steel Strength, $f_s = 1.25 \cdot f_{sm} = 555.5556$

#####

Max Height, $H_{max} = 750.00$

Min Height, $H_{min} = 400.00$

Max Width, $W_{max} = 750.00$

Min Width, $W_{min} = 400.00$

Jacket Thickness, $t_j = 100.00$

Cover Thickness, $c = 25.00$

Mean Confinement Factor overall section = 1.03889

Element Length, $L = 3000.00$

Secondary Member

Ribbed Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

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, $V_a = -0.00051441$

EDGE -B-

Shear Force, $V_b = 0.00051441$

BOTH EDGES

Axial Force, $F = -16273.616$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: $As_t = 0.00$

-Compression: $As_c = 5353.274$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

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

-Compression: $As_{l,com} = 2208.54$

-Middle: $As_{l,mid} = 2007.478$

Calculation of Shear Capacity ratio , $V_e/V_r = 0.55377356$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 552827.824$
with

$M_{pr1} = \text{Max}(M_{u1+}, M_{u1-}) = 8.2924E+008$

$M_{u1+} = 5.1260E+008$, 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

$M_{u1-} = 8.2924E+008$, 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

$M_{pr2} = \text{Max}(M_{u2+}, M_{u2-}) = 8.2924E+008$

$M_{u2+} = 5.1260E+008$, 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

$M_{u2-} = 8.2924E+008$, 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 ϕ_u according to 4.1, Biskinis/Fardis 2013:

$\phi_u = 9.5578758E-006$

$M_u = 5.1260E+008$

with full section properties:

$b = 750.00$

$d = 707.00$

$d' = 43.00$

$v = 0.00093001$

$N = 16273.616$

$f_c = 33.00$

α_1 (5A.5, TBDY) = 0.002

Final value of ϕ_u : $\phi_u^* = \text{shear_factor} * \text{Max}(\phi_u, \phi_c) = 0.01288354$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $\phi_u = 0.01288354$

ω_e ((5.4c), TBDY) = $\alpha_1 * \text{sh}_{\min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.05503171$

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

 $f_x = 0.04286225$

Expression ((15B.6), TBDY) is modified as $\alpha_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$\alpha_f = 0.31984848$

with Unconfined area = $((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 140733.333$

$b_{\max} = 750.00$

$h_{\max} = 750.00$

From EC8 A.4.4.3(6), $\rho_f = 2t_f / b_w = 0.00508$

$b_w = 400.00$

effective stress from (A.35), $f_{fe} = 870.5244$

$f_y = 0.04286225$

Expression ((15B.6), TBDY) is modified as $\alpha_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$\alpha_f = 0.31984848$

with Unconfined area = $((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 140733.333$

$b_{\max} = 750.00$

$h_{\max} = 750.00$

From EC8 A.4.4.3(6), $\rho_f = 2t_f / b_w = 0.00508$

$b_w = 400.00$

effective stress from (A.35), $f_{fe} = 870.5244$

$R = 40.00$

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

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{f} = 0.015$

α_{se} ((5.4d), TBDY) = $(\alpha_{se1} * A_{\text{ext}} + \alpha_{se2} * A_{\text{int}}) / A_{\text{sec}} = 0.45746528$

$\alpha_{se1} = \text{Max}(((A_{\text{conf,max1}} - A_{\text{noConf1}}) / A_{\text{conf,max1}}) * (A_{\text{conf,min1}} / A_{\text{conf,max1}}), 0) = 0.45746528$

The definitions of A_{noConf} , $A_{\text{conf,min}}$ and $A_{\text{conf,max}}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max1} = 353600.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the external perimeter hoops.
 $A_{conf,min1} = 293525.00$ is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area $A_{conf,max1}$ by a length equal to half the clear spacing between external hoops.

$A_{noConf1} = 158733.333$ is the unconfined external core area which is equal to $b_i^2/6$ as defined at (A.2).
 $a_{se2} (>= a_{se1}) = \text{Max}(((A_{conf,max2} - A_{noConf2})/A_{conf,max2}) * (A_{conf,min2}/A_{conf,max2}), 0) = 0.45746528$

The definitions of A_{noConf} , $A_{conf,min}$ and $A_{conf,max}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max2} = 171264.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

$A_{conf,min2} = 54741.00$ is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area $A_{conf,max2}$ by a length equal to half the clear spacing between internal hoops.

$A_{noConf2} = 106242.667$ is the unconfined internal core area which is equal to $b_i^2/6$ as defined at (A.2).
 $p_{sh,min} * F_{ywe} = \text{Min}(p_{sh,x} * F_{ywe}, p_{sh,y} * F_{ywe}) = 2.92621$

Expression (5.4d) 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)

 $p_{sh,x} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{s2} * F_{ywe2} = 2.92621$
 p_{sh1} ((5.4d), TBDY) = $L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00367709$
 L_{stir1} (Length of stirrups along Y) = 2060.00
 A_{stir1} (stirrups area) = 78.53982
 p_{sh2} (5.4d) = $L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00067082$
 L_{stir2} (Length of stirrups along Y) = 1468.00
 A_{stir2} (stirrups area) = 50.26548

 $p_{sh,y} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{s2} * F_{ywe2} = 2.92621$
 p_{sh1} ((5.4d), TBDY) = $L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00367709$
 L_{stir1} (Length of stirrups along X) = 2060.00
 A_{stir1} (stirrups area) = 78.53982
 p_{sh2} ((5.4d), TBDY) = $L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00067082$
 L_{stir2} (Length of stirrups along X) = 1468.00
 A_{stir2} (stirrups area) = 50.26548

 $A_{sec} = 440000.00$
 $s1 = 100.00$
 $s2 = 250.00$
 $f_{ywe1} = 694.4444$
 $f_{ywe2} = 555.5556$
 $f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY: $cc = 0.00238888$
 $c = \text{confinement factor} = 1.03889$

$y1 = 0.00145721$
 $sh1 = 0.00466307$
 $ft1 = 459.4373$
 $fy1 = 382.8645$
 $su1 = 0.00582756$

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

$l_o/l_{ou,min} = l_b/l_d = 0.318426$
 $su1 = 0.4 * esu1_{nominal}$ ((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 $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE 41-17.

with $fs1 = (f_{s,jacket} * A_{s1,ten,jacket} + f_{s,core} * A_{s1,ten,core}) / A_{s1,ten} = 382.8645$

with $Es1 = (E_{s,jacket} * A_{s1,ten,jacket} + E_{s,core} * A_{s1,ten,core}) / A_{s1,ten} = 200000.00$

$y2 = 0.00145721$
 $sh2 = 0.00466307$
 $ft2 = 465.423$

$f_y2 = 387.8525$
 $s_u2 = 0.00582756$
 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
 $l_o/l_{o,min} = l_b/l_{b,min} = 0.318426$
 $s_u2 = 0.4 * e_{su2_nominal} ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $e_{su2_nominal} = 0.08$,
 For calculation of $e_{su2_nominal}$ and y_2, sh_2, ft_2, f_y2 , it is considered
 characteristic value $f_{sy2} = f_{s2}/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, f_y1 , are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE 41-17.
 with $f_{s2} = (f_{s,jacket} * A_{s1,com,jacket} + f_{s,core} * A_{s1,com,core}) / A_{s1,com} = 387.8525$
 with $E_{s2} = (E_{s,jacket} * A_{s1,com,jacket} + E_{s,core} * A_{s1,com,core}) / A_{s1,com} = 200000.00$
 $y_v = 0.00145721$
 $sh_v = 0.00466307$
 $ft_v = 463.3885$
 $f_{y_v} = 386.157$
 $s_{u_v} = 0.00582756$
 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
 $l_o/l_{o,min} = l_b/l_d = 0.318426$
 $s_{u_v} = 0.4 * e_{suv_nominal} ((5.5), TBDY) = 0.032$
 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, f_{y_v} , it is considered
 characteristic value $f_{syv} = f_{sv}/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, f_y1 , are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE 41-17.
 with $f_{sv} = (f_{s,jacket} * A_{s1,mid,jacket} + f_{s,mid} * A_{s1,mid,core}) / A_{s1,mid} = 386.157$
 with $E_{sv} = (E_{s,jacket} * A_{s1,mid,jacket} + E_{s,mid} * A_{s1,mid,core}) / A_{s1,mid} = 200000.00$
 $1 = A_{s1,ten} / (b * d) * (f_{s1} / f_c) = 0.02488335$
 $2 = A_{s1,com} / (b * d) * (f_{s2} / f_c) = 0.04895276$
 $v = A_{s1,mid} / (b * d) * (f_{sv} / f_c) = 0.04430167$

and confined core properties:

$b = 690.00$
 $d = 677.00$
 $d' = 13.00$
 $f_{cc} (5A.2, TBDY) = 34.2833$
 $cc (5A.5, TBDY) = 0.00238888$
 $c = \text{confinement factor} = 1.03889$
 $1 = A_{s1,ten} / (b * d) * (f_{s1} / f_c) = 0.02824566$
 $2 = A_{s1,com} / (b * d) * (f_{s2} / f_c) = 0.05556741$
 $v = A_{s1,mid} / (b * d) * (f_{sv} / f_c) = 0.05028784$

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

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

--->
 $s_u (4.9) = 0.13760581$
 $M_u = M_{Rc} (4.14) = 5.1260E+008$
 $u = s_u (4.1) = 9.5578758E-006$

 Calculation of ratio l_b/l_d

 Lap Length: $l_b/l_d = 0.318426$
 $l_b = 300.00$
 $l_d = 942.1341$

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: $f_y = 655.5556$
 Mean concrete strength: $f_c' = (f_c'_{jacket} * Area_{jacket} + f_c'_{core} * Area_{core}) / Area_{section} = 27.68182$, 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 = 1.7174

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) = 250.00

n = 24.00

Calculation of Mu1-

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

$\kappa_u = 1.0408734E-005$

Mu = 8.2924E+008

with full section properties:

b = 400.00

d = 707.00

d' = 43.00

v = 0.00174378

N = 16273.616

fc = 33.00

co (5A.5, TBDY) = 0.002

Final value of κ_u : $\kappa_u^* = \text{shear_factor} * \text{Max}(\kappa_u, \kappa_c) = 0.01288354$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $\kappa_u = 0.01288354$

we ((5.4c), TBDY) = $\text{ase} * \text{sh}_{\min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.05503171$

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

 $f_x = 0.04286225$

Expression ((15B.6), TBDY) is modified as $\text{af} = 1 - (\text{Unconfined area}) / (\text{total area})$

$\text{af} = 0.31984848$

with Unconfined area = $((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 140733.333$

$b_{\max} = 750.00$

$h_{\max} = 750.00$

From EC8 A.4.4.3(6), $\text{pf} = 2t_f / b_w = 0.00508$

$b_w = 400.00$

effective stress from (A.35), $f_{f,e} = 870.5244$

 $f_y = 0.04286225$

Expression ((15B.6), TBDY) is modified as $\text{af} = 1 - (\text{Unconfined area}) / (\text{total area})$

$\text{af} = 0.31984848$

with Unconfined area = $((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 140733.333$

$b_{\max} = 750.00$

$h_{\max} = 750.00$

From EC8 A.4.4.3(6), $\text{pf} = 2t_f / b_w = 0.00508$

$b_w = 400.00$

effective stress from (A.35), $f_{f,e} = 870.5244$

R = 40.00

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

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{,f} = 0.015$

$\text{ase} ((5.4d), \text{TBDY}) = (\text{ase}_1 * A_{\text{ext}} + \text{ase}_2 * A_{\text{int}}) / A_{\text{sec}} = 0.45746528$

$\text{ase}_1 = \text{Max}(((A_{\text{conf,max1}} - A_{\text{noConf1}}) / A_{\text{conf,max1}}) * (A_{\text{conf,min1}} / A_{\text{conf,max1}}), 0) = 0.45746528$

The definitions of A_{noConf} , $A_{\text{conf,min}}$ and $A_{\text{conf,max}}$ are derived from generalization

of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{\text{conf,max1}} = 353600.00$ is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{\text{conf,min1}} = 293525.00$ is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area $A_{\text{conf,max1}}$ by a length

equal to half the clear spacing between external hoops.

AnoConf1 = 158733.333 is the unconfined external core area which is equal to $b_i^2/6$ as defined at (A.2).
ase2 (\geq ase1) = $\text{Max}(((A_{\text{conf,max2}} - \text{AnoConf2}) / A_{\text{conf,max2}}) * (A_{\text{conf,min2}} / A_{\text{conf,max2}}), 0) = 0.45746528$

The definitions of AnoConf, Aconf,min and Aconf,max are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

Aconf,max2 = 171264.00 is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

Aconf,min2 = 54741.00 is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area Aconf,max2 by a length

equal to half the clear spacing between internal hoops.

AnoConf2 = 106242.667 is the unconfined internal core area which is equal to $b_i^2/6$ as defined at (A.2).

psh,min*Fywe = $\text{Min}(psh_x * Fywe, psh_y * Fywe) = 2.92621$

Expression (5.4d) 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 = 2.92621

psh1 ((5.4d), TBDY) = $L_{\text{stir1}} * A_{\text{stir1}} / (A_{\text{sec}} * s1) = 0.00367709$

Lstir1 (Length of stirrups along Y) = 2060.00

Astir1 (stirrups area) = 78.53982

psh2 (5.4d) = $L_{\text{stir2}} * A_{\text{stir2}} / (A_{\text{sec}} * s2) = 0.00067082$

Lstir2 (Length of stirrups along Y) = 1468.00

Astir2 (stirrups area) = 50.26548

psh_y*Fywe = psh1*Fywe1 + ps2*Fywe2 = 2.92621

psh1 ((5.4d), TBDY) = $L_{\text{stir1}} * A_{\text{stir1}} / (A_{\text{sec}} * s1) = 0.00367709$

Lstir1 (Length of stirrups along X) = 2060.00

Astir1 (stirrups area) = 78.53982

psh2 ((5.4d), TBDY) = $L_{\text{stir2}} * A_{\text{stir2}} / (A_{\text{sec}} * s2) = 0.00067082$

Lstir2 (Length of stirrups along X) = 1468.00

Astir2 (stirrups area) = 50.26548

Asec = 440000.00

s1 = 100.00

s2 = 250.00

fywe1 = 694.4444

fywe2 = 555.5556

fce = 33.00

From ((5.A5), TBDY), TBDY: cc = 0.00238888

c = confinement factor = 1.03889

y1 = 0.00145721

sh1 = 0.00466307

ft1 = 465.423

fy1 = 387.8525

su1 = 0.00582756

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 = 0.318426

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

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.

with fs1 = $(f_{s,\text{jacket}} * A_{s1,\text{ten,jacket}} + f_{s,\text{core}} * A_{s1,\text{ten,core}}) / A_{s1,\text{ten}} = 387.8525$

with Es1 = $(E_{s,\text{jacket}} * A_{s1,\text{ten,jacket}} + E_{s,\text{core}} * A_{s1,\text{ten,core}}) / A_{s1,\text{ten}} = 200000.00$

y2 = 0.00145721

sh2 = 0.00466307

ft2 = 459.4373

fy2 = 382.8645

su2 = 0.00582756

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 = 0.318426

$su_2 = 0.4 * esu_2_nominal ((5.5), TBDY) = 0.032$
 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 $fs_2 = (fs_jacket * Asl_com_jacket + fs_core * Asl_com_core) / Asl_com = 382.8645$
 with $Es_2 = (Es_jacket * Asl_com_jacket + Es_core * Asl_com_core) / Asl_com = 200000.00$
 $yv = 0.00145721$
 $shv = 0.00466307$
 $ftv = 463.3885$
 $fyv = 386.157$
 $suv = 0.00582756$
 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
 $lo/lo_{u,min} = lb/ld = 0.318426$
 $suv = 0.4 * esuv_nominal ((5.5), TBDY) = 0.032$
 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 $fsv = (fs_jacket * Asl_mid_jacket + fs_mid * Asl_mid_core) / Asl_mid = 386.157$
 with $Es_v = (Es_jacket * Asl_mid_jacket + Es_mid * Asl_mid_core) / Asl_mid = 200000.00$
 $1 = Asl_ten / (b * d) * (fs_1 / fc) = 0.09178643$
 $2 = Asl_com / (b * d) * (fs_2 / fc) = 0.04665628$
 $v = Asl_mid / (b * d) * (fsv / fc) = 0.08306563$
 and confined core properties:
 $b = 340.00$
 $d = 677.00$
 $d' = 13.00$
 $fcc (5A.2, TBDY) = 34.2833$
 $cc (5A.5, TBDY) = 0.00238888$
 $c = \text{confinement factor} = 1.03889$
 $1 = Asl_ten / (b * d) * (fs_1 / fc) = 0.11276915$
 $2 = Asl_com / (b * d) * (fs_2 / fc) = 0.05732208$
 $v = Asl_mid / (b * d) * (fsv / fc) = 0.10205474$
 Case/Assumption: Unconfined full section - Steel rupture
 ' satisfies Eq. (4.3)
 --->
 $v < v_{s,y_2}$ - LHS eq.(4.5) is satisfied
 --->
 $su (4.9) = 0.20810191$
 $Mu = MRc (4.14) = 8.2924E+008$
 $u = su (4.1) = 1.0408734E-005$

 Calculation of ratio lb/ld

 Lap Length: $lb/ld = 0.318426$
 $lb = 300.00$
 $ld = 942.1341$
 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: $fy = 655.5556$
 Mean concrete strength: $fc' = (fc'_jacket * Area_jacket + fc'_core * Area_core) / Area_section = 27.68182$, but $fc'^{0.5} < =$
 $8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$
 $t = 1.00$
 $s = 0.80$
 $e = 1.00$
 $cb = 25.00$
 $Ktr = 1.7174$
 $Atr = Min(Atr_x, Atr_y) = 257.6106$
 where Atr_x, Atr_y are the sum of the area of all stirrup legs along X and Y loxal axis
 $s = Max(s_external, s_internal) = 250.00$
 $n = 24.00$

Calculation of Mu2+

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

$$\mu = 9.5578758E-006$$

$$Mu = 5.1260E+008$$

with full section properties:

$$b = 750.00$$

$$d = 707.00$$

$$d' = 43.00$$

$$v = 0.00093001$$

$$N = 16273.616$$

$$f_c = 33.00$$

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

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_o) = 0.01288354$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } c_u = 0.01288354$$

$$w_e \text{ ((5.4c), TBDY)} = a_{se} * s_{h,\min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.05503171$$

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

$$f_x = 0.04286225$$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area})/(\text{total area})$

$$a_f = 0.31984848$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2)/3 = 140733.333$$

$$b_{\max} = 750.00$$

$$h_{\max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 870.5244$$

$$f_y = 0.04286225$$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area})/(\text{total area})$

$$a_f = 0.31984848$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2)/3 = 140733.333$$

$$b_{\max} = 750.00$$

$$h_{\max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 870.5244$$

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$a_{se} \text{ ((5.4d), TBDY)} = (a_{se1} * A_{ext} + a_{se2} * A_{int})/A_{sec} = 0.45746528$$

$$a_{se1} = \text{Max}(((A_{conf,max1} - A_{noConf1})/A_{conf,max1}) * (A_{conf,min1}/A_{conf,max1}), 0) = 0.45746528$$

The definitions of A_{noConf} , $A_{conf,min}$ and $A_{conf,max}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max1} = 353600.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{conf,min1} = 293525.00$ is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area $A_{conf,max1}$ by a length equal to half the clear spacing between external hoops.

$A_{noConf1} = 158733.333$ is the unconfined external core area which is equal to $b_i^2/6$ as defined at (A.2).

$$a_{se2} (\geq a_{se1}) = \text{Max}(((A_{conf,max2} - A_{noConf2})/A_{conf,max2}) * (A_{conf,min2}/A_{conf,max2}), 0) = 0.45746528$$

The definitions of A_{noConf} , $A_{conf,min}$ and $A_{conf,max}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max2} = 171264.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

$A_{conf,min2} = 54741.00$ is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area $A_{conf,max2}$ by a length equal to half the clear spacing between internal hoops.

$A_{noConf2} = 106242.667$ is the unconfined internal core area which is equal to $b_i^2/6$ as defined at (A.2).

$p_{sh,min} * F_{ywe} = \text{Min}(p_{sh,x} * F_{ywe}, p_{sh,y} * F_{ywe}) = 2.92621$

Expression (5.4d) 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)

$p_{sh,x} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{sh2} * F_{ywe2} = 2.92621$

p_{sh1} ((5.4d), TBDY) = $L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00367709$

L_{stir1} (Length of stirrups along Y) = 2060.00

A_{stir1} (stirrups area) = 78.53982

p_{sh2} (5.4d) = $L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00067082$

L_{stir2} (Length of stirrups along Y) = 1468.00

A_{stir2} (stirrups area) = 50.26548

$p_{sh,y} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{sh2} * F_{ywe2} = 2.92621$

p_{sh1} ((5.4d), TBDY) = $L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00367709$

L_{stir1} (Length of stirrups along X) = 2060.00

A_{stir1} (stirrups area) = 78.53982

p_{sh2} ((5.4d), TBDY) = $L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00067082$

L_{stir2} (Length of stirrups along X) = 1468.00

A_{stir2} (stirrups area) = 50.26548

$A_{sec} = 440000.00$

$s1 = 100.00$

$s2 = 250.00$

$f_{ywe1} = 694.4444$

$f_{ywe2} = 555.5556$

$f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY: $cc = 0.00238888$

$c =$ confinement factor = 1.03889

$y1 = 0.00145721$

$sh1 = 0.00466307$

$ft1 = 459.4373$

$fy1 = 382.8645$

$su1 = 0.00582756$

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

$l_o/l_{o,min} = l_b/l_d = 0.318426$

$su1 = 0.4 * esu1_{nominal}$ ((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 $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE 41-17.

with $fs1 = (f_{s,jacket} * A_{s,ten,jacket} + f_{s,core} * A_{s,ten,core}) / A_{s,ten} = 382.8645$

with $Es1 = (E_{s,jacket} * A_{s,ten,jacket} + E_{s,core} * A_{s,ten,core}) / A_{s,ten} = 200000.00$

$y2 = 0.00145721$

$sh2 = 0.00466307$

$ft2 = 465.423$

$fy2 = 387.8525$

$su2 = 0.00582756$

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

$l_o/l_{o,min} = l_b/l_{b,min} = 0.318426$

$su2 = 0.4 * esu2_{nominal}$ ((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 $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE 41-17.

with $fs2 = (f_{s,jacket} * A_{s,com,jacket} + f_{s,core} * A_{s,com,core}) / A_{s,com} = 387.8525$

with $E_s2 = (E_{s,jacket} \cdot A_{s,com,jacket} + E_{s,core} \cdot A_{s,com,core}) / A_{s,com} = 200000.00$
 $y_v = 0.00145721$
 $sh_v = 0.00466307$
 $ft_v = 463.3885$
 $fy_v = 386.157$
 $suv = 0.00582756$
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
 $l_o/l_{o,min} = l_b/l_d = 0.318426$
 $suv = 0.4 \cdot esuv_{nominal} ((5.5), TBDY) = 0.032$
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 $f_{sv} = (f_{s,jacket} \cdot A_{s,mid,jacket} + f_{s,mid} \cdot A_{s,mid,core}) / A_{s,mid} = 386.157$
with $E_{sv} = (E_{s,jacket} \cdot A_{s,mid,jacket} + E_{s,mid} \cdot A_{s,mid,core}) / A_{s,mid} = 200000.00$
 $1 = A_{s,ten} / (b \cdot d) \cdot (f_{s1} / f_c) = 0.02488335$
 $2 = A_{s,com} / (b \cdot d) \cdot (f_{s2} / f_c) = 0.04895276$
 $v = A_{s,mid} / (b \cdot d) \cdot (f_{sv} / f_c) = 0.04430167$
and confined core properties:
 $b = 690.00$
 $d = 677.00$
 $d' = 13.00$
 $f_{cc} (5A.2, TBDY) = 34.2833$
 $cc (5A.5, TBDY) = 0.00238888$
 $c = \text{confinement factor} = 1.03889$
 $1 = A_{s,ten} / (b \cdot d) \cdot (f_{s1} / f_c) = 0.02824566$
 $2 = A_{s,com} / (b \cdot d) \cdot (f_{s2} / f_c) = 0.05556741$
 $v = A_{s,mid} / (b \cdot d) \cdot (f_{sv} / f_c) = 0.05028784$
Case/Assumption: Unconfined full section - Steel rupture
satisfies Eq. (4.3)
--->
 $v < v_{s,y2}$ - LHS eq.(4.5) is satisfied
--->
 $su (4.9) = 0.13760581$
 $Mu = MRc (4.14) = 5.1260E+008$
 $u = su (4.1) = 9.5578758E-006$

Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.318426$
 $l_b = 300.00$
 $l_d = 942.1341$
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: $fy = 655.5556$
Mean concrete strength: $fc' = (fc'_{jacket} \cdot Area_{jacket} + fc'_{core} \cdot Area_{core}) / Area_{section} = 27.68182$, but $fc'^{0.5} < =$
8.3 MPa (22.5.3.1, ACI 318-14)
 $t = 1.00$
 $s = 0.80$
 $e = 1.00$
 $cb = 25.00$
 $K_{tr} = 1.7174$
 $A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 257.6106$
where A_{tr_x}, A_{tr_y} are the sum of the area of all stirrup legs along X and Y loxal axis
 $s = \text{Max}(s_{external}, s_{internal}) = 250.00$
 $n = 24.00$

Calculation of $Mu2$ -

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

$$u = 1.0408734E-005$$

$$Mu = 8.2924E+008$$

with full section properties:

$$b = 400.00$$

$$d = 707.00$$

$$d' = 43.00$$

$$v = 0.00174378$$

$$N = 16273.616$$

$$f_c = 33.00$$

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

$$\text{Final value of } \phi_u: \phi_u^* = \text{shear_factor} * \text{Max}(\phi_u, \phi_c) = 0.01288354$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \phi_u = 0.01288354$$

$$\omega_e \text{ (5.4c), TBDY} = a_{se} * \text{sh}_{, \min} * f_{ywe} / f_{ce} + \text{Min}(\phi_x, \phi_y) = 0.05503171$$

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

$$\phi_x = 0.04286225$$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.31984848$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 140733.333$$

$$b_{\max} = 750.00$$

$$h_{\max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 870.5244$$

$$\phi_y = 0.04286225$$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.31984848$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 140733.333$$

$$b_{\max} = 750.00$$

$$h_{\max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 870.5244$$

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$a_{se} \text{ (5.4d), TBDY} = (a_{se1} * A_{ext} + a_{se2} * A_{int}) / A_{sec} = 0.45746528$$

$$a_{se1} = \text{Max}(((A_{\text{conf,max1}} - A_{\text{noConf1}}) / A_{\text{conf,max1}}) * (A_{\text{conf,min1}} / A_{\text{conf,max1}}), 0) = 0.45746528$$

The definitions of A_{noConf} , $A_{\text{conf,min}}$ and $A_{\text{conf,max}}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{\text{conf,max1}} = 353600.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{\text{conf,min1}} = 293525.00$ is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area $A_{\text{conf,max1}}$ by a length equal to half the clear spacing between external hoops.

$A_{\text{noConf1}} = 158733.333$ is the unconfined external core area which is equal to $b_i^2/6$ as defined at (A.2).

$$a_{se2} (\geq a_{se1}) = \text{Max}(((A_{\text{conf,max2}} - A_{\text{noConf2}}) / A_{\text{conf,max2}}) * (A_{\text{conf,min2}} / A_{\text{conf,max2}}), 0) = 0.45746528$$

The definitions of A_{noConf} , $A_{\text{conf,min}}$ and $A_{\text{conf,max}}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{\text{conf,max2}} = 171264.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

$A_{\text{conf,min2}} = 54741.00$ is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area $A_{\text{conf,max2}}$ by a length

equal to half the clear spacing between internal hoops.

AnoConf2 = 106242.667 is the unconfined internal core area which is equal to $bi^2/6$ as defined at (A.2).

$psh_{min} * Fywe = \text{Min}(psh_x * Fywe, psh_y * Fywe) = 2.92621$

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

 $psh_x * Fywe = psh1 * Fywe1 + ps2 * Fywe2 = 2.92621$
 $psh1$ ((5.4d), TBDY) = $Lstir1 * Astir1 / (Asec * s1) = 0.00367709$
Lstir1 (Length of stirrups along Y) = 2060.00
Astir1 (stirrups area) = 78.53982
 $psh2$ (5.4d) = $Lstir2 * Astir2 / (Asec * s2) = 0.00067082$
Lstir2 (Length of stirrups along Y) = 1468.00
Astir2 (stirrups area) = 50.26548

$psh_y * Fywe = psh1 * Fywe1 + ps2 * Fywe2 = 2.92621$
 $psh1$ ((5.4d), TBDY) = $Lstir1 * Astir1 / (Asec * s1) = 0.00367709$
Lstir1 (Length of stirrups along X) = 2060.00
Astir1 (stirrups area) = 78.53982
 $psh2$ ((5.4d), TBDY) = $Lstir2 * Astir2 / (Asec * s2) = 0.00067082$
Lstir2 (Length of stirrups along X) = 1468.00
Astir2 (stirrups area) = 50.26548

Asec = 440000.00

s1 = 100.00

s2 = 250.00

fywe1 = 694.4444

fywe2 = 555.5556

fce = 33.00

From ((5.A5), TBDY), TBDY: cc = 0.00238888

c = confinement factor = 1.03889

y1 = 0.00145721

sh1 = 0.00466307

ft1 = 465.423

fy1 = 387.8525

su1 = 0.00582756

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 = 0.318426

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 $\text{Min}(1, 1.25 * (lb/lb)^{2/3})$, from 10.3.5, ASCE 41-17.

with fs1 = $(fs_{jacket} * Asl_{ten,jacket} + fs_{core} * Asl_{ten,core}) / Asl_{ten} = 387.8525$

with Es1 = $(Es_{jacket} * Asl_{ten,jacket} + Es_{core} * Asl_{ten,core}) / Asl_{ten} = 200000.00$

y2 = 0.00145721

sh2 = 0.00466307

ft2 = 459.4373

fy2 = 382.8645

su2 = 0.00582756

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 = 0.318426

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 $\text{Min}(1, 1.25 * (lb/lb)^{2/3})$, from 10.3.5, ASCE 41-17.

with fs2 = $(fs_{jacket} * Asl_{com,jacket} + fs_{core} * Asl_{com,core}) / Asl_{com} = 382.8645$

with Es2 = $(Es_{jacket} * Asl_{com,jacket} + Es_{core} * Asl_{com,core}) / Asl_{com} = 200000.00$

yv = 0.00145721

shv = 0.00466307

ftv = 463.3885

fyv = 386.157

su v = 0.00582756

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

$$l_0/l_{ou,min} = l_b/l_d = 0.318426$$

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

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 γ_v , sh_v, ft_v, fy_v , it is considered
characteristic value $f_{sv} = f_{sv}/1.2$, from table 5.1, TBDY.

$$\gamma_1, sh_1, ft_1, fy_1, \text{ are also multiplied by } \text{Min}(1, 1.25 * (l_b/l_d)^{2/3}), \text{ from } 10.3.5, \text{ ASCE } 41-17.$$

$$\text{with } f_{sv} = (f_{s,jacket} * A_{s,mid,jacket} + f_{s,mid} * A_{s,mid,core}) / A_{s,mid} = 386.157$$

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

$$1 = A_{s,ten} / (b * d) * (f_{s1} / f_c) = 0.09178643$$

$$2 = A_{s,com} / (b * d) * (f_{s2} / f_c) = 0.04665628$$

$$v = A_{s,mid} / (b * d) * (f_{sv} / f_c) = 0.08306563$$

and confined core properties:

$$b = 340.00$$

$$d = 677.00$$

$$d' = 13.00$$

$$f_{cc} (5A.2, TBDY) = 34.2833$$

$$c_c (5A.5, TBDY) = 0.00238888$$

$$c = \text{confinement factor} = 1.03889$$

$$1 = A_{s,ten} / (b * d) * (f_{s1} / f_c) = 0.11276915$$

$$2 = A_{s,com} / (b * d) * (f_{s2} / f_c) = 0.05732208$$

$$v = A_{s,mid} / (b * d) * (f_{sv} / f_c) = 0.10205474$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

$$s_u (4.9) = 0.20810191$$

$$M_u = M_{Rc} (4.14) = 8.2924E+008$$

$$u = s_u (4.1) = 1.0408734E-005$$

Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.318426$

$$l_b = 300.00$$

$$l_d = 942.1341$$

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: $f_y = 655.5556$

Mean concrete strength: $f'_c = (f'_{c,jacket} * Area_{jacket} + f'_{c,core} * Area_{core}) / Area_{section} = 27.68182$, but $f_c^{0.5} <=$
8.3 MPa (22.5.3.1, ACI 318-14)

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 25.00$$

$$K_{tr} = 1.7174$$

$$A_{tr} = \text{Min}(A_{tr,x}, A_{tr,y}) = 257.6106$$

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

$$s = \text{Max}(s_{external}, s_{internal}) = 250.00$$

$$n = 24.00$$

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 998292.205$

Calculation of Shear Strength at edge 1, $V_{r1} = 998292.205$

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

$$V_{Col0} = 998292.205$$

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

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

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

= 1 (normal-weight concrete)

Mean concrete strength: $f'_c = (f'_{c,jacket} \cdot Area_{jacket} + f'_{c,core} \cdot Area_{core}) / Area_{section} = 27.68182$, but $f_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 4.00$

$\mu_u = 11.77537$

$V_u = 0.00051441$

$d = 0.8 \cdot h = 600.00$

$N_u = 16273.616$

$A_g = 300000.00$

From (11.5.4.8), ACI 318-14: $V_s = V_{s,jacket} + V_{s,core} = 881489.011$

where:

$V_{s,jacket} = V_{s,j1} + V_{s,j2} = 802851.456$

$V_{s,j1} = 523598.776$ is calculated for section web jacket, with:

$d = 600.00$

$A_v = 157079.633$

$f_y = 555.5556$

$s = 100.00$

$V_{s,j1}$ is multiplied by $Col_{j1} = 1.00$

$s/d = 0.16666667$

$V_{s,j2} = 279252.68$ is calculated for section flange jacket, with:

$d = 320.00$

$A_v = 157079.633$

$f_y = 555.5556$

$s = 100.00$

$V_{s,j2}$ is multiplied by $Col_{j2} = 1.00$

$s/d = 0.3125$

$V_{s,core} = V_{s,c1} + V_{s,c2} = 78637.555$

$V_{s,c1} = 78637.555$ is calculated for section web core, with:

$d = 440.00$

$A_v = 100530.965$

$f_y = 444.4444$

$s = 250.00$

$V_{s,c1}$ is multiplied by $Col_{c1} = 1.00$

$s/d = 0.56818182$

$V_{s,c2} = 0.00$ is calculated for section flange core, with:

$d = 160.00$

$A_v = 100530.965$

$f_y = 444.4444$

$s = 250.00$

$V_{s,c2}$ is multiplied by $Col_{c2} = 0.00$

$s/d = 1.5625$

V_f ((11-3)-(11.4), ACI 440) = 372533.843

$f = 0.95$, for fully-wrapped sections

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

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

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

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

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

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

$d_{fv} = d$ (figure 11.2, ACI 440) = 707.00

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: $V_s + V_f \leq 838832.606$

$b_w = 400.00$

Calculation of Shear Strength at edge 2, $V_{r2} = 998292.205$

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

$V_{Col0} = 998292.205$

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

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

= 1 (normal-weight concrete)

Mean concrete strength: $f_c' = (f_c'_{\text{jacket}} \cdot \text{Area}_{\text{jacket}} + f_c'_{\text{core}} \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 27.68182$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 4.00$

$\mu_u = 11.77482$

$V_u = 0.00051441$

$d = 0.8 \cdot h = 600.00$

$N_u = 16273.616$

$A_g = 300000.00$

From (11.5.4.8), ACI 318-14: $V_s = V_{s,\text{jacket}} + V_{s,\text{core}} = 881489.011$

where:

$V_{s,\text{jacket}} = V_{s,j1} + V_{s,j2} = 802851.456$

$V_{s,j1} = 523598.776$ is calculated for section web jacket, with:

$d = 600.00$

$A_v = 157079.633$

$f_y = 555.5556$

$s = 100.00$

$V_{s,j1}$ is multiplied by $\text{Col},j1 = 1.00$

$s/d = 0.16666667$

$V_{s,j2} = 279252.68$ is calculated for section flange jacket, with:

$d = 320.00$

$A_v = 157079.633$

$f_y = 555.5556$

$s = 100.00$

$V_{s,j2}$ is multiplied by $\text{Col},j2 = 1.00$

$s/d = 0.3125$

$V_{s,\text{core}} = V_{s,c1} + V_{s,c2} = 78637.555$

$V_{s,c1} = 78637.555$ is calculated for section web core, with:

$d = 440.00$

$A_v = 100530.965$

$f_y = 444.4444$

$s = 250.00$

$V_{s,c1}$ is multiplied by $\text{Col},c1 = 1.00$

$s/d = 0.56818182$

$V_{s,c2} = 0.00$ is calculated for section flange core, with:

$d = 160.00$

$A_v = 100530.965$

$f_y = 444.4444$

$s = 250.00$

$V_{s,c2}$ is multiplied by $\text{Col},c2 = 0.00$

$s/d = 1.5625$

V_f ((11-3)-(11.4), ACI 440) = 372533.843

$f = 0.95$, for fully-wrapped sections

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

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

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

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

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

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

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

$d_{fv} = d$ (figure 11.2, ACI 440) = 707.00

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: $V_s + V_f \leq 838832.606$

$b_w = 400.00$

End Of Calculation of Shear Capacity ratio for element: column JLC1 of floor 1

At local axis: 3

Start Of Calculation of Shear Capacity ratio for element: column JLC1 of floor 1
At Shear local axis: 2
(Bending local axis: 3)
Section Type: rcjlc

Constant Properties

Knowledge Factor, $\gamma = 0.85$
Mean strength values are used for both shear and moment calculations.
Consequently:
Jacket
New material of Secondary Member: Concrete Strength, $f_c = f_{cm} = 33.00$
New material of Secondary Member: Steel Strength, $f_s = f_{sm} = 555.5556$
Concrete Elasticity, $E_c = 26999.444$
Steel Elasticity, $E_s = 200000.00$
Existing Column
Existing material of Secondary Member: Concrete Strength, $f_c = f_{cm} = 20.00$
Existing material of Secondary Member: Steel Strength, $f_s = f_{sm} = 444.4444$
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, $f_s = 1.25 \cdot f_{sm} = 694.4444$
Existing Column
Existing material: Steel Strength, $f_s = 1.25 \cdot f_{sm} = 555.5556$
#####

Max Height, $H_{max} = 750.00$
Min Height, $H_{min} = 400.00$
Max Width, $W_{max} = 750.00$
Min Width, $W_{min} = 400.00$
Jacket Thickness, $t_j = 100.00$
Cover Thickness, $c = 25.00$
Mean Confinement Factor overall section = 1.03889
Element Length, $L = 3000.00$
Secondary Member
Ribbed Bars
Ductile Steel
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
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, $V_a = -0.00051441$
EDGE -B-
Shear Force, $V_b = 0.00051441$
BOTH EDGES
Axial Force, $F = -16273.616$
Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: Aslt = 0.00

-Compression: Aslc = 5353.274

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension: Asl,ten = 1137.257

-Compression: Asl,com = 2208.54

-Middle: Asl,mid = 2007.478

Calculation of Shear Capacity ratio , $V_e/V_r = 0.55377356$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 552827.824$

with

$M_{pr1} = \text{Max}(M_{u1+}, M_{u1-}) = 8.2924E+008$

$M_{u1+} = 5.1260E+008$, 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

$M_{u1-} = 8.2924E+008$, 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

$M_{pr2} = \text{Max}(M_{u2+}, M_{u2-}) = 8.2924E+008$

$M_{u2+} = 5.1260E+008$, 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

$M_{u2-} = 8.2924E+008$, 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 ϕ_u according to 4.1, Biskinis/Fardis 2013:

$\phi_u = 9.5578758E-006$

$M_u = 5.1260E+008$

with full section properties:

$b = 750.00$

$d = 707.00$

$d' = 43.00$

$v = 0.00093001$

$N = 16273.616$

$f_c = 33.00$

ϕ_c (5A.5, TBDY) = 0.002

Final value of ϕ_u : $\phi_u^* = \text{shear_factor} * \text{Max}(\phi_c, \phi_c) = 0.01288354$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $\phi_u = 0.01288354$

ϕ_{ve} ((5.4c), TBDY) = $\phi_u * \text{sh}_{\min} * f_{yve}/f_{ce} + \text{Min}(\phi_x, \phi_y) = 0.05503171$

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

$\phi_x = 0.04286225$

Expression ((15B.6), TBDY) is modified as $\phi_f = 1 - (\text{Unconfined area})/(\text{total area})$

$\phi_f = 0.31984848$

with Unconfined area = $((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2)/3 = 140733.333$

$b_{\max} = 750.00$

$h_{\max} = 750.00$

From EC8 A.4.4.3(6), $\phi_f = 2t_f/b_w = 0.00508$

$b_w = 400.00$

effective stress from (A.35), $f_{f,e} = 870.5244$

$\phi_y = 0.04286225$

Expression ((15B.6), TBDY) is modified as $\phi_f = 1 - (\text{Unconfined area})/(\text{total area})$

$\phi_f = 0.31984848$

with Unconfined area = $((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2)/3 = 140733.333$

$b_{\max} = 750.00$

$h_{\max} = 750.00$

From EC8 A.4.4.3(6), $\phi_f = 2t_f/b_w = 0.00508$

$b_w = 400.00$

effective stress from (A.35), $f_{f,e} = 870.5244$

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$\text{ase ((5.4d), TBDY)} = (\text{ase}_1 \cdot A_{\text{ext}} + \text{ase}_2 \cdot A_{\text{int}}) / A_{\text{sec}} = 0.45746528$$

$$\text{ase}_1 = \text{Max}(((A_{\text{conf,max1}} - A_{\text{noConf1}}) / A_{\text{conf,max1}}) \cdot (A_{\text{conf,min1}} / A_{\text{conf,max1}}), 0) = 0.45746528$$

The definitions of A_{noConf} , $A_{\text{conf,min}}$ and $A_{\text{conf,max}}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{\text{conf,max1}} = 353600.00$ is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{\text{conf,min1}} = 293525.00$ is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area $A_{\text{conf,max1}}$ by a length

equal to half the clear spacing between external hoops.

$A_{\text{noConf1}} = 158733.333$ is the unconfined external core area which is equal to $b_i^2/6$ as defined at (A.2).

$$\text{ase}_2 (> = \text{ase}_1) = \text{Max}(((A_{\text{conf,max2}} - A_{\text{noConf2}}) / A_{\text{conf,max2}}) \cdot (A_{\text{conf,min2}} / A_{\text{conf,max2}}), 0) = 0.45746528$$

The definitions of A_{noConf} , $A_{\text{conf,min}}$ and $A_{\text{conf,max}}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{\text{conf,max2}} = 171264.00$ is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

$A_{\text{conf,min2}} = 54741.00$ is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area $A_{\text{conf,max2}}$ by a length

equal to half the clear spacing between internal hoops.

$A_{\text{noConf2}} = 106242.667$ is the unconfined internal core area which is equal to $b_i^2/6$ as defined at (A.2).

$$p_{\text{sh,min}} \cdot F_{ywe} = \text{Min}(p_{\text{sh,x}} \cdot F_{ywe}, p_{\text{sh,y}} \cdot F_{ywe}) = 2.92621$$

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

$$p_{\text{sh,x}} \cdot F_{ywe} = p_{\text{sh1}} \cdot F_{ywe1} + p_{\text{sh2}} \cdot F_{ywe2} = 2.92621$$

$$p_{\text{sh1}} \text{ ((5.4d), TBDY)} = L_{\text{stir1}} \cdot A_{\text{stir1}} / (A_{\text{sec}} \cdot s_1) = 0.00367709$$

L_{stir1} (Length of stirrups along Y) = 2060.00

A_{stir1} (stirrups area) = 78.53982

$$p_{\text{sh2}} \text{ (5.4d)} = L_{\text{stir2}} \cdot A_{\text{stir2}} / (A_{\text{sec}} \cdot s_2) = 0.00067082$$

L_{stir2} (Length of stirrups along Y) = 1468.00

A_{stir2} (stirrups area) = 50.26548

$$p_{\text{sh,y}} \cdot F_{ywe} = p_{\text{sh1}} \cdot F_{ywe1} + p_{\text{sh2}} \cdot F_{ywe2} = 2.92621$$

$$p_{\text{sh1}} \text{ ((5.4d), TBDY)} = L_{\text{stir1}} \cdot A_{\text{stir1}} / (A_{\text{sec}} \cdot s_1) = 0.00367709$$

L_{stir1} (Length of stirrups along X) = 2060.00

A_{stir1} (stirrups area) = 78.53982

$$p_{\text{sh2}} \text{ ((5.4d), TBDY)} = L_{\text{stir2}} \cdot A_{\text{stir2}} / (A_{\text{sec}} \cdot s_2) = 0.00067082$$

L_{stir2} (Length of stirrups along X) = 1468.00

A_{stir2} (stirrups area) = 50.26548

$$A_{\text{sec}} = 440000.00$$

$$s_1 = 100.00$$

$$s_2 = 250.00$$

$$f_{ywe1} = 694.4444$$

$$f_{ywe2} = 555.5556$$

$$f_{ce} = 33.00$$

From ((5.A5), TBDY), TBDY: $cc = 0.00238888$

c = confinement factor = 1.03889

$$y_1 = 0.00145721$$

$$sh_1 = 0.00466307$$

$$ft_1 = 459.4373$$

$$fy_1 = 382.8645$$

$$su_1 = 0.00582756$$

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

$$l_0/l_{ou,min} = l_b/l_d = 0.318426$$

$$s_u1 = 0.4 * e_{su1_nominal} ((5.5), TBDY) = 0.032$$

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.

$$\text{with } f_{s1} = (f_{s,jacket} * A_{sl,ten,jacket} + f_{s,core} * A_{sl,ten,core}) / A_{sl,ten} = 382.8645$$

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

$$y_2 = 0.00145721$$

$$sh_2 = 0.00466307$$

$$ft_2 = 465.423$$

$$fy_2 = 387.8525$$

$$s_u2 = 0.00582756$$

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

$$l_0/l_{ou,min} = l_b/l_{b,min} = 0.318426$$

$$s_u2 = 0.4 * e_{su2_nominal} ((5.5), TBDY) = 0.032$$

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.

$$\text{with } f_{s2} = (f_{s,jacket} * A_{sl,com,jacket} + f_{s,core} * A_{sl,com,core}) / A_{sl,com} = 387.8525$$

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

$$y_v = 0.00145721$$

$$sh_v = 0.00466307$$

$$ft_v = 463.3885$$

$$fy_v = 386.157$$

$$s_{uv} = 0.00582756$$

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

$$l_0/l_{ou,min} = l_b/l_d = 0.318426$$

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

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.

$$\text{with } f_{sv} = (f_{s,jacket} * A_{sl,mid,jacket} + f_{s,mid} * A_{sl,mid,core}) / A_{sl,mid} = 386.157$$

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

$$1 = A_{sl,ten} / (b * d) * (f_{s1} / f_c) = 0.02488335$$

$$2 = A_{sl,com} / (b * d) * (f_{s2} / f_c) = 0.04895276$$

$$v = A_{sl,mid} / (b * d) * (f_{sv} / f_c) = 0.04430167$$

and confined core properties:

$$b = 690.00$$

$$d = 677.00$$

$$d' = 13.00$$

$$f_{cc} (5A.2, TBDY) = 34.2833$$

$$c_c (5A.5, TBDY) = 0.00238888$$

$$c = \text{confinement factor} = 1.03889$$

$$1 = A_{sl,ten} / (b * d) * (f_{s1} / f_c) = 0.02824566$$

$$2 = A_{sl,com} / (b * d) * (f_{s2} / f_c) = 0.05556741$$

$$v = A_{sl,mid} / (b * d) * (f_{sv} / f_c) = 0.05028784$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

$$s_u (4.9) = 0.13760581$$

$$\mu_u = M R_c (4.14) = 5.1260E+008$$

$$u = s_u (4.1) = 9.5578758E-006$$

Calculation of ratio l_b/l_d

$$\text{Lap Length: } l_b/l_d = 0.318426$$

$$l_b = 300.00$$

$$l_d = 942.1341$$

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

$$= 1$$

$$d_b = 16.66667$$

$$\text{Mean strength value of all re-bars: } f_y = 655.5556$$

$$\text{Mean concrete strength: } f_c' = (f_c'_{\text{jacket}} \cdot \text{Area}_{\text{jacket}} + f_c'_{\text{core}} \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 27.68182, \text{ but } f_c'^{0.5} <= 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 25.00$$

$$K_{tr} = 1.7174$$

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

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

$$s = \text{Max}(s_{\text{external}}, s_{\text{internal}}) = 250.00$$

$$n = 24.00$$

Calculation of μ_1 -

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

$$\mu = 1.0408734E-005$$

$$\mu_1 = 8.2924E+008$$

with full section properties:

$$b = 400.00$$

$$d = 707.00$$

$$d' = 43.00$$

$$v = 0.00174378$$

$$N = 16273.616$$

$$f_c = 33.00$$

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

$$\text{Final value of } \mu: \mu^* = \text{shear_factor} \cdot \text{Max}(\mu_c, \mu_s) = 0.01288354$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \mu_c = 0.01288354$$

$$\mu_s \text{ ((5.4c), TBDY)} = a_s e^* \cdot \text{sh}_{\text{min}} \cdot f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.05503171$$

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)

$$f_x = 0.04286225$$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.31984848$$

$$\text{with Unconfined area} = ((b_{\text{max}} - 2R)^2 + (h_{\text{max}} - 2R)^2) / 3 = 140733.333$$

$$b_{\text{max}} = 750.00$$

$$h_{\text{max}} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{fe} = 870.5244$$

$$f_y = 0.04286225$$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.31984848$$

$$\text{with Unconfined area} = ((b_{\text{max}} - 2R)^2 + (h_{\text{max}} - 2R)^2) / 3 = 140733.333$$

$$b_{\text{max}} = 750.00$$

$$h_{\text{max}} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{fe} = 870.5244$$

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$ase((5.4d), TBDY) = (ase1 * A_{ext} + ase2 * A_{int}) / A_{sec} = 0.45746528$$

$$ase1 = \text{Max}(((A_{conf,max1} - A_{noConf1}) / A_{conf,max1}) * (A_{conf,min1} / A_{conf,max1}), 0) = 0.45746528$$

The definitions of A_{noConf} , $A_{conf,min}$ and $A_{conf,max}$ are derived from generalization

of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max1} = 353600.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{conf,min1} = 293525.00$ is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area $A_{conf,max1}$ by a length equal to half the clear spacing between external hoops.

$A_{noConf1} = 158733.333$ is the unconfined external core area which is equal to $b_i^2/6$ as defined at (A.2).

$$ase2 (>= ase1) = \text{Max}(((A_{conf,max2} - A_{noConf2}) / A_{conf,max2}) * (A_{conf,min2} / A_{conf,max2}), 0) = 0.45746528$$

The definitions of A_{noConf} , $A_{conf,min}$ and $A_{conf,max}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max2} = 171264.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

$A_{conf,min2} = 54741.00$ is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area $A_{conf,max2}$ by a length equal to half the clear spacing between internal hoops.

$A_{noConf2} = 106242.667$ is the unconfined internal core area which is equal to $b_i^2/6$ as defined at (A.2).

$$psh_{min} * F_{ywe} = \text{Min}(psh_x * F_{ywe}, psh_y * F_{ywe}) = 2.92621$$

Expression (5.4d) 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)

$$psh_x * F_{ywe} = psh1 * F_{ywe1} + ps2 * F_{ywe2} = 2.92621$$

$$psh1((5.4d), TBDY) = L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00367709$$

$$L_{stir1} \text{ (Length of stirrups along Y)} = 2060.00$$

$$A_{stir1} \text{ (stirrups area)} = 78.53982$$

$$psh2(5.4d) = L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00067082$$

$$L_{stir2} \text{ (Length of stirrups along Y)} = 1468.00$$

$$A_{stir2} \text{ (stirrups area)} = 50.26548$$

$$psh_y * F_{ywe} = psh1 * F_{ywe1} + ps2 * F_{ywe2} = 2.92621$$

$$psh1((5.4d), TBDY) = L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00367709$$

$$L_{stir1} \text{ (Length of stirrups along X)} = 2060.00$$

$$A_{stir1} \text{ (stirrups area)} = 78.53982$$

$$psh2((5.4d), TBDY) = L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00067082$$

$$L_{stir2} \text{ (Length of stirrups along X)} = 1468.00$$

$$A_{stir2} \text{ (stirrups area)} = 50.26548$$

$$A_{sec} = 440000.00$$

$$s1 = 100.00$$

$$s2 = 250.00$$

$$fywe1 = 694.4444$$

$$fywe2 = 555.5556$$

$$fce = 33.00$$

$$\text{From } ((5.A.5), TBDY), TBDY: cc = 0.00238888$$

$$c = \text{confinement factor} = 1.03889$$

$$y1 = 0.00145721$$

$$sh1 = 0.00466307$$

$$ft1 = 465.423$$

$$fy1 = 387.8525$$

$$su1 = 0.00582756$$

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

$$lo/lou_{min} = lb/ld = 0.318426$$

$$su1 = 0.4 * esu1_{nominal}((5.5), TBDY) = 0.032$$

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 $fs1 = (fs_{jacket} \cdot Asl_{ten,jacket} + fs_{core} \cdot Asl_{ten,core}) / Asl_{ten} = 387.8525$
 with $Es1 = (Es_{jacket} \cdot Asl_{ten,jacket} + Es_{core} \cdot Asl_{ten,core}) / Asl_{ten} = 200000.00$
 $y2 = 0.00145721$
 $sh2 = 0.00466307$
 $ft2 = 459.4373$
 $fy2 = 382.8645$
 $su2 = 0.00582756$
 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
 $lo/lo_{ou,min} = lb/lb_{min} = 0.318426$
 $su2 = 0.4 \cdot esu2_{nominal} ((5.5), TBDY) = 0.032$
 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 $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$, from 10.3.5, ASCE 41-17.
 with $fs2 = (fs_{jacket} \cdot Asl_{com,jacket} + fs_{core} \cdot Asl_{com,core}) / Asl_{com} = 382.8645$
 with $Es2 = (Es_{jacket} \cdot Asl_{com,jacket} + Es_{core} \cdot Asl_{com,core}) / Asl_{com} = 200000.00$
 $yv = 0.00145721$
 $shv = 0.00466307$
 $ftv = 463.3885$
 $fyv = 386.157$
 $suv = 0.00582756$
 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
 $lo/lo_{ou,min} = lb/ld = 0.318426$
 $suv = 0.4 \cdot esuv_{nominal} ((5.5), TBDY) = 0.032$
 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 $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$, from 10.3.5, ASCE 41-17.
 with $fsv = (fs_{jacket} \cdot Asl_{mid,jacket} + fs_{mid} \cdot Asl_{mid,core}) / Asl_{mid} = 386.157$
 with $Esv = (Es_{jacket} \cdot Asl_{mid,jacket} + Es_{mid} \cdot Asl_{mid,core}) / Asl_{mid} = 200000.00$
 $1 = Asl_{ten} / (b \cdot d) \cdot (fs1 / fc) = 0.09178643$
 $2 = Asl_{com} / (b \cdot d) \cdot (fs2 / fc) = 0.04665628$
 $v = Asl_{mid} / (b \cdot d) \cdot (fsv / fc) = 0.08306563$
 and confined core properties:
 $b = 340.00$
 $d = 677.00$
 $d' = 13.00$
 $fcc (5A.2, TBDY) = 34.2833$
 $cc (5A.5, TBDY) = 0.00238888$
 $c = \text{confinement factor} = 1.03889$
 $1 = Asl_{ten} / (b \cdot d) \cdot (fs1 / fc) = 0.11276915$
 $2 = Asl_{com} / (b \cdot d) \cdot (fs2 / fc) = 0.05732208$
 $v = Asl_{mid} / (b \cdot d) \cdot (fsv / fc) = 0.10205474$
 Case/Assumption: Unconfined full section - Steel rupture
 ' satisfies Eq. (4.3)
 --->
 $v < vs, y2$ - LHS eq.(4.5) is satisfied
 --->
 $su (4.9) = 0.20810191$
 $Mu = MRc (4.14) = 8.2924E+008$
 $u = su (4.1) = 1.0408734E-005$

 Calculation of ratio lb/ld

Lap Length: $lb/ld = 0.318426$

$lb = 300.00$

$ld = 942.1341$

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: $fy = 655.5556$

Mean concrete strength: $f_c' = (f_{c'}^{\text{jacket}} \cdot A_{\text{jacket}} + f_{c'}^{\text{core}} \cdot A_{\text{core}}) / A_{\text{section}} = 27.68182$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 25.00$$

$$K_{tr} = 1.7174$$

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

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

$$s = \text{Max}(s_{\text{external}}, s_{\text{internal}}) = 250.00$$

$$n = 24.00$$

Calculation of μ_{2+}

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

$$\mu = 9.5578758E-006$$

$$\mu_{2+} = 5.1260E+008$$

with full section properties:

$$b = 750.00$$

$$d = 707.00$$

$$d' = 43.00$$

$$v = 0.00093001$$

$$N = 16273.616$$

$$f_c = 33.00$$

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

$$\text{Final value of } \mu: \mu^* = \text{shear_factor} \cdot \text{Max}(\mu, c_o) = 0.01288354$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \mu = 0.01288354$$

$$\text{we ((5.4c), TBDY) } = a_{se} \cdot \text{sh}_{\text{min}} \cdot f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.05503171$$

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)

$$f_x = 0.04286225$$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.31984848$$

$$\text{with Unconfined area} = ((b_{\text{max}} - 2R)^2 + (h_{\text{max}} - 2R)^2) / 3 = 140733.333$$

$$b_{\text{max}} = 750.00$$

$$h_{\text{max}} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{fe} = 870.5244$$

$$f_y = 0.04286225$$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.31984848$$

$$\text{with Unconfined area} = ((b_{\text{max}} - 2R)^2 + (h_{\text{max}} - 2R)^2) / 3 = 140733.333$$

$$b_{\text{max}} = 750.00$$

$$h_{\text{max}} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{fe} = 870.5244$$

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$a_{se} \text{ ((5.4d), TBDY)} = (a_{se1} \cdot A_{\text{ext}} + a_{se2} \cdot A_{\text{int}}) / A_{\text{sec}} = 0.45746528$$

$$a_{se1} = \text{Max}(((A_{\text{conf,max1}} - A_{\text{noConf1}}) / A_{\text{conf,max1}}) \cdot (A_{\text{conf,min1}} / A_{\text{conf,max1}}), 0) = 0.45746528$$

The definitions of A_{noConf} , $A_{\text{conf,min}}$ and $A_{\text{conf,max}}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max1} = 353600.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{conf,min1} = 293525.00$ is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area $A_{conf,max1}$ by a length equal to half the clear spacing between external hoops.

$A_{noConf1} = 158733.333$ is the unconfined external core area which is equal to $b_i^2/6$ as defined at (A.2).
 $ase_2 (>=ase_1) = \text{Max}(((A_{conf,max2}-A_{noConf2})/A_{conf,max2})*(A_{conf,min2}/A_{conf,max2}),0) = 0.45746528$

The definitions of A_{noConf} , $A_{conf,min}$ and $A_{conf,max}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988) "Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max2} = 171264.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

$A_{conf,min2} = 54741.00$ is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area $A_{conf,max2}$ by a length equal to half the clear spacing between internal hoops.

$A_{noConf2} = 106242.667$ is the unconfined internal core area which is equal to $b_i^2/6$ as defined at (A.2).

$p_{sh,min}*F_{ywe} = \text{Min}(p_{sh,x}*F_{ywe}, p_{sh,y}*F_{ywe}) = 2.92621$

Expression (5.4d) 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)

$p_{sh,x}*F_{ywe} = p_{sh1}*F_{ywe1} + p_{s2}*F_{ywe2} = 2.92621$

p_{sh1} ((5.4d), TBDY) = $L_{stir1}*A_{stir1}/(A_{sec}*s_1) = 0.00367709$

L_{stir1} (Length of stirrups along Y) = 2060.00

A_{stir1} (stirrups area) = 78.53982

p_{sh2} (5.4d) = $L_{stir2}*A_{stir2}/(A_{sec}*s_2) = 0.00067082$

L_{stir2} (Length of stirrups along Y) = 1468.00

A_{stir2} (stirrups area) = 50.26548

$p_{sh,y}*F_{ywe} = p_{sh1}*F_{ywe1} + p_{s2}*F_{ywe2} = 2.92621$

p_{sh1} ((5.4d), TBDY) = $L_{stir1}*A_{stir1}/(A_{sec}*s_1) = 0.00367709$

L_{stir1} (Length of stirrups along X) = 2060.00

A_{stir1} (stirrups area) = 78.53982

p_{sh2} ((5.4d), TBDY) = $L_{stir2}*A_{stir2}/(A_{sec}*s_2) = 0.00067082$

L_{stir2} (Length of stirrups along X) = 1468.00

A_{stir2} (stirrups area) = 50.26548

$A_{sec} = 440000.00$

$s_1 = 100.00$

$s_2 = 250.00$

$f_{ywe1} = 694.4444$

$f_{ywe2} = 555.5556$

$f_{ce} = 33.00$

From ((5.A.5), TBDY), TBDY: $cc = 0.00238888$

$c =$ confinement factor = 1.03889

$y_1 = 0.00145721$

$sh_1 = 0.00466307$

$ft_1 = 459.4373$

$fy_1 = 382.8645$

$su_1 = 0.00582756$

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

$l_o/l_{ou,min} = l_b/l_d = 0.318426$

$su_1 = 0.4*es_{u1,nominal}$ ((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 $fs_1 = fs_1/1.2$, 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 $fs_1 = (f_{s,jacket}*A_{s,ten,jacket} + f_{s,core}*A_{s,ten,core})/A_{s,ten} = 382.8645$

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

$y_2 = 0.00145721$

$sh_2 = 0.00466307$

$ft_2 = 465.423$

$fy_2 = 387.8525$

$$su_2 = 0.00582756$$

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

$$lo/lou,min = lb/lb,min = 0.318426$$

$$su_2 = 0.4 * esu_2,nominal ((5.5), TBDY) = 0.032$$

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 $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE 41-17.

$$\text{with } fs_2 = (fs_{jacket} * A_{sl,com,jacket} + fs_{core} * A_{sl,com,core}) / A_{sl,com} = 387.8525$$

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

$$yv = 0.00145721$$

$$shv = 0.00466307$$

$$ftv = 463.3885$$

$$fyv = 386.157$$

$$suv = 0.00582756$$

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

$$lo/lou,min = lb/ld = 0.318426$$

$$suv = 0.4 * esuv,nominal ((5.5), TBDY) = 0.032$$

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 , 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 $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE 41-17.

$$\text{with } fsv = (fs_{jacket} * A_{sl,mid,jacket} + fs_{mid} * A_{sl,mid,core}) / A_{sl,mid} = 386.157$$

$$\text{with } Esv = (Es_{jacket} * A_{sl,mid,jacket} + Es_{mid} * A_{sl,mid,core}) / A_{sl,mid} = 200000.00$$

$$1 = A_{sl,ten} / (b * d) * (fs_1 / fc) = 0.02488335$$

$$2 = A_{sl,com} / (b * d) * (fs_2 / fc) = 0.04895276$$

$$v = A_{sl,mid} / (b * d) * (fsv / fc) = 0.04430167$$

and confined core properties:

$$b = 690.00$$

$$d = 677.00$$

$$d' = 13.00$$

$$fcc (5A.2, TBDY) = 34.2833$$

$$cc (5A.5, TBDY) = 0.00238888$$

$$c = \text{confinement factor} = 1.03889$$

$$1 = A_{sl,ten} / (b * d) * (fs_1 / fc) = 0.02824566$$

$$2 = A_{sl,com} / (b * d) * (fs_2 / fc) = 0.05556741$$

$$v = A_{sl,mid} / (b * d) * (fsv / fc) = 0.05028784$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

$$su (4.9) = 0.13760581$$

$$\mu = MRc (4.14) = 5.1260E+008$$

$$u = su (4.1) = 9.5578758E-006$$

Calculation of ratio lb/ld

Lap Length: lb/ld = 0.318426

$$lb = 300.00$$

$$ld = 942.1341$$

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 = 655.5556

Mean concrete strength: fc' = (fc'_jacket * Area_jacket + fc'_core * Area_core) / Area_section = 27.68182, but $fc'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$cb = 25.00$$

$$K_{tr} = 1.7174$$

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

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

$$s = \text{Max}(s_{\text{external}}, s_{\text{internal}}) = 250.00$$

$$n = 24.00$$

Calculation of μ_2 -

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

$$\mu = 1.0408734E-005$$

$$\mu_2 = 8.2924E+008$$

with full section properties:

$$b = 400.00$$

$$d = 707.00$$

$$d' = 43.00$$

$$v = 0.00174378$$

$$N = 16273.616$$

$$f_c = 33.00$$

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

$$\text{Final value of } \mu_2: \mu_2^* = \text{shear_factor} * \text{Max}(\mu_2, \mu_c) = 0.01288354$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \mu_2 = 0.01288354$$

$$\mu_2 \text{ (5.4c), TBDY} = \alpha s_e * \text{sh}_{\text{min}} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.05503171$$

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

$$f_x = 0.04286225$$

Expression ((15B.6), TBDY) is modified as $\alpha f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$\alpha f = 0.31984848$$

$$\text{with Unconfined area} = ((b_{\text{max}} - 2R)^2 + (h_{\text{max}} - 2R)^2) / 3 = 140733.333$$

$$b_{\text{max}} = 750.00$$

$$h_{\text{max}} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 870.5244$$

$$f_y = 0.04286225$$

Expression ((15B.6), TBDY) is modified as $\alpha f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$\alpha f = 0.31984848$$

$$\text{with Unconfined area} = ((b_{\text{max}} - 2R)^2 + (h_{\text{max}} - 2R)^2) / 3 = 140733.333$$

$$b_{\text{max}} = 750.00$$

$$h_{\text{max}} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 870.5244$$

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u_{f} = 0.015$$

$$\alpha s_e \text{ ((5.4d), TBDY)} = (\alpha s_{e1} * A_{\text{ext}} + \alpha s_{e2} * A_{\text{int}}) / A_{\text{sec}} = 0.45746528$$

$$\alpha s_{e1} = \text{Max}(((A_{\text{conf,max1}} - A_{\text{noConf1}}) / A_{\text{conf,max1}}) * (A_{\text{conf,min1}} / A_{\text{conf,max1}}), 0) = 0.45746528$$

The definitions of A_{noConf} , $A_{\text{conf,min}}$ and $A_{\text{conf,max}}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{\text{conf,max1}} = 353600.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{\text{conf,min1}} = 293525.00$ is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area $A_{\text{conf,max1}}$ by a length equal to half the clear spacing between external hoops.

AnoConf1 = 158733.333 is the unconfined external core area which is equal to $b_i^2/6$ as defined at (A.2).
 $ase_2 (> ase_1) = \text{Max}(((A_{conf,max2} - \text{AnoConf2})/A_{conf,max2}) * (A_{conf,min2}/A_{conf,max2}), 0) = 0.45746528$

The definitions of AnoConf, Aconf,min and Aconf,max are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

Aconf,max2 = 171264.00 is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

Aconf,min2 = 54741.00 is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area Aconf,max2 by a length equal to half the clear spacing between internal hoops.

AnoConf2 = 106242.667 is the unconfined internal core area which is equal to $b_i^2/6$ as defined at (A.2).
 $psh_{min} * Fy_{we} = \text{Min}(psh_x * Fy_{we}, psh_y * Fy_{we}) = 2.92621$

Expression (5.4d) 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)

 $psh_x * Fy_{we} = psh_1 * Fy_{we1} + ps_2 * Fy_{we2} = 2.92621$
 $psh_1 \text{ ((5.4d), TBDY)} = L_{stir1} * Astir1 / (A_{sec} * s_1) = 0.00367709$
Lstir1 (Length of stirrups along Y) = 2060.00
Astir1 (stirrups area) = 78.53982
 $psh_2 \text{ (5.4d)} = L_{stir2} * Astir2 / (A_{sec} * s_2) = 0.00067082$
Lstir2 (Length of stirrups along Y) = 1468.00
Astir2 (stirrups area) = 50.26548

 $psh_y * Fy_{we} = psh_1 * Fy_{we1} + ps_2 * Fy_{we2} = 2.92621$
 $psh_1 \text{ ((5.4d), TBDY)} = L_{stir1} * Astir1 / (A_{sec} * s_1) = 0.00367709$
Lstir1 (Length of stirrups along X) = 2060.00
Astir1 (stirrups area) = 78.53982
 $psh_2 \text{ ((5.4d), TBDY)} = L_{stir2} * Astir2 / (A_{sec} * s_2) = 0.00067082$
Lstir2 (Length of stirrups along X) = 1468.00
Astir2 (stirrups area) = 50.26548

Asec = 440000.00
s1 = 100.00
s2 = 250.00
fywe1 = 694.4444
fywe2 = 555.5556
fce = 33.00

From ((5.A.5), TBDY), TBDY: cc = 0.00238888
c = confinement factor = 1.03889

y1 = 0.00145721
sh1 = 0.00466307
ft1 = 465.423
fy1 = 387.8525
su1 = 0.00582756

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 = 0.318426

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.

with fs1 = (fs_jacket * Asl_ten_jacket + fs_core * Asl_ten_core) / Asl_ten = 387.8525

with Es1 = (Es_jacket * Asl_ten_jacket + Es_core * Asl_ten_core) / Asl_ten = 200000.00

y2 = 0.00145721
sh2 = 0.00466307
ft2 = 459.4373
fy2 = 382.8645
su2 = 0.00582756

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 = 0.318426

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 $fs2 = (fs_jacket \cdot Asl_com_jacket + fs_core \cdot Asl_com_core) / Asl_com = 382.8645$

with $Es2 = (Es_jacket \cdot Asl_com_jacket + Es_core \cdot Asl_com_core) / Asl_com = 200000.00$

$yv = 0.00145721$

$shv = 0.00466307$

$ftv = 463.3885$

$fyv = 386.157$

$suv = 0.00582756$

using (30) in Biskinis/Fardis (2013) multiplied with $shear_factor$

and also multiplied by the $shear_factor$ according to 15.7.1.4, with

$Shear_factor = 1.00$

$lo/lo_{u,min} = lb/ld = 0.318426$

$suv = 0.4 \cdot esuv_nominal$ ((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 $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$, from 10.3.5, ASCE 41-17.

with $fsv = (fs_jacket \cdot Asl_mid_jacket + fs_mid \cdot Asl_mid_core) / Asl_mid = 386.157$

with $Esv = (Es_jacket \cdot Asl_mid_jacket + Es_mid \cdot Asl_mid_core) / Asl_mid = 200000.00$

$1 = Asl_ten / (b \cdot d) \cdot (fs1 / fc) = 0.09178643$

$2 = Asl_com / (b \cdot d) \cdot (fs2 / fc) = 0.04665628$

$v = Asl_mid / (b \cdot d) \cdot (fsv / fc) = 0.08306563$

and confined core properties:

$b = 340.00$

$d = 677.00$

$d' = 13.00$

fcc (5A.2, TBDY) = 34.2833

cc (5A.5, TBDY) = 0.00238888

$c =$ confinement factor = 1.03889

$1 = Asl_ten / (b \cdot d) \cdot (fs1 / fc) = 0.11276915$

$2 = Asl_com / (b \cdot d) \cdot (fs2 / fc) = 0.05732208$

$v = Asl_mid / (b \cdot d) \cdot (fsv / fc) = 0.10205474$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < vs_y2$ - LHS eq.(4.5) is satisfied

--->

su (4.9) = 0.20810191

$Mu = MRc$ (4.14) = 8.2924E+008

$u = su$ (4.1) = 1.0408734E-005

Calculation of ratio lb/ld

Lap Length: $lb/ld = 0.318426$

$lb = 300.00$

$ld = 942.1341$

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: $fy = 655.5556$

Mean concrete strength: $fc' = (fc'_jacket \cdot Area_jacket + fc'_core \cdot Area_core) / Area_section = 27.68182$, but $fc'^{0.5} < = 8.3$ MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$Ktr = 1.7174$

$Atr = \text{Min}(Atr_x, Atr_y) = 257.6106$

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

$s = \text{Max}(s_external, s_internal) = 250.00$

$n = 24.00$

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 998292.205$

Calculation of Shear Strength at edge 1, $V_{r1} = 998292.205$

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

$V_{\text{Col}0} = 998292.205$

$k_{nl} = 1$ (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: $f_c' = (f_c'_{\text{jacket}} * \text{Area}_{\text{jacket}} + f_c'_{\text{core}} * \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 27.68182$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M / Vd = 4.00$

$\mu_u = 11.78089$

$V_u = 0.00051441$

$d = 0.8 * h = 600.00$

$N_u = 16273.616$

$A_g = 300000.00$

From (11.5.4.8), ACI 318-14: $V_s = V_{s,\text{jacket}} + V_{s,\text{core}} = 881489.011$

where:

$V_{s,\text{jacket}} = V_{s,j1} + V_{s,j2} = 802851.456$

$V_{s,j1} = 279252.68$ is calculated for section web jacket, with:

$d = 320.00$

$A_v = 157079.633$

$f_y = 555.5556$

$s = 100.00$

$V_{s,j1}$ is multiplied by $\text{Col},j1 = 1.00$

$s/d = 0.3125$

$V_{s,j2} = 523598.776$ is calculated for section flange jacket, with:

$d = 600.00$

$A_v = 157079.633$

$f_y = 555.5556$

$s = 100.00$

$V_{s,j2}$ is multiplied by $\text{Col},j2 = 1.00$

$s/d = 0.16666667$

$V_{s,\text{core}} = V_{s,c1} + V_{s,c2} = 78637.555$

$V_{s,c1} = 0.00$ is calculated for section web core, with:

$d = 160.00$

$A_v = 100530.965$

$f_y = 444.4444$

$s = 250.00$

$V_{s,c1}$ is multiplied by $\text{Col},c1 = 0.00$

$s/d = 1.5625$

$V_{s,c2} = 78637.555$ is calculated for section flange core, with:

$d = 440.00$

$A_v = 100530.965$

$f_y = 444.4444$

$s = 250.00$

$V_{s,c2}$ is multiplied by $\text{Col},c2 = 1.00$

$s/d = 0.56818182$

$V_f ((11-3)-(11.4), \text{ACI } 440) = 372533.843$

$f = 0.95$, for fully-wrapped sections

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

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

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

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

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

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

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

$d_{fv} = d$ (figure 11.2, ACI 440) = 707.00

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

$E_f = 64828.00$

$f_e = 0.004$, from (11.6a), ACI 440
with $f_u = 0.01$
From (11-11), ACI 440: $V_s + V_f \leq 838832.606$
 $bw = 400.00$

Calculation of Shear Strength at edge 2, $V_{r2} = 998292.205$
 $V_{r2} = V_{Col} ((10.3), ASCE 41-17) = knl * V_{Col0}$
 $V_{Col0} = 998292.205$
 $knl = 1$ (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: $f'_c = (f'_{c,jacket} * Area_{jacket} + f'_{c,core} * Area_{core}) / Area_{section} = 27.68182$, but $f_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 4.00$

$\mu_u = 11.78144$

$V_u = 0.00051441$

$d = 0.8 * h = 600.00$

$N_u = 16273.616$

$A_g = 300000.00$

From (11.5.4.8), ACI 318-14: $V_s = V_{s,jacket} + V_{s,core} = 881489.011$

where:

$V_{s,jacket} = V_{s,j1} + V_{s,j2} = 802851.456$

$V_{s,j1} = 279252.68$ is calculated for section web jacket, with:

$d = 320.00$

$A_v = 157079.633$

$f_y = 555.5556$

$s = 100.00$

$V_{s,j1}$ is multiplied by $Col_{j1} = 1.00$

$s/d = 0.3125$

$V_{s,j2} = 523598.776$ is calculated for section flange jacket, with:

$d = 600.00$

$A_v = 157079.633$

$f_y = 555.5556$

$s = 100.00$

$V_{s,j2}$ is multiplied by $Col_{j2} = 1.00$

$s/d = 0.16666667$

$V_{s,core} = V_{s,c1} + V_{s,c2} = 78637.555$

$V_{s,c1} = 0.00$ is calculated for section web core, with:

$d = 160.00$

$A_v = 100530.965$

$f_y = 444.4444$

$s = 250.00$

$V_{s,c1}$ is multiplied by $Col_{c1} = 0.00$

$s/d = 1.5625$

$V_{s,c2} = 78637.555$ is calculated for section flange core, with:

$d = 440.00$

$A_v = 100530.965$

$f_y = 444.4444$

$s = 250.00$

$V_{s,c2}$ is multiplied by $Col_{c2} = 1.00$

$s/d = 0.56818182$

V_f ((11-3)-(11.4), ACI 440) = 372533.843

$f = 0.95$, 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 $V_f(\theta, a_i)$, 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: $\theta = b1 + 90^\circ = 90.00$

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

total thickness per orientation, $tf1 = NL * t / \text{NoDir} = 1.016$

$dfv = d$ (figure 11.2, ACI 440) = 707.00

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 <= 838832.606
bw = 400.00

End Of Calculation of Shear Capacity ratio for element: column JLC1 of floor 1
At local axis: 2

Start Of Calculation of Chord Rotation Capacity for element: column JLC1 of floor 1
At local axis: 2
Integration Section: (a)
Section Type: rcjlc

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 Secondary Member: Concrete Strength, $f_c = f_{cm} = 33.00$
New material of Secondary Member: Steel Strength, $f_s = f_{sm} = 555.5556$
Concrete Elasticity, $E_c = 26999.444$
Steel Elasticity, $E_s = 200000.00$
Existing Column
Existing material of Secondary Member: Concrete Strength, $f_c = f_{cm} = 20.00$
Existing material of Secondary Member: Steel Strength, $f_s = f_{sm} = 444.4444$
Concrete Elasticity, $E_c = 21019.039$
Steel Elasticity, $E_s = 200000.00$
Max Height, $H_{max} = 750.00$
Min Height, $H_{min} = 400.00$
Max Width, $W_{max} = 750.00$
Min Width, $W_{min} = 400.00$
Jacket Thickness, $t_j = 100.00$
Cover Thickness, $c = 25.00$
Element Length, $L = 3000.00$
Secondary Member
Ribbed Bars
Ductile Steel
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
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, $M = -251948.766$
Shear Force, $V_2 = -6560.264$
Shear Force, $V_3 = 122.9023$
Axial Force, $F = -16937.611$
Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: $As_{lt} = 0.00$

-Compression: $As_{lc} = 5353.274$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

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

-Compression: $As_{l,com} = 2208.54$

-Middle: $As_{l,mid} = 2007.478$

Longitudinal External Reinforcement Area Distribution (in 3 divisions)

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

-Compression: $As_{l,com,jacket} = 1746.726$

-Middle: $As_{l,mid,jacket} = 1545.664$

Longitudinal Internal Reinforcement Area Distribution (in 3 divisions)

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

-Compression: $As_{l,com,core} = 461.8141$

-Middle: $As_{l,mid,core} = 461.8141$

Mean Diameter of Tension Reinforcement, $DbL = 16.80$

Existing component: From table 7-7, ASCE 41_17: Final chord rotation Capacity $u_{,R} = \phi u = 0.02718736$
 $u = y + p = 0.03198513$

- Calculation of y -

$y = (M_y * L_s / 3) / E_{eff} = 0.00198513$ ((4.29), Biskinis Phd))

$M_y = 4.2097E+008$

$L_s = M/V$ (with $L_s > 0.1 * L$ and $L_s < 2 * L$) = 2049.992

From table 10.5, ASCE 41_17: $E_{eff} = factor * E_c * I_g = 1.4491E+014$

factor = 0.30

$A_g = 440000.00$

Mean concrete strength: $f_c' = (f_c'_{jacket} * Area_{jacket} + f_c'_{core} * Area_{core}) / Area_{section} = 27.68182$

$N = 16937.611$

$E_c * I_g = E_c * I_{g,jacket} + E_c * I_{g,core} = 4.8303E+014$

Calculation of Yielding Moment M_y

Calculation of y and M_y according to Annex 7 -

Assuming neutral axis within flange ($y < t/d$, compression zone rectangular) with:

flange width, $b = 750.00$

web width, $b_w = 400.00$

flange thickness, $t = 400.00$

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

$y_{ten} = 3.1431513E-006$

with ((10.1), ASCE 41-17) $f_y = \text{Min}(f_y, 1.25 * f_y * (I_b / I_d)^{2/3}) = 358.4764$

$d = 707.00$

$y = 0.19342282$

$A = 0.01018486$

$B = 0.00449527$

with $p_t = 0.00671906$

$p_c = 0.00416509$

$p_v = 0.00378591$

$N = 16937.611$

$b = 750.00$

$" = 0.06082037$

$y_{comp} = 1.6462780E-005$

with f_c^* (12.3, (ACI 440)) = 33.48734

$f_c = 33.00$

$f_l = 0.49678681$

$b = b_{max} = 750.00$

$h = h_{max} = 750.00$

$A_g = 0.44$

$g = p_t + p_c + p_v = 0.01009575$

$rc = 40.00$
 $Ae/Ac = 0.31291181$
 Effective FRP thickness, $tf = NL*t*\text{Cos}(b1) = 1.016$
 effective strain from (12.5) and (12.12), $efe = 0.004$
 $fu = 0.01$
 $Ef = 64828.00$
 $Ec = 26999.444$
 $y = 0.19181197$
 $A = 0.01002422$
 $B = 0.00440616$
 with $Es = 200000.00$
 CONFIRMATION: $y = 0.19278073 < t/d$

 Calculation of ratio lb/l_d

Lap Length: $l_d/l_{d,min} = 0.39803249$

$lb = 300.00$

$l_d = 753.7073$

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: $fy = 524.4444$

Mean concrete strength: $fc' = (fc'_{jacket}*Area_{jacket} + fc'_{core}*Area_{core})/Area_{section} = 27.68182$, but $fc'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 1.7174$

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

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

$s = \text{Max}(s_{external}, s_{internal}) = 250.00$

$n = 24.00$

 - Calculation of p -

From table 10-8: $p = 0.03$

with:

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

shear control ratio $V_y E / V_{col} O E = 0.55377356$

$d = d_{external} = 707.00$

$s = s_{external} = 0.00$

- $t = s_1 + s_2 + 2*tf/bw*(ffe/fs) = 0.00671906$

jacket: $s_1 = Av_1*Lstir_1/(s_1*Ag) = 0.00367709$

$Av_1 = 78.53982$, is the area of every stirrup parallel to loading (shear) direction

$Lstir_1 = 2060.00$, is the total Length of all stirrups parallel to loading (shear) direction

$s_1 = 100.00$

core: $s_2 = Av_2*Lstir_2/(s_2*Ag) = 0.00067082$

$Av_2 = 50.26548$, is the area of every stirrup parallel to loading (shear) direction

$Lstir_2 = 1468.00$, is the total Length of all stirrups parallel to loading (shear) direction

$s_2 = 250.00$

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

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

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

For the normalisation fs of jacket is used.

$NUD = 16937.611$

$Ag = 440000.00$

$f_{cE} = (fc_{jacket}*Area_{jacket} + fc_{core}*Area_{core})/section_area = 27.68182$

$f_{yIE} = (fy_{ext_Long_Reinf}*Area_{ext_Long_Reinf} + fy_{int_Long_Reinf}*Area_{int_Long_Reinf})/Area_{Tot_Long_Rein} = 529.9948$

$f_{yIE} = (fy_{ext_Trans_Reinf}*s_1 + fy_{int_Trans_Reinf}*s_2)/(s_1 + s_2) = 538.4128$

$pl = Area_{Tot_Long_Rein}/(b*d) = 0.01009575$

$b = 750.00$

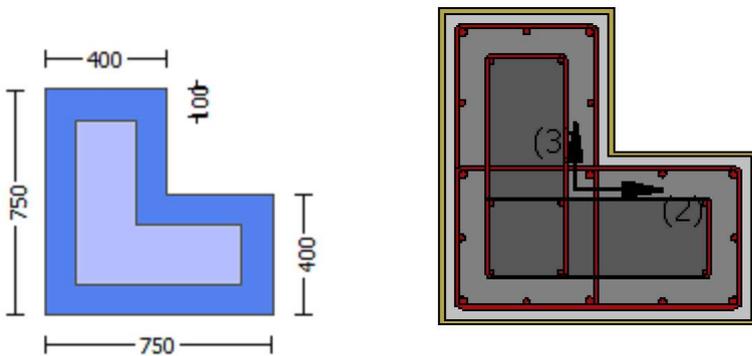
$d = 707.00$

$$f_{cE} = 27.68182$$

End Of Calculation of Chord Rotation Capacity for element: column JLC1 of floor 1
At local axis: 2
Integration Section: (a)

Calculation No. 11

column C1, Floor 1
Limit State: Life Safety (data interpolation between analysis steps 1 and 2)
Analysis: Uniform +X
Check: Shear capacity V_{Rd}
Edge: Start
Local Axis: (3)



Start Of Calculation of Shear Capacity for element: column JLC1 of floor 1
At local axis: 3
Integration Section: (a)
Section Type: rcjcs

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 Secondary Member: Concrete Strength, $f_c = f_{c_lower_bound} = 25.00$
New material of Secondary Member: Steel Strength, $f_s = f_{s_lower_bound} = 500.00$
Concrete Elasticity, $E_c = 26999.444$
Steel Elasticity, $E_s = 200000.00$
Existing Column
Existing material of Secondary Member: Concrete Strength, $f_c = f_{c_lower_bound} = 16.00$
Existing material of Secondary Member: Steel Strength, $f_s = f_{s_lower_bound} = 400.00$

Concrete Elasticity, $E_c = 21019.039$
 Steel Elasticity, $E_s = 200000.00$
 #####
 Note: Especially for the calculation of γ for displacement ductility demand,
 the expected (mean value) strengths are used (7.5.1.3, ASCE 41-17) because bending is considered as
 Deformation-Controlled Action (Table C7-1, ASCE 41-17).
 Jacket
 New material: Concrete Strength, $f_c = f_{cm} = 33.00$
 New material: Steel Strength, $f_s = f_{sm} = 555.5556$
 Existing Column
 Existing material: Concrete Strength, $f_c = f_{cm} = 20.00$
 Existing material: Steel Strength, $f_s = f_{sm} = 444.4444$
 #####
 Max Height, $H_{max} = 750.00$
 Min Height, $H_{min} = 400.00$
 Max Width, $W_{max} = 750.00$
 Min Width, $W_{min} = 400.00$
 Jacket Thickness, $t_j = 100.00$
 Cover Thickness, $c = 25.00$
 Element Length, $L = 3000.00$
 Secondary Member
 Ribbed Bars
 Ductile Steel
 Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
 Longitudinal Bars With Ends Lapped Starting at the End Sections
 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, $M_a = -251948.766$
 Shear Force, $V_a = 122.9023$
 EDGE -B-
 Bending Moment, $M_b = -114915.564$
 Shear Force, $V_b = -122.9023$
 BOTH EDGES
 Axial Force, $F = -16937.611$
 Longitudinal Reinforcement Area Distribution (in 2 divisions)
 -Tension: $A_{sl,t} = 0.00$
 -Compression: $A_{sl,c} = 5353.274$
 Longitudinal Reinforcement Area Distribution (in 3 divisions)
 -Tension: $A_{sl,ten} = 1137.257$
 -Compression: $A_{sl,com} = 2208.54$
 -Middle: $A_{sl,mid} = 2007.478$
 Mean Diameter of Tension Reinforcement, $Db_{L,ten} = 16.80$

Existing component: From table 7-7, ASCE 41_17: Final Shear Capacity $V_R = \phi V_n = 765223.44$
 V_n ((10.3), ASCE 41-17) = $k_n l^* V_{CoI} = 900262.87$
 $V_{CoI} = 900262.87$
 $k_n l = 1.00$
 displacement_ductility_demand = 0.01582155

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

= 1 (normal-weight concrete)

Mean concrete strength: $f_c' = (f_c'_{\text{jacket}} \cdot \text{Area}_{\text{jacket}} + f_c'_{\text{core}} \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 21.31818$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 3.41665$

$\mu_u = 251948.766$

$V_u = 122.9023$

$d = 0.8 \cdot h = 600.00$

$N_u = 16937.611$

$A_g = 300000.00$

From (11.5.4.8), ACI 318-14: $V_s = V_{s,\text{jacket}} + V_{s,\text{core}} = 793340.11$

where:

$V_{s,\text{jacket}} = V_{s,j1} + V_{s,j2} = 722566.31$

$V_{s,j1} = 471238.898$ is calculated for section web jacket, with:

$d = 600.00$

$A_v = 157079.633$

$f_y = 500.00$

$s = 100.00$

$V_{s,j1}$ is multiplied by $\text{Col},j1 = 1.00$

$s/d = 0.16666667$

$V_{s,j2} = 251327.412$ is calculated for section flange jacket, with:

$d = 320.00$

$A_v = 157079.633$

$f_y = 500.00$

$s = 100.00$

$V_{s,j2}$ is multiplied by $\text{Col},j2 = 1.00$

$s/d = 0.3125$

$V_{s,\text{core}} = V_{s,c1} + V_{s,c2} = 70773.799$

$V_{s,c1} = 70773.799$ is calculated for section web core, with:

$d = 440.00$

$A_v = 100530.965$

$f_y = 400.00$

$s = 250.00$

$V_{s,c1}$ is multiplied by $\text{Col},c1 = 1.00$

$s/d = 0.56818182$

$V_{s,c2} = 0.00$ is calculated for section flange core, with:

$d = 160.00$

$A_v = 100530.965$

$f_y = 400.00$

$s = 250.00$

$V_{s,c2}$ is multiplied by $\text{Col},c2 = 0.00$

$s/d = 1.5625$

V_f ((11-3)-(11.4), ACI 440) = 372533.843

$f = 0.95$, for fully-wrapped sections

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

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

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

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

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

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

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

$d_{fv} = d$ (figure 11.2, ACI 440) = 707.00

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: $V_s + V_f \leq 736127.561$

$b_w = 400.00$

displacement ductility demand is calculated as δ / y

- Calculation of δ / y for END A -

for rotation axis 2 and integ. section (a)

From analysis, chord rotation = $3.1407899E-005$

$y = (M_y * L_s / 3) / E_{eff} = 0.00198513$ ((4.29), Biskinis Phd))

$M_y = 4.2097E+008$

$L_s = M/V$ (with $L_s > 0.1 * L$ and $L_s < 2 * L$) = 2049.992

From table 10.5, ASCE 41_17: $E_{eff} = factor * E_c * I_g = 1.4491E+014$

factor = 0.30

$A_g = 440000.00$

Mean concrete strength: $f_c' = (f_c'_{jacket} * Area_{jacket} + f_c'_{core} * Area_{core}) / Area_{section} = 27.68182$

$N = 16937.611$

$E_c * I_g = E_c_{jacket} * I_{g,jacket} + E_c_{core} * I_{g,core} = 4.8303E+014$

Calculation of Yielding Moment M_y

Calculation of y and M_y according to Annex 7 -

Assuming neutral axis within flange ($y < t/d$, compression zone rectangular) with:

flange width, $b = 750.00$

web width, $b_w = 400.00$

flange thickness, $t = 400.00$

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

$y_{ten} = 3.1431513E-006$

with ((10.1), ASCE 41-17) $f_y = \text{Min}(f_y, 1.25 * f_y * (l_b / d)^{2/3}) = 358.4764$

$d = 707.00$

$y = 0.19342282$

$A = 0.01018486$

$B = 0.00449527$

with $pt = 0.00214476$

$pc = 0.00416509$

$pv = 0.00378591$

$N = 16937.611$

$b = 750.00$

" = 0.06082037

$y_{comp} = 1.6462780E-005$

with $f_c' (12.3, (ACI 440)) = 33.48734$

$f_c = 33.00$

$f_l = 0.49678681$

$b = b_{max} = 750.00$

$h = h_{max} = 750.00$

$A_g = 0.44$

$g = pt + pc + pv = 0.01009575$

$rc = 40.00$

$A_e / A_c = 0.31291181$

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

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

$f_u = 0.01$

$E_f = 64828.00$

$E_c = 26999.444$

$y = 0.19181197$

$A = 0.01002422$

$B = 0.00440616$

with $E_s = 200000.00$

CONFIRMATION: $y = 0.19278073 < t/d$

Calculation of ratio l_b/d

Lap Length: $l_d / l_{d,min} = 0.39803249$

$l_b = 300.00$

$l_d = 753.7073$

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

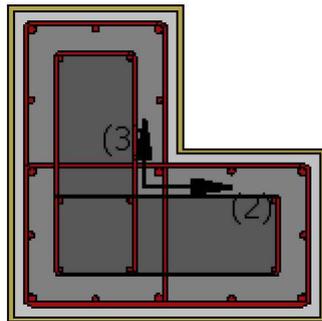
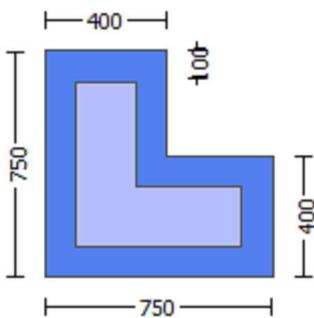
= 1

$db = 16.66667$
 Mean strength value of all re-bars: $f_y = 524.4444$
 Mean concrete strength: $f_c' = (f_c'_{jacket} \cdot Area_{jacket} + f_c'_{core} \cdot Area_{core}) / Area_{section} = 27.68182$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $t = 1.00$
 $s = 0.80$
 $e = 1.00$
 $cb = 25.00$
 $K_{tr} = 1.7174$
 $A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 257.6106$
 where A_{tr_x}, A_{tr_y} are the sum of the area of all stirrup legs along X and Y local axis
 $s = \text{Max}(s_{external}, s_{internal}) = 250.00$
 $n = 24.00$

End Of Calculation of Shear Capacity for element: column JLC1 of floor 1
 At local axis: 3
 Integration Section: (a)

Calculation No. 12

column C1, Floor 1
 Limit State: Life Safety (data interpolation between analysis steps 1 and 2)
 Analysis: Uniform +X
 Check: Chord rotation capacity (θ_u)
 Edge: Start
 Local Axis: (3)



Start Of Calculation of Shear Capacity ratio for element: column JLC1 of floor 1
 At Shear local axis: 3
 (Bending local axis: 2)
 Section Type: rcjlc

Constant Properties

Knowledge Factor, $\phi = 0.85$
 Mean strength values are used for both shear and moment calculations.
 Consequently:

```

Jacket
New material of Secondary Member: Concrete Strength, fc = fcm = 33.00
New material of Secondary Member: Steel Strength, fs = fsm = 555.5556
Concrete Elasticity, Ec = 26999.444
Steel Elasticity, Es = 200000.00
Existing Column
Existing material of Secondary Member: Concrete Strength, fc = fcm = 20.00
Existing material of Secondary Member: Steel Strength, fs = fsm = 444.4444
Concrete Elasticity, Ec = 21019.039
Steel Elasticity, Es = 200000.00
#####
Note: Especially for the calculation of moment strengths,
the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14
Jacket
New material: Steel Strength, fs = 1.25*fsm = 694.4444
Existing Column
Existing material: Steel Strength, fs = 1.25*fsm = 555.5556
#####
Max Height, Hmax = 750.00
Min Height, Hmin = 400.00
Max Width, Wmax = 750.00
Min Width, Wmin = 400.00
Jacket Thickness, tj = 100.00
Cover Thickness, c = 25.00
Mean Confinement Factor overall section = 1.03889
Element Length, L = 3000.00
Secondary Member
Ribbed Bars
Ductile Steel
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
Lap Length lo = 300.00
FRP Wrapping Data
Type: Carbon
Cured laminate properties (design values)
Thickness, t = 1.016
Tensile Strength, ffu = 1055.00
Tensile Modulus, Ef = 64828.00
Elongation, efu = 0.01
Number of directions, NoDir = 1
Fiber orientations, bi: 0.00°
Number of layers, NL = 1
Radius of rounding corners, R = 40.00
-----

Stepwise Properties
-----
At local axis: 3
EDGE -A-
Shear Force, Va = -0.00051441
EDGE -B-
Shear Force, Vb = 0.00051441
BOTH EDGES
Axial Force, F = -16273.616
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: Aslt = 0.00
-Compression: Aslc = 5353.274
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension: Asl,ten = 1137.257
-Compression: Asl,com = 2208.54
-Middle: Asl,mid = 2007.478
-----
-----

Calculation of Shear Capacity ratio , Ve/Vr = 0.55377356
Member Controlled by Flexure (Ve/Vr < 1)

```

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 552827.824$

with
 $M_{pr1} = \text{Max}(M_{u1+}, M_{u1-}) = 8.2924E+008$
 $M_{u1+} = 5.1260E+008$, 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
 $M_{u1-} = 8.2924E+008$, 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
 $M_{pr2} = \text{Max}(M_{u2+}, M_{u2-}) = 8.2924E+008$
 $M_{u2+} = 5.1260E+008$, 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
 $M_{u2-} = 8.2924E+008$, 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 ϕ_u according to 4.1, Biskinis/Fardis 2013:

$\phi_u = 9.5578758E-006$
 $M_u = 5.1260E+008$

with full section properties:

$b = 750.00$
 $d = 707.00$
 $d' = 43.00$
 $v = 0.00093001$
 $N = 16273.616$
 $f_c = 33.00$
 $\alpha (5A.5, \text{TBDY}) = 0.002$
Final value of ϕ_u : $\phi_u^* = \text{shear_factor} * \text{Max}(\phi_u, \alpha) = 0.01288354$
The Shear_factor is considered equal to 1 (pure moment strength)
From (5.4b), TBDY: $\phi_u = 0.01288354$
 $\phi_{we} ((5.4c), \text{TBDY}) = \alpha_{se} * \phi_{w, \min} * f_{ywe} / f_{ce} + \text{Min}(\phi_x, \phi_y) = 0.05503171$
where $\phi = \alpha_f * \rho_f * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

 $\phi_x = 0.04286225$

Expression ((15B.6), TBDY) is modified as $\alpha_f = 1 - (\text{Unconfined area}) / (\text{total area})$
 $\alpha_f = 0.31984848$

with Unconfined area = $((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 140733.333$

$b_{\max} = 750.00$
 $h_{\max} = 750.00$
From EC8 A.4.4.3(6), $\rho_f = 2t_f / b_w = 0.00508$
 $b_w = 400.00$
effective stress from (A.35), $f_{fe} = 870.5244$

 $\phi_y = 0.04286225$

Expression ((15B.6), TBDY) is modified as $\alpha_f = 1 - (\text{Unconfined area}) / (\text{total area})$
 $\alpha_f = 0.31984848$

with Unconfined area = $((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 140733.333$

$b_{\max} = 750.00$
 $h_{\max} = 750.00$
From EC8 A.4.4.3(6), $\rho_f = 2t_f / b_w = 0.00508$
 $b_w = 400.00$
effective stress from (A.35), $f_{fe} = 870.5244$

 $R = 40.00$

Effective FRP thickness, $t_f = N L * t * \text{Cos}(\beta_1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{,f} = 0.015$

$\alpha_{se} ((5.4d), \text{TBDY}) = (\alpha_{se1} * A_{ext} + \alpha_{se2} * A_{int}) / A_{sec} = 0.45746528$

$\alpha_{se1} = \text{Max}(((A_{conf, \max 1} - A_{noConf1}) / A_{conf, \max 1}) * (A_{conf, \min 1} / A_{conf, \max 1}), 0) = 0.45746528$

The definitions of A_{noConf} , $A_{conf, \min}$ and $A_{conf, \max}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max1} = 353600.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{conf,min1} = 293525.00$ is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area $A_{conf,max1}$ by a length equal to half the clear spacing between external hoops.

$A_{noConf1} = 158733.333$ is the unconfined external core area which is equal to $b_i^2/6$ as defined at (A.2).
 $ase_2 (>=ase_1) = \text{Max}(((A_{conf,max2}-A_{noConf2})/A_{conf,max2})*(A_{conf,min2}/A_{conf,max2}),0) = 0.45746528$

The definitions of A_{noConf} , $A_{conf,min}$ and $A_{conf,max}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988) "Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max2} = 171264.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

$A_{conf,min2} = 54741.00$ is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area $A_{conf,max2}$ by a length equal to half the clear spacing between internal hoops.

$A_{noConf2} = 106242.667$ is the unconfined internal core area which is equal to $b_i^2/6$ as defined at (A.2).
 $psh_{min}*F_{ywe} = \text{Min}(psh_x*F_{ywe}, psh_y*F_{ywe}) = 2.92621$

Expression (5.4d) 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)

$psh_x*F_{ywe} = psh_1*F_{ywe1} + ps_2*F_{ywe2} = 2.92621$

psh_1 ((5.4d), TBDY) = $L_{stir1}*A_{stir1}/(A_{sec}*s_1) = 0.00367709$

L_{stir1} (Length of stirrups along Y) = 2060.00

A_{stir1} (stirrups area) = 78.53982

psh_2 (5.4d) = $L_{stir2}*A_{stir2}/(A_{sec}*s_2) = 0.00067082$

L_{stir2} (Length of stirrups along Y) = 1468.00

A_{stir2} (stirrups area) = 50.26548

$psh_y*F_{ywe} = psh_1*F_{ywe1} + ps_2*F_{ywe2} = 2.92621$

psh_1 ((5.4d), TBDY) = $L_{stir1}*A_{stir1}/(A_{sec}*s_1) = 0.00367709$

L_{stir1} (Length of stirrups along X) = 2060.00

A_{stir1} (stirrups area) = 78.53982

psh_2 ((5.4d), TBDY) = $L_{stir2}*A_{stir2}/(A_{sec}*s_2) = 0.00067082$

L_{stir2} (Length of stirrups along X) = 1468.00

A_{stir2} (stirrups area) = 50.26548

$A_{sec} = 440000.00$

$s_1 = 100.00$

$s_2 = 250.00$

$f_{ywe1} = 694.4444$

$f_{ywe2} = 555.5556$

$f_{ce} = 33.00$

From ((5.A.5), TBDY), TBDY: $cc = 0.00238888$

c = confinement factor = 1.03889

$y_1 = 0.00145721$

$sh_1 = 0.00466307$

$ft_1 = 459.4373$

$fy_1 = 382.8645$

$su_1 = 0.00582756$

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

$l_o/l_{ou,min} = l_b/l_d = 0.318426$

$su_1 = 0.4*es_{u1,nominal}$ ((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 $fs_1 = fs_1/1.2$, 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 $fs_1 = (f_{s,jacket}*A_{s,ten,jacket} + f_{s,core}*A_{s,ten,core})/A_{s,ten} = 382.8645$

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

$y_2 = 0.00145721$

$sh_2 = 0.00466307$

$ft_2 = 465.423$

$fy_2 = 387.8525$

$$su_2 = 0.00582756$$

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

$$lo/lou,min = lb/lb,min = 0.318426$$

$$su_2 = 0.4 * esu_2,nominal ((5.5), TBDY) = 0.032$$

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 $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE 41-17.

$$\text{with } fs_2 = (fs_{jacket} * A_{sl,com,jacket} + fs_{core} * A_{sl,com,core}) / A_{sl,com} = 387.8525$$

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

$$yv = 0.00145721$$

$$shv = 0.00466307$$

$$ftv = 463.3885$$

$$fyv = 386.157$$

$$suv = 0.00582756$$

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

$$lo/lou,min = lb/ld = 0.318426$$

$$suv = 0.4 * esuv_nominal ((5.5), TBDY) = 0.032$$

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 , 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 $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE 41-17.

$$\text{with } fsv = (fs_{jacket} * A_{sl,mid,jacket} + fs_{mid} * A_{sl,mid,core}) / A_{sl,mid} = 386.157$$

$$\text{with } Esv = (Es_{jacket} * A_{sl,mid,jacket} + Es_{mid} * A_{sl,mid,core}) / A_{sl,mid} = 200000.00$$

$$1 = A_{sl,ten} / (b * d) * (fs_1 / fc) = 0.02488335$$

$$2 = A_{sl,com} / (b * d) * (fs_2 / fc) = 0.04895276$$

$$v = A_{sl,mid} / (b * d) * (fsv / fc) = 0.04430167$$

and confined core properties:

$$b = 690.00$$

$$d = 677.00$$

$$d' = 13.00$$

$$fcc (5A.2, TBDY) = 34.2833$$

$$cc (5A.5, TBDY) = 0.00238888$$

$$c = \text{confinement factor} = 1.03889$$

$$1 = A_{sl,ten} / (b * d) * (fs_1 / fc) = 0.02824566$$

$$2 = A_{sl,com} / (b * d) * (fs_2 / fc) = 0.05556741$$

$$v = A_{sl,mid} / (b * d) * (fsv / fc) = 0.05028784$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

$$su (4.9) = 0.13760581$$

$$\mu = MRc (4.14) = 5.1260E+008$$

$$u = su (4.1) = 9.5578758E-006$$

Calculation of ratio lb/ld

Lap Length: lb/ld = 0.318426

$$lb = 300.00$$

$$ld = 942.1341$$

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 = 655.5556

Mean concrete strength: fc' = (fc'_jacket * Area_jacket + fc'_core * Area_core) / Area_section = 27.68182, but $fc'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$cb = 25.00$$

$$K_{tr} = 1.7174$$

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

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

$$s = \text{Max}(s_{\text{external}}, s_{\text{internal}}) = 250.00$$

$$n = 24.00$$

Calculation of μ_1 -

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

$$\mu = 1.0408734E-005$$

$$\mu_1 = 8.2924E+008$$

with full section properties:

$$b = 400.00$$

$$d = 707.00$$

$$d' = 43.00$$

$$v = 0.00174378$$

$$N = 16273.616$$

$$f_c = 33.00$$

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

$$\text{Final value of } \mu_1: \mu_1^* = \text{shear_factor} * \text{Max}(\mu_1, \mu_2) = 0.01288354$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \mu_1 = 0.01288354$$

$$\mu_2 \text{ ((5.4c), TBDY)} = a_{se} * s_{h, \text{min}} * f_{y, \text{we}} / f_{ce} + \text{Min}(f_x, f_y) = 0.05503171$$

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

$$f_x = 0.04286225$$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.31984848$$

$$\text{with Unconfined area} = ((b_{\text{max}} - 2R)^2 + (h_{\text{max}} - 2R)^2) / 3 = 140733.333$$

$$b_{\text{max}} = 750.00$$

$$h_{\text{max}} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{f, e} = 870.5244$$

$$f_y = 0.04286225$$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.31984848$$

$$\text{with Unconfined area} = ((b_{\text{max}} - 2R)^2 + (h_{\text{max}} - 2R)^2) / 3 = 140733.333$$

$$b_{\text{max}} = 750.00$$

$$h_{\text{max}} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{f, e} = 870.5244$$

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u_{, f} = 0.015$$

$$a_{se} \text{ ((5.4d), TBDY)} = (a_{se1} * A_{\text{ext}} + a_{se2} * A_{\text{int}}) / A_{\text{sec}} = 0.45746528$$

$$a_{se1} = \text{Max}(((A_{\text{conf, max1}} - A_{\text{noConf1}}) / A_{\text{conf, max1}}) * (A_{\text{conf, min1}} / A_{\text{conf, max1}}), 0) = 0.45746528$$

The definitions of A_{noConf} , $A_{\text{conf, min}}$ and $A_{\text{conf, max}}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{\text{conf, max1}} = 353600.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{\text{conf, min1}} = 293525.00$ is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area $A_{\text{conf, max1}}$ by a length equal to half the clear spacing between external hoops.

AnoConf1 = 158733.333 is the unconfined external core area which is equal to $b_i^2/6$ as defined at (A.2).
 $ase_2 (> ase_1) = \text{Max}(((A_{conf,max2} - \text{AnoConf}_2)/A_{conf,max2}) * (A_{conf,min2}/A_{conf,max2}), 0) = 0.45746528$

The definitions of AnoConf, Aconf,min and Aconf,max are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

Aconf,max2 = 171264.00 is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

Aconf,min2 = 54741.00 is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area Aconf,max2 by a length equal to half the clear spacing between internal hoops.

AnoConf2 = 106242.667 is the unconfined internal core area which is equal to $b_i^2/6$ as defined at (A.2).
 $psh_{,min} * Fy_{we} = \text{Min}(psh_x * Fy_{we}, psh_y * Fy_{we}) = 2.92621$

Expression (5.4d) 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)

 $psh_x * Fy_{we} = psh_1 * Fy_{we1} + ps_2 * Fy_{we2} = 2.92621$
 $psh_1 ((5.4d), \text{TBDY}) = L_{stir1} * Astir1 / (A_{sec} * s_1) = 0.00367709$
Lstir1 (Length of stirrups along Y) = 2060.00
Astir1 (stirrups area) = 78.53982
 $psh_2 (5.4d) = L_{stir2} * Astir2 / (A_{sec} * s_2) = 0.00067082$
Lstir2 (Length of stirrups along Y) = 1468.00
Astir2 (stirrups area) = 50.26548

 $psh_y * Fy_{we} = psh_1 * Fy_{we1} + ps_2 * Fy_{we2} = 2.92621$
 $psh_1 ((5.4d), \text{TBDY}) = L_{stir1} * Astir1 / (A_{sec} * s_1) = 0.00367709$
Lstir1 (Length of stirrups along X) = 2060.00
Astir1 (stirrups area) = 78.53982
 $psh_2 ((5.4d), \text{TBDY}) = L_{stir2} * Astir2 / (A_{sec} * s_2) = 0.00067082$
Lstir2 (Length of stirrups along X) = 1468.00
Astir2 (stirrups area) = 50.26548

Asec = 440000.00
s1 = 100.00
s2 = 250.00
fywe1 = 694.4444
fywe2 = 555.5556
fce = 33.00

From ((5.A.5), TBDY), TBDY: cc = 0.00238888
c = confinement factor = 1.03889

y1 = 0.00145721
sh1 = 0.00466307
ft1 = 465.423
fy1 = 387.8525
su1 = 0.00582756

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 = 0.318426

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.

with fs1 = (fs,jacket * Asl,tens,jacket + fs,core * Asl,tens,core) / Asl,tens = 387.8525

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

y2 = 0.00145721
sh2 = 0.00466307
ft2 = 459.4373
fy2 = 382.8645
su2 = 0.00582756

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 = 0.318426

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 $fs2 = (fs_jacket \cdot Asl,com,jacket + fs_core \cdot Asl,com,core) / Asl,com = 382.8645$

with $Es2 = (Es_jacket \cdot Asl,com,jacket + Es_core \cdot Asl,com,core) / Asl,com = 200000.00$

$yv = 0.00145721$

$shv = 0.00466307$

$ftv = 463.3885$

$fyv = 386.157$

$suv = 0.00582756$

using (30) in Biskinis/Fardis (2013) multiplied with $shear_factor$

and also multiplied by the $shear_factor$ according to 15.7.1.4, with

$Shear_factor = 1.00$

$lo/lou,min = lb/d = 0.318426$

$suv = 0.4 \cdot esuv_nominal$ ((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 $\text{Min}(1, 1.25 \cdot (lb/d)^{2/3})$, from 10.3.5, ASCE 41-17.

with $fsv = (fs_jacket \cdot Asl,mid,jacket + fs_mid \cdot Asl,mid,core) / Asl,mid = 386.157$

with $Es_v = (Es_jacket \cdot Asl,mid,jacket + Es_mid \cdot Asl,mid,core) / Asl,mid = 200000.00$

$1 = Asl,ten / (b \cdot d) \cdot (fs1 / fc) = 0.09178643$

$2 = Asl,com / (b \cdot d) \cdot (fs2 / fc) = 0.04665628$

$v = Asl,mid / (b \cdot d) \cdot (fsv / fc) = 0.08306563$

and confined core properties:

$b = 340.00$

$d = 677.00$

$d' = 13.00$

fcc (5A.2, TBDY) = 34.2833

cc (5A.5, TBDY) = 0.00238888

c = confinement factor = 1.03889

$1 = Asl,ten / (b \cdot d) \cdot (fs1 / fc) = 0.11276915$

$2 = Asl,com / (b \cdot d) \cdot (fs2 / fc) = 0.05732208$

$v = Asl,mid / (b \cdot d) \cdot (fsv / fc) = 0.10205474$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < vs,y2$ - LHS eq.(4.5) is satisfied

--->

su (4.9) = 0.20810191

$Mu = MRc$ (4.14) = 8.2924E+008

$u = su$ (4.1) = 1.0408734E-005

Calculation of ratio lb/d

Lap Length: $lb/d = 0.318426$

$lb = 300.00$

$ld = 942.1341$

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: $fy = 655.5556$

Mean concrete strength: $fc' = (fc'_jacket \cdot Area_jacket + fc'_core \cdot Area_core) / Area_section = 27.68182$, but $fc'^{0.5} < = 8.3$ MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$Ktr = 1.7174$

$Atr = \text{Min}(Atr_x, Atr_y) = 257.6106$

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

$s = \text{Max}(s_external, s_internal) = 250.00$

$n = 24.00$

Calculation of Mu2+

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

$$\mu = 9.5578758E-006$$

$$Mu = 5.1260E+008$$

with full section properties:

$$b = 750.00$$

$$d = 707.00$$

$$d' = 43.00$$

$$v = 0.00093001$$

$$N = 16273.616$$

$$f_c = 33.00$$

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

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.01288354$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } c_u = 0.01288354$$

$$w_e \text{ ((5.4c), TBDY)} = a_{se} * s_{h,\min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.05503171$$

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

$$f_x = 0.04286225$$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area})/(\text{total area})$

$$a_f = 0.31984848$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2)/3 = 140733.333$$

$$b_{\max} = 750.00$$

$$h_{\max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 870.5244$$

$$f_y = 0.04286225$$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area})/(\text{total area})$

$$a_f = 0.31984848$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2)/3 = 140733.333$$

$$b_{\max} = 750.00$$

$$h_{\max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 870.5244$$

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u_{f} = 0.015$$

$$a_{se} \text{ ((5.4d), TBDY)} = (a_{se1} * A_{ext} + a_{se2} * A_{int})/A_{sec} = 0.45746528$$

$$a_{se1} = \text{Max}(((A_{conf,max1} - A_{noConf1})/A_{conf,max1}) * (A_{conf,min1}/A_{conf,max1}), 0) = 0.45746528$$

The definitions of A_{noConf} , $A_{conf,min}$ and $A_{conf,max}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max1} = 353600.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{conf,min1} = 293525.00$ is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area $A_{conf,max1}$ by a length equal to half the clear spacing between external hoops.

$A_{noConf1} = 158733.333$ is the unconfined external core area which is equal to $b_i^2/6$ as defined at (A.2).

$$a_{se2} (>= a_{se1}) = \text{Max}(((A_{conf,max2} - A_{noConf2})/A_{conf,max2}) * (A_{conf,min2}/A_{conf,max2}), 0) = 0.45746528$$

The definitions of A_{noConf} , $A_{conf,min}$ and $A_{conf,max}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max2} = 171264.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

$A_{conf,min2} = 54741.00$ is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area $A_{conf,max2}$ by a length equal to half the clear spacing between internal hoops.

$A_{noConf2} = 106242.667$ is the unconfined internal core area which is equal to $b_i^2/6$ as defined at (A.2).

$p_{sh,min} * F_{ywe} = \text{Min}(p_{sh,x} * F_{ywe}, p_{sh,y} * F_{ywe}) = 2.92621$

Expression (5.4d) 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)

 $p_{sh,x} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{s2} * F_{ywe2} = 2.92621$

p_{sh1} ((5.4d), TBDY) = $L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00367709$

L_{stir1} (Length of stirrups along Y) = 2060.00

A_{stir1} (stirrups area) = 78.53982

p_{sh2} (5.4d) = $L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00067082$

L_{stir2} (Length of stirrups along Y) = 1468.00

A_{stir2} (stirrups area) = 50.26548

 $p_{sh,y} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{s2} * F_{ywe2} = 2.92621$

p_{sh1} ((5.4d), TBDY) = $L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00367709$

L_{stir1} (Length of stirrups along X) = 2060.00

A_{stir1} (stirrups area) = 78.53982

p_{sh2} ((5.4d), TBDY) = $L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00067082$

L_{stir2} (Length of stirrups along X) = 1468.00

A_{stir2} (stirrups area) = 50.26548

 $A_{sec} = 440000.00$

$s1 = 100.00$

$s2 = 250.00$

$f_{ywe1} = 694.4444$

$f_{ywe2} = 555.5556$

$f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY: $cc = 0.00238888$

$c = \text{confinement factor} = 1.03889$

$y1 = 0.00145721$

$sh1 = 0.00466307$

$ft1 = 459.4373$

$fy1 = 382.8645$

$su1 = 0.00582756$

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

$l_o/l_{o,min} = l_b/l_d = 0.318426$

$su1 = 0.4 * esu1_{nominal}$ ((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 $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE 41-17.

with $fs1 = (f_{s,jacket} * A_{sl,ten,jacket} + f_{s,core} * A_{sl,ten,core}) / A_{sl,ten} = 382.8645$

with $Es1 = (E_{s,jacket} * A_{sl,ten,jacket} + E_{s,core} * A_{sl,ten,core}) / A_{sl,ten} = 200000.00$

$y2 = 0.00145721$

$sh2 = 0.00466307$

$ft2 = 465.423$

$fy2 = 387.8525$

$su2 = 0.00582756$

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

$l_o/l_{o,min} = l_b/l_{b,min} = 0.318426$

$su2 = 0.4 * esu2_{nominal}$ ((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 $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE 41-17.

with $fs2 = (f_{s,jacket} * A_{sl,com,jacket} + f_{s,core} * A_{sl,com,core}) / A_{sl,com} = 387.8525$

with $Es2 = (E_{s,jacket} * A_{sl,com,jacket} + E_{s,core} * A_{sl,com,core}) / A_{sl,com} = 200000.00$

yv = 0.00145721
shv = 0.00466307
ftv = 463.3885
fyv = 386.157
suv = 0.00582756

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 = 0.318426

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 = 386.157

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

1 = Asl,ten/(b*d)*(fs1/fc) = 0.02488335

2 = Asl,com/(b*d)*(fs2/fc) = 0.04895276

v = Asl,mid/(b*d)*(fsv/fc) = 0.04430167

and confined core properties:

b = 690.00

d = 677.00

d' = 13.00

fcc (5A.2, TBDY) = 34.2833

cc (5A.5, TBDY) = 0.00238888

c = confinement factor = 1.03889

1 = Asl,ten/(b*d)*(fs1/fc) = 0.02824566

2 = Asl,com/(b*d)*(fs2/fc) = 0.05556741

v = Asl,mid/(b*d)*(fsv/fc) = 0.05028784

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

v < vs,y2 - LHS eq.(4.5) is satisfied

--->

su (4.9) = 0.13760581

Mu = MRc (4.14) = 5.1260E+008

u = su (4.1) = 9.5578758E-006

Calculation of ratio lb/ld

Lap Length: lb/ld = 0.318426

lb = 300.00

ld = 942.1341

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 = 655.5556

Mean concrete strength: fc' = (fc'_jacket*Area_jacket + fc'_core*Area_core)/Area_section = 27.68182, but $fc'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

t = 1.00

s = 0.80

e = 1.00

cb = 25.00

Ktr = 1.7174

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 = $\text{Max}(s_{\text{external}}, s_{\text{internal}})$ = 250.00

n = 24.00

Calculation of Mu2-

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

$$u = 1.0408734E-005$$

$$\mu = 8.2924E+008$$

with full section properties:

$$b = 400.00$$

$$d = 707.00$$

$$d' = 43.00$$

$$v = 0.00174378$$

$$N = 16273.616$$

$$f_c = 33.00$$

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

$$\text{Final value of } \phi_u: \phi_u^* = \text{shear_factor} * \text{Max}(\phi_u, \phi_c) = 0.01288354$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \phi_u = 0.01288354$$

$$\omega_e \text{ ((5.4c), TBDY)} = a_{se} * \text{sh, min} * f_{ywe} / f_{ce} + \text{Min}(\phi_x, \phi_y) = 0.05503171$$

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

$$\phi_x = 0.04286225$$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.31984848$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 140733.333$$

$$b_{\max} = 750.00$$

$$h_{\max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 870.5244$$

$$\phi_y = 0.04286225$$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.31984848$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 140733.333$$

$$b_{\max} = 750.00$$

$$h_{\max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 870.5244$$

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$a_{se} \text{ ((5.4d), TBDY)} = (a_{se1} * A_{ext} + a_{se2} * A_{int}) / A_{sec} = 0.45746528$$

$$a_{se1} = \text{Max}(((A_{conf,max1} - A_{noConf1}) / A_{conf,max1}) * (A_{conf,min1} / A_{conf,max1}), 0) = 0.45746528$$

The definitions of A_{noConf} , $A_{conf,min}$ and $A_{conf,max}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max1} = 353600.00$ is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{conf,min1} = 293525.00$ is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area $A_{conf,max1}$ by a length equal to half the clear spacing between external hoops.

$A_{noConf1} = 158733.333$ is the unconfined external core area which is equal to $b_i^2/6$ as defined at (A.2).

$$a_{se2} (>= a_{se1}) = \text{Max}(((A_{conf,max2} - A_{noConf2}) / A_{conf,max2}) * (A_{conf,min2} / A_{conf,max2}), 0) = 0.45746528$$

The definitions of A_{noConf} , $A_{conf,min}$ and $A_{conf,max}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max2} = 171264.00$ is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

$A_{conf,min2} = 54741.00$ is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area $A_{conf,max2}$ by a length equal to half the clear spacing between internal hoops.

AnoConf2 = 106242.667 is the unconfined internal core area which is equal to $b_i^2/6$ as defined at (A.2).

$$psh_{min} * F_{ywe} = \text{Min}(psh_x * F_{ywe}, psh_y * F_{ywe}) = 2.92621$$

Expression (5.4d) 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)

$$psh_x * F_{ywe} = psh1 * F_{ywe1} + ps2 * F_{ywe2} = 2.92621$$

$$psh1 \text{ ((5.4d), TBDY)} = Lstir1 * Astir1 / (Asec * s1) = 0.00367709$$

$$Lstir1 \text{ (Length of stirrups along Y)} = 2060.00$$

$$Astir1 \text{ (stirrups area)} = 78.53982$$

$$psh2 \text{ (5.4d)} = Lstir2 * Astir2 / (Asec * s2) = 0.00067082$$

$$Lstir2 \text{ (Length of stirrups along Y)} = 1468.00$$

$$Astir2 \text{ (stirrups area)} = 50.26548$$

$$psh_y * F_{ywe} = psh1 * F_{ywe1} + ps2 * F_{ywe2} = 2.92621$$

$$psh1 \text{ ((5.4d), TBDY)} = Lstir1 * Astir1 / (Asec * s1) = 0.00367709$$

$$Lstir1 \text{ (Length of stirrups along X)} = 2060.00$$

$$Astir1 \text{ (stirrups area)} = 78.53982$$

$$psh2 \text{ ((5.4d), TBDY)} = Lstir2 * Astir2 / (Asec * s2) = 0.00067082$$

$$Lstir2 \text{ (Length of stirrups along X)} = 1468.00$$

$$Astir2 \text{ (stirrups area)} = 50.26548$$

$$Asec = 440000.00$$

$$s1 = 100.00$$

$$s2 = 250.00$$

$$fywe1 = 694.4444$$

$$fywe2 = 555.5556$$

$$fce = 33.00$$

$$\text{From ((5.A5), TBDY), TBDY: } cc = 0.00238888$$

$$c = \text{confinement factor} = 1.03889$$

$$y1 = 0.00145721$$

$$sh1 = 0.00466307$$

$$ft1 = 465.423$$

$$fy1 = 387.8525$$

$$su1 = 0.00582756$$

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

$$lo/lou_{min} = lb/ld = 0.318426$$

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

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.

$$\text{with } fs1 = (fs_{jacket} * Asl_{ten,jacket} + fs_{core} * Asl_{ten,core}) / Asl_{ten} = 387.8525$$

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

$$y2 = 0.00145721$$

$$sh2 = 0.00466307$$

$$ft2 = 459.4373$$

$$fy2 = 382.8645$$

$$su2 = 0.00582756$$

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

$$lo/lou_{min} = lb/lb_{min} = 0.318426$$

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

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.

$$\text{with } fs2 = (fs_{jacket} * Asl_{com,jacket} + fs_{core} * Asl_{com,core}) / Asl_{com} = 382.8645$$

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

$$yv = 0.00145721$$

$$shv = 0.00466307$$

$$ftv = 463.3885$$

$$fyv = 386.157$$

$$suv = 0.00582756$$

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 = 0.318426

su_v = 0.4*esuv_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esuv_nominal = 0.08,

considering characteristic value fs_{yv} = 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 fs_{yv} = fsv/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 fsv = (fs_{jacket}*Asl_{mid,jacket} + fs_{mid}*Asl_{mid,core})/Asl_{mid} = 386.157

with Es_v = (Es_{jacket}*Asl_{mid,jacket} + Es_{mid}*Asl_{mid,core})/Asl_{mid} = 200000.00

1 = Asl_{ten}/(b*d)*(fs₁/fc) = 0.09178643

2 = Asl_{com}/(b*d)*(fs₂/fc) = 0.04665628

v = Asl_{mid}/(b*d)*(fsv/fc) = 0.08306563

and confined core properties:

b = 340.00

d = 677.00

d' = 13.00

fcc (5A.2, TBDY) = 34.2833

cc (5A.5, TBDY) = 0.00238888

c = confinement factor = 1.03889

1 = Asl_{ten}/(b*d)*(fs₁/fc) = 0.11276915

2 = Asl_{com}/(b*d)*(fs₂/fc) = 0.05732208

v = Asl_{mid}/(b*d)*(fsv/fc) = 0.10205474

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

su (4.9) = 0.20810191

Mu = MRc (4.14) = 8.2924E+008

u = su (4.1) = 1.0408734E-005

Calculation of ratio lb/ld

Lap Length: lb/ld = 0.318426

lb = 300.00

ld = 942.1341

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 = 655.5556

Mean concrete strength: fc' = (fc'_jacket*Area_jacket + fc'_core*Area_core)/Area_section = 27.68182, 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} = 1.7174

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 loxal axis

s = Max(s_{external},s_{internal}) = 250.00

n = 24.00

Calculation of Shear Strength Vr = Min(Vr1,Vr2) = 998292.205

Calculation of Shear Strength at edge 1, Vr1 = 998292.205

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

VCol0 = 998292.205

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: $f_c' = (f_c'_{jacket} \cdot Area_{jacket} + f_c'_{core} \cdot Area_{core}) / Area_{section} = 27.68182$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $M/Vd = 4.00$
 $\mu_u = 11.77537$
 $V_u = 0.00051441$
 $d = 0.8 \cdot h = 600.00$
 $N_u = 16273.616$
 $A_g = 300000.00$
 From (11.5.4.8), ACI 318-14: $V_s = V_{sjacket} + V_{s,core} = 881489.011$
 where:
 $V_{sjacket} = V_{sj1} + V_{sj2} = 802851.456$
 $V_{sj1} = 523598.776$ is calculated for section web jacket, with:
 $d = 600.00$
 $A_v = 157079.633$
 $f_y = 555.5556$
 $s = 100.00$
 V_{sj1} is multiplied by $Col_{j1} = 1.00$
 $s/d = 0.16666667$
 $V_{sj2} = 279252.68$ is calculated for section flange jacket, with:
 $d = 320.00$
 $A_v = 157079.633$
 $f_y = 555.5556$
 $s = 100.00$
 V_{sj2} is multiplied by $Col_{j2} = 1.00$
 $s/d = 0.3125$
 $V_{s,core} = V_{s,c1} + V_{s,c2} = 78637.555$
 $V_{s,c1} = 78637.555$ is calculated for section web core, with:
 $d = 440.00$
 $A_v = 100530.965$
 $f_y = 444.4444$
 $s = 250.00$
 $V_{s,c1}$ is multiplied by $Col_{c1} = 1.00$
 $s/d = 0.56818182$
 $V_{s,c2} = 0.00$ is calculated for section flange core, with:
 $d = 160.00$
 $A_v = 100530.965$
 $f_y = 444.4444$
 $s = 250.00$
 $V_{s,c2}$ is multiplied by $Col_{c2} = 0.00$
 $s/d = 1.5625$
 V_f ((11-3)-(11.4), ACI 440) = 372533.843
 $f = 0.95$, for fully-wrapped sections
 $w_f/s_f = 1$ (FRP strips adjacent to one another).
 In (11.3) $\sin \theta + \cos \theta$ is replaced with $(\cot \theta + \cot \alpha) \sin \alpha$ which is more a generalised expression,
 where θ is the angle of the crack direction (see KANEPE).
 This later relation, considered as a function $V_f(\theta, \alpha)$, is implemented for every different fiber orientation α_i ,
 as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.
 orientation 1: $\theta = b_1 + 90^\circ = 90.00$
 $V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, \theta)|)$, with:
 total thickness per orientation, $t_{f1} = NL \cdot t / NoDir = 1.016$
 $d_{fv} = d$ (figure 11.2, ACI 440) = 707.00
 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: $V_s + V_f \leq 838832.606$
 $b_w = 400.00$

Calculation of Shear Strength at edge 2, $V_{r2} = 998292.205$
 $V_{r2} = V_{Col}$ ((10.3), ASCE 41-17) = $k_{nl} \cdot V_{Col0}$
 $V_{Col0} = 998292.205$
 $k_{nl} = 1$ (zero step-static loading)

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

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

= 1 (normal-weight concrete)

Mean concrete strength: $f_c' = (f_c'_{\text{jacket}} \cdot \text{Area}_{\text{jacket}} + f_c'_{\text{core}} \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 27.68182$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 4.00$

$\mu_u = 11.77482$

$V_u = 0.00051441$

$d = 0.8 \cdot h = 600.00$

$N_u = 16273.616$

$A_g = 300000.00$

From (11.5.4.8), ACI 318-14: $V_s = V_{s,\text{jacket}} + V_{s,\text{core}} = 881489.011$

where:

$V_{s,\text{jacket}} = V_{s,j1} + V_{s,j2} = 802851.456$

$V_{s,j1} = 523598.776$ is calculated for section web jacket, with:

$d = 600.00$

$A_v = 157079.633$

$f_y = 555.5556$

$s = 100.00$

$V_{s,j1}$ is multiplied by $\text{Col},j1 = 1.00$

$s/d = 0.16666667$

$V_{s,j2} = 279252.68$ is calculated for section flange jacket, with:

$d = 320.00$

$A_v = 157079.633$

$f_y = 555.5556$

$s = 100.00$

$V_{s,j2}$ is multiplied by $\text{Col},j2 = 1.00$

$s/d = 0.3125$

$V_{s,\text{core}} = V_{s,c1} + V_{s,c2} = 78637.555$

$V_{s,c1} = 78637.555$ is calculated for section web core, with:

$d = 440.00$

$A_v = 100530.965$

$f_y = 444.4444$

$s = 250.00$

$V_{s,c1}$ is multiplied by $\text{Col},c1 = 1.00$

$s/d = 0.56818182$

$V_{s,c2} = 0.00$ is calculated for section flange core, with:

$d = 160.00$

$A_v = 100530.965$

$f_y = 444.4444$

$s = 250.00$

$V_{s,c2}$ is multiplied by $\text{Col},c2 = 0.00$

$s/d = 1.5625$

V_f ((11-3)-(11.4), ACI 440) = 372533.843

$f = 0.95$, 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 α 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, $t_{f1} = NL \cdot t / \text{NoDir} = 1.016$

$d_{fv} = d$ (figure 11.2, ACI 440) = 707.00

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: $V_s + V_f \leq 838832.606$

$b_w = 400.00$

End Of Calculation of Shear Capacity ratio for element: column JLC1 of floor 1

At local axis: 3

Start Of Calculation of Shear Capacity ratio for element: column JLC1 of floor 1

At Shear local axis: 2

(Bending local axis: 3)

Section Type: rcjcs

Constant Properties

Knowledge Factor, $\gamma = 0.85$

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

Consequently:

Jacket

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

New material of Secondary Member: Steel Strength, $f_s = f_{sm} = 555.5556$

Concrete Elasticity, $E_c = 26999.444$

Steel Elasticity, $E_s = 200000.00$

Existing Column

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

Existing material of Secondary Member: Steel Strength, $f_s = f_{sm} = 444.4444$

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, $f_s = 1.25 \cdot f_{sm} = 694.4444$

Existing Column

Existing material: Steel Strength, $f_s = 1.25 \cdot f_{sm} = 555.5556$

#####

Max Height, $H_{max} = 750.00$

Min Height, $H_{min} = 400.00$

Max Width, $W_{max} = 750.00$

Min Width, $W_{min} = 400.00$

Jacket Thickness, $t_j = 100.00$

Cover Thickness, $c = 25.00$

Mean Confinement Factor overall section = 1.03889

Element Length, $L = 3000.00$

Secondary Member

Ribbed Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

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, $V_a = -0.00051441$

EDGE -B-

Shear Force, $V_b = 0.00051441$

BOTH EDGES

Axial Force, $F = -16273.616$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: $A_{st} = 0.00$

-Compression: $Aslc = 5353.274$
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension: $Asl,ten = 1137.257$
-Compression: $Asl,com = 2208.54$
-Middle: $Asl,mid = 2007.478$

Calculation of Shear Capacity ratio , $Ve/Vr = 0.55377356$
Member Controlled by Flexure ($Ve/Vr < 1$)
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $Ve = (Mpr1 + Mpr2)/ln = 552827.824$
with

$Mpr1 = \text{Max}(Mu1+ , Mu1-) = 8.2924E+008$
 $Mu1+ = 5.1260E+008$, is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination
 $Mu1- = 8.2924E+008$, is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination
 $Mpr2 = \text{Max}(Mu2+ , Mu2-) = 8.2924E+008$
 $Mu2+ = 5.1260E+008$, 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
 $Mu2- = 8.2924E+008$, 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 u according to 4.1, Biskinis/Fardis 2013:
 $u = 9.5578758E-006$
 $Mu = 5.1260E+008$

with full section properties:

$b = 750.00$
 $d = 707.00$
 $d' = 43.00$
 $v = 0.00093001$
 $N = 16273.616$
 $fc = 33.00$
 co (5A.5, TBDY) = 0.002
Final value of cu : $cu^* = \text{shear_factor} * \text{Max}(cu, cc) = 0.01288354$
The Shear_factor is considered equal to 1 (pure moment strength)
From (5.4b), TBDY: $cu = 0.01288354$
 w_e ((5.4c), TBDY) = $ase * sh_{min} * fy_{we} / f_{ce} + \text{Min}(fx, fy) = 0.05503171$
where $f = af * pf * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

 $fx = 0.04286225$
Expression ((15B.6), TBDY) is modified as $af = 1 - (\text{Unconfined area}) / (\text{total area})$
 $af = 0.31984848$
with Unconfined area = $((b_{max} - 2R)^2 + (h_{max} - 2R)^2) / 3 = 140733.333$
 $b_{max} = 750.00$
 $h_{max} = 750.00$
From EC8 A.4.4.3(6), $pf = 2tf/bw = 0.00508$
 $bw = 400.00$
effective stress from (A.35), $ff,e = 870.5244$

 $fy = 0.04286225$
Expression ((15B.6), TBDY) is modified as $af = 1 - (\text{Unconfined area}) / (\text{total area})$
 $af = 0.31984848$
with Unconfined area = $((b_{max} - 2R)^2 + (h_{max} - 2R)^2) / 3 = 140733.333$
 $b_{max} = 750.00$
 $h_{max} = 750.00$
From EC8 A.4.4.3(6), $pf = 2tf/bw = 0.00508$
 $bw = 400.00$
effective stress from (A.35), $ff,e = 870.5244$

R = 40.00

Effective FRP thickness, $t_f = NL \cdot t \cdot \cos(b_1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{,f} = 0.015$

$ase \text{ ((5.4d), TBDY)} = (ase_1 \cdot A_{ext} + ase_2 \cdot A_{int}) / A_{sec} = 0.45746528$

$ase_1 = \text{Max}(((A_{conf,max1} - A_{noConf1}) / A_{conf,max1}) \cdot (A_{conf,min1} / A_{conf,max1}), 0) = 0.45746528$

The definitions of A_{noConf} , $A_{conf,min}$ and $A_{conf,max}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max1} = 353600.00$ is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{conf,min1} = 293525.00$ is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area $A_{conf,max1}$ by a length equal to half the clear spacing between external hoops.

$A_{noConf1} = 158733.333$ is the unconfined external core area which is equal to $b_i^2/6$ as defined at (A.2).

$ase_2 (\geq ase_1) = \text{Max}(((A_{conf,max2} - A_{noConf2}) / A_{conf,max2}) \cdot (A_{conf,min2} / A_{conf,max2}), 0) = 0.45746528$

The definitions of A_{noConf} , $A_{conf,min}$ and $A_{conf,max}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max2} = 171264.00$ is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

$A_{conf,min2} = 54741.00$ is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area $A_{conf,max2}$ by a length equal to half the clear spacing between internal hoops.

$A_{noConf2} = 106242.667$ is the unconfined internal core area which is equal to $b_i^2/6$ as defined at (A.2).

$p_{sh,min} \cdot F_{ywe} = \text{Min}(p_{sh,x} \cdot F_{ywe}, p_{sh,y} \cdot F_{ywe}) = 2.92621$

Expression (5.4d) 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)

 $p_{sh,x} \cdot F_{ywe} = p_{sh1} \cdot F_{ywe1} + p_{sh2} \cdot F_{ywe2} = 2.92621$

$p_{sh1} \text{ ((5.4d), TBDY)} = L_{stir1} \cdot A_{stir1} / (A_{sec} \cdot s_1) = 0.00367709$

L_{stir1} (Length of stirrups along Y) = 2060.00

A_{stir1} (stirrups area) = 78.53982

$p_{sh2} \text{ (5.4d)} = L_{stir2} \cdot A_{stir2} / (A_{sec} \cdot s_2) = 0.00067082$

L_{stir2} (Length of stirrups along Y) = 1468.00

A_{stir2} (stirrups area) = 50.26548

 $p_{sh,y} \cdot F_{ywe} = p_{sh1} \cdot F_{ywe1} + p_{sh2} \cdot F_{ywe2} = 2.92621$

$p_{sh1} \text{ ((5.4d), TBDY)} = L_{stir1} \cdot A_{stir1} / (A_{sec} \cdot s_1) = 0.00367709$

L_{stir1} (Length of stirrups along X) = 2060.00

A_{stir1} (stirrups area) = 78.53982

$p_{sh2} \text{ ((5.4d), TBDY)} = L_{stir2} \cdot A_{stir2} / (A_{sec} \cdot s_2) = 0.00067082$

L_{stir2} (Length of stirrups along X) = 1468.00

A_{stir2} (stirrups area) = 50.26548

 $A_{sec} = 440000.00$

$s_1 = 100.00$

$s_2 = 250.00$

$f_{ywe1} = 694.4444$

$f_{ywe2} = 555.5556$

$f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY: $cc = 0.00238888$

c = confinement factor = 1.03889

$y_1 = 0.00145721$

$sh_1 = 0.00466307$

$ft_1 = 459.4373$

$fy_1 = 382.8645$

$su_1 = 0.00582756$

using (30) in Biskinis/Fardis (2013) multiplied with $shear_factor$

and also multiplied by the $shear_factor$ according to 15.7.1.4, with

$Shear_factor = 1.00$

$l_o / l_{ou,min} = l_b / d = 0.318426$

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

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.

$$\text{with } fs_1 = (fs_{jacket} * Asl_{ten,jacket} + fs_{core} * Asl_{ten,core}) / Asl_{ten} = 382.8645$$

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

$$y_2 = 0.00145721$$

$$sh_2 = 0.00466307$$

$$ft_2 = 465.423$$

$$fy_2 = 387.8525$$

$$su_2 = 0.00582756$$

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

$$lo/lou_{min} = lb/lb_{min} = 0.318426$$

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

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.

$$\text{with } fs_2 = (fs_{jacket} * Asl_{com,jacket} + fs_{core} * Asl_{com,core}) / Asl_{com} = 387.8525$$

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

$$yv = 0.00145721$$

$$shv = 0.00466307$$

$$ftv = 463.3885$$

$$fyv = 386.157$$

$$suv = 0.00582756$$

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

$$lo/lou_{min} = lb/ld = 0.318426$$

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

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 $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE 41-17.

$$\text{with } fsv = (fs_{jacket} * Asl_{mid,jacket} + fs_{mid} * Asl_{mid,core}) / Asl_{mid} = 386.157$$

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

$$1 = Asl_{ten} / (b * d) * (fs_1 / fc) = 0.02488335$$

$$2 = Asl_{com} / (b * d) * (fs_2 / fc) = 0.04895276$$

$$v = Asl_{mid} / (b * d) * (fsv / fc) = 0.04430167$$

and confined core properties:

$$b = 690.00$$

$$d = 677.00$$

$$d' = 13.00$$

$$fcc (5A.2, TBDY) = 34.2833$$

$$cc (5A.5, TBDY) = 0.00238888$$

$$c = \text{confinement factor} = 1.03889$$

$$1 = Asl_{ten} / (b * d) * (fs_1 / fc) = 0.02824566$$

$$2 = Asl_{com} / (b * d) * (fs_2 / fc) = 0.05556741$$

$$v = Asl_{mid} / (b * d) * (fsv / fc) = 0.05028784$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < vs, y_2$ - LHS eq.(4.5) is satisfied

--->

$$su (4.9) = 0.13760581$$

$$Mu = MRc (4.14) = 5.1260E+008$$

$$u = su (4.1) = 9.5578758E-006$$

Calculation of ratio lb/ld

$$\text{Lap Length: } lb/ld = 0.318426$$

$$lb = 300.00$$

ld = 942.1341

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 = 655.5556

Mean concrete strength: fc' = (fc'_jacket*Area_jacket + fc'_core*Area_core)/Area_section = 27.68182, but fc'^0.5 <= 8.3 MPa (22.5.3.1, ACI 318-14)

t = 1.00

s = 0.80

e = 1.00

cb = 25.00

Ktr = 1.7174

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) = 250.00

n = 24.00

Calculation of Mu1-

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

u = 1.0408734E-005

Mu = 8.2924E+008

with full section properties:

b = 400.00

d = 707.00

d' = 43.00

v = 0.00174378

N = 16273.616

fc = 33.00

co (5A.5, TBDY) = 0.002

Final value of cu: cu* = shear_factor * Max(cu, cc) = 0.01288354

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: cu = 0.01288354

we ((5.4c), TBDY) = ase* sh,min*fywe/fce+Min(fx, fy) = 0.05503171

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

fx = 0.04286225

Expression ((15B.6), TBDY) is modified as af = 1 - (Unconfined area)/(total area)

af = 0.31984848

with Unconfined area = ((bmax-2R)^2+(hmax-2R)^2)/3 = 140733.333

bmax = 750.00

hmax = 750.00

From EC8 A.4.4.3(6), pf = 2tf/bw = 0.00508

bw = 400.00

effective stress from (A.35), ff,e = 870.5244

fy = 0.04286225

Expression ((15B.6), TBDY) is modified as af = 1 - (Unconfined area)/(total area)

af = 0.31984848

with Unconfined area = ((bmax-2R)^2+(hmax-2R)^2)/3 = 140733.333

bmax = 750.00

hmax = 750.00

From EC8 A.4.4.3(6), pf = 2tf/bw = 0.00508

bw = 400.00

effective stress from (A.35), ff,e = 870.5244

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 = 0.45746528

$$ase1 = \text{Max}(((Aconf,max1 - AnoConf1)/Aconf,max1) * (Aconf,min1/Aconf,max1), 0) = 0.45746528$$

The definitions of AnoConf, Aconf,min and Aconf,max are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988) "Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

Aconf,max1 = 353600.00 is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

Aconf,min1 = 293525.00 is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area Aconf,max1 by a length equal to half the clear spacing between external hoops.

AnoConf1 = 158733.333 is the unconfined external core area which is equal to $b_i^2/6$ as defined at (A.2).

$$ase2 (>= ase1) = \text{Max}(((Aconf,max2 - AnoConf2)/Aconf,max2) * (Aconf,min2/Aconf,max2), 0) = 0.45746528$$

The definitions of AnoConf, Aconf,min and Aconf,max are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988) "Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

Aconf,max2 = 171264.00 is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

Aconf,min2 = 54741.00 is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area Aconf,max2 by a length equal to half the clear spacing between internal hoops.

AnoConf2 = 106242.667 is the unconfined internal core area which is equal to $b_i^2/6$ as defined at (A.2).

$$psh,min * Fywe = \text{Min}(psh,x * Fywe, psh,y * Fywe) = 2.92621$$

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

$$psh_x * Fywe = psh1 * Fywe1 + ps2 * Fywe2 = 2.92621$$

$$psh1 \text{ ((5.4d), TBDY)} = Lstir1 * Astir1 / (Asec * s1) = 0.00367709$$

$$Lstir1 \text{ (Length of stirrups along Y)} = 2060.00$$

$$Astir1 \text{ (stirrups area)} = 78.53982$$

$$psh2 \text{ (5.4d)} = Lstir2 * Astir2 / (Asec * s2) = 0.00067082$$

$$Lstir2 \text{ (Length of stirrups along Y)} = 1468.00$$

$$Astir2 \text{ (stirrups area)} = 50.26548$$

$$psh_y * Fywe = psh1 * Fywe1 + ps2 * Fywe2 = 2.92621$$

$$psh1 \text{ ((5.4d), TBDY)} = Lstir1 * Astir1 / (Asec * s1) = 0.00367709$$

$$Lstir1 \text{ (Length of stirrups along X)} = 2060.00$$

$$Astir1 \text{ (stirrups area)} = 78.53982$$

$$psh2 \text{ ((5.4d), TBDY)} = Lstir2 * Astir2 / (Asec * s2) = 0.00067082$$

$$Lstir2 \text{ (Length of stirrups along X)} = 1468.00$$

$$Astir2 \text{ (stirrups area)} = 50.26548$$

$$Asec = 440000.00$$

$$s1 = 100.00$$

$$s2 = 250.00$$

$$fywe1 = 694.4444$$

$$fywe2 = 555.5556$$

$$fce = 33.00$$

$$\text{From ((5.A5), TBDY), TBDY: } cc = 0.00238888$$

$$c = \text{confinement factor} = 1.03889$$

$$y1 = 0.00145721$$

$$sh1 = 0.00466307$$

$$ft1 = 465.423$$

$$fy1 = 387.8525$$

$$su1 = 0.00582756$$

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

$$lo/lou,min = lb/ld = 0.318426$$

$$su1 = 0.4 * esu1_nominal \text{ ((5.5), TBDY)} = 0.032$$

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.

$$\text{with } fs1 = (fs,jacket * Asl,ten,jacket + fs,core * Asl,ten,core) / Asl,ten = 387.8525$$

with $E_{s1} = (E_{s,jacket} \cdot A_{s,ten,jacket} + E_{s,core} \cdot A_{s,ten,core}) / A_{s,ten} = 200000.00$
 $y_2 = 0.00145721$
 $sh_2 = 0.00466307$
 $ft_2 = 459.4373$
 $fy_2 = 382.8645$
 $su_2 = 0.00582756$
 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
 $l_0/l_{ou,min} = l_b/l_{b,min} = 0.318426$
 $su_2 = 0.4 \cdot esu_{2,nominal} ((5.5), TBDY) = 0.032$
 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 $fs_2 = fs_2/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$, from 10.3.5, ASCE 41-17.
 with $fs_2 = (fs_{jacket} \cdot A_{s,com,jacket} + fs_{core} \cdot A_{s,com,core}) / A_{s,com} = 382.8645$
 with $E_{s2} = (E_{s,jacket} \cdot A_{s,com,jacket} + E_{s,core} \cdot A_{s,com,core}) / A_{s,com} = 200000.00$
 $y_v = 0.00145721$
 $sh_v = 0.00466307$
 $ft_v = 463.3885$
 $fy_v = 386.157$
 $suv = 0.00582756$
 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
 $l_0/l_{ou,min} = l_b/l_d = 0.318426$
 $suv = 0.4 \cdot esuv_{nominal} ((5.5), TBDY) = 0.032$
 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 $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$, from 10.3.5, ASCE 41-17.
 with $fs_v = (fs_{jacket} \cdot A_{s,mid,jacket} + fs_{mid} \cdot A_{s,mid,core}) / A_{s,mid} = 386.157$
 with $E_{sv} = (E_{s,jacket} \cdot A_{s,mid,jacket} + E_{s,mid} \cdot A_{s,mid,core}) / A_{s,mid} = 200000.00$
 $1 = A_{s,ten} / (b \cdot d) \cdot (fs_1 / fc) = 0.09178643$
 $2 = A_{s,com} / (b \cdot d) \cdot (fs_2 / fc) = 0.04665628$
 $v = A_{s,mid} / (b \cdot d) \cdot (fs_v / fc) = 0.08306563$

and confined core properties:

$b = 340.00$
 $d = 677.00$
 $d' = 13.00$
 $fcc (5A.2, TBDY) = 34.2833$
 $cc (5A.5, TBDY) = 0.00238888$
 $c = \text{confinement factor} = 1.03889$
 $1 = A_{s,ten} / (b \cdot d) \cdot (fs_1 / fc) = 0.11276915$
 $2 = A_{s,com} / (b \cdot d) \cdot (fs_2 / fc) = 0.05732208$
 $v = A_{s,mid} / (b \cdot d) \cdot (fs_v / fc) = 0.10205474$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

$v < v_s, y_2$ - LHS eq.(4.5) is satisfied

$su (4.9) = 0.20810191$
 $M_u = MR_c (4.14) = 8.2924E+008$
 $u = su (4.1) = 1.0408734E-005$

 Calculation of ratio l_b/l_d

 Lap Length: $l_b/l_d = 0.318426$

$l_b = 300.00$
 $l_d = 942.1341$

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: $fy = 655.5556$

Mean concrete strength: $fc' = (fc'_{jacket} \cdot Area_{jacket} + fc'_{core} \cdot Area_{core}) / Area_{section} = 27.68182$, but $fc'^{0.5} < =$

8.3 MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 1.7174$

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

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

$s = \text{Max}(s_{\text{external}}, s_{\text{internal}}) = 250.00$

$n = 24.00$

Calculation of μ_{2+}

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

$\mu = 9.5578758E-006$

$\mu = 5.1260E+008$

with full section properties:

$b = 750.00$

$d = 707.00$

$d' = 43.00$

$v = 0.00093001$

$N = 16273.616$

$f_c = 33.00$

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

Final value of μ : $\mu^* = \text{shear_factor} * \text{Max}(\mu, \alpha) = 0.01288354$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $\mu = 0.01288354$

where $\mu = \alpha * \text{sh}_{\text{min}} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.05503171$

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

 $f_x = 0.04286225$

Expression ((15B.6), TBDY) is modified as $\alpha_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$\alpha_f = 0.31984848$

with Unconfined area = $((b_{\text{max}} - 2R)^2 + (h_{\text{max}} - 2R)^2) / 3 = 140733.333$

$b_{\text{max}} = 750.00$

$h_{\text{max}} = 750.00$

From EC8 A.4.4.3(6), $\text{pf} = 2t_f / b_w = 0.00508$

$b_w = 400.00$

effective stress from (A.35), $f_{fe} = 870.5244$

 $f_y = 0.04286225$

Expression ((15B.6), TBDY) is modified as $\alpha_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$\alpha_f = 0.31984848$

with Unconfined area = $((b_{\text{max}} - 2R)^2 + (h_{\text{max}} - 2R)^2) / 3 = 140733.333$

$b_{\text{max}} = 750.00$

$h_{\text{max}} = 750.00$

From EC8 A.4.4.3(6), $\text{pf} = 2t_f / b_w = 0.00508$

$b_w = 400.00$

effective stress from (A.35), $f_{fe} = 870.5244$

 $R = 40.00$

Effective FRP thickness, $t_f = NL * t * \text{Cos}(\beta_1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_f = 0.015$

α_{se} ((5.4d), TBDY) = $(\alpha_{se1} * A_{\text{ext}} + \alpha_{se2} * A_{\text{int}}) / A_{\text{sec}} = 0.45746528$

$\alpha_{se1} = \text{Max}(((A_{\text{conf,max1}} - A_{\text{noConf1}}) / A_{\text{conf,max1}}) * (A_{\text{conf,min1}} / A_{\text{conf,max1}}), 0) = 0.45746528$

The definitions of A_{noConf} , $A_{\text{conf,min}}$ and $A_{\text{conf,max}}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

Aconf,max1 = 353600.00 is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

Aconf,min1 = 293525.00 is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area Aconf,max1 by a length equal to half the clear spacing between external hoops.

AnoConf1 = 158733.333 is the unconfined external core area which is equal to $b_i^2/6$ as defined at (A.2).
ase2 (\geq ase1) = $\text{Max}((A_{\text{conf,max2}} - \text{AnoConf2}) / A_{\text{conf,max2}} * (A_{\text{conf,min2}} / A_{\text{conf,max2}}), 0) = 0.45746528$

The definitions of AnoConf, Aconf,min and Aconf,max are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988) "Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

Aconf,max2 = 171264.00 is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

Aconf,min2 = 54741.00 is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area Aconf,max2 by a length equal to half the clear spacing between internal hoops.

AnoConf2 = 106242.667 is the unconfined internal core area which is equal to $b_i^2/6$ as defined at (A.2).

psh,min*Fywe = $\text{Min}(psh_x * Fywe, psh_y * Fywe) = 2.92621$

Expression (5.4d) 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 = 2.92621

psh1 ((5.4d), TBDY) = $L_{\text{stir1}} * A_{\text{stir1}} / (A_{\text{sec}} * s_1) = 0.00367709$

Lstir1 (Length of stirrups along Y) = 2060.00

Astir1 (stirrups area) = 78.53982

psh2 (5.4d) = $L_{\text{stir2}} * A_{\text{stir2}} / (A_{\text{sec}} * s_2) = 0.00067082$

Lstir2 (Length of stirrups along Y) = 1468.00

Astir2 (stirrups area) = 50.26548

psh_y*Fywe = psh1*Fywe1 + ps2*Fywe2 = 2.92621

psh1 ((5.4d), TBDY) = $L_{\text{stir1}} * A_{\text{stir1}} / (A_{\text{sec}} * s_1) = 0.00367709$

Lstir1 (Length of stirrups along X) = 2060.00

Astir1 (stirrups area) = 78.53982

psh2 ((5.4d), TBDY) = $L_{\text{stir2}} * A_{\text{stir2}} / (A_{\text{sec}} * s_2) = 0.00067082$

Lstir2 (Length of stirrups along X) = 1468.00

Astir2 (stirrups area) = 50.26548

Asec = 440000.00

s1 = 100.00

s2 = 250.00

fywe1 = 694.4444

fywe2 = 555.5556

fce = 33.00

From ((5.A5), TBDY), TBDY: cc = 0.00238888

c = confinement factor = 1.03889

y1 = 0.00145721

sh1 = 0.00466307

ft1 = 459.4373

fy1 = 382.8645

su1 = 0.00582756

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 = 0.318426

su1 = $0.4 * e_{s1_nominal} ((5.5), TBDY) = 0.032$

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 = $(f_{s,jacket} * A_{s,ten,jacket} + f_{s,core} * A_{s,ten,core}) / A_{s,ten} = 382.8645$

with Es1 = $(E_{s,jacket} * A_{s,ten,jacket} + E_{s,core} * A_{s,ten,core}) / A_{s,ten} = 200000.00$

y2 = 0.00145721

sh2 = 0.00466307

ft2 = 465.423

fy2 = 387.8525

su2 = 0.00582756

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

$l_o/l_{o,min} = l_b/l_{b,min} = 0.318426$

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

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 $Min(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE 41-17.

with $fs_2 = (fs_{jacket} * A_{sl,com,jacket} + fs_{core} * A_{sl,com,core}) / A_{sl,com} = 387.8525$

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

$y_v = 0.00145721$

$sh_v = 0.00466307$

$ft_v = 463.3885$

$fy_v = 386.157$

$su_v = 0.00582756$

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

$l_o/l_{o,min} = l_b/l_d = 0.318426$

$su_v = 0.4 * esu_{v,nominal} ((5.5), TBDY) = 0.032$

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

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

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

with $fsv = (fs_{jacket} * A_{sl,mid,jacket} + fs_{mid} * A_{sl,mid,core}) / A_{sl,mid} = 386.157$

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

$1 = A_{sl,ten} / (b * d) * (fs_1 / fc) = 0.02488335$

$2 = A_{sl,com} / (b * d) * (fs_2 / fc) = 0.04895276$

$v = A_{sl,mid} / (b * d) * (fsv / fc) = 0.04430167$

and confined core properties:

$b = 690.00$

$d = 677.00$

$d' = 13.00$

$fcc (5A.2, TBDY) = 34.2833$

$cc (5A.5, TBDY) = 0.00238888$

$c =$ confinement factor $= 1.03889$

$1 = A_{sl,ten} / (b * d) * (fs_1 / fc) = 0.02824566$

$2 = A_{sl,com} / (b * d) * (fs_2 / fc) = 0.05556741$

$v = A_{sl,mid} / (b * d) * (fsv / fc) = 0.05028784$

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

--->

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

--->

$su (4.9) = 0.13760581$

$Mu = MRc (4.14) = 5.1260E+008$

$u = su (4.1) = 9.5578758E-006$

Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.318426$

$l_b = 300.00$

$l_d = 942.1341$

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: $fy = 655.5556$

Mean concrete strength: $fc' = (fc'_{jacket} * Area_{jacket} + fc'_{core} * Area_{core}) / Area_{section} = 27.68182$, but $fc'^{0.5} < =$
8.3 MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 1.7174$

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

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

$$s = \text{Max}(s_{\text{external}}, s_{\text{internal}}) = 250.00$$

$$n = 24.00$$

Calculation of μ_2

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

$$\mu = 1.0408734E-005$$

$$\mu_2 = 8.2924E+008$$

with full section properties:

$$b = 400.00$$

$$d = 707.00$$

$$d' = 43.00$$

$$v = 0.00174378$$

$$N = 16273.616$$

$$f_c = 33.00$$

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

$$\text{Final value of } \mu_2: \mu_2^* = \text{shear_factor} * \text{Max}(\mu_2, \omega) = 0.01288354$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \mu_2 = 0.01288354$$

$$\omega (5.4c, \text{TBDY}) = \text{ase} * \text{sh_min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.05503171$$

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

$$f_x = 0.04286225$$

Expression ((15B.6), TBDY) is modified as $\text{af} = 1 - (\text{Unconfined area}) / (\text{total area})$

$$\text{af} = 0.31984848$$

$$\text{with Unconfined area} = ((b_{\text{max}} - 2R)^2 + (h_{\text{max}} - 2R)^2) / 3 = 140733.333$$

$$b_{\text{max}} = 750.00$$

$$h_{\text{max}} = 750.00$$

$$\text{From EC8 A.4.4.3(6), pf} = 2t_f / b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), ff,e} = 870.5244$$

$$f_y = 0.04286225$$

Expression ((15B.6), TBDY) is modified as $\text{af} = 1 - (\text{Unconfined area}) / (\text{total area})$

$$\text{af} = 0.31984848$$

$$\text{with Unconfined area} = ((b_{\text{max}} - 2R)^2 + (h_{\text{max}} - 2R)^2) / 3 = 140733.333$$

$$b_{\text{max}} = 750.00$$

$$h_{\text{max}} = 750.00$$

$$\text{From EC8 A.4.4.3(6), pf} = 2t_f / b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), ff,e} = 870.5244$$

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$\text{ase ((5.4d), TBDY)} = (\text{ase}_1 * A_{\text{ext}} + \text{ase}_2 * A_{\text{int}}) / A_{\text{sec}} = 0.45746528$$

$$\text{ase}_1 = \text{Max}(((A_{\text{conf,max1}} - A_{\text{noConf1}}) / A_{\text{conf,max1}}) * (A_{\text{conf,min1}} / A_{\text{conf,max1}}), 0) = 0.45746528$$

The definitions of A_{noConf} , $A_{\text{conf,min}}$ and $A_{\text{conf,max}}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{\text{conf,max1}} = 353600.00$ is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{\text{conf,min1}} = 293525.00$ is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area $A_{\text{conf,max1}}$ by a length

equal to half the clear spacing between external hoops.

$A_{\text{noConf1}} = 158733.333$ is the unconfined external core area which is equal to $b_i^2/6$ as defined at (A.2).

$$ase2 (>= ase1) = \text{Max}(((Aconf,max2 - AnoConf2)/Aconf,max2) * (Aconf,min2/Aconf,max2), 0) = 0.45746528$$

The definitions of AnoConf, Aconf,min and Aconf,max are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988) "Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

Aconf,max2 = 171264.00 is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

Aconf,min2 = 54741.00 is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area Aconf,max2 by a length equal to half the clear spacing between internal hoops.

AnoConf2 = 106242.667 is the unconfined internal core area which is equal to $b_i^2/6$ as defined at (A.2).

$$psh,min * Fywe = \text{Min}(psh,x * Fywe, psh,y * Fywe) = 2.92621$$

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

$$psh,x * Fywe = psh1 * Fywe1 + ps2 * Fywe2 = 2.92621$$

$$psh1 \text{ ((5.4d), TBDY)} = Lstir1 * Astir1 / (Asec * s1) = 0.00367709$$

$$Lstir1 \text{ (Length of stirrups along Y)} = 2060.00$$

$$Astir1 \text{ (stirrups area)} = 78.53982$$

$$psh2 \text{ (5.4d)} = Lstir2 * Astir2 / (Asec * s2) = 0.00067082$$

$$Lstir2 \text{ (Length of stirrups along Y)} = 1468.00$$

$$Astir2 \text{ (stirrups area)} = 50.26548$$

$$psh,y * Fywe = psh1 * Fywe1 + ps2 * Fywe2 = 2.92621$$

$$psh1 \text{ ((5.4d), TBDY)} = Lstir1 * Astir1 / (Asec * s1) = 0.00367709$$

$$Lstir1 \text{ (Length of stirrups along X)} = 2060.00$$

$$Astir1 \text{ (stirrups area)} = 78.53982$$

$$psh2 \text{ ((5.4d), TBDY)} = Lstir2 * Astir2 / (Asec * s2) = 0.00067082$$

$$Lstir2 \text{ (Length of stirrups along X)} = 1468.00$$

$$Astir2 \text{ (stirrups area)} = 50.26548$$

$$Asec = 440000.00$$

$$s1 = 100.00$$

$$s2 = 250.00$$

$$fywe1 = 694.4444$$

$$fywe2 = 555.5556$$

$$fce = 33.00$$

From ((5.A5), TBDY), TBDY: $cc = 0.00238888$

$$c = \text{confinement factor} = 1.03889$$

$$y1 = 0.00145721$$

$$sh1 = 0.00466307$$

$$ft1 = 465.423$$

$$fy1 = 387.8525$$

$$su1 = 0.00582756$$

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

$$lo/lou,min = lb/ld = 0.318426$$

$$su1 = 0.4 * esu1_nominal \text{ ((5.5), TBDY)} = 0.032$$

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.

$$\text{with } fs1 = (fs,jacket * Asl,ten,jacket + fs,core * Asl,ten,core) / Asl,ten = 387.8525$$

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

$$y2 = 0.00145721$$

$$sh2 = 0.00466307$$

$$ft2 = 459.4373$$

$$fy2 = 382.8645$$

$$su2 = 0.00582756$$

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

$$lo/lou,min = lb/lb,min = 0.318426$$

$$su2 = 0.4 * esu2_nominal \text{ ((5.5), TBDY)} = 0.032$$

From table 5A.1, TBDY: $esu2_nominal = 0.08$,

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_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 $fs_2 = (fs_{jacket} \cdot Asl_{com,jacket} + fs_{core} \cdot Asl_{com,core}) / Asl_{com} = 382.8645$

with $Es_2 = (Es_{jacket} \cdot Asl_{com,jacket} + Es_{core} \cdot Asl_{com,core}) / Asl_{com} = 200000.00$

$y_v = 0.00145721$

$sh_v = 0.00466307$

$ft_v = 463.3885$

$fy_v = 386.157$

$suv = 0.00582756$

using (30) in Bisquinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$lo/lo_{u,min} = lb/ld = 0.318426$

$suv = 0.4 \cdot es_{uv_nominal} ((5,5), TBDY) = 0.032$

From table 5A.1, TBDY: $es_{uv_nominal} = 0.08$,

considering characteristic value $fs_{yv} = fs_v/1.2$, 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 $fs_{yv} = fs_v/1.2$, from table 5.1, TBDY.

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

with $fs_v = (fs_{jacket} \cdot Asl_{mid,jacket} + fs_{mid} \cdot Asl_{mid,core}) / Asl_{mid} = 386.157$

with $Es_v = (Es_{jacket} \cdot Asl_{mid,jacket} + Es_{mid} \cdot Asl_{mid,core}) / Asl_{mid} = 200000.00$

$1 = Asl_{ten} / (b \cdot d) \cdot (fs_1 / fc) = 0.09178643$

$2 = Asl_{com} / (b \cdot d) \cdot (fs_2 / fc) = 0.04665628$

$v = Asl_{mid} / (b \cdot d) \cdot (fs_v / fc) = 0.08306563$

and confined core properties:

$b = 340.00$

$d = 677.00$

$d' = 13.00$

fcc (5A.2, TBDY) = 34.2833

cc (5A.5, TBDY) = 0.00238888

c = confinement factor = 1.03889

$1 = Asl_{ten} / (b \cdot d) \cdot (fs_1 / fc) = 0.11276915$

$2 = Asl_{com} / (b \cdot d) \cdot (fs_2 / fc) = 0.05732208$

$v = Asl_{mid} / (b \cdot d) \cdot (fs_v / fc) = 0.10205474$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

su (4.9) = 0.20810191

$Mu = MRc$ (4.14) = 8.2924E+008

$u = su$ (4.1) = 1.0408734E-005

Calculation of ratio lb/ld

Lap Length: $lb/ld = 0.318426$

$lb = 300.00$

$ld = 942.1341$

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: $fy = 655.5556$

Mean concrete strength: $fc' = (fc'_{jacket} \cdot Area_{jacket} + fc'_{core} \cdot Area_{core}) / Area_{section} = 27.68182$, but $fc'^{0.5} < = 8.3$ MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 1.7174$

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

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

$s = \text{Max}(s_{external}, s_{internal}) = 250.00$

$n = 24.00$

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 998292.205$

Calculation of Shear Strength at edge 1, $V_{r1} = 998292.205$

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

$V_{\text{Col}0} = 998292.205$

$k_{nl} = 1$ (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: $f_c' = (f_c'_{\text{jacket}} * \text{Area}_{\text{jacket}} + f_c'_{\text{core}} * \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 27.68182$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M / Vd = 4.00$

$\mu_u = 11.78089$

$V_u = 0.00051441$

$d = 0.8 * h = 600.00$

$N_u = 16273.616$

$A_g = 300000.00$

From (11.5.4.8), ACI 318-14: $V_s = V_{s,\text{jacket}} + V_{s,\text{core}} = 881489.011$

where:

$V_{s,\text{jacket}} = V_{s,j1} + V_{s,j2} = 802851.456$

$V_{s,j1} = 279252.68$ is calculated for section web jacket, with:

$d = 320.00$

$A_v = 157079.633$

$f_y = 555.5556$

$s = 100.00$

$V_{s,j1}$ is multiplied by $\text{Col},j1 = 1.00$

$s/d = 0.3125$

$V_{s,j2} = 523598.776$ is calculated for section flange jacket, with:

$d = 600.00$

$A_v = 157079.633$

$f_y = 555.5556$

$s = 100.00$

$V_{s,j2}$ is multiplied by $\text{Col},j2 = 1.00$

$s/d = 0.16666667$

$V_{s,\text{core}} = V_{s,c1} + V_{s,c2} = 78637.555$

$V_{s,c1} = 0.00$ is calculated for section web core, with:

$d = 160.00$

$A_v = 100530.965$

$f_y = 444.4444$

$s = 250.00$

$V_{s,c1}$ is multiplied by $\text{Col},c1 = 0.00$

$s/d = 1.5625$

$V_{s,c2} = 78637.555$ is calculated for section flange core, with:

$d = 440.00$

$A_v = 100530.965$

$f_y = 444.4444$

$s = 250.00$

$V_{s,c2}$ is multiplied by $\text{Col},c2 = 1.00$

$s/d = 0.56818182$

$V_f ((11-3)-(11.4), \text{ACI } 440) = 372533.843$

$f = 0.95$, for fully-wrapped sections

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

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

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

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

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

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

$d_{fv} = d$ (figure 11.2, ACI 440) = 707.00

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

$E_f = 64828.00$

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

with $f_u = 0.01$

From (11-11), ACI 440: $V_s + V_f \leq 838832.606$

$bw = 400.00$

Calculation of Shear Strength at edge 2, $V_{r2} = 998292.205$

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

$V_{Col0} = 998292.205$

$kn1 = 1$ (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: $f_c' = (f_c'_{jacket} * Area_{jacket} + f_c'_{core} * Area_{core}) / Area_{section} = 27.68182$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M / Vd = 4.00$

$\mu_u = 11.78144$

$V_u = 0.00051441$

$d = 0.8 * h = 600.00$

$N_u = 16273.616$

$A_g = 300000.00$

From (11.5.4.8), ACI 318-14: $V_s = V_{sjacket} + V_{s,core} = 881489.011$

where:

$V_{sjacket} = V_{sj1} + V_{sj2} = 802851.456$

$V_{sj1} = 279252.68$ is calculated for section web jacket, with:

$d = 320.00$

$A_v = 157079.633$

$f_y = 555.5556$

$s = 100.00$

V_{sj1} is multiplied by $Col_{j1} = 1.00$

$s/d = 0.3125$

$V_{sj2} = 523598.776$ is calculated for section flange jacket, with:

$d = 600.00$

$A_v = 157079.633$

$f_y = 555.5556$

$s = 100.00$

V_{sj2} is multiplied by $Col_{j2} = 1.00$

$s/d = 0.16666667$

$V_{s,core} = V_{s,c1} + V_{s,c2} = 78637.555$

$V_{s,c1} = 0.00$ is calculated for section web core, with:

$d = 160.00$

$A_v = 100530.965$

$f_y = 444.4444$

$s = 250.00$

$V_{s,c1}$ is multiplied by $Col_{c1} = 0.00$

$s/d = 1.5625$

$V_{s,c2} = 78637.555$ is calculated for section flange core, with:

$d = 440.00$

$A_v = 100530.965$

$f_y = 444.4444$

$s = 250.00$

$V_{s,c2}$ is multiplied by $Col_{c2} = 1.00$

$s/d = 0.56818182$

$V_f ((11-3)-(11.4), ACI 440) = 372533.843$

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

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

total thickness per orientation, $tf1 = NL * t / \text{NoDir} = 1.016$

$dfv = d$ (figure 11.2, ACI 440) = 707.00

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

$E_f = 64828.00$

fe = 0.004, from (11.6a), ACI 440
with fu = 0.01
From (11-11), ACI 440: Vs + Vf <= 838832.606
bw = 400.00

End Of Calculation of Shear Capacity ratio for element: column JLC1 of floor 1
At local axis: 2

Start Of Calculation of Chord Rotation Capacity for element: column JLC1 of floor 1
At local axis: 3
Integration Section: (a)
Section Type: rcjls

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 Secondary Member: Concrete Strength, $f_c = f_{cm} = 33.00$
New material of Secondary Member: Steel Strength, $f_s = f_{sm} = 555.5556$
Concrete Elasticity, $E_c = 26999.444$
Steel Elasticity, $E_s = 200000.00$
Existing Column
Existing material of Secondary Member: Concrete Strength, $f_c = f_{cm} = 20.00$
Existing material of Secondary Member: Steel Strength, $f_s = f_{sm} = 444.4444$
Concrete Elasticity, $E_c = 21019.039$
Steel Elasticity, $E_s = 200000.00$
Max Height, $H_{max} = 750.00$
Min Height, $H_{min} = 400.00$
Max Width, $W_{max} = 750.00$
Min Width, $W_{min} = 400.00$
Jacket Thickness, $t_j = 100.00$
Cover Thickness, $c = 25.00$
Element Length, $L = 3000.00$
Secondary Member
Ribbed Bars
Ductile Steel
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
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, $M = -1.9757E+007$
Shear Force, $V_2 = -6560.264$
Shear Force, $V_3 = 122.9023$
Axial Force, $F = -16937.611$
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: $A_{st} = 0.00$

-Compression: Asl,com = 5353.274

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension: Asl,ten = 1137.257

-Compression: Asl,com = 2208.54

-Middle: Asl,mid = 2007.478

Longitudinal External Reinforcement Area Distribution (in 3 divisions)

-Tension: Asl,ten,jacket = 829.3805

-Compression: Asl,com,jacket = 1746.726

-Middle: Asl,mid,jacket = 1545.664

Longitudinal Internal Reinforcement Area Distribution (in 3 divisions)

-Tension: Asl,ten,core = 307.8761

-Compression: Asl,com,core = 461.8141

-Middle: Asl,mid,core = 461.8141

Mean Diameter of Tension Reinforcement, DbL = 16.80

Existing component: From table 7-7, ASCE 41_17: Final chord rotation Capacity $u,R = \phi u = 0.02797891$
 $u = y + p = 0.03291637$

- Calculation of y -

$y = (My*Ls/3)/Eleff = 0.00291637$ ((4.29),Biskinis Phd))

$My = 4.2097E+008$

$Ls = M/V$ (with $Ls > 0.1*L$ and $Ls < 2*L$) = 3011.65

From table 10.5, ASCE 41_17: $Eleff = factor*Ec*Ig = 1.4491E+014$

$factor = 0.30$

$Ag = 440000.00$

Mean concrete strength: $fc' = (fc'_jacket*Area_jacket + fc'_core*Area_core)/Area_section = 27.68182$

$N = 16937.611$

$Ec*Ig = Ec_jacket*Ig_jacket + Ec_core*Ig_core = 4.8303E+014$

Calculation of Yielding Moment My

Calculation of y and My according to Annex 7 -

Assuming neutral axis within flange ($y < t/d$, compression zone rectangular) with:

flange width, $b = 750.00$

web width, $bw = 400.00$

flange thickness, $t = 400.00$

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

$y_{ten} = 3.1431513E-006$

with ((10.1), ASCE 41-17) $f_y = \text{Min}(f_y, 1.25*f_y*(lb/d)^{2/3}) = 358.4764$

$d = 707.00$

$y = 0.19342282$

$A = 0.01018486$

$B = 0.00449527$

with $pt = 0.00671906$

$pc = 0.00416509$

$pv = 0.00378591$

$N = 16937.611$

$b = 750.00$

$" = 0.06082037$

$y_{comp} = 1.6462780E-005$

with fc' (12.3, (ACI 440)) = 33.48734

$fc = 33.00$

$fl = 0.49678681$

$b = b_{max} = 750.00$

$h = h_{max} = 750.00$

$Ag = 0.44$

$g = pt + pc + pv = 0.01009575$

$rc = 40.00$

$$A_e/A_c = 0.31291181$$

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

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

$$f_u = 0.01$$

$$E_f = 64828.00$$

$$E_c = 26999.444$$

$$y = 0.19181197$$

$$A = 0.01002422$$

$$B = 0.00440616$$

$$\text{with } E_s = 200000.00$$

CONFIRMATION: $y = 0.19278073 < t/d$

Calculation of ratio l_b/l_d

$$\text{Lap Length: } l_b/l_d, \min = 0.39803249$$

$$l_b = 300.00$$

$$l_d = 753.7073$$

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

$$= 1$$

$$d_b = 16.66667$$

$$\text{Mean strength value of all re-bars: } f_y = 524.4444$$

$$\text{Mean concrete strength: } f_c' = (f_c'_{\text{jacket}} \cdot \text{Area}_{\text{jacket}} + f_c'_{\text{core}} \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 27.68182, \text{ but } f_c'^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 25.00$$

$$K_{tr} = 1.7174$$

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

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

$$s = \max(s_{\text{external}}, s_{\text{internal}}) = 250.00$$

$$n = 24.00$$

- Calculation of p -

From table 10-8: $p = 0.03$

with:

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

$$\text{shear control ratio } V_y E / V_{CoI} E = 0.55377356$$

$$d = d_{\text{external}} = 707.00$$

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

- $t = s_1 + s_2 + 2 \cdot t_f / b_w \cdot (f_{fe} / f_s) = 0.00671906$

$$\text{jacket: } s_1 = A_{v1} \cdot L_{\text{stir1}} / (s_1 \cdot A_g) = 0.00367709$$

$A_{v1} = 78.53982$, is the area of every stirrup parallel to loading (shear) direction

$L_{\text{stir1}} = 2060.00$, is the total Length of all stirrups parallel to loading (shear) direction

$$s_1 = 100.00$$

$$\text{core: } s_2 = A_{v2} \cdot L_{\text{stir2}} / (s_2 \cdot A_g) = 0.00067082$$

$A_{v2} = 50.26548$, is the area of every stirrup parallel to loading (shear) direction

$L_{\text{stir2}} = 1468.00$, is the total Length of all stirrups parallel to loading (shear) direction

$$s_2 = 250.00$$

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

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

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

For the normalisation f_s of jacket is used.

$$N_{UD} = 16937.611$$

$$A_g = 440000.00$$

$$f_c E = (f_c'_{\text{jacket}} \cdot \text{Area}_{\text{jacket}} + f_c'_{\text{core}} \cdot \text{Area}_{\text{core}}) / \text{section_area} = 27.68182$$

$$f_y E = (f_y_{\text{ext_Long_Reinf}} \cdot \text{Area}_{\text{ext_Long_Reinf}} + f_y_{\text{int_Long_Reinf}} \cdot \text{Area}_{\text{int_Long_Reinf}}) / \text{Area}_{\text{Tot_Long_Rein}} = 529.9948$$

$$f_y E = (f_y_{\text{ext_Trans_Reinf}} \cdot s_1 + f_y_{\text{int_Trans_Reinf}} \cdot s_2) / (s_1 + s_2) = 538.4128$$

$$p_l = \text{Area}_{\text{Tot_Long_Rein}} / (b \cdot d) = 0.01009575$$

$$b = 750.00$$

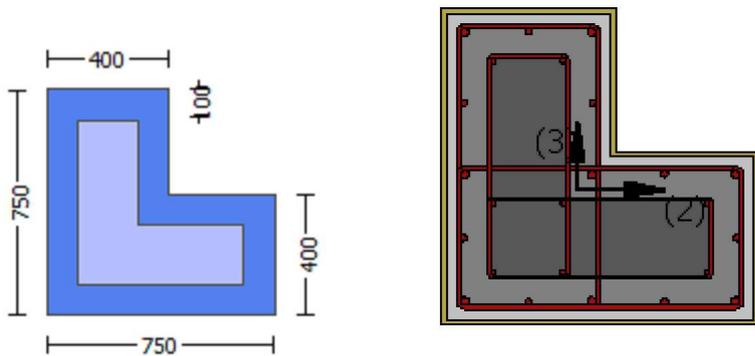
$$d = 707.00$$

$$f_c E = 27.68182$$

End Of Calculation of Chord Rotation Capacity for element: column JLC1 of floor 1
At local axis: 3
Integration Section: (a)

Calculation No. 13

column C1, Floor 1
Limit State: Life Safety (data interpolation between analysis steps 1 and 2)
Analysis: Uniform +X
Check: Shear capacity VRd
Edge: End
Local Axis: (2)



Start Of Calculation of Shear Capacity for element: column JLC1 of floor 1
At local axis: 2
Integration Section: (b)
Section Type: rcjics

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 Secondary Member: Concrete Strength, $f_c = f_{c_lower_bound} = 25.00$
New material of Secondary Member: Steel Strength, $f_s = f_{s_lower_bound} = 500.00$
Concrete Elasticity, $E_c = 26999.444$
Steel Elasticity, $E_s = 200000.00$
Existing Column
Existing material of Secondary Member: Concrete Strength, $f_c = f_{c_lower_bound} = 16.00$
Existing material of Secondary Member: Steel Strength, $f_s = f_{s_lower_bound} = 400.00$
Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

Note: Especially for the calculation of γ for displacement ductility demand,
the expected (mean value) strengths are used (7.5.1.3, ASCE 41-17) because bending is considered as
Deformation-Controlled Action (Table C7-1, ASCE 41-17).
Jacket
New material: Concrete Strength, $f_c = f_{cm} = 33.00$
New material: Steel Strength, $f_s = f_{sm} = 555.5556$
Existing Column
Existing material: Concrete Strength, $f_c = f_{cm} = 20.00$
Existing material: Steel Strength, $f_s = f_{sm} = 444.4444$

Max Height, $H_{max} = 750.00$
Min Height, $H_{min} = 400.00$
Max Width, $W_{max} = 750.00$
Min Width, $W_{min} = 400.00$
Jacket Thickness, $t_j = 100.00$
Cover Thickness, $c = 25.00$
Element Length, $L = 3000.00$
Secondary Member
Ribbed Bars
Ductile Steel
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
Lap Length $l_o = l_b = 300.00$
FRP Wrapping Data
Type: Carbon
Cured laminate properties (design values)
Thickness, $t = 1.016$
Tensile Strength, $f_{fu} = 1055.00$
Tensile Modulus, $E_f = 64828.00$
Elongation, $e_{fu} = 0.01$
Number of directions, $N_{oDir} = 1$
Fiber orientations, $b_i: 0.00^\circ$
Number of layers, $N_L = 1$
Radius of rounding corners, $R = 40.00$

Stepwise Properties

EDGE -A-
Bending Moment, $M_a = -1.9757E+007$
Shear Force, $V_a = -6560.264$
EDGE -B-
Bending Moment, $M_b = 71505.406$
Shear Force, $V_b = 6560.264$
BOTH EDGES
Axial Force, $F = -16937.611$
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: $A_{sl,t} = 0.00$
-Compression: $A_{sl,c} = 5353.274$
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension: $A_{sl,ten} = 1137.257$
-Compression: $A_{sl,com} = 2208.54$
-Middle: $A_{sl,mid} = 2007.478$
Mean Diameter of Tension Reinforcement, $Db_{L,ten} = 16.80$

Existing component: From table 7-7, ASCE 41_17: Final Shear Capacity $V_R = \phi V_n = 864045.673$
 $V_n ((10.3), ASCE 41-17) = k_n l^* V_{CoI} = 1.0165E+006$
 $V_{CoI} = 1.0165E+006$
 $k_n l = 1.00$
displacement_ductility_demand = 0.0709274

NOTE: In expression (10-3) ' $V_s = A_v * f_y * d / s$ ' is replaced by ' $V_s + \phi * V_f$ '

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

= 1 (normal-weight concrete)

Mean concrete strength: $f'_c = (f'_{c,jacket} \cdot Area_{jacket} + f'_{c,core} \cdot Area_{core}) / Area_{section} = 21.31818$, but $f_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$\mu_u = 71505.406$

$V_u = 6560.264$

$d = 0.8 \cdot h = 600.00$

$N_u = 16937.611$

$A_g = 300000.00$

From (11.5.4.8), ACI 318-14: $V_s = V_{s,jacket} + V_{s,core} = 793340.11$

where:

$V_{s,jacket} = V_{s,j1} + V_{s,j2} = 722566.31$

$V_{s,j1} = 251327.412$ is calculated for section web jacket, with:

$d = 320.00$

$A_v = 157079.633$

$f_y = 500.00$

$s = 100.00$

$V_{s,j1}$ is multiplied by $Col_{j1} = 1.00$

$s/d = 0.3125$

$V_{s,j2} = 471238.898$ is calculated for section flange jacket, with:

$d = 600.00$

$A_v = 157079.633$

$f_y = 500.00$

$s = 100.00$

$V_{s,j2}$ is multiplied by $Col_{j2} = 1.00$

$s/d = 0.16666667$

$V_{s,core} = V_{s,c1} + V_{s,c2} = 70773.799$

$V_{s,c1} = 0.00$ is calculated for section web core, with:

$d = 160.00$

$A_v = 100530.965$

$f_y = 400.00$

$s = 250.00$

$V_{s,c1}$ is multiplied by $Col_{c1} = 0.00$

$s/d = 1.5625$

$V_{s,c2} = 70773.799$ is calculated for section flange core, with:

$d = 440.00$

$A_v = 100530.965$

$f_y = 400.00$

$s = 250.00$

$V_{s,c2}$ is multiplied by $Col_{c2} = 1.00$

$s/d = 0.56818182$

V_f ((11-3)-(11.4), ACI 440) = 372533.843

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

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

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

$d_{fv} = d$ (figure 11.2, ACI 440) = 707.00

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: $V_s + V_f \leq 736127.561$

$b_w = 400.00$

displacement_ductility_demand is calculated as δ / y

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

From analysis, chord rotation = 2.0605021E-005
 $y = (M_y * L_s / 3) / E_{eff} = 0.00029051$ ((4.29), Biskinis Phd))
 $M_y = 4.2097E+008$
 $L_s = M/V$ (with $L_s > 0.1 * L$ and $L_s < 2 * L$) = 300.00
 From table 10.5, ASCE 41_17: $E_{eff} = factor * E_c * I_g = 1.4491E+014$
 $factor = 0.30$
 $A_g = 440000.00$
 Mean concrete strength: $f'_c = (f'_{c_jacket} * Area_{jacket} + f'_{c_core} * Area_{core}) / Area_{section} = 27.68182$
 $N = 16937.611$
 $E_c * I_g = E_{c_jacket} * I_{g_jacket} + E_{c_core} * I_{g_core} = 4.8303E+014$

Calculation of Yielding Moment M_y

Calculation of y and M_y according to Annex 7 -

Assuming neutral axis within flange ($y < t/d$, compression zone rectangular) with:

flange width, $b = 750.00$
 web width, $b_w = 400.00$
 flange thickness, $t = 400.00$

$y = \text{Min}(y_{ten}, y_{com})$
 $y_{ten} = 3.1431513E-006$
 with ((10.1), ASCE 41-17) $f_y = \text{Min}(f_y, 1.25 * f_y * (b/d)^{2/3}) = 358.4764$
 $d = 707.00$
 $y = 0.19342282$
 $A = 0.01018486$
 $B = 0.00449527$
 with $p_t = 0.00214476$
 $p_c = 0.00416509$
 $p_v = 0.00378591$
 $N = 16937.611$
 $b = 750.00$
 $" = 0.06082037$
 $y_{comp} = 1.6462780E-005$
 with f'_c (12.3, (ACI 440)) = 33.48734
 $f_c = 33.00$
 $f_l = 0.49678681$
 $b = b_{max} = 750.00$
 $h = h_{max} = 750.00$
 $A_g = 0.44$
 $g = p_t + p_c + p_v = 0.01009575$
 $r_c = 40.00$
 $A_e / A_c = 0.31291181$
 Effective FRP thickness, $t_f = N L * t * \text{Cos}(\theta_1) = 1.016$
 effective strain from (12.5) and (12.12), $\epsilon_{fe} = 0.004$
 $f_u = 0.01$
 $E_f = 64828.00$
 $E_c = 26999.444$
 $y = 0.19181197$
 $A = 0.01002422$
 $B = 0.00440616$
 with $E_s = 200000.00$
 CONFIRMATION: $y = 0.19278073 < t/d$

Calculation of ratio l_b/d

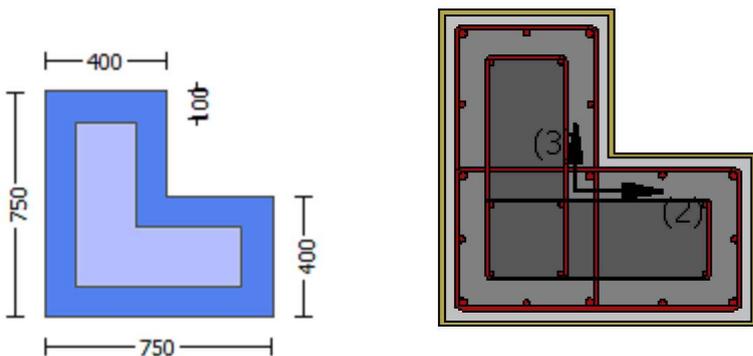
Lap Length: $l_d / l_{d,min} = 0.39803249$
 $l_b = 300.00$
 $l_d = 753.7073$
 Calculation of l according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
 $= 1$
 $db = 16.66667$

Mean strength value of all re-bars: $f_y = 524.4444$
 Mean concrete strength: $f_c' = (f_c'_{\text{jacket}} \cdot \text{Area}_{\text{jacket}} + f_c'_{\text{core}} \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 27.68182$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $t = 1.00$
 $s = 0.80$
 $e = 1.00$
 $cb = 25.00$
 $K_{tr} = 1.7174$
 $A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 257.6106$
 where A_{tr_x}, A_{tr_y} are the sum of the area of all stirrup legs along X and Y local axis
 $s = \text{Max}(s_{\text{external}}, s_{\text{internal}}) = 250.00$
 $n = 24.00$

End Of Calculation of Shear Capacity for element: column JLC1 of floor 1
 At local axis: 2
 Integration Section: (b)

Calculation No. 14

column C1, Floor 1
 Limit State: Life Safety (data interpolation between analysis steps 1 and 2)
 Analysis: Uniform +X
 Check: Chord rotation capacity (θ_r)
 Edge: End
 Local Axis: (2)



Start Of Calculation of Shear Capacity ratio for element: column JLC1 of floor 1
 At Shear local axis: 3
 (Bending local axis: 2)
 Section Type: rcjcs

Constant Properties

Knowledge Factor, $\phi = 0.85$
 Mean strength values are used for both shear and moment calculations.
 Consequently:
 Jacket

· New material of Secondary Member: Concrete Strength, $f_c = f_{cm} = 33.00$
 · New material of Secondary Member: Steel Strength, $f_s = f_{sm} = 555.5556$
 · Concrete Elasticity, $E_c = 26999.444$
 · Steel Elasticity, $E_s = 200000.00$
 · Existing Column
 · Existing material of Secondary Member: Concrete Strength, $f_c = f_{cm} = 20.00$
 · Existing material of Secondary Member: Steel Strength, $f_s = f_{sm} = 444.4444$
 · 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, $f_s = 1.25 \cdot f_{sm} = 694.4444$
 · Existing Column
 · Existing material: Steel Strength, $f_s = 1.25 \cdot f_{sm} = 555.5556$
 · #####
 · Max Height, $H_{max} = 750.00$
 · Min Height, $H_{min} = 400.00$
 · Max Width, $W_{max} = 750.00$
 · Min Width, $W_{min} = 400.00$
 · Jacket Thickness, $t_j = 100.00$
 · Cover Thickness, $c = 25.00$
 · Mean Confinement Factor overall section = 1.03889
 · Element Length, $L = 3000.00$
 · Secondary Member
 · Ribbed Bars
 · Ductile Steel
 · Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
 · Longitudinal Bars With Ends Lapped Starting at the End Sections
 · 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, $V_a = -0.00051441$
 · EDGE -B-
 · Shear Force, $V_b = 0.00051441$
 · BOTH EDGES
 · Axial Force, $F = -16273.616$
 · Longitudinal Reinforcement Area Distribution (in 2 divisions)
 · -Tension: $A_{sl,t} = 0.00$
 · -Compression: $A_{sl,c} = 5353.274$
 · Longitudinal Reinforcement Area Distribution (in 3 divisions)
 · -Tension: $A_{sl,ten} = 1137.257$
 · -Compression: $A_{sl,com} = 2208.54$
 · -Middle: $A_{sl,mid} = 2007.478$

· Calculation of Shear Capacity ratio , $V_e/V_r = 0.55377356$
 · Member Controlled by Flexure ($V_e/V_r < 1$)
 · Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 552827.824$

with
 $M_{pr1} = \text{Max}(\mu_{1+}, \mu_{1-}) = 8.2924E+008$
 $\mu_{1+} = 5.1260E+008$, 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
 $\mu_{1-} = 8.2924E+008$, 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
 $M_{pr2} = \text{Max}(\mu_{2+}, \mu_{2-}) = 8.2924E+008$
 $\mu_{2+} = 5.1260E+008$, 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
 $\mu_{2-} = 8.2924E+008$, 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 μ_{1+}

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

$\mu = 9.5578758E-006$
 $M_u = 5.1260E+008$

 with full section properties:

$b = 750.00$
 $d = 707.00$
 $d' = 43.00$
 $v = 0.00093001$
 $N = 16273.616$
 $f_c = 33.00$
 $\alpha (5A.5, \text{TBDY}) = 0.002$
 Final value of μ : $\mu^* = \text{shear_factor} * \text{Max}(\mu_c, \mu_{cc}) = 0.01288354$
 The Shear_factor is considered equal to 1 (pure moment strength)
 From (5.4b), TBDY: $\mu_c = 0.01288354$
 $\mu_{cc} ((5.4c), \text{TBDY}) = \alpha \cdot \text{sh}_{\min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.05503171$
 where $f = \alpha * \rho_f * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

 $f_x = 0.04286225$
 Expression ((15B.6), TBDY) is modified as $\alpha_f = 1 - (\text{Unconfined area}) / (\text{total area})$
 $\alpha_f = 0.31984848$

with Unconfined area = $((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 140733.333$
 $b_{\max} = 750.00$
 $h_{\max} = 750.00$
 From EC8 A.4.4.3(6), $\rho_f = 2t_f / b_w = 0.00508$
 $b_w = 400.00$
 effective stress from (A.35), $f_{fe} = 870.5244$

 $f_y = 0.04286225$
 Expression ((15B.6), TBDY) is modified as $\alpha_f = 1 - (\text{Unconfined area}) / (\text{total area})$
 $\alpha_f = 0.31984848$

with Unconfined area = $((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 140733.333$
 $b_{\max} = 750.00$
 $h_{\max} = 750.00$
 From EC8 A.4.4.3(6), $\rho_f = 2t_f / b_w = 0.00508$
 $b_w = 400.00$
 effective stress from (A.35), $f_{fe} = 870.5244$

 $R = 40.00$
 Effective FRP thickness, $t_f = N L * t * \text{Cos}(\beta_1) = 1.016$
 $f_{u,f} = 1055.00$
 $E_f = 64828.00$
 $u_{,f} = 0.015$

$\alpha_{se} ((5.4d), \text{TBDY}) = (\alpha_{se1} * A_{ext} + \alpha_{se2} * A_{int}) / A_{sec} = 0.45746528$
 $\alpha_{se1} = \text{Max}(((A_{conf,max1} - A_{noConf1}) / A_{conf,max1}) * (A_{conf,min1} / A_{conf,max1}), 0) = 0.45746528$
 The definitions of A_{noConf} , $A_{conf,min}$ and $A_{conf,max}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).
 The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988) "Theoretical Stress-Strain Model for Confined Concrete."
 J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

Aconf,max1 = 353600.00 is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

Aconf,min1 = 293525.00 is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area Aconf,max1 by a length equal to half the clear spacing between external hoops.

AnoConf1 = 158733.333 is the unconfined external core area which is equal to $b_i^2/6$ as defined at (A.2).
ase2 (>=ase1) = $\text{Max}(((Aconf,max2 - AnoConf2)/Aconf,max2) * (Aconf,min2/Aconf,max2), 0) = 0.45746528$

The definitions of AnoConf, Aconf,min and Aconf,max are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988) "Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

Aconf,max2 = 171264.00 is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

Aconf,min2 = 54741.00 is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area Aconf,max2 by a length equal to half the clear spacing between internal hoops.

AnoConf2 = 106242.667 is the unconfined internal core area which is equal to $b_i^2/6$ as defined at (A.2).

psh,min*Fywe = $\text{Min}(psh,x*Fywe, psh,y*Fywe) = 2.92621$

Expression (5.4d) 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 = 2.92621

psh1 ((5.4d), TBDY) = $Lstir1 * Astir1 / (Asec * s1) = 0.00367709$

Lstir1 (Length of stirrups along Y) = 2060.00

Astir1 (stirrups area) = 78.53982

psh2 (5.4d) = $Lstir2 * Astir2 / (Asec * s2) = 0.00067082$

Lstir2 (Length of stirrups along Y) = 1468.00

Astir2 (stirrups area) = 50.26548

psh_y*Fywe = psh1*Fywe1 + ps2*Fywe2 = 2.92621

psh1 ((5.4d), TBDY) = $Lstir1 * Astir1 / (Asec * s1) = 0.00367709$

Lstir1 (Length of stirrups along X) = 2060.00

Astir1 (stirrups area) = 78.53982

psh2 ((5.4d), TBDY) = $Lstir2 * Astir2 / (Asec * s2) = 0.00067082$

Lstir2 (Length of stirrups along X) = 1468.00

Astir2 (stirrups area) = 50.26548

Asec = 440000.00

s1 = 100.00

s2 = 250.00

fywe1 = 694.4444

fywe2 = 555.5556

fce = 33.00

From ((5.A5), TBDY), TBDY: cc = 0.00238888

c = confinement factor = 1.03889

y1 = 0.00145721

sh1 = 0.00466307

ft1 = 459.4373

fy1 = 382.8645

su1 = 0.00582756

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 = 0.318426

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 = $(fs_jacket * Asl,ten,jacket + fs_core * Asl,ten,core) / Asl,ten = 382.8645$

with Es1 = $(Es_jacket * Asl,ten,jacket + Es_core * Asl,ten,core) / Asl,ten = 200000.00$

y2 = 0.00145721

sh2 = 0.00466307

ft2 = 465.423

fy2 = 387.8525

su2 = 0.00582756

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

$l_o/l_{o,min} = l_b/l_{b,min} = 0.318426$

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

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 $Min(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE 41-17.

with $fs_2 = (fs_{jacket} * A_{sl,com,jacket} + fs_{core} * A_{sl,com,core}) / A_{sl,com} = 387.8525$

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

$y_v = 0.00145721$

$sh_v = 0.00466307$

$ft_v = 463.3885$

$fy_v = 386.157$

$su_v = 0.00582756$

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

$l_o/l_{o,min} = l_b/l_d = 0.318426$

$su_v = 0.4 * esu_{v,nominal} ((5.5), TBDY) = 0.032$

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

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

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

with $fsv = (fs_{jacket} * A_{sl,mid,jacket} + fs_{mid} * A_{sl,mid,core}) / A_{sl,mid} = 386.157$

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

$1 = A_{sl,ten} / (b * d) * (fs_1 / fc) = 0.02488335$

$2 = A_{sl,com} / (b * d) * (fs_2 / fc) = 0.04895276$

$v = A_{sl,mid} / (b * d) * (fsv / fc) = 0.04430167$

and confined core properties:

$b = 690.00$

$d = 677.00$

$d' = 13.00$

$fcc (5A.2, TBDY) = 34.2833$

$cc (5A.5, TBDY) = 0.00238888$

$c = \text{confinement factor} = 1.03889$

$1 = A_{sl,ten} / (b * d) * (fs_1 / fc) = 0.02824566$

$2 = A_{sl,com} / (b * d) * (fs_2 / fc) = 0.05556741$

$v = A_{sl,mid} / (b * d) * (fsv / fc) = 0.05028784$

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

--->

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

--->

$su (4.9) = 0.13760581$

$Mu = MRc (4.14) = 5.1260E+008$

$u = su (4.1) = 9.5578758E-006$

Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.318426$

$l_b = 300.00$

$l_d = 942.1341$

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: $fy = 655.5556$

Mean concrete strength: $fc' = (fc'_{jacket} * Area_{jacket} + fc'_{core} * Area_{core}) / Area_{section} = 27.68182$, but $fc'^{0.5} < =$
8.3 MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 1.7174$

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

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

$$s = \text{Max}(s_{\text{external}}, s_{\text{internal}}) = 250.00$$

$$n = 24.00$$

Calculation of μ_1 -

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

$$\mu = 1.0408734E-005$$

$$\mu_1 = 8.2924E+008$$

with full section properties:

$$b = 400.00$$

$$d = 707.00$$

$$d' = 43.00$$

$$v = 0.00174378$$

$$N = 16273.616$$

$$f_c = 33.00$$

$$c_0 \text{ (5A.5, TBDY)} = 0.002$$

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.01288354$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } c_u = 0.01288354$$

$$w_e \text{ ((5.4c), TBDY)} = a_{se} * s_{h,\text{min}} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.05503171$$

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

$$f_x = 0.04286225$$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.31984848$$

$$\text{with Unconfined area} = ((b_{\text{max}} - 2R)^2 + (h_{\text{max}} - 2R)^2) / 3 = 140733.333$$

$$b_{\text{max}} = 750.00$$

$$h_{\text{max}} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 870.5244$$

$$f_y = 0.04286225$$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.31984848$$

$$\text{with Unconfined area} = ((b_{\text{max}} - 2R)^2 + (h_{\text{max}} - 2R)^2) / 3 = 140733.333$$

$$b_{\text{max}} = 750.00$$

$$h_{\text{max}} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 870.5244$$

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$a_{se} \text{ ((5.4d), TBDY)} = (a_{se1} * A_{\text{ext}} + a_{se2} * A_{\text{int}}) / A_{\text{sec}} = 0.45746528$$

$$a_{se1} = \text{Max}(((A_{\text{conf,max1}} - A_{\text{noConf1}}) / A_{\text{conf,max1}}) * (A_{\text{conf,min1}} / A_{\text{conf,max1}}), 0) = 0.45746528$$

The definitions of A_{noConf} , $A_{\text{conf,min}}$ and $A_{\text{conf,max}}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{\text{conf,max1}} = 353600.00$ is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{\text{conf,min1}} = 293525.00$ is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area $A_{\text{conf,max1}}$ by a length

equal to half the clear spacing between external hoops.

$A_{\text{noConf1}} = 158733.333$ is the unconfined external core area which is equal to $b_i^2/6$ as defined at (A.2).

$$ase2 (>= ase1) = \text{Max}(((Aconf,max2 - AnoConf2)/Aconf,max2) * (Aconf,min2/Aconf,max2), 0) = 0.45746528$$

The definitions of AnoConf, Aconf,min and Aconf,max are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988) "Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

Aconf,max2 = 171264.00 is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

Aconf,min2 = 54741.00 is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area Aconf,max2 by a length equal to half the clear spacing between internal hoops.

AnoConf2 = 106242.667 is the unconfined internal core area which is equal to $bi^2/6$ as defined at (A.2).

$$psh,min * Fywe = \text{Min}(psh,x * Fywe, psh,y * Fywe) = 2.92621$$

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

$$psh,x * Fywe = psh1 * Fywe1 + ps2 * Fywe2 = 2.92621$$

$$psh1 \text{ ((5.4d), TBDY)} = Lstir1 * Astir1 / (Asec * s1) = 0.00367709$$

$$Lstir1 \text{ (Length of stirrups along Y)} = 2060.00$$

$$Astir1 \text{ (stirrups area)} = 78.53982$$

$$psh2 \text{ (5.4d)} = Lstir2 * Astir2 / (Asec * s2) = 0.00067082$$

$$Lstir2 \text{ (Length of stirrups along Y)} = 1468.00$$

$$Astir2 \text{ (stirrups area)} = 50.26548$$

$$psh,y * Fywe = psh1 * Fywe1 + ps2 * Fywe2 = 2.92621$$

$$psh1 \text{ ((5.4d), TBDY)} = Lstir1 * Astir1 / (Asec * s1) = 0.00367709$$

$$Lstir1 \text{ (Length of stirrups along X)} = 2060.00$$

$$Astir1 \text{ (stirrups area)} = 78.53982$$

$$psh2 \text{ ((5.4d), TBDY)} = Lstir2 * Astir2 / (Asec * s2) = 0.00067082$$

$$Lstir2 \text{ (Length of stirrups along X)} = 1468.00$$

$$Astir2 \text{ (stirrups area)} = 50.26548$$

$$Asec = 440000.00$$

$$s1 = 100.00$$

$$s2 = 250.00$$

$$fywe1 = 694.4444$$

$$fywe2 = 555.5556$$

$$fce = 33.00$$

$$\text{From ((5.A5), TBDY), TBDY: } cc = 0.00238888$$

$$c = \text{confinement factor} = 1.03889$$

$$y1 = 0.00145721$$

$$sh1 = 0.00466307$$

$$ft1 = 465.423$$

$$fy1 = 387.8525$$

$$su1 = 0.00582756$$

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

$$lo/lou,min = lb/l_d = 0.318426$$

$$su1 = 0.4 * esu1_nominal \text{ ((5.5), TBDY)} = 0.032$$

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 $\text{Min}(1, 1.25 * (lb/l_d)^{2/3})$, from 10.3.5, ASCE 41-17.

$$\text{with } fs1 = (fs,jacket * Asl,ten,jacket + fs,core * Asl,ten,core) / Asl,ten = 387.8525$$

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

$$y2 = 0.00145721$$

$$sh2 = 0.00466307$$

$$ft2 = 459.4373$$

$$fy2 = 382.8645$$

$$su2 = 0.00582756$$

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

$$lo/lou,min = lb/l_b,min = 0.318426$$

$$su2 = 0.4 * esu2_nominal \text{ ((5.5), TBDY)} = 0.032$$

From table 5A.1, TBDY: esu2_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_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 $fs_2 = (fs_{jacket} \cdot Asl_{com,jacket} + fs_{core} \cdot Asl_{com,core}) / Asl_{com} = 382.8645$

with $Es_2 = (Es_{jacket} \cdot Asl_{com,jacket} + Es_{core} \cdot Asl_{com,core}) / Asl_{com} = 200000.00$

$y_v = 0.00145721$

$sh_v = 0.00466307$

$ft_v = 463.3885$

$fy_v = 386.157$

$suv = 0.00582756$

using (30) in Bisquinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$lo/lo_{u,min} = lb/ld = 0.318426$

$suv = 0.4 \cdot es_{uv_nominal} ((5,5), TBDY) = 0.032$

From table 5A.1, TBDY: $es_{uv_nominal} = 0.08$,

considering characteristic value $fs_{yv} = fs_v/1.2$, 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 $fs_{yv} = fs_v/1.2$, from table 5.1, TBDY.

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

with $fs_v = (fs_{jacket} \cdot Asl_{mid,jacket} + fs_{mid} \cdot Asl_{mid,core}) / Asl_{mid} = 386.157$

with $Es_v = (Es_{jacket} \cdot Asl_{mid,jacket} + Es_{mid} \cdot Asl_{mid,core}) / Asl_{mid} = 200000.00$

$1 = Asl_{ten} / (b \cdot d) \cdot (fs_1 / fc) = 0.09178643$

$2 = Asl_{com} / (b \cdot d) \cdot (fs_2 / fc) = 0.04665628$

$v = Asl_{mid} / (b \cdot d) \cdot (fs_v / fc) = 0.08306563$

and confined core properties:

$b = 340.00$

$d = 677.00$

$d' = 13.00$

fcc (5A.2, TBDY) = 34.2833

cc (5A.5, TBDY) = 0.00238888

c = confinement factor = 1.03889

$1 = Asl_{ten} / (b \cdot d) \cdot (fs_1 / fc) = 0.11276915$

$2 = Asl_{com} / (b \cdot d) \cdot (fs_2 / fc) = 0.05732208$

$v = Asl_{mid} / (b \cdot d) \cdot (fs_v / fc) = 0.10205474$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

su (4.9) = 0.20810191

$Mu = MRc$ (4.14) = 8.2924E+008

$u = su$ (4.1) = 1.0408734E-005

Calculation of ratio lb/ld

Lap Length: $lb/ld = 0.318426$

$lb = 300.00$

$ld = 942.1341$

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: $fy = 655.5556$

Mean concrete strength: $fc' = (fc'_{jacket} \cdot Area_{jacket} + fc'_{core} \cdot Area_{core}) / Area_{section} = 27.68182$, but $fc'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 1.7174$

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

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

$s = \text{Max}(s_{external}, s_{internal}) = 250.00$

$n = 24.00$

Calculation of μ_{2+}

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

$$\mu = 9.5578758E-006$$

$$\mu = 5.1260E+008$$

with full section properties:

$$b = 750.00$$

$$d = 707.00$$

$$d' = 43.00$$

$$v = 0.00093001$$

$$N = 16273.616$$

$$f_c = 33.00$$

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

$$\text{Final value of } \mu: \mu = \text{shear_factor} * \text{Max}(\mu_c, \mu_{cc}) = 0.01288354$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \mu_c = 0.01288354$$

$$\mu_{cc} ((5.4c), TBDY) = a_{se} * s_{h, \min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.05503171$$

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

$$f_x = 0.04286225$$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.31984848$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 140733.333$$

$$b_{\max} = 750.00$$

$$h_{\max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{fe} = 870.5244$$

$$f_y = 0.04286225$$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.31984848$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 140733.333$$

$$b_{\max} = 750.00$$

$$h_{\max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{fe} = 870.5244$$

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u_{f} = 0.015$$

$$a_{se} ((5.4d), TBDY) = (a_{se1} * A_{ext} + a_{se2} * A_{int}) / A_{sec} = 0.45746528$$

$$a_{se1} = \text{Max}(((A_{\text{conf,max1}} - A_{\text{noConf1}}) / A_{\text{conf,max1}}) * (A_{\text{conf,min1}} / A_{\text{conf,max1}}), 0) = 0.45746528$$

The definitions of A_{noConf} , $A_{\text{conf,min}}$ and $A_{\text{conf,max}}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{\text{conf,max1}} = 353600.00$ is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{\text{conf,min1}} = 293525.00$ is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area $A_{\text{conf,max1}}$ by a length

equal to half the clear spacing between external hoops.

$A_{\text{noConf1}} = 158733.333$ is the unconfined external core area which is equal to $b_i^2/6$ as defined at (A.2).

$$a_{se2} (>= a_{se1}) = \text{Max}(((A_{\text{conf,max2}} - A_{\text{noConf2}}) / A_{\text{conf,max2}}) * (A_{\text{conf,min2}} / A_{\text{conf,max2}}), 0) = 0.45746528$$

The definitions of A_{noConf} , $A_{\text{conf,min}}$ and $A_{\text{conf,max}}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

Aconf,max2 = 171264.00 is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

Aconf,min2 = 54741.00 is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area Aconf,max2 by a length equal to half the clear spacing between internal hoops.

AnoConf2 = 106242.667 is the unconfined internal core area which is equal to $b_i^2/6$ as defined at (A.2).

$$psh_{min} \cdot F_{ywe} = \text{Min}(psh_x \cdot F_{ywe}, psh_y \cdot F_{ywe}) = 2.92621$$

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

$$psh_x \cdot F_{ywe} = psh1 \cdot F_{ywe1} + ps2 \cdot F_{ywe2} = 2.92621$$
$$psh1 \text{ ((5.4d), TBDY)} = L_{stir1} \cdot A_{stir1} / (A_{sec} \cdot s1) = 0.00367709$$

Lstir1 (Length of stirrups along Y) = 2060.00
Astir1 (stirrups area) = 78.53982

$$psh2 \text{ (5.4d)} = L_{stir2} \cdot A_{stir2} / (A_{sec} \cdot s2) = 0.00067082$$

Lstir2 (Length of stirrups along Y) = 1468.00
Astir2 (stirrups area) = 50.26548

$$psh_y \cdot F_{ywe} = psh1 \cdot F_{ywe1} + ps2 \cdot F_{ywe2} = 2.92621$$
$$psh1 \text{ ((5.4d), TBDY)} = L_{stir1} \cdot A_{stir1} / (A_{sec} \cdot s1) = 0.00367709$$

Lstir1 (Length of stirrups along X) = 2060.00
Astir1 (stirrups area) = 78.53982

$$psh2 \text{ ((5.4d), TBDY)} = L_{stir2} \cdot A_{stir2} / (A_{sec} \cdot s2) = 0.00067082$$

Lstir2 (Length of stirrups along X) = 1468.00
Astir2 (stirrups area) = 50.26548

$$A_{sec} = 440000.00$$

$$s1 = 100.00$$

$$s2 = 250.00$$

$$fy_{we1} = 694.4444$$

$$fy_{we2} = 555.5556$$

$$f_{ce} = 33.00$$

$$\text{From ((5.A5), TBDY), TBDY: } cc = 0.00238888$$

$$c = \text{confinement factor} = 1.03889$$

$$y1 = 0.00145721$$

$$sh1 = 0.00466307$$

$$ft1 = 459.4373$$

$$fy1 = 382.8645$$

$$su1 = 0.00582756$$

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

$$l_o/l_{o,min} = l_b/l_d = 0.318426$$

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

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

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

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

$$\text{with } fs1 = (f_{s,jacket} \cdot A_{sl,ten,jacket} + f_{s,core} \cdot A_{sl,ten,core}) / A_{sl,ten} = 382.8645$$

$$\text{with } Es1 = (E_{s,jacket} \cdot A_{sl,ten,jacket} + E_{s,core} \cdot A_{sl,ten,core}) / A_{sl,ten} = 200000.00$$

$$y2 = 0.00145721$$

$$sh2 = 0.00466307$$

$$ft2 = 465.423$$

$$fy2 = 387.8525$$

$$su2 = 0.00582756$$

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

$$l_o/l_{o,min} = l_b/l_{b,min} = 0.318426$$

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

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

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

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

$$\text{with } fs2 = (f_{s,jacket} \cdot A_{sl,com,jacket} + f_{s,core} \cdot A_{sl,com,core}) / A_{sl,com} = 387.8525$$

$$\text{with } Es2 = (E_{s,jacket} \cdot A_{sl,com,jacket} + E_{s,core} \cdot A_{sl,com,core}) / A_{sl,com} = 200000.00$$

$$y_v = 0.00145721$$

$shv = 0.00466307$
 $ftv = 463.3885$
 $fyv = 386.157$
 $suv = 0.00582756$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 $Shear_factor = 1.00$
 $lo/lou,min = lb/ld = 0.318426$
 $suv = 0.4 * esuv_nominal ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $esuv_nominal = 0.08$,
 considering characteristic value $fsv = fsv/1.2$, from table 5.1, TBDY
 For calculation of $esuv_nominal$ and yv , shv,ftv,fyv , it is considered
 characteristic value $fsv = fsv/1.2$, 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 $fsv = (fs,jacket*Asl,mid,jacket + fs,mid*Asl,mid,core)/Asl,mid = 386.157$
 with $Esv = (Es,jacket*Asl,mid,jacket + Es,mid*Asl,mid,core)/Asl,mid = 200000.00$
 $1 = Asl,ten/(b*d)*(fs1/fc) = 0.02488335$
 $2 = Asl,com/(b*d)*(fs2/fc) = 0.04895276$
 $v = Asl,mid/(b*d)*(fsv/fc) = 0.04430167$

and confined core properties:

$b = 690.00$
 $d = 677.00$
 $d' = 13.00$
 $fcc (5A.2, TBDY) = 34.2833$
 $cc (5A.5, TBDY) = 0.00238888$
 $c = \text{confinement factor} = 1.03889$
 $1 = Asl,ten/(b*d)*(fs1/fc) = 0.02824566$
 $2 = Asl,com/(b*d)*(fs2/fc) = 0.05556741$
 $v = Asl,mid/(b*d)*(fsv/fc) = 0.05028784$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

$v < vs,y2$ - LHS eq.(4.5) is satisfied

$su (4.9) = 0.13760581$
 $Mu = MRc (4.14) = 5.1260E+008$
 $u = su (4.1) = 9.5578758E-006$

 Calculation of ratio lb/ld

Lap Length: $lb/ld = 0.318426$

$lb = 300.00$

$ld = 942.1341$

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: $fy = 655.5556$

Mean concrete strength: $fc' = (fc',jacket*Area,jacket + fc',core*Area,core)/Area,section = 27.68182$, but $fc'^{0.5} <=$
 8.3 MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$Ktr = 1.7174$

$Atr = Min(Atr,x,Atr,y) = 257.6106$

where Atr,x, Atr,y are the sum of the area of all stirrup legs along X and Y local axis

$s = Max(s,external,s,internal) = 250.00$

$n = 24.00$

 Calculation of $Mu2$ -

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

u = 1.0408734E-005
Mu = 8.2924E+008

with full section properties:

b = 400.00
d = 707.00
d' = 43.00
v = 0.00174378
N = 16273.616
fc = 33.00
co (5A.5, TBDY) = 0.002

Final value of cu: $cu^* = \text{shear_factor} * \text{Max}(cu, cc) = 0.01288354$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $cu = 0.01288354$

$we ((5.4c), TBDY) = ase * sh_{min} * fy_{we} / f_{ce} + \text{Min}(fx, fy) = 0.05503171$

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

$fx = 0.04286225$

Expression ((15B.6), TBDY) is modified as $af = 1 - (\text{Unconfined area}) / (\text{total area})$

$af = 0.31984848$

with Unconfined area = $((b_{max} - 2R)^2 + (h_{max} - 2R)^2) / 3 = 140733.333$

$b_{max} = 750.00$

$h_{max} = 750.00$

From EC8 A 4.4.3(6), $pf = 2tf / bw = 0.00508$

$bw = 400.00$

effective stress from (A.35), $ff_{e} = 870.5244$

$fy = 0.04286225$

Expression ((15B.6), TBDY) is modified as $af = 1 - (\text{Unconfined area}) / (\text{total area})$

$af = 0.31984848$

with Unconfined area = $((b_{max} - 2R)^2 + (h_{max} - 2R)^2) / 3 = 140733.333$

$b_{max} = 750.00$

$h_{max} = 750.00$

From EC8 A 4.4.3(6), $pf = 2tf / bw = 0.00508$

$bw = 400.00$

effective stress from (A.35), $ff_{e} = 870.5244$

R = 40.00

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

$fu_{f} = 1055.00$

$E_{f} = 64828.00$

$u_{f} = 0.015$

$ase ((5.4d), TBDY) = (ase1 * A_{ext} + ase2 * A_{int}) / A_{sec} = 0.45746528$

$ase1 = \text{Max}(((A_{conf,max1} - A_{noConf1}) / A_{conf,max1}) * (A_{conf,min1} / A_{conf,max1}), 0) = 0.45746528$

The definitions of A_{noConf} , $A_{conf,min}$ and $A_{conf,max}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max1} = 353600.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{conf,min1} = 293525.00$ is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area $A_{conf,max1}$ by a length equal to half the clear spacing between external hoops.

$A_{noConf1} = 158733.333$ is the unconfined external core area which is equal to $b_i^2/6$ as defined at (A.2).

$ase2 (>= ase1) = \text{Max}(((A_{conf,max2} - A_{noConf2}) / A_{conf,max2}) * (A_{conf,min2} / A_{conf,max2}), 0) = 0.45746528$

The definitions of A_{noConf} , $A_{conf,min}$ and $A_{conf,max}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max2} = 171264.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

$A_{conf,min2} = 54741.00$ is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area $A_{conf,max2}$ by a length equal to half the clear spacing between internal hoops.

$A_{noConf2} = 106242.667$ is the unconfined internal core area which is equal to $b_i^2/6$ as defined at (A.2).

$$psh_{min} * Fy_{we} = \text{Min}(psh_x * Fy_{we}, psh_y * Fy_{we}) = 2.92621$$

Expression (5.4d) 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)

$$psh_x * Fy_{we} = psh1 * Fy_{we1} + ps2 * Fy_{we2} = 2.92621$$

$$psh1 \text{ ((5.4d), TBDY)} = Lstir1 * Astir1 / (Asec * s1) = 0.00367709$$

$$Lstir1 \text{ (Length of stirrups along Y)} = 2060.00$$

$$Astir1 \text{ (stirrups area)} = 78.53982$$

$$psh2 \text{ (5.4d)} = Lstir2 * Astir2 / (Asec * s2) = 0.00067082$$

$$Lstir2 \text{ (Length of stirrups along Y)} = 1468.00$$

$$Astir2 \text{ (stirrups area)} = 50.26548$$

$$psh_y * Fy_{we} = psh1 * Fy_{we1} + ps2 * Fy_{we2} = 2.92621$$

$$psh1 \text{ ((5.4d), TBDY)} = Lstir1 * Astir1 / (Asec * s1) = 0.00367709$$

$$Lstir1 \text{ (Length of stirrups along X)} = 2060.00$$

$$Astir1 \text{ (stirrups area)} = 78.53982$$

$$psh2 \text{ ((5.4d), TBDY)} = Lstir2 * Astir2 / (Asec * s2) = 0.00067082$$

$$Lstir2 \text{ (Length of stirrups along X)} = 1468.00$$

$$Astir2 \text{ (stirrups area)} = 50.26548$$

$$Asec = 440000.00$$

$$s1 = 100.00$$

$$s2 = 250.00$$

$$fy_{we1} = 694.4444$$

$$fy_{we2} = 555.5556$$

$$f_{ce} = 33.00$$

$$\text{From ((5.A5), TBDY), TBDY: } cc = 0.00238888$$

$$c = \text{confinement factor} = 1.03889$$

$$y1 = 0.00145721$$

$$sh1 = 0.00466307$$

$$ft1 = 465.423$$

$$fy1 = 387.8525$$

$$su1 = 0.00582756$$

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

$$lo/lou_{min} = lb/ld = 0.318426$$

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

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.

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

$$\text{with } fs1 = (fs_{jacket} * Asl_{ten,jacket} + fs_{core} * Asl_{ten,core}) / Asl_{ten} = 387.8525$$

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

$$y2 = 0.00145721$$

$$sh2 = 0.00466307$$

$$ft2 = 459.4373$$

$$fy2 = 382.8645$$

$$su2 = 0.00582756$$

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

$$lo/lou_{min} = lb/lb_{min} = 0.318426$$

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

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.

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

$$\text{with } fs2 = (fs_{jacket} * Asl_{com,jacket} + fs_{core} * Asl_{com,core}) / Asl_{com} = 382.8645$$

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

$$y_v = 0.00145721$$

$$sh_v = 0.00466307$$

$$ft_v = 463.3885$$

$$fy_v = 386.157$$

$$su_v = 0.00582756$$

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

lb/lou,min = lb/ld = 0.318426

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 = (fsjacket*Asl,mid,jacket + fs,mid*Asl,mid,core)/Asl,mid = 386.157

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

1 = Asl,ten/(b*d)*(fs1/fc) = 0.09178643

2 = Asl,com/(b*d)*(fs2/fc) = 0.04665628

v = Asl,mid/(b*d)*(fsv/fc) = 0.08306563

and confined core properties:

b = 340.00

d = 677.00

d' = 13.00

fcc (5A.2, TBDY) = 34.2833

cc (5A.5, TBDY) = 0.00238888

c = confinement factor = 1.03889

1 = Asl,ten/(b*d)*(fs1/fc) = 0.11276915

2 = Asl,com/(b*d)*(fs2/fc) = 0.05732208

v = Asl,mid/(b*d)*(fsv/fc) = 0.10205474

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

v < vs,y2 - LHS eq.(4.5) is satisfied

su (4.9) = 0.20810191

Mu = MRc (4.14) = 8.2924E+008

u = su (4.1) = 1.0408734E-005

Calculation of ratio lb/ld

Lap Length: lb/ld = 0.318426

lb = 300.00

ld = 942.1341

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 = 655.5556

Mean concrete strength: fc' = (fc'_jacket*Area_jacket + fc'_core*Area_core)/Area_section = 27.68182, but $fc'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

t = 1.00

s = 0.80

e = 1.00

cb = 25.00

Ktr = 1.7174

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 = $\text{Max}(s_{\text{external}}, s_{\text{internal}})$ = 250.00

n = 24.00

Calculation of Shear Strength Vr = $\text{Min}(Vr1, Vr2)$ = 998292.205

Calculation of Shear Strength at edge 1, Vr1 = 998292.205

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

VCol0 = 998292.205

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: $f_c' = (f_c'_{\text{jacket}} \cdot \text{Area}_{\text{jacket}} + f_c'_{\text{core}} \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 27.68182$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 4.00$

$\mu_u = 11.77537$

$V_u = 0.00051441$

$d = 0.8 \cdot h = 600.00$

$N_u = 16273.616$

$A_g = 300000.00$

From (11.5.4.8), ACI 318-14: $V_s = V_{s,\text{jacket}} + V_{s,\text{core}} = 881489.011$

where:

$V_{s,\text{jacket}} = V_{s,j1} + V_{s,j2} = 802851.456$

$V_{s,j1} = 523598.776$ is calculated for section web jacket, with:

$d = 600.00$

$A_v = 157079.633$

$f_y = 555.5556$

$s = 100.00$

$V_{s,j1}$ is multiplied by $\text{Col},j1 = 1.00$

$s/d = 0.16666667$

$V_{s,j2} = 279252.68$ is calculated for section flange jacket, with:

$d = 320.00$

$A_v = 157079.633$

$f_y = 555.5556$

$s = 100.00$

$V_{s,j2}$ is multiplied by $\text{Col},j2 = 1.00$

$s/d = 0.3125$

$V_{s,\text{core}} = V_{s,c1} + V_{s,c2} = 78637.555$

$V_{s,c1} = 78637.555$ is calculated for section web core, with:

$d = 440.00$

$A_v = 100530.965$

$f_y = 444.4444$

$s = 250.00$

$V_{s,c1}$ is multiplied by $\text{Col},c1 = 1.00$

$s/d = 0.56818182$

$V_{s,c2} = 0.00$ is calculated for section flange core, with:

$d = 160.00$

$A_v = 100530.965$

$f_y = 444.4444$

$s = 250.00$

$V_{s,c2}$ is multiplied by $\text{Col},c2 = 0.00$

$s/d = 1.5625$

V_f ((11-3)-(11.4), ACI 440) = 372533.843

$f = 0.95$, for fully-wrapped sections

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

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

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

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

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

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

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

$d_{fv} = d$ (figure 11.2, ACI 440) = 707.00

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: $V_s + V_f \leq 838832.606$

$b_w = 400.00$

Calculation of Shear Strength at edge 2, $V_{r2} = 998292.205$

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

$V_{\text{Col}0} = 998292.205$

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

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

= 1 (normal-weight concrete)
 Mean concrete strength: $f'_c = (f'_c \text{ jacket} \cdot \text{Area}_{\text{jacket}} + f'_c \text{ core} \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 27.68182$, but $f'_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $M/Vd = 4.00$
 $\mu_u = 11.77482$
 $V_u = 0.00051441$
 $d = 0.8 \cdot h = 600.00$
 $N_u = 16273.616$
 $A_g = 300000.00$
 From (11.5.4.8), ACI 318-14: $V_s = V_{s,\text{jacket}} + V_{s,\text{core}} = 881489.011$
 where:
 $V_{s,\text{jacket}} = V_{s,j1} + V_{s,j2} = 802851.456$
 $V_{s,j1} = 523598.776$ is calculated for section web jacket, with:
 $d = 600.00$
 $A_v = 157079.633$
 $f_y = 555.5556$
 $s = 100.00$
 $V_{s,j1}$ is multiplied by $\text{Col},j1 = 1.00$
 $s/d = 0.16666667$
 $V_{s,j2} = 279252.68$ is calculated for section flange jacket, with:
 $d = 320.00$
 $A_v = 157079.633$
 $f_y = 555.5556$
 $s = 100.00$
 $V_{s,j2}$ is multiplied by $\text{Col},j2 = 1.00$
 $s/d = 0.3125$
 $V_{s,\text{core}} = V_{s,c1} + V_{s,c2} = 78637.555$
 $V_{s,c1} = 78637.555$ is calculated for section web core, with:
 $d = 440.00$
 $A_v = 100530.965$
 $f_y = 444.4444$
 $s = 250.00$
 $V_{s,c1}$ is multiplied by $\text{Col},c1 = 1.00$
 $s/d = 0.56818182$
 $V_{s,c2} = 0.00$ is calculated for section flange core, with:
 $d = 160.00$
 $A_v = 100530.965$
 $f_y = 444.4444$
 $s = 250.00$
 $V_{s,c2}$ is multiplied by $\text{Col},c2 = 0.00$
 $s/d = 1.5625$
 V_f ((11-3)-(11.4), ACI 440) = 372533.843
 $f = 0.95$, for fully-wrapped sections
 $w_f/s_f = 1$ (FRP strips adjacent to one another).
 In (11.3) $\sin \theta + \cos \theta$ is replaced with $(\cot \theta + \cot \alpha) \sin \alpha$ which is more a generalised expression,
 where θ is the angle of the crack direction (see KANEPE).
 This later relation, considered as a function $V_f(\theta, \alpha)$, is implemented for every different fiber orientation α_i ,
 as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.
 orientation 1: $\theta = 45^\circ + 90^\circ = 135^\circ$
 $V_f = \text{Min}(|V_f(45^\circ, \alpha)|, |V_f(-45^\circ, \alpha)|)$, with:
 total thickness per orientation, $t_{f1} = N_L \cdot t / N_{\text{Dir}} = 1.016$
 $d_{fv} = d$ (figure 11.2, ACI 440) = 707.00
 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: $V_s + V_f \leq 838832.606$
 $b_w = 400.00$

End Of Calculation of Shear Capacity ratio for element: column JLC1 of floor 1
 At local axis: 3

Start Of Calculation of Shear Capacity ratio for element: column JLC1 of floor 1

At Shear local axis: 2

(Bending local axis: 3)

Section Type: rcjcs

Constant Properties

Knowledge Factor, $\gamma = 0.85$

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

Consequently:

Jacket

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

New material of Secondary Member: Steel Strength, $f_s = f_{sm} = 555.5556$

Concrete Elasticity, $E_c = 26999.444$

Steel Elasticity, $E_s = 200000.00$

Existing Column

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

Existing material of Secondary Member: Steel Strength, $f_s = f_{sm} = 444.4444$

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, $f_s = 1.25 * f_{sm} = 694.4444$

Existing Column

Existing material: Steel Strength, $f_s = 1.25 * f_{sm} = 555.5556$

#####

Max Height, $H_{max} = 750.00$

Min Height, $H_{min} = 400.00$

Max Width, $W_{max} = 750.00$

Min Width, $W_{min} = 400.00$

Jacket Thickness, $t_j = 100.00$

Cover Thickness, $c = 25.00$

Mean Confinement Factor overall section = 1.03889

Element Length, $L = 3000.00$

Secondary Member

Ribbed Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

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, $V_a = -0.00051441$

EDGE -B-

Shear Force, $V_b = 0.00051441$

BOTH EDGES

Axial Force, $F = -16273.616$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: $A_{st} = 0.00$

-Compression: $A_{sc} = 5353.274$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension: $Asl,ten = 1137.257$

-Compression: $Asl,com = 2208.54$

-Middle: $Asl,mid = 2007.478$

Calculation of Shear Capacity ratio , $Ve/Vr = 0.55377356$

Member Controlled by Flexure ($Ve/Vr < 1$)

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $Ve = (Mpr1 + Mpr2)/ln = 552827.824$

with

$Mpr1 = \text{Max}(Mu1+, Mu1-) = 8.2924E+008$

$Mu1+ = 5.1260E+008$, is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination

$Mu1- = 8.2924E+008$, is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination

$Mpr2 = \text{Max}(Mu2+, Mu2-) = 8.2924E+008$

$Mu2+ = 5.1260E+008$, 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

$Mu2- = 8.2924E+008$, 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 u according to 4.1, Biskinis/Fardis 2013:

$u = 9.5578758E-006$

$Mu = 5.1260E+008$

with full section properties:

$b = 750.00$

$d = 707.00$

$d' = 43.00$

$v = 0.00093001$

$N = 16273.616$

$fc = 33.00$

co (5A.5, TBDY) = 0.002

Final value of cu : $cu^* = \text{shear_factor} * \text{Max}(cu, cc) = 0.01288354$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $cu = 0.01288354$

we ((5.4c), TBDY) = $ase * sh, \text{min} * fywe / fce + \text{Min}(fx, fy) = 0.05503171$

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

$fx = 0.04286225$

Expression ((15B.6), TBDY) is modified as $af = 1 - (\text{Unconfined area}) / (\text{total area})$

$af = 0.31984848$

with Unconfined area = $((b_{\text{max}} - 2R)^2 + (h_{\text{max}} - 2R)^2) / 3 = 140733.333$

$b_{\text{max}} = 750.00$

$h_{\text{max}} = 750.00$

From EC8 A.4.4.3(6), $pf = 2tf / bw = 0.00508$

$bw = 400.00$

effective stress from (A.35), $ffe = 870.5244$

$fy = 0.04286225$

Expression ((15B.6), TBDY) is modified as $af = 1 - (\text{Unconfined area}) / (\text{total area})$

$af = 0.31984848$

with Unconfined area = $((b_{\text{max}} - 2R)^2 + (h_{\text{max}} - 2R)^2) / 3 = 140733.333$

$b_{\text{max}} = 750.00$

$h_{\text{max}} = 750.00$

From EC8 A.4.4.3(6), $pf = 2tf / bw = 0.00508$

$bw = 400.00$

effective stress from (A.35), $ffe = 870.5244$

$R = 40.00$

Effective FRP thickness, $t_f = NL \cdot t \cdot \cos(b_1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{,f} = 0.015$

$ase((5.4d), TBDY) = (ase_1 \cdot A_{ext} + ase_2 \cdot A_{int}) / A_{sec} = 0.45746528$

$ase_1 = \text{Max}(((A_{conf,max1} - A_{noConf1}) / A_{conf,max1}) \cdot (A_{conf,min1} / A_{conf,max1}), 0) = 0.45746528$

The definitions of A_{noConf} , $A_{conf,min}$ and $A_{conf,max}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max1} = 353600.00$ is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{conf,min1} = 293525.00$ is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area $A_{conf,max1}$ by a length equal to half the clear spacing between external hoops.

$A_{noConf1} = 158733.333$ is the unconfined external core area which is equal to $b_i^2/6$ as defined at (A.2).

$ase_2 (>= ase_1) = \text{Max}(((A_{conf,max2} - A_{noConf2}) / A_{conf,max2}) \cdot (A_{conf,min2} / A_{conf,max2}), 0) = 0.45746528$

The definitions of A_{noConf} , $A_{conf,min}$ and $A_{conf,max}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max2} = 171264.00$ is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

$A_{conf,min2} = 54741.00$ is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area $A_{conf,max2}$ by a length equal to half the clear spacing between internal hoops.

$A_{noConf2} = 106242.667$ is the unconfined internal core area which is equal to $b_i^2/6$ as defined at (A.2).

$p_{sh,min} \cdot F_{ywe} = \text{Min}(p_{sh,x} \cdot F_{ywe}, p_{sh,y} \cdot F_{ywe}) = 2.92621$

Expression (5.4d) 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)

 $p_{sh,x} \cdot F_{ywe} = p_{sh1} \cdot F_{ywe1} + p_{sh2} \cdot F_{ywe2} = 2.92621$

$p_{sh1}((5.4d), TBDY) = L_{stir1} \cdot A_{stir1} / (A_{sec} \cdot s_1) = 0.00367709$

L_{stir1} (Length of stirrups along Y) = 2060.00

A_{stir1} (stirrups area) = 78.53982

$p_{sh2}((5.4d)) = L_{stir2} \cdot A_{stir2} / (A_{sec} \cdot s_2) = 0.00067082$

L_{stir2} (Length of stirrups along Y) = 1468.00

A_{stir2} (stirrups area) = 50.26548

 $p_{sh,y} \cdot F_{ywe} = p_{sh1} \cdot F_{ywe1} + p_{sh2} \cdot F_{ywe2} = 2.92621$

$p_{sh1}((5.4d), TBDY) = L_{stir1} \cdot A_{stir1} / (A_{sec} \cdot s_1) = 0.00367709$

L_{stir1} (Length of stirrups along X) = 2060.00

A_{stir1} (stirrups area) = 78.53982

$p_{sh2}((5.4d), TBDY) = L_{stir2} \cdot A_{stir2} / (A_{sec} \cdot s_2) = 0.00067082$

L_{stir2} (Length of stirrups along X) = 1468.00

A_{stir2} (stirrups area) = 50.26548

 $A_{sec} = 440000.00$

$s_1 = 100.00$

$s_2 = 250.00$

$f_{ywe1} = 694.4444$

$f_{ywe2} = 555.5556$

$f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY: $cc = 0.00238888$

$c = \text{confinement factor} = 1.03889$

$y_1 = 0.00145721$

$sh_1 = 0.00466307$

$ft_1 = 459.4373$

$fy_1 = 382.8645$

$su_1 = 0.00582756$

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

$l_o/l_{ou,min} = l_b/l_d = 0.318426$

$su_1 = 0.4 \cdot e_{su1_nominal}((5.5), TBDY) = 0.032$

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 $fs1 = (fs_jacket \cdot Asl,ten,jacket + fs_core \cdot Asl,ten,core) / Asl,ten = 382.8645$

with $Es1 = (Es_jacket \cdot Asl,ten,jacket + Es_core \cdot Asl,ten,core) / Asl,ten = 200000.00$

$y2 = 0.00145721$

$sh2 = 0.00466307$

$ft2 = 465.423$

$fy2 = 387.8525$

$su2 = 0.00582756$

using (30) in Biskinis/Fardis (2013) multiplied with $shear_factor$

and also multiplied by the $shear_factor$ according to 15.7.1.4, with

$Shear_factor = 1.00$

$lo/lou,min = lb/lb,min = 0.318426$

$su2 = 0.4 \cdot esu2_nominal ((5.5), TBDY) = 0.032$

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 $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$, from 10.3.5, ASCE 41-17.

with $fs2 = (fs_jacket \cdot Asl,com,jacket + fs_core \cdot Asl,com,core) / Asl,com = 387.8525$

with $Es2 = (Es_jacket \cdot Asl,com,jacket + Es_core \cdot Asl,com,core) / Asl,com = 200000.00$

$yv = 0.00145721$

$shv = 0.00466307$

$ftv = 463.3885$

$fyv = 386.157$

$suv = 0.00582756$

using (30) in Biskinis/Fardis (2013) multiplied with $shear_factor$

and also multiplied by the $shear_factor$ according to 15.7.1.4, with

$Shear_factor = 1.00$

$lo/lou,min = lb/ld = 0.318426$

$suv = 0.4 \cdot esuv_nominal ((5.5), TBDY) = 0.032$

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 $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$, from 10.3.5, ASCE 41-17.

with $fsv = (fs_jacket \cdot Asl,mid,jacket + fs_mid \cdot Asl,mid,core) / Asl,mid = 386.157$

with $Esv = (Es_jacket \cdot Asl,mid,jacket + Es_mid \cdot Asl,mid,core) / Asl,mid = 200000.00$

$1 = Asl,ten / (b \cdot d) \cdot (fs1 / fc) = 0.02488335$

$2 = Asl,com / (b \cdot d) \cdot (fs2 / fc) = 0.04895276$

$v = Asl,mid / (b \cdot d) \cdot (fsv / fc) = 0.04430167$

and confined core properties:

$b = 690.00$

$d = 677.00$

$d' = 13.00$

$fcc (5A.2, TBDY) = 34.2833$

$cc (5A.5, TBDY) = 0.00238888$

$c = \text{confinement factor} = 1.03889$

$1 = Asl,ten / (b \cdot d) \cdot (fs1 / fc) = 0.02824566$

$2 = Asl,com / (b \cdot d) \cdot (fs2 / fc) = 0.05556741$

$v = Asl,mid / (b \cdot d) \cdot (fsv / fc) = 0.05028784$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < vs,y2$ - LHS eq.(4.5) is satisfied

--->

$su (4.9) = 0.13760581$

$Mu = MRc (4.14) = 5.1260E+008$

$u = su (4.1) = 9.5578758E-006$

Calculation of ratio lb/ld

Lap Length: $lb/ld = 0.318426$

$lb = 300.00$

$ld = 942.1341$

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: $f_y = 655.5556$

Mean concrete strength: $f_c' = (f_c'_{jacket} \cdot Area_{jacket} + f_c'_{core} \cdot Area_{core}) / Area_{section} = 27.68182$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 25.00$$

$$K_{tr} = 1.7174$$

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

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

$$s = \text{Max}(s_{external}, s_{internal}) = 250.00$$

$$n = 24.00$$

Calculation of μ_{u1} -

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

$$\mu_u = 1.0408734E-005$$

$$\mu_u = 8.2924E+008$$

with full section properties:

$$b = 400.00$$

$$d = 707.00$$

$$d' = 43.00$$

$$v = 0.00174378$$

$$N = 16273.616$$

$$f_c = 33.00$$

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

Final value of μ_u : $\mu_u^* = \text{shear_factor} \cdot \text{Max}(\mu_u, \mu_c) = 0.01288354$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $\mu_u = 0.01288354$

$$\mu_u \text{ (5.4c), TBDY} = a_{se} \cdot \text{sh}_{min} \cdot f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.05503171$$

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)

$$f_x = 0.04286225$$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.31984848$$

with Unconfined area = $((b_{max} - 2R)^2 + (h_{max} - 2R)^2) / 3 = 140733.333$

$$b_{max} = 750.00$$

$$h_{max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 870.5244$$

$$f_y = 0.04286225$$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.31984848$$

with Unconfined area = $((b_{max} - 2R)^2 + (h_{max} - 2R)^2) / 3 = 140733.333$

$$b_{max} = 750.00$$

$$h_{max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 870.5244$$

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$a_{se} \text{ ((5.4d), TBDY)} = (a_{se1} \cdot A_{ext} + a_{se2} \cdot A_{int}) / A_{sec} = 0.45746528$$

$$a_{se1} = \text{Max}(((A_{conf,max1} - A_{noConf1}) / A_{conf,max1}) \cdot (A_{conf,min1} / A_{conf,max1}), 0) = 0.45746528$$

The definitions of A_{noConf} , $A_{conf,min}$ and $A_{conf,max}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max1} = 353600.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{conf,min1} = 293525.00$ is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area $A_{conf,max1}$ by a length equal to half the clear spacing between external hoops.

$A_{noConf1} = 158733.333$ is the unconfined external core area which is equal to $b_i^2/6$ as defined at (A.2).
 $ase2 (>= ase1) = \text{Max}(((A_{conf,max2} - A_{noConf2})/A_{conf,max2}) * (A_{conf,min2}/A_{conf,max2}), 0) = 0.45746528$

The definitions of A_{noConf} , $A_{conf,min}$ and $A_{conf,max}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max2} = 171264.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

$A_{conf,min2} = 54741.00$ is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area $A_{conf,max2}$ by a length equal to half the clear spacing between internal hoops.

$A_{noConf2} = 106242.667$ is the unconfined internal core area which is equal to $b_i^2/6$ as defined at (A.2).
 $psh_{min} * F_{ywe} = \text{Min}(psh_x * F_{ywe}, psh_y * F_{ywe}) = 2.92621$

Expression (5.4d) 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)

 $psh_x * F_{ywe} = psh1 * F_{ywe1} + ps2 * F_{ywe2} = 2.92621$
 $psh1$ ((5.4d), TBDY) = $L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00367709$
 L_{stir1} (Length of stirrups along Y) = 2060.00
 A_{stir1} (stirrups area) = 78.53982
 $psh2$ (5.4d) = $L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00067082$
 L_{stir2} (Length of stirrups along Y) = 1468.00
 A_{stir2} (stirrups area) = 50.26548

 $psh_y * F_{ywe} = psh1 * F_{ywe1} + ps2 * F_{ywe2} = 2.92621$
 $psh1$ ((5.4d), TBDY) = $L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00367709$
 L_{stir1} (Length of stirrups along X) = 2060.00
 A_{stir1} (stirrups area) = 78.53982
 $psh2$ ((5.4d), TBDY) = $L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00067082$
 L_{stir2} (Length of stirrups along X) = 1468.00
 A_{stir2} (stirrups area) = 50.26548

 $A_{sec} = 440000.00$

$s1 = 100.00$

$s2 = 250.00$

$f_{ywe1} = 694.4444$

$f_{ywe2} = 555.5556$

$f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY: $cc = 0.00238888$

$c = \text{confinement factor} = 1.03889$

$y1 = 0.00145721$

$sh1 = 0.00466307$

$ft1 = 465.423$

$fy1 = 387.8525$

$su1 = 0.00582756$

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

$lo/lou_{min} = lb/ld = 0.318426$

$su1 = 0.4 * esu1_{nominal}$ ((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 $fs1 = (fs_{jacket} * A_{sl,ten,jacket} + fs_{core} * A_{sl,ten,core}) / A_{sl,ten} = 387.8525$

with $Es1 = (Es_{jacket} * A_{sl,ten,jacket} + Es_{core} * A_{sl,ten,core}) / A_{sl,ten} = 200000.00$

y2 = 0.00145721
sh2 = 0.00466307
ft2 = 459.4373
fy2 = 382.8645
su2 = 0.00582756

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 = 0.318426

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 = 382.8645

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

yv = 0.00145721
shv = 0.00466307

ftv = 463.3885

fyv = 386.157

suv = 0.00582756

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 = 0.318426

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 = 386.157

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

1 = Asl,ten/(b*d)*(fs1/fc) = 0.09178643

2 = Asl,com/(b*d)*(fs2/fc) = 0.04665628

v = Asl,mid/(b*d)*(fsv/fc) = 0.08306563

and confined core properties:

b = 340.00

d = 677.00

d' = 13.00

fcc (5A.2, TBDY) = 34.2833

cc (5A.5, TBDY) = 0.00238888

c = confinement factor = 1.03889

1 = Asl,ten/(b*d)*(fs1/fc) = 0.11276915

2 = Asl,com/(b*d)*(fs2/fc) = 0.05732208

v = Asl,mid/(b*d)*(fsv/fc) = 0.10205474

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

v < vs,y2 - LHS eq.(4.5) is satisfied

--->

su (4.9) = 0.20810191

Mu = MRc (4.14) = 8.2924E+008

u = su (4.1) = 1.0408734E-005

Calculation of ratio lb/ld

Lap Length: lb/ld = 0.318426

lb = 300.00

ld = 942.1341

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 = 655.5556

Mean concrete strength: fc' = (fc'_jacket*Area_jacket + fc'_core*Area_core)/Area_section = 27.68182, but $fc'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$t = 1.00$
 $s = 0.80$
 $e = 1.00$
 $cb = 25.00$
 $K_{tr} = 1.7174$
 $A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 257.6106$
 where A_{tr_x} , A_{tr_y} are the sum of the area of all stirrup legs along X and Y local axis
 $s = \text{Max}(s_{\text{external}}, s_{\text{internal}}) = 250.00$
 $n = 24.00$

 Calculation of μ_{2+}

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

$\mu = 9.5578758E-006$
 $\mu_{2+} = 5.1260E+008$

 with full section properties:

$b = 750.00$
 $d = 707.00$
 $d' = 43.00$
 $v = 0.00093001$
 $N = 16273.616$
 $f_c = 33.00$
 $\alpha_{co} (5A.5, \text{TBDY}) = 0.002$
 Final value of μ_{cu} : $\mu_{cu}^* = \text{shear_factor} * \text{Max}(\mu_{cu}, \mu_{cc}) = 0.01288354$
 The Shear_factor is considered equal to 1 (pure moment strength)
 From (5.4b), TBDY: $\mu_{cu} = 0.01288354$
 $\mu_{cc} ((5.4c), \text{TBDY}) = \alpha_{se} * \text{sh}_{\text{min}} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.05503171$
 where $f = \alpha_f * p_f * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

 $f_x = 0.04286225$

Expression ((15B.6), TBDY) is modified as $\alpha_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$\alpha_f = 0.31984848$

with Unconfined area = $((b_{\text{max}} - 2R)^2 + (h_{\text{max}} - 2R)^2) / 3 = 140733.333$

$b_{\text{max}} = 750.00$

$h_{\text{max}} = 750.00$

From EC8 A.4.4.3(6), $p_f = 2t_f / b_w = 0.00508$

$b_w = 400.00$

effective stress from (A.35), $f_{fe} = 870.5244$

 $f_y = 0.04286225$

Expression ((15B.6), TBDY) is modified as $\alpha_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$\alpha_f = 0.31984848$

with Unconfined area = $((b_{\text{max}} - 2R)^2 + (h_{\text{max}} - 2R)^2) / 3 = 140733.333$

$b_{\text{max}} = 750.00$

$h_{\text{max}} = 750.00$

From EC8 A.4.4.3(6), $p_f = 2t_f / b_w = 0.00508$

$b_w = 400.00$

effective stress from (A.35), $f_{fe} = 870.5244$

 $R = 40.00$

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

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{f} = 0.015$

$\alpha_{se} ((5.4d), \text{TBDY}) = (\alpha_{se1} * A_{\text{ext}} + \alpha_{se2} * A_{\text{int}}) / A_{\text{sec}} = 0.45746528$

$\alpha_{se1} = \text{Max}(((A_{\text{conf,max1}} - A_{\text{noConf1}}) / A_{\text{conf,max1}}) * (A_{\text{conf,min1}} / A_{\text{conf,max1}}), 0) = 0.45746528$

The definitions of A_{noConf} , $A_{\text{conf,min}}$ and $A_{\text{conf,max}}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{\text{conf,max1}} = 353600.00$ is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{conf,min1} = 293525.00$ is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area $A_{conf,max1}$ by a length equal to half the clear spacing between external hoops.

$A_{noConf1} = 158733.333$ is the unconfined external core area which is equal to $b_i^2/6$ as defined at (A.2).
 $ase_2 (>= ase_1) = \text{Max}(((A_{conf,max2} - A_{noConf2})/A_{conf,max2}) * (A_{conf,min2}/A_{conf,max2}), 0) = 0.45746528$

The definitions of A_{noConf} , $A_{conf,min}$ and $A_{conf,max}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max2} = 171264.00$ is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

$A_{conf,min2} = 54741.00$ is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area $A_{conf,max2}$ by a length equal to half the clear spacing between internal hoops.

$A_{noConf2} = 106242.667$ is the unconfined internal core area which is equal to $b_i^2/6$ as defined at (A.2).

$p_{sh,min} * F_{ywe} = \text{Min}(p_{sh,x} * F_{ywe}, p_{sh,y} * F_{ywe}) = 2.92621$

Expression (5.4d) 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)

 $p_{sh,x} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{s2} * F_{ywe2} = 2.92621$

$p_{sh1} ((5.4d), \text{TBDY}) = L_{stir1} * A_{stir1} / (A_{sec} * s_1) = 0.00367709$

L_{stir1} (Length of stirrups along Y) = 2060.00

A_{stir1} (stirrups area) = 78.53982

$p_{sh2} (5.4d) = L_{stir2} * A_{stir2} / (A_{sec} * s_2) = 0.00067082$

L_{stir2} (Length of stirrups along Y) = 1468.00

A_{stir2} (stirrups area) = 50.26548

 $p_{sh,y} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{s2} * F_{ywe2} = 2.92621$

$p_{sh1} ((5.4d), \text{TBDY}) = L_{stir1} * A_{stir1} / (A_{sec} * s_1) = 0.00367709$

L_{stir1} (Length of stirrups along X) = 2060.00

A_{stir1} (stirrups area) = 78.53982

$p_{sh2} ((5.4d), \text{TBDY}) = L_{stir2} * A_{stir2} / (A_{sec} * s_2) = 0.00067082$

L_{stir2} (Length of stirrups along X) = 1468.00

A_{stir2} (stirrups area) = 50.26548

 $A_{sec} = 440000.00$

$s_1 = 100.00$

$s_2 = 250.00$

$f_{ywe1} = 694.4444$

$f_{ywe2} = 555.5556$

$f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY: $cc = 0.00238888$

$c = \text{confinement factor} = 1.03889$

$y_1 = 0.00145721$

$sh_1 = 0.00466307$

$ft_1 = 459.4373$

$fy_1 = 382.8645$

$su_1 = 0.00582756$

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

$l_0/l_{ou,min} = l_b/l_d = 0.318426$

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

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 $fs_1 = (f_{s,jacket} * A_{sl,ten,jacket} + f_{s,core} * A_{sl,ten,core}) / A_{sl,ten} = 382.8645$

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

$y_2 = 0.00145721$

$sh_2 = 0.00466307$

$ft_2 = 465.423$

$fy_2 = 387.8525$

$su_2 = 0.00582756$

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 = 0.318426

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 = 387.8525

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

yv = 0.00145721

shv = 0.00466307

ftv = 463.3885

fyv = 386.157

suv = 0.00582756

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 = 0.318426

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 = 386.157

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

1 = Asl,ten/(b*d)*(fs1/fc) = 0.02488335

2 = Asl,com/(b*d)*(fs2/fc) = 0.04895276

v = Asl,mid/(b*d)*(fsv/fc) = 0.04430167

and confined core properties:

b = 690.00

d = 677.00

d' = 13.00

fcc (5A.2, TBDY) = 34.2833

cc (5A.5, TBDY) = 0.00238888

c = confinement factor = 1.03889

1 = Asl,ten/(b*d)*(fs1/fc) = 0.02824566

2 = Asl,com/(b*d)*(fs2/fc) = 0.05556741

v = Asl,mid/(b*d)*(fsv/fc) = 0.05028784

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

v < vs,y2 - LHS eq.(4.5) is satisfied

--->

su (4.9) = 0.13760581

Mu = MRc (4.14) = 5.1260E+008

u = su (4.1) = 9.5578758E-006

Calculation of ratio lb/ld

Lap Length: lb/ld = 0.318426

lb = 300.00

ld = 942.1341

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 = 655.5556

Mean concrete strength: fc' = (fc',jacket*Area_jacket + fc',core*Area_core)/Area_section = 27.68182, but $fc'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

t = 1.00

s = 0.80

e = 1.00

cb = 25.00

Ktr = 1.7174

Atr = $\text{Min}(Atr_x, Atr_y)$ = 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
 $s = \text{Max}(s_{\text{external}}, s_{\text{internal}}) = 250.00$
 $n = 24.00$

Calculation of μ_2 -

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

$$u = 1.0408734E-005$$

$$\mu = 8.2924E+008$$

with full section properties:

$$b = 400.00$$

$$d = 707.00$$

$$d' = 43.00$$

$$v = 0.00174378$$

$$N = 16273.616$$

$$f_c = 33.00$$

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

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.01288354$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } c_u = 0.01288354$$

$$w_e \text{ ((5.4c), TBDY)} = a_{se} * s_{h, \min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.05503171$$

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

$$f_x = 0.04286225$$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.31984848$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 140733.333$$

$$b_{\max} = 750.00$$

$$h_{\max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 870.5244$$

$$f_y = 0.04286225$$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.31984848$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 140733.333$$

$$b_{\max} = 750.00$$

$$h_{\max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 870.5244$$

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u_{f} = 0.015$$

$$a_{se} \text{ ((5.4d), TBDY)} = (a_{se1} * A_{ext} + a_{se2} * A_{int}) / A_{sec} = 0.45746528$$

$$a_{se1} = \text{Max}(((A_{\text{conf,max1}} - A_{\text{noConf1}}) / A_{\text{conf,max1}}) * (A_{\text{conf,min1}} / A_{\text{conf,max1}}), 0) = 0.45746528$$

The definitions of A_{noConf} , $A_{\text{conf,min}}$ and $A_{\text{conf,max}}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{\text{conf,max1}} = 353600.00$ is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{\text{conf,min1}} = 293525.00$ is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area $A_{\text{conf,max1}}$ by a length

equal to half the clear spacing between external hoops.

$A_{\text{noConf1}} = 158733.333$ is the unconfined external core area which is equal to $b_i^2/6$ as defined at (A.2).

$$a_{se2} (>= a_{se1}) = \text{Max}(((A_{\text{conf,max2}} - A_{\text{noConf2}}) / A_{\text{conf,max2}}) * (A_{\text{conf,min2}} / A_{\text{conf,max2}}), 0) = 0.45746528$$

The definitions of A_{noConf} , $A_{conf,min}$ and $A_{conf,max}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max2} = 171264.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

$A_{conf,min2} = 54741.00$ is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area $A_{conf,max2}$ by a length equal to half the clear spacing between internal hoops.

$A_{noConf2} = 106242.667$ is the unconfined internal core area which is equal to $b_i^2/6$ as defined at (A.2).

$$p_{sh,min} * F_{ywe} = \text{Min}(p_{sh,x} * F_{ywe}, p_{sh,y} * F_{ywe}) = 2.92621$$

Expression (5.4d) 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)

$$p_{sh,x} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{sh2} * F_{ywe2} = 2.92621$$

$$p_{sh1} \text{ ((5.4d), TBDY)} = L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00367709$$

$$L_{stir1} \text{ (Length of stirrups along Y)} = 2060.00$$

$$A_{stir1} \text{ (stirrups area)} = 78.53982$$

$$p_{sh2} \text{ (5.4d)} = L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00067082$$

$$L_{stir2} \text{ (Length of stirrups along Y)} = 1468.00$$

$$A_{stir2} \text{ (stirrups area)} = 50.26548$$

$$p_{sh,y} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{sh2} * F_{ywe2} = 2.92621$$

$$p_{sh1} \text{ ((5.4d), TBDY)} = L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00367709$$

$$L_{stir1} \text{ (Length of stirrups along X)} = 2060.00$$

$$A_{stir1} \text{ (stirrups area)} = 78.53982$$

$$p_{sh2} \text{ ((5.4d), TBDY)} = L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00067082$$

$$L_{stir2} \text{ (Length of stirrups along X)} = 1468.00$$

$$A_{stir2} \text{ (stirrups area)} = 50.26548$$

$$A_{sec} = 440000.00$$

$$s1 = 100.00$$

$$s2 = 250.00$$

$$f_{ywe1} = 694.4444$$

$$f_{ywe2} = 555.5556$$

$$f_{ce} = 33.00$$

$$\text{From ((5.A5), TBDY), TBDY: } cc = 0.00238888$$

$$c = \text{confinement factor} = 1.03889$$

$$y1 = 0.00145721$$

$$sh1 = 0.00466307$$

$$ft1 = 465.423$$

$$fy1 = 387.8525$$

$$su1 = 0.00582756$$

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

$$l_o/l_{ou,min} = l_b/l_d = 0.318426$$

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

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

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

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

$$\text{with } fs1 = (f_{s,jacket} * A_{s,ten,jacket} + f_{s,core} * A_{s,ten,core}) / A_{s,ten} = 387.8525$$

$$\text{with } Es1 = (E_{s,jacket} * A_{s,ten,jacket} + E_{s,core} * A_{s,ten,core}) / A_{s,ten} = 200000.00$$

$$y2 = 0.00145721$$

$$sh2 = 0.00466307$$

$$ft2 = 459.4373$$

$$fy2 = 382.8645$$

$$su2 = 0.00582756$$

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

$$l_o/l_{ou,min} = l_b/l_{b,min} = 0.318426$$

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

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

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 $f_{s2} = (f_{s,jacket} \cdot A_{s1,com,jacket} + f_{s,core} \cdot A_{s1,com,core})/A_{s1,com} = 382.8645$

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

$y_v = 0.00145721$

$sh_v = 0.00466307$

$ft_v = 463.3885$

$f_{y_v} = 386.157$

$s_{u_v} = 0.00582756$

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

$l_o/l_{o,min} = l_b/l_d = 0.318426$

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

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 $f_{s_{y_v}} = (f_{s,jacket} \cdot A_{s1,mid,jacket} + f_{s,mid} \cdot A_{s1,mid,core})/A_{s1,mid} = 386.157$

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

$1 = A_{s1,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.09178643$

$2 = A_{s1,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.04665628$

$v = A_{s1,mid}/(b \cdot d) \cdot (f_{s_{y_v}}/f_c) = 0.08306563$

and confined core properties:

$b = 340.00$

$d = 677.00$

$d' = 13.00$

$f_{cc} (5A.2, TBDY) = 34.2833$

$cc (5A.5, TBDY) = 0.00238888$

$c = \text{confinement factor} = 1.03889$

$1 = A_{s1,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.11276915$

$2 = A_{s1,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.05732208$

$v = A_{s1,mid}/(b \cdot d) \cdot (f_{s_{y_v}}/f_c) = 0.10205474$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

$s_u (4.9) = 0.20810191$

$\mu_u = M_{Rc} (4.14) = 8.2924E+008$

$u = s_u (4.1) = 1.0408734E-005$

Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.318426$

$l_b = 300.00$

$l_d = 942.1341$

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: $f_y = 655.5556$

Mean concrete strength: $f'_c = (f'_{c,jacket} \cdot Area_{jacket} + f'_{c,core} \cdot Area_{core})/Area_{section} = 27.68182$, but $f_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 1.7174$

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

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

$s = \text{Max}(s_{external}, s_{internal}) = 250.00$

$n = 24.00$

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 998292.205$

Calculation of Shear Strength at edge 1, $V_{r1} = 998292.205$

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

$V_{Col0} = 998292.205$

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

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

$= 1$ (normal-weight concrete)

Mean concrete strength: $f_c' = (f_c'_{jacket} * Area_{jacket} + f_c'_{core} * Area_{core}) / Area_{section} = 27.68182$, but $f_c'^{0.5} < = 8.3$ MPa (22.5.3.1, ACI 318-14)

$M / Vd = 4.00$

$\mu_u = 11.78089$

$V_u = 0.00051441$

$d = 0.8 * h = 600.00$

$N_u = 16273.616$

$A_g = 300000.00$

From (11.5.4.8), ACI 318-14: $V_s = V_{sjacket} + V_{s,core} = 881489.011$

where:

$V_{sjacket} = V_{sj1} + V_{sj2} = 802851.456$

$V_{sj1} = 279252.68$ is calculated for section web jacket, with:

$d = 320.00$

$A_v = 157079.633$

$f_y = 555.5556$

$s = 100.00$

V_{sj1} is multiplied by $Col_{j1} = 1.00$

$s/d = 0.3125$

$V_{sj2} = 523598.776$ is calculated for section flange jacket, with:

$d = 600.00$

$A_v = 157079.633$

$f_y = 555.5556$

$s = 100.00$

V_{sj2} is multiplied by $Col_{j2} = 1.00$

$s/d = 0.16666667$

$V_{s,core} = V_{s,c1} + V_{s,c2} = 78637.555$

$V_{s,c1} = 0.00$ is calculated for section web core, with:

$d = 160.00$

$A_v = 100530.965$

$f_y = 444.4444$

$s = 250.00$

$V_{s,c1}$ is multiplied by $Col_{c1} = 0.00$

$s/d = 1.5625$

$V_{s,c2} = 78637.555$ is calculated for section flange core, with:

$d = 440.00$

$A_v = 100530.965$

$f_y = 444.4444$

$s = 250.00$

$V_{s,c2}$ is multiplied by $Col_{c2} = 1.00$

$s/d = 0.56818182$

$V_f \text{ ((11-3)-(11.4), ACI 440)} = 372533.843$

$f = 0.95$, for fully-wrapped sections

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

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

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

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

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

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

$d_{fv} = d$ (figure 11.2, ACI 440) = 707.00

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

$E_f = 64828.00$

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

with $f_u = 0.01$

From (11-11), ACI 440: $V_s + V_f \leq 838832.606$
 $bw = 400.00$

Calculation of Shear Strength at edge 2, $V_r2 = 998292.205$

$V_r2 = V_{Col} ((10.3), ASCE 41-17) = knl * V_{Col0}$

$V_{Col0} = 998292.205$

$knl = 1$ (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: $f_c' = (f_c'_{jacket} * Area_{jacket} + f_c'_{core} * Area_{core}) / Area_{section} = 27.68182$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M / Vd = 4.00$

$\mu_u = 11.78144$

$V_u = 0.00051441$

$d = 0.8 * h = 600.00$

$N_u = 16273.616$

$A_g = 300000.00$

From (11.5.4.8), ACI 318-14: $V_s = V_{s,jacket} + V_{s,core} = 881489.011$

where:

$V_{s,jacket} = V_{s,j1} + V_{s,j2} = 802851.456$

$V_{s,j1} = 279252.68$ is calculated for section web jacket, with:

$d = 320.00$

$A_v = 157079.633$

$f_y = 555.5556$

$s = 100.00$

$V_{s,j1}$ is multiplied by $Col,j1 = 1.00$

$s/d = 0.3125$

$V_{s,j2} = 523598.776$ is calculated for section flange jacket, with:

$d = 600.00$

$A_v = 157079.633$

$f_y = 555.5556$

$s = 100.00$

$V_{s,j2}$ is multiplied by $Col,j2 = 1.00$

$s/d = 0.16666667$

$V_{s,core} = V_{s,c1} + V_{s,c2} = 78637.555$

$V_{s,c1} = 0.00$ is calculated for section web core, with:

$d = 160.00$

$A_v = 100530.965$

$f_y = 444.4444$

$s = 250.00$

$V_{s,c1}$ is multiplied by $Col,c1 = 0.00$

$s/d = 1.5625$

$V_{s,c2} = 78637.555$ is calculated for section flange core, with:

$d = 440.00$

$A_v = 100530.965$

$f_y = 444.4444$

$s = 250.00$

$V_{s,c2}$ is multiplied by $Col,c2 = 1.00$

$s/d = 0.56818182$

$V_f ((11-3)-(11.4), ACI 440) = 372533.843$

$f = 0.95$, 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: $\theta = 1 = b1 + 90^\circ = 90.00$

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

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

$d_{fv} = d$ (figure 11.2, ACI 440) = 707.00

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

$E_f = 64828.00$

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

with $f_u = 0.01$

From (11-11), ACI 440: $V_s + V_f \leq 838832.606$

$b_w = 400.00$

End Of Calculation of Shear Capacity ratio for element: column JLC1 of floor 1
At local axis: 2

Start Of Calculation of Chord Rotation Capacity for element: column JLC1 of floor 1

At local axis: 2

Integration Section: (b)

Section Type: rcjcs

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

New material of Secondary Member: Steel Strength, $f_s = f_{sm} = 555.5556$

Concrete Elasticity, $E_c = 26999.444$

Steel Elasticity, $E_s = 200000.00$

Existing Column

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

Existing material of Secondary Member: Steel Strength, $f_s = f_{sm} = 444.4444$

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

Max Height, $H_{max} = 750.00$

Min Height, $H_{min} = 400.00$

Max Width, $W_{max} = 750.00$

Min Width, $W_{min} = 400.00$

Jacket Thickness, $t_j = 100.00$

Cover Thickness, $c = 25.00$

Element Length, $L = 3000.00$

Secondary Member

Ribbed Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

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, $M = -114915.564$

Shear Force, $V_2 = 6560.264$

Shear Force, $V_3 = -122.9023$

Axial Force, $F = -16937.611$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: $A_{st} = 0.00$

-Compression: $A_{sc} = 5353.274$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

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

-Compression: $A_{s,com} = 2208.54$

-Middle: $A_{s,mid} = 2007.478$

Longitudinal External Reinforcement Area Distribution (in 3 divisions)

-Tension: $A_{s,ten,jacket} = 829.3805$

-Compression: $A_{s,com,jacket} = 1746.726$

-Middle: $A_{s,mid,jacket} = 1545.664$

Longitudinal Internal Reinforcement Area Distribution (in 3 divisions)

-Tension: $A_{s,ten,core} = 307.8761$

-Compression: $A_{s,com,core} = 461.8141$

-Middle: $A_{s,mid,core} = 461.8141$

Mean Diameter of Tension Reinforcement, $DbL = 16.80$

Existing component: From table 7-7, ASCE 41_17: Final chord rotation Capacity $u_{,R} = u = 0.02626962$

$u = y + p = 0.03090543$

- Calculation of y -

$y = (M_y * L_s / 3) / E_{eff} = 0.00090543$ ((4.29), Biskinis Phd))

$M_y = 4.2097E+008$

$L_s = M/V$ (with $L_s > 0.1 * L$ and $L_s < 2 * L$) = 935.0156

From table 10.5, ASCE 41_17: $E_{eff} = factor * E_c * I_g = 1.4491E+014$

factor = 0.30

$A_g = 440000.00$

Mean concrete strength: $f_c' = (f_c'_{jacket} * Area_{jacket} + f_c'_{core} * Area_{core}) / Area_{section} = 27.68182$

$N = 16937.611$

$E_c * I_g = E_c_{jacket} * I_{g,jacket} + E_c_{core} * I_{g,core} = 4.8303E+014$

Calculation of Yielding Moment M_y

Calculation of y and M_y according to Annex 7 -

Assuming neutral axis within flange ($y < t/d$, compression zone rectangular) with:

flange width, $b = 750.00$

web width, $b_w = 400.00$

flange thickness, $t = 400.00$

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

$y_{ten} = 3.1431513E-006$

with ((10.1), ASCE 41-17) $f_y = \text{Min}(f_y, 1.25 * f_y * (b/d)^{2/3}) = 358.4764$

$d = 707.00$

$y = 0.19342282$

$A = 0.01018486$

$B = 0.00449527$

with $pt = 0.00671906$

$pc = 0.00416509$

$pv = 0.00378591$

$N = 16937.611$

$b = 750.00$

" = 0.06082037

$y_{comp} = 1.6462780E-005$

with $f_c' (12.3, (ACI 440)) = 33.48734$

$f_c = 33.00$

$f_l = 0.49678681$

$b = b_{max} = 750.00$

$h = h_{max} = 750.00$

$A_g = 0.44$

$g = pt + pc + pv = 0.01009575$

$rc = 40.00$

$A_e/A_c = 0.31291181$

Effective FRP thickness, $t_f = NL \cdot t \cdot \cos(b_1) = 1.016$
 effective strain from (12.5) and (12.12), $\epsilon_{fe} = 0.004$
 $f_u = 0.01$
 $E_f = 64828.00$
 $E_c = 26999.444$
 $\gamma = 0.19181197$
 $A = 0.01002422$
 $B = 0.00440616$
 with $E_s = 200000.00$
 CONFIRMATION: $\gamma = 0.19278073 < t/d$

 Calculation of ratio l_b/l_d

Lap Length: $l_d/l_{d,min} = 0.39803249$

$l_b = 300.00$

$l_d = 753.7073$

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: $f_y = 524.4444$

Mean concrete strength: $f_c' = (f_c'_{jacket} \cdot Area_{jacket} + f_c'_{core} \cdot Area_{core}) / Area_{section} = 27.68182$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$c_b = 25.00$

$K_{tr} = 1.7174$

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

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

$s = \max(s_{external}, s_{internal}) = 250.00$

$n = 24.00$

 - Calculation of p -

From table 10-8: $p = 0.03$

with:

- Columns controlled by inadequate development or splicing along the clear height because $l_b/l_d < 1$

shear control ratio $V_y E / V_{CoI} O E = 0.55377356$

$d = d_{external} = 707.00$

$s = s_{external} = 0.00$

- $t = s_1 + s_2 + 2 \cdot t_f / b_w \cdot (f_{fe} / f_s) = 0.00671906$

jacket: $s_1 = A_{v1} \cdot L_{stir1} / (s_1 \cdot A_g) = 0.00367709$

$A_{v1} = 78.53982$, is the area of every stirrup parallel to loading (shear) direction

$L_{stir1} = 2060.00$, is the total Length of all stirrups parallel to loading (shear) direction

$s_1 = 100.00$

core: $s_2 = A_{v2} \cdot L_{stir2} / (s_2 \cdot A_g) = 0.00067082$

$A_{v2} = 50.26548$, is the area of every stirrup parallel to loading (shear) direction

$L_{stir2} = 1468.00$, is the total Length of all stirrups parallel to loading (shear) direction

$s_2 = 250.00$

The term $2 \cdot t_f / b_w \cdot (f_{fe} / f_s)$ is implemented to account for FRP contribution

where $f = 2 \cdot t_f / b_w$ is FRP ratio (EC8 - 3, A.4.4.3(6)) and f_{fe} / f_s normalises f to steel strength

All these variables have already been given in Shear control ratio calculation.

For the normalisation f_s of jacket is used.

$NUD = 16937.611$

$A_g = 440000.00$

$f_c E = (f_c'_{jacket} \cdot Area_{jacket} + f_c'_{core} \cdot Area_{core}) / section_area = 27.68182$

$f_y E = (f_{y_ext_Long_Reinf} \cdot Area_{ext_Long_Reinf} + f_{y_int_Long_Reinf} \cdot Area_{int_Long_Reinf}) / Area_{Tot_Long_Rein} = 529.9948$

$f_y t E = (f_{y_ext_Trans_Reinf} \cdot s_1 + f_{y_int_Trans_Reinf} \cdot s_2) / (s_1 + s_2) = 538.4128$

$p_l = Area_{Tot_Long_Rein} / (b \cdot d) = 0.01009575$

$b = 750.00$

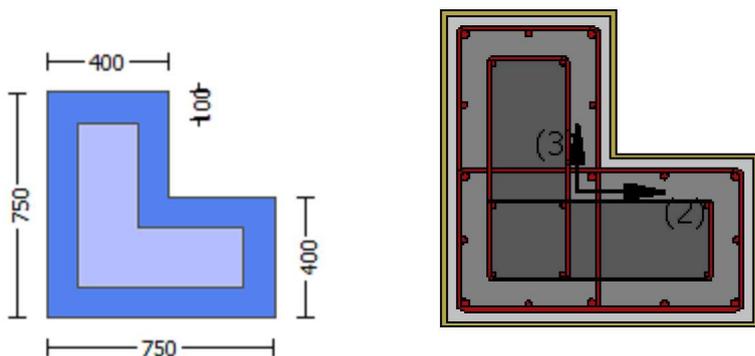
$d = 707.00$

$f_c E = 27.68182$

End Of Calculation of Chord Rotation Capacity for element: column JLC1 of floor 1
At local axis: 2
Integration Section: (b)

Calculation No. 15

column C1, Floor 1
Limit State: Life Safety (data interpolation between analysis steps 1 and 2)
Analysis: Uniform +X
Check: Shear capacity V_{Rd}
Edge: End
Local Axis: (3)



Start Of Calculation of Shear Capacity for element: column JLC1 of floor 1
At local axis: 3
Integration Section: (b)
Section Type: rcjics

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 Secondary Member: Concrete Strength, $f_c = f_{c_lower_bound} = 25.00$
New material of Secondary Member: Steel Strength, $f_s = f_{s_lower_bound} = 500.00$
Concrete Elasticity, $E_c = 26999.444$
Steel Elasticity, $E_s = 200000.00$
Existing Column
Existing material of Secondary Member: Concrete Strength, $f_c = f_{c_lower_bound} = 16.00$
Existing material of Secondary 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 μ 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, $f_s = f_{sm} = 555.5556$

Existing Column

Existing material: Concrete Strength, $f_c = f_{cm} = 20.00$

Existing material: Steel Strength, $f_s = f_{sm} = 444.4444$

#####

Max Height, $H_{max} = 750.00$

Min Height, $H_{min} = 400.00$

Max Width, $W_{max} = 750.00$

Min Width, $W_{min} = 400.00$

Jacket Thickness, $t_j = 100.00$

Cover Thickness, $c = 25.00$

Element Length, $L = 3000.00$

Secondary Member

Ribbed Bars

Ductile Steel

Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)

Longitudinal Bars With Ends Lapped Starting at the End Sections

Lap Length $l_o = l_b = 300.00$

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $e_{fu} = 0.01$

Number of directions, $N_{oDir} = 1$

Fiber orientations, $b_i: 0.00^\circ$

Number of layers, $N_L = 1$

Radius of rounding corners, $R = 40.00$

Stepwise Properties

EDGE -A-

Bending Moment, $M_a = -251948.766$

Shear Force, $V_a = 122.9023$

EDGE -B-

Bending Moment, $M_b = -114915.564$

Shear Force, $V_b = -122.9023$

BOTH EDGES

Axial Force, $F = -16937.611$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: $A_{sl,t} = 0.00$

-Compression: $A_{sl,c} = 5353.274$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension: $A_{sl,ten} = 1137.257$

-Compression: $A_{sl,com} = 2208.54$

-Middle: $A_{sl,mid} = 2007.478$

Mean Diameter of Tension Reinforcement, $Db_{L,ten} = 16.80$

Existing component: From table 7-7, ASCE 41_17: Final Shear Capacity $V_R = \phi V_n = 864045.673$

V_n ((10.3), ASCE 41-17) = $k_n \cdot V_{CoI} = 1.0165E+006$

$V_{CoI} = 1.0165E+006$

$k_n = 1.00$

$\text{displacement_ductility_demand} = 3.2791262E-005$

NOTE: In expression (10-3) ' $V_s = A_v \cdot f_y \cdot d / s$ ' is replaced by ' $V_s + \phi \cdot V_f$ ' where V_f is the contribution of FRPs (11.3), ACI 440).

= 1 (normal-weight concrete)
 Mean concrete strength: $f'_c = (f'_{c,jacket} \cdot Area_{jacket} + f'_{c,core} \cdot Area_{core}) / Area_{section} = 21.31818$, but $f'_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $M/Vd = 2.00$
 $\mu_u = 114915.564$
 $V_u = 122.9023$
 $d = 0.8 \cdot h = 600.00$
 $N_u = 16937.611$
 $A_g = 300000.00$
 From (11.5.4.8), ACI 318-14: $V_s = V_{s,jacket} + V_{s,core} = 793340.11$
 where:
 $V_{s,jacket} = V_{s,j1} + V_{s,j2} = 722566.31$
 $V_{s,j1} = 471238.898$ is calculated for section web jacket, with:
 $d = 600.00$
 $A_v = 157079.633$
 $f_y = 500.00$
 $s = 100.00$
 $V_{s,j1}$ is multiplied by $Col,j1 = 1.00$
 $s/d = 0.16666667$
 $V_{s,j2} = 251327.412$ is calculated for section flange jacket, with:
 $d = 320.00$
 $A_v = 157079.633$
 $f_y = 500.00$
 $s = 100.00$
 $V_{s,j2}$ is multiplied by $Col,j2 = 1.00$
 $s/d = 0.3125$
 $V_{s,core} = V_{s,c1} + V_{s,c2} = 70773.799$
 $V_{s,c1} = 70773.799$ is calculated for section web core, with:
 $d = 440.00$
 $A_v = 100530.965$
 $f_y = 400.00$
 $s = 250.00$
 $V_{s,c1}$ is multiplied by $Col,c1 = 1.00$
 $s/d = 0.56818182$
 $V_{s,c2} = 0.00$ is calculated for section flange core, with:
 $d = 160.00$
 $A_v = 100530.965$
 $f_y = 400.00$
 $s = 250.00$
 $V_{s,c2}$ is multiplied by $Col,c2 = 0.00$
 $s/d = 1.5625$
 V_f ((11-3)-(11.4), ACI 440) = 372533.843
 $f = 0.95$, for fully-wrapped sections
 $w_f/s_f = 1$ (FRP strips adjacent to one another).
 In (11.3) $\sin \theta + \cos \theta$ is replaced with $(\cot \theta + \csc \theta) \sin \alpha$ which is more a generalised expression,
 where θ is the angle of the crack direction (see KANEPE).
 This later relation, considered as a function $V_f(\theta, \alpha)$, is implemented for every different fiber orientation α_i ,
 as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.
 orientation 1: $\theta = 45^\circ + 90^\circ = 135^\circ$
 $V_f = \text{Min}(|V_f(45, 135)|, |V_f(-45, 135)|)$, with:
 total thickness per orientation, $t_{f1} = NL \cdot t / NoDir = 1.016$
 $d_{fv} = d$ (figure 11.2, ACI 440) = 707.00
 f_{fe} ((11-5), ACI 440) = 259.312
 $E_f = 64828.00$
 $f_{e1} = 0.004$, from (11.6a), ACI 440
 with $f_u = 0.01$
 From (11-11), ACI 440: $V_s + V_f \leq 736127.561$
 $b_w = 400.00$

displacement ductility demand is calculated as δ_u / y

- Calculation of δ_u / y for END B -
 for rotation axis 2 and integ. section (b)

From analysis, chord rotation = 2.9690310E-008

$y = (M_y * L_s / 3) / E_{eff} = 0.00090543$ ((4.29), Biskinis Phd))

$M_y = 4.2097E+008$

$L_s = M/V$ (with $L_s > 0.1 * L$ and $L_s < 2 * L$) = 935.0156

From table 10.5, ASCE 41_17: $E_{eff} = factor * E_c * I_g = 1.4491E+014$

factor = 0.30

$A_g = 440000.00$

Mean concrete strength: $f_c' = (f_c'_{jacket} * Area_{jacket} + f_c'_{core} * Area_{core}) / Area_{section} = 27.68182$

$N = 16937.611$

$E_c * I_g = E_c_{jacket} * I_{g,jacket} + E_c_{core} * I_{g,core} = 4.8303E+014$

Calculation of Yielding Moment M_y

Calculation of y and M_y according to Annex 7 -

Assuming neutral axis within flange ($y < t/d$, compression zone rectangular) with:

flange width, $b = 750.00$

web width, $b_w = 400.00$

flange thickness, $t = 400.00$

$y = \text{Min}(y_{ten}, y_{com})$

$y_{ten} = 3.1431513E-006$

with ((10.1), ASCE 41-17) $f_y = \text{Min}(f_y, 1.25 * f_y * (l_b / l_d)^{2/3}) = 358.4764$

$d = 707.00$

$y = 0.19342282$

$A = 0.01018486$

$B = 0.00449527$

with $p_t = 0.00214476$

$p_c = 0.00416509$

$p_v = 0.00378591$

$N = 16937.611$

$b = 750.00$

" = 0.06082037

$y_{comp} = 1.6462780E-005$

with f_c^* (12.3, (ACI 440)) = 33.48734

$f_c = 33.00$

$f_l = 0.49678681$

$b = b_{max} = 750.00$

$h = h_{max} = 750.00$

$A_g = 0.44$

$g = p_t + p_c + p_v = 0.01009575$

$r_c = 40.00$

$A_e / A_c = 0.31291181$

Effective FRP thickness, $t_f = N L * t * \text{Cos}(\theta_1) = 1.016$

effective strain from (12.5) and (12.12), $\epsilon_{fe} = 0.004$

$f_u = 0.01$

$E_f = 64828.00$

$E_c = 26999.444$

$y = 0.19181197$

$A = 0.01002422$

$B = 0.00440616$

with $E_s = 200000.00$

CONFIRMATION: $y = 0.19278073 < t/d$

Calculation of ratio l_b / l_d

Lap Length: $l_d / l_d, \text{min} = 0.39803249$

$l_b = 300.00$

$l_d = 753.7073$

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: $f_y = 524.4444$

Mean concrete strength: $f_c' = (f_c'_{\text{jacket}} \cdot \text{Area}_{\text{jacket}} + f_c'_{\text{core}} \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 27.68182$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 1.7174$

$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 257.6106$

where A_{tr_x}, A_{tr_y} are the sum of the area of all stirrup legs along X and Y local axis

$s = \text{Max}(s_{\text{external}}, s_{\text{internal}}) = 250.00$

$n = 24.00$

End Of Calculation of Shear Capacity for element: column JLC1 of floor 1

At local axis: 3

Integration Section: (b)

Calculation No. 16

column C1, Floor 1

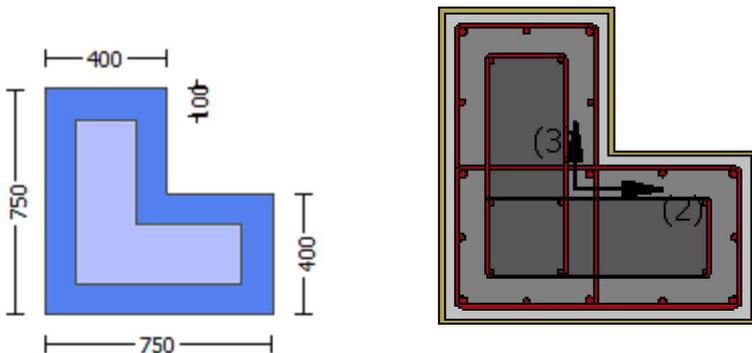
Limit State: Life Safety (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity (θ)

Edge: End

Local Axis: (3)



Start Of Calculation of Shear Capacity ratio for element: column JLC1 of floor 1

At Shear local axis: 3

(Bending local axis: 2)

Section Type: rcjcs

Constant Properties

Knowledge Factor, $\phi = 0.85$

Mean strength values are used for both shear and moment calculations.

Consequently:

Jacket

New material of Secondary Member: Concrete Strength, $f_c = f_{cm} = 33.00$

```

: New material of Secondary Member: Steel Strength, fs = fsm = 555.5556
: Concrete Elasticity, Ec = 26999.444
: Steel Elasticity, Es = 200000.00
: Existing Column
: Existing material of Secondary Member: Concrete Strength, fc = fcm = 20.00
: Existing material of Secondary Member: Steel Strength, fs = fsm = 444.4444
: Concrete Elasticity, Ec = 21019.039
: Steel Elasticity, Es = 200000.00
: #####
: Note: Especially for the calculation of moment strengths,
: the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14
: Jacket
: New material: Steel Strength, fs = 1.25*fsm = 694.4444
: Existing Column
: Existing material: Steel Strength, fs = 1.25*fsm = 555.5556
: #####
: Max Height, Hmax = 750.00
: Min Height, Hmin = 400.00
: Max Width, Wmax = 750.00
: Min Width, Wmin = 400.00
: Jacket Thickness, tj = 100.00
: Cover Thickness, c = 25.00
: Mean Confinement Factor overall section = 1.03889
: Element Length, L = 3000.00
: Secondary Member
: Ribbed Bars
: Ductile Steel
: Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
: Longitudinal Bars With Ends Lapped Starting at the End Sections
: Lap Length lo = 300.00
: FRP Wrapping Data
: Type: Carbon
: Cured laminate properties (design values)
: Thickness, t = 1.016
: Tensile Strength, ffu = 1055.00
: Tensile Modulus, Ef = 64828.00
: Elongation, efu = 0.01
: Number of directions, NoDir = 1
: Fiber orientations, bi: 0.00°
: Number of layers, NL = 1
: Radius of rounding corners, R = 40.00
: -----
: Stepwise Properties
: -----
: At local axis: 3
: EDGE -A-
: Shear Force, Va = -0.00051441
: EDGE -B-
: Shear Force, Vb = 0.00051441
: BOTH EDGES
: Axial Force, F = -16273.616
: Longitudinal Reinforcement Area Distribution (in 2 divisions)
:   -Tension: Aslt = 0.00
:   -Compression: Aslc = 5353.274
: Longitudinal Reinforcement Area Distribution (in 3 divisions)
:   -Tension: Asl,ten = 1137.257
:   -Compression: Asl,com = 2208.54
:   -Middle: Asl,mid = 2007.478
: -----
: -----
: Calculation of Shear Capacity ratio , Ve/Vr = 0.55377356
: Member Controlled by Flexure (Ve/Vr < 1)
: Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 Ve = (Mpr1 + Mpr2)/ln = 552827.824
: with

```

$$M_{pr1} = \text{Max}(M_{u1+}, M_{u1-}) = 8.2924E+008$$

$M_{u1+} = 5.1260E+008$, 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

$M_{u1-} = 8.2924E+008$, 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

$$M_{pr2} = \text{Max}(M_{u2+}, M_{u2-}) = 8.2924E+008$$

$M_{u2+} = 5.1260E+008$, 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

$M_{u2-} = 8.2924E+008$, 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 ϕ_u according to 4.1, Biskinis/Fardis 2013:

$$\phi_u = 9.5578758E-006$$

$$M_u = 5.1260E+008$$

with full section properties:

$$b = 750.00$$

$$d = 707.00$$

$$d' = 43.00$$

$$v = 0.00093001$$

$$N = 16273.616$$

$$f_c = 33.00$$

$$\alpha_{co} (5A.5, \text{TBDY}) = 0.002$$

$$\text{Final value of } \phi_{cu}: \phi_{cu}^* = \text{shear_factor} * \text{Max}(\phi_{cu}, \phi_{cc}) = 0.01288354$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \phi_{cu} = 0.01288354$$

$$\omega_e \text{ ((5.4c), TBDY)} = \alpha_{se} * \text{sh}_{,\min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.05503171$$

where $f = \alpha_f * \rho_f * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.04286225$$

Expression ((15B.6), TBDY) is modified as $\alpha_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$\alpha_f = 0.31984848$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 140733.333$$

$$b_{\max} = 750.00$$

$$h_{\max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } \rho_f = 2t_f / b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{fe} = 870.5244$$

$$f_y = 0.04286225$$

Expression ((15B.6), TBDY) is modified as $\alpha_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$\alpha_f = 0.31984848$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 140733.333$$

$$b_{\max} = 750.00$$

$$h_{\max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } \rho_f = 2t_f / b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{fe} = 870.5244$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L * t * \text{Cos}(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$\alpha_{se} \text{ ((5.4d), TBDY)} = (\alpha_{se1} * A_{ext} + \alpha_{se2} * A_{int}) / A_{sec} = 0.45746528$$

$$\alpha_{se1} = \text{Max}(((A_{\text{conf,max1}} - A_{\text{noConf1}}) / A_{\text{conf,max1}}) * (A_{\text{conf,min1}} / A_{\text{conf,max1}}), 0) = 0.45746528$$

The definitions of A_{noConf} , $A_{\text{conf,min}}$ and $A_{\text{conf,max}}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.11061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{\text{conf,max1}} = 353600.00$ is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{conf,min1} = 293525.00$ is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area $A_{conf,max1}$ by a length equal to half the clear spacing between external hoops.

$A_{noConf1} = 158733.333$ is the unconfined external core area which is equal to $b_i^2/6$ as defined at (A.2).
 $ase_2 (>= ase_1) = \text{Max}(((A_{conf,max2} - A_{noConf2})/A_{conf,max2}) * (A_{conf,min2}/A_{conf,max2}), 0) = 0.45746528$

The definitions of A_{noConf} , $A_{conf,min}$ and $A_{conf,max}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max2} = 171264.00$ is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

$A_{conf,min2} = 54741.00$ is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area $A_{conf,max2}$ by a length equal to half the clear spacing between internal hoops.

$A_{noConf2} = 106242.667$ is the unconfined internal core area which is equal to $b_i^2/6$ as defined at (A.2).

$p_{sh,min} * F_{ywe} = \text{Min}(p_{sh,x} * F_{ywe}, p_{sh,y} * F_{ywe}) = 2.92621$

Expression (5.4d) 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)

 $p_{sh,x} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{s2} * F_{ywe2} = 2.92621$

$p_{sh1} ((5.4d), \text{TBDY}) = L_{stir1} * A_{stir1} / (A_{sec} * s_1) = 0.00367709$

L_{stir1} (Length of stirrups along Y) = 2060.00

A_{stir1} (stirrups area) = 78.53982

$p_{sh2} (5.4d) = L_{stir2} * A_{stir2} / (A_{sec} * s_2) = 0.00067082$

L_{stir2} (Length of stirrups along Y) = 1468.00

A_{stir2} (stirrups area) = 50.26548

 $p_{sh,y} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{s2} * F_{ywe2} = 2.92621$

$p_{sh1} ((5.4d), \text{TBDY}) = L_{stir1} * A_{stir1} / (A_{sec} * s_1) = 0.00367709$

L_{stir1} (Length of stirrups along X) = 2060.00

A_{stir1} (stirrups area) = 78.53982

$p_{sh2} ((5.4d), \text{TBDY}) = L_{stir2} * A_{stir2} / (A_{sec} * s_2) = 0.00067082$

L_{stir2} (Length of stirrups along X) = 1468.00

A_{stir2} (stirrups area) = 50.26548

 $A_{sec} = 440000.00$

$s_1 = 100.00$

$s_2 = 250.00$

$f_{ywe1} = 694.4444$

$f_{ywe2} = 555.5556$

$f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY: $cc = 0.00238888$

$c = \text{confinement factor} = 1.03889$

$y_1 = 0.00145721$

$sh_1 = 0.00466307$

$ft_1 = 459.4373$

$fy_1 = 382.8645$

$su_1 = 0.00582756$

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

$l_0/l_{ou,min} = l_b/l_d = 0.318426$

$su_1 = 0.4 * esu_{1,nominal} ((5.5), \text{TBDY}) = 0.032$

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 $fs_1 = (f_{s,jacket} * A_{sl,ten,jacket} + f_{s,core} * A_{sl,ten,core}) / A_{sl,ten} = 382.8645$

with $Es_1 = (E_{s,jacket} * A_{sl,ten,jacket} + E_{s,core} * A_{sl,ten,core}) / A_{sl,ten} = 200000.00$

$y_2 = 0.00145721$

$sh_2 = 0.00466307$

$ft_2 = 465.423$

$fy_2 = 387.8525$

$su_2 = 0.00582756$

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 = 0.318426

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 = 387.8525

with Es2 = (Es,jacket*Asl,com,jacket + Es,core*Asl,com,core)/Asl,com = 200000.00

yv = 0.00145721

shv = 0.00466307

ftv = 463.3885

fyv = 386.157

suv = 0.00582756

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 = 0.318426

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 = 386.157

with Esv = (Es,jacket*Asl,mid,jacket + Es,mid*Asl,mid,core)/Asl,mid = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.02488335

2 = Asl,com/(b*d)*(fs2/fc) = 0.04895276

v = Asl,mid/(b*d)*(fsv/fc) = 0.04430167

and confined core properties:

b = 690.00

d = 677.00

d' = 13.00

fcc (5A.2, TBDY) = 34.2833

cc (5A.5, TBDY) = 0.00238888

c = confinement factor = 1.03889

1 = Asl,ten/(b*d)*(fs1/fc) = 0.02824566

2 = Asl,com/(b*d)*(fs2/fc) = 0.05556741

v = Asl,mid/(b*d)*(fsv/fc) = 0.05028784

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

v < vs,y2 - LHS eq.(4.5) is satisfied

--->

su (4.9) = 0.13760581

Mu = MRc (4.14) = 5.1260E+008

u = su (4.1) = 9.5578758E-006

Calculation of ratio lb/ld

Lap Length: lb/ld = 0.318426

lb = 300.00

ld = 942.1341

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 = 655.5556

Mean concrete strength: fc' = (fc',jacket*Area_jacket + fc',core*Area_core)/Area_section = 27.68182, but $fc'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

t = 1.00

s = 0.80

e = 1.00

cb = 25.00

Ktr = 1.7174

Atr = Min(Atr_x,Atr_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
 $s = \text{Max}(s_{\text{external}}, s_{\text{internal}}) = 250.00$
 $n = 24.00$

Calculation of μ_1 -

Calculation of ultimate curvature μ according to 4.1, Biskinis/Fardis 2013:

$$u = 1.0408734E-005$$

$$\mu = 8.2924E+008$$

with full section properties:

$$b = 400.00$$

$$d = 707.00$$

$$d' = 43.00$$

$$v = 0.00174378$$

$$N = 16273.616$$

$$f_c = 33.00$$

$$c_o \text{ (5A.5, TBDY)} = 0.002$$

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.01288354$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } c_u = 0.01288354$$

$$w_e \text{ ((5.4c), TBDY)} = a_{se} * s_{h, \min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.05503171$$

where $f = a_f * p_f * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.04286225$$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.31984848$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 140733.333$$

$$b_{\max} = 750.00$$

$$h_{\max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 870.5244$$

$$f_y = 0.04286225$$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.31984848$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 140733.333$$

$$b_{\max} = 750.00$$

$$h_{\max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 870.5244$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L * t * \text{Cos}(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$a_{se} \text{ ((5.4d), TBDY)} = (a_{se1} * A_{ext} + a_{se2} * A_{int}) / A_{sec} = 0.45746528$$

$$a_{se1} = \text{Max}(((A_{\text{conf,max1}} - A_{\text{noConf1}}) / A_{\text{conf,max1}}) * (A_{\text{conf,min1}} / A_{\text{conf,max1}}), 0) = 0.45746528$$

The definitions of A_{noConf} , $A_{\text{conf,min}}$ and $A_{\text{conf,max}}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{\text{conf,max1}} = 353600.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{\text{conf,min1}} = 293525.00$ is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area $A_{\text{conf,max1}}$ by a length equal to half the clear spacing between external hoops.

$A_{\text{noConf1}} = 158733.333$ is the unconfined external core area which is equal to $b_i^2/6$ as defined at (A.2).

$$a_{se2} (>= a_{se1}) = \text{Max}(((A_{\text{conf,max2}} - A_{\text{noConf2}}) / A_{\text{conf,max2}}) * (A_{\text{conf,min2}} / A_{\text{conf,max2}}), 0) = 0.45746528$$

The definitions of A_{noConf} , $A_{conf,min}$ and $A_{conf,max}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max2} = 171264.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

$A_{conf,min2} = 54741.00$ is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area $A_{conf,max2}$ by a length equal to half the clear spacing between internal hoops.

$A_{noConf2} = 106242.667$ is the unconfined internal core area which is equal to $b_i^2/6$ as defined at (A.2).

$p_{sh,min} * F_{ywe} = \text{Min}(p_{sh,x} * F_{ywe}, p_{sh,y} * F_{ywe}) = 2.92621$

Expression (5.4d) 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)

 $p_{sh,x} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{sh2} * F_{ywe2} = 2.92621$

p_{sh1} ((5.4d), TBDY) = $L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00367709$

L_{stir1} (Length of stirrups along Y) = 2060.00

A_{stir1} (stirrups area) = 78.53982

p_{sh2} (5.4d) = $L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00067082$

L_{stir2} (Length of stirrups along Y) = 1468.00

A_{stir2} (stirrups area) = 50.26548

 $p_{sh,y} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{sh2} * F_{ywe2} = 2.92621$

p_{sh1} ((5.4d), TBDY) = $L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00367709$

L_{stir1} (Length of stirrups along X) = 2060.00

A_{stir1} (stirrups area) = 78.53982

p_{sh2} ((5.4d), TBDY) = $L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00067082$

L_{stir2} (Length of stirrups along X) = 1468.00

A_{stir2} (stirrups area) = 50.26548

 $A_{sec} = 440000.00$

$s1 = 100.00$

$s2 = 250.00$

$f_{ywe1} = 694.4444$

$f_{ywe2} = 555.5556$

$f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY: $cc = 0.00238888$

$c = \text{confinement factor} = 1.03889$

$y1 = 0.00145721$

$sh1 = 0.00466307$

$ft1 = 465.423$

$fy1 = 387.8525$

$su1 = 0.00582756$

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

$l_o/l_{ou,min} = l_b/l_d = 0.318426$

$su1 = 0.4 * esu1_{nominal}$ ((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 $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE 41-17.

with $fs1 = (f_{s,jacket} * A_{s,ten,jacket} + f_{s,core} * A_{s,ten,core}) / A_{s,ten} = 387.8525$

with $Es1 = (E_{s,jacket} * A_{s,ten,jacket} + E_{s,core} * A_{s,ten,core}) / A_{s,ten} = 200000.00$

$y2 = 0.00145721$

$sh2 = 0.00466307$

$ft2 = 459.4373$

$fy2 = 382.8645$

$su2 = 0.00582756$

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

$l_o/l_{ou,min} = l_b/l_{b,min} = 0.318426$

$su2 = 0.4 * esu2_{nominal}$ ((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 $f_{s2} = (f_{s,jacket} \cdot A_{s1,com,jacket} + f_{s,core} \cdot A_{s1,com,core})/A_{s1,com} = 382.8645$

with $E_{s2} = (E_{s,jacket} \cdot A_{s1,com,jacket} + E_{s,core} \cdot A_{s1,com,core})/A_{s1,com} = 200000.00$

$y_v = 0.00145721$

$sh_v = 0.00466307$

$ft_v = 463.3885$

$f_{y_v} = 386.157$

$s_{u_v} = 0.00582756$

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

$l_o/l_{o,min} = l_b/l_d = 0.318426$

$s_{u_v} = 0.4 \cdot e_{s_{u_v,nominal}} ((5.5), TBDY) = 0.032$

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 $f_{s_{y_v}} = (f_{s,jacket} \cdot A_{s1,mid,jacket} + f_{s,mid} \cdot A_{s1,mid,core})/A_{s1,mid} = 386.157$

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 = $A_{s1,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.09178643$

2 = $A_{s1,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.04665628$

v = $A_{s1,mid}/(b \cdot d) \cdot (f_{s_{y_v}}/f_c) = 0.08306563$

and confined core properties:

b = 340.00

d = 677.00

d' = 13.00

f_{cc} (5A.2, TBDY) = 34.2833

cc (5A.5, TBDY) = 0.00238888

c = confinement factor = 1.03889

1 = $A_{s1,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.11276915$

2 = $A_{s1,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.05732208$

v = $A_{s1,mid}/(b \cdot d) \cdot (f_{s_{y_v}}/f_c) = 0.10205474$

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) = 0.20810191

M_u = M_{Rc} (4.14) = 8.2924E+008

u = s_u (4.1) = 1.0408734E-005

Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.318426$

$l_b = 300.00$

$l_d = 942.1341$

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: $f_y = 655.5556$

Mean concrete strength: $f'_c = (f'_{c,jacket} \cdot Area_{jacket} + f'_{c,core} \cdot Area_{core})/Area_{section} = 27.68182$, but $f_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

t = 1.00

s = 0.80

e = 1.00

cb = 25.00

K_{tr} = 1.7174

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 = $\text{Max}(s_{external}, s_{internal}) = 250.00$

n = 24.00

Calculation of μ_{2+}

Calculation of ultimate curvature μ according to 4.1, Biskinis/Fardis 2013:

$$\mu = 9.5578758E-006$$

$$\mu = 5.1260E+008$$

with full section properties:

$$b = 750.00$$

$$d = 707.00$$

$$d' = 43.00$$

$$v = 0.00093001$$

$$N = 16273.616$$

$$f_c = 33.00$$

$$c_o(5A.5, TBDY) = 0.002$$

$$\text{Final value of } \mu: \mu^* = \text{shear_factor} * \text{Max}(\mu, c_o) = 0.01288354$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \mu = 0.01288354$$

$$\mu_e(5.4c, TBDY) = a_{se} * \text{sh}_{, \min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.05503171$$

where $f = a_f * p_f * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.04286225$$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.31984848$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 140733.333$$

$$b_{\max} = 750.00$$

$$h_{\max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 870.5244$$

$$f_y = 0.04286225$$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.31984848$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 140733.333$$

$$b_{\max} = 750.00$$

$$h_{\max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 870.5244$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L * t * \text{Cos}(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$a_{se}((5.4d), TBDY) = (a_{se1} * A_{ext} + a_{se2} * A_{int}) / A_{sec} = 0.45746528$$

$$a_{se1} = \text{Max}(((A_{\text{conf,max1}} - A_{\text{noConf1}}) / A_{\text{conf,max1}}) * (A_{\text{conf,min1}} / A_{\text{conf,max1}}), 0) = 0.45746528$$

The definitions of A_{noConf} , $A_{\text{conf,min}}$ and $A_{\text{conf,max}}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{\text{conf,max1}} = 353600.00$ is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{\text{conf,min1}} = 293525.00$ is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area $A_{\text{conf,max1}}$ by a length

equal to half the clear spacing between external hoops.

$A_{\text{noConf1}} = 158733.333$ is the unconfined external core area which is equal to $b_i^2/6$ as defined at (A.2).

$$a_{se2} (>= a_{se1}) = \text{Max}(((A_{\text{conf,max2}} - A_{\text{noConf2}}) / A_{\text{conf,max2}}) * (A_{\text{conf,min2}} / A_{\text{conf,max2}}), 0) = 0.45746528$$

The definitions of A_{noConf} , $A_{\text{conf,min}}$ and $A_{\text{conf,max}}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{\text{conf,max2}} = 171264.00$ is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

$A_{conf,min2} = 54741.00$ is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area $A_{conf,max2}$ by a length

equal to half the clear spacing between internal hoops.

$A_{noConf2} = 106242.667$ is the unconfined internal core area which is equal to $b_i^2/6$ as defined at (A.2).

$p_{sh,min} * F_{ywe} = \text{Min}(p_{sh,x} * F_{ywe}, p_{sh,y} * F_{ywe}) = 2.92621$

Expression (5.4d) 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)

 $p_{sh,x} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{s2} * F_{ywe2} = 2.92621$

p_{sh1} ((5.4d), TBDY) = $L_{stir1} * A_{stir1} / (A_{sec} * s_1) = 0.00367709$

L_{stir1} (Length of stirrups along Y) = 2060.00

A_{stir1} (stirrups area) = 78.53982

p_{sh2} (5.4d) = $L_{stir2} * A_{stir2} / (A_{sec} * s_2) = 0.00067082$

L_{stir2} (Length of stirrups along Y) = 1468.00

A_{stir2} (stirrups area) = 50.26548

$p_{sh,y} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{s2} * F_{ywe2} = 2.92621$

p_{sh1} ((5.4d), TBDY) = $L_{stir1} * A_{stir1} / (A_{sec} * s_1) = 0.00367709$

L_{stir1} (Length of stirrups along X) = 2060.00

A_{stir1} (stirrups area) = 78.53982

p_{sh2} ((5.4d), TBDY) = $L_{stir2} * A_{stir2} / (A_{sec} * s_2) = 0.00067082$

L_{stir2} (Length of stirrups along X) = 1468.00

A_{stir2} (stirrups area) = 50.26548

$A_{sec} = 440000.00$

$s_1 = 100.00$

$s_2 = 250.00$

$f_{ywe1} = 694.4444$

$f_{ywe2} = 555.5556$

$f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY: $cc = 0.00238888$

$c = \text{confinement factor} = 1.03889$

$y_1 = 0.00145721$

$sh_1 = 0.00466307$

$ft_1 = 459.4373$

$fy_1 = 382.8645$

$su_1 = 0.00582756$

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

$l_o/l_{ou,min} = l_b/l_d = 0.318426$

$su_1 = 0.4 * esu1_{nominal}$ ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: $esu1_{nominal} = 0.08$,

For calculation of $esu1_{nominal}$ 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 $fs_1 = (f_{s,jacket} * A_{sl,ten,jacket} + f_{s,core} * A_{sl,ten,core}) / A_{sl,ten} = 382.8645$

with $Es_1 = (E_{s,jacket} * A_{sl,ten,jacket} + E_{s,core} * A_{sl,ten,core}) / A_{sl,ten} = 200000.00$

$y_2 = 0.00145721$

$sh_2 = 0.00466307$

$ft_2 = 465.423$

$fy_2 = 387.8525$

$su_2 = 0.00582756$

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

$l_o/l_{ou,min} = l_b/l_{b,min} = 0.318426$

$su_2 = 0.4 * esu2_{nominal}$ ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: $esu2_{nominal} = 0.08$,

For calculation of $esu2_{nominal}$ 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 $fs_2 = (f_{s,jacket} * A_{sl,com,jacket} + f_{s,core} * A_{sl,com,core}) / A_{sl,com} = 387.8525$

with $Es_2 = (E_{s,jacket} * A_{sl,com,jacket} + E_{s,core} * A_{sl,com,core}) / A_{sl,com} = 200000.00$

$y_v = 0.00145721$

$sh_v = 0.00466307$

$$f_{tv} = 463.3885$$

$$f_{yv} = 386.157$$

$$s_{uv} = 0.00582756$$

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

$$l_o/l_{ou,min} = l_b/l_d = 0.318426$$

$$s_{uv} = 0.4 * e_{suv,nominal} ((5.5), TBDY) = 0.032$$

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 γ_v , sh_v, f_{tv}, f_{yv} , it is considered
characteristic value $f_{sv} = f_{sv}/1.2$, from table 5.1, TBDY.

γ_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.

$$\text{with } f_{sv} = (f_{s,jacket} * A_{s,mid,jacket} + f_{s,mid} * A_{s,mid,core}) / A_{s,mid} = 386.157$$

$$\text{with } E_{sv} = (E_{s,jacket} * A_{s,mid,jacket} + E_{s,mid} * A_{s,mid,core}) / A_{s,mid} = 200000.00$$

$$1 = A_{s,ten} / (b * d) * (f_{s1} / f_c) = 0.02488335$$

$$2 = A_{s,com} / (b * d) * (f_{s2} / f_c) = 0.04895276$$

$$v = A_{s,mid} / (b * d) * (f_{sv} / f_c) = 0.04430167$$

and confined core properties:

$$b = 690.00$$

$$d = 677.00$$

$$d' = 13.00$$

$$f_{cc} (5A.2, TBDY) = 34.2833$$

$$c_c (5A.5, TBDY) = 0.00238888$$

$$c = \text{confinement factor} = 1.03889$$

$$1 = A_{s,ten} / (b * d) * (f_{s1} / f_c) = 0.02824566$$

$$2 = A_{s,com} / (b * d) * (f_{s2} / f_c) = 0.05556741$$

$$v = A_{s,mid} / (b * d) * (f_{sv} / f_c) = 0.05028784$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < v_{s,y2}$ - LHS eq.(4.5) is satisfied

--->

$$s_u (4.9) = 0.13760581$$

$$\mu_u = M_{Rc} (4.14) = 5.1260E+008$$

$$u = s_u (4.1) = 9.5578758E-006$$

Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.318426$

$$l_b = 300.00$$

$$l_d = 942.1341$$

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: $f_y = 655.5556$

Mean concrete strength: $f'_c = (f'_{c,jacket} * Area_{jacket} + f'_{c,core} * Area_{core}) / Area_{section} = 27.68182$, but $f_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 25.00$$

$$K_{tr} = 1.7174$$

$$A_{tr} = \text{Min}(A_{tr,x}, A_{tr,y}) = 257.6106$$

where $A_{tr,x}$, $A_{tr,y}$ are the sum of the area of all stirrup legs along X and Y local axis

$$s = \text{Max}(s_{external}, s_{internal}) = 250.00$$

$$n = 24.00$$

Calculation of μ_u -

Calculation of ultimate curvature μ_u according to 4.1, Biskinis/Fardis 2013:

$$u = 1.0408734E-005$$

Mu = 8.2924E+008

with full section properties:

b = 400.00

d = 707.00

d' = 43.00

v = 0.00174378

N = 16273.616

fc = 33.00

co (5A.5, TBDY) = 0.002

Final value of cu: $cu^* = \text{shear_factor} * \text{Max}(cu, cc) = 0.01288354$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $cu = 0.01288354$

we ((5.4c), TBDY) = $ase^* sh_{\min} * fy_{we} / f_{ce} + \text{Min}(fx, fy) = 0.05503171$

where $f = af * pf * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$fx = 0.04286225$

Expression ((15B.6), TBDY) is modified as $af = 1 - (\text{Unconfined area}) / (\text{total area})$

$af = 0.31984848$

with Unconfined area = $((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 140733.333$

$b_{\max} = 750.00$

$h_{\max} = 750.00$

From EC8 A.4.4.3(6), $pf = 2tf / bw = 0.00508$

$bw = 400.00$

effective stress from (A.35), $f_{f,e} = 870.5244$

$fy = 0.04286225$

Expression ((15B.6), TBDY) is modified as $af = 1 - (\text{Unconfined area}) / (\text{total area})$

$af = 0.31984848$

with Unconfined area = $((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 140733.333$

$b_{\max} = 750.00$

$h_{\max} = 750.00$

From EC8 A.4.4.3(6), $pf = 2tf / bw = 0.00508$

$bw = 400.00$

effective stress from (A.35), $f_{f,e} = 870.5244$

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) = $(ase1 * A_{ext} + ase2 * A_{int}) / A_{sec} = 0.45746528$

$ase1 = \text{Max}(((A_{conf,max1} - A_{noConf1}) / A_{conf,max1}) * (A_{conf,min1} / A_{conf,max1}), 0) = 0.45746528$

The definitions of A_{noConf} , $A_{conf,min}$ and $A_{conf,max}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max1} = 353600.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{conf,min1} = 293525.00$ is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area $A_{conf,max1}$ by a length equal to half the clear spacing between external hoops.

$A_{noConf1} = 158733.333$ is the unconfined external core area which is equal to $b_i^2 / 6$ as defined at (A.2).

$ase2$ ($\geq ase1$) = $\text{Max}(((A_{conf,max2} - A_{noConf2}) / A_{conf,max2}) * (A_{conf,min2} / A_{conf,max2}), 0) = 0.45746528$

The definitions of A_{noConf} , $A_{conf,min}$ and $A_{conf,max}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max2} = 171264.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

$A_{conf,min2} = 54741.00$ is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area $A_{conf,max2}$ by a length equal to half the clear spacing between internal hoops.

$A_{noConf2} = 106242.667$ is the unconfined internal core area which is equal to $b_i^2 / 6$ as defined at (A.2).

$p_{sh,min} * F_{ywe} = \text{Min}(p_{sh,x} * F_{ywe}, p_{sh,y} * F_{ywe}) = 2.92621$

Expression (5.4d) for $psh_{min} \cdot F_{ywe}$ has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$psh_x \cdot F_{ywe} = psh1 \cdot F_{ywe1} + ps2 \cdot F_{ywe2} = 2.92621$
 $psh1$ ((5.4d), TBDY) = $Lstir1 \cdot Astir1 / (Asec \cdot s1) = 0.00367709$
Lstir1 (Length of stirrups along Y) = 2060.00
Astir1 (stirrups area) = 78.53982
 $psh2$ (5.4d) = $Lstir2 \cdot Astir2 / (Asec \cdot s2) = 0.00067082$
Lstir2 (Length of stirrups along Y) = 1468.00
Astir2 (stirrups area) = 50.26548

$psh_y \cdot F_{ywe} = psh1 \cdot F_{ywe1} + ps2 \cdot F_{ywe2} = 2.92621$
 $psh1$ ((5.4d), TBDY) = $Lstir1 \cdot Astir1 / (Asec \cdot s1) = 0.00367709$
Lstir1 (Length of stirrups along X) = 2060.00
Astir1 (stirrups area) = 78.53982
 $psh2$ ((5.4d), TBDY) = $Lstir2 \cdot Astir2 / (Asec \cdot s2) = 0.00067082$
Lstir2 (Length of stirrups along X) = 1468.00
Astir2 (stirrups area) = 50.26548

Asec = 440000.00

s1 = 100.00

s2 = 250.00

fywe1 = 694.4444

fywe2 = 555.5556

fce = 33.00

From ((5.A5), TBDY), TBDY: cc = 0.00238888

c = confinement factor = 1.03889

y1 = 0.00145721

sh1 = 0.00466307

ft1 = 465.423

fy1 = 387.8525

su1 = 0.00582756

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 = 0.318426

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 = $(fs_{jacket} \cdot Asl_{ten,jacket} + fs_{core} \cdot Asl_{ten,core}) / Asl_{ten} = 387.8525$

with Es1 = $(Es_{jacket} \cdot Asl_{ten,jacket} + Es_{core} \cdot Asl_{ten,core}) / Asl_{ten} = 200000.00$

y2 = 0.00145721

sh2 = 0.00466307

ft2 = 459.4373

fy2 = 382.8645

su2 = 0.00582756

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 = 0.318426

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 = $(fs_{jacket} \cdot Asl_{com,jacket} + fs_{core} \cdot Asl_{com,core}) / Asl_{com} = 382.8645$

with Es2 = $(Es_{jacket} \cdot Asl_{com,jacket} + Es_{core} \cdot Asl_{com,core}) / Asl_{com} = 200000.00$

yv = 0.00145721

shv = 0.00466307

ftv = 463.3885

fyv = 386.157

suv = 0.00582756

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

$$l_0/l_{ou,min} = l_b/l_d = 0.318426$$

$$s_{uv} = 0.4 * e_{suv_nominal} ((5.5), TBDY) = 0.032$$

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 γ_v , sh_v, ft_v, fy_v , it is considered

characteristic value $f_{sv} = f_{sv}/1.2$, from table 5.1, TBDY.

$$\gamma_1, sh_1, ft_1, fy_1, \text{ are also multiplied by } \text{Min}(1, 1.25 * (l_b/l_d)^{2/3}), \text{ from 10.3.5, ASCE 41-17.}$$

$$\text{with } f_{sv} = (f_{s,jacket} * A_{s,mid,jacket} + f_{s,mid} * A_{s,mid,core}) / A_{s,mid} = 386.157$$

$$\text{with } E_{sv} = (E_{s,jacket} * A_{s,mid,jacket} + E_{s,mid} * A_{s,mid,core}) / A_{s,mid} = 200000.00$$

$$1 = A_{s,ten} / (b * d) * (f_{s1} / f_c) = 0.09178643$$

$$2 = A_{s,com} / (b * d) * (f_{s2} / f_c) = 0.04665628$$

$$v = A_{s,mid} / (b * d) * (f_{sv} / f_c) = 0.08306563$$

and confined core properties:

$$b = 340.00$$

$$d = 677.00$$

$$d' = 13.00$$

$$f_{cc} (5A.2, TBDY) = 34.2833$$

$$c_c (5A.5, TBDY) = 0.00238888$$

$$c = \text{confinement factor} = 1.03889$$

$$1 = A_{s,ten} / (b * d) * (f_{s1} / f_c) = 0.11276915$$

$$2 = A_{s,com} / (b * d) * (f_{s2} / f_c) = 0.05732208$$

$$v = A_{s,mid} / (b * d) * (f_{sv} / f_c) = 0.10205474$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < v_{s,y2}$ - LHS eq.(4.5) is satisfied

--->

$$s_u (4.9) = 0.20810191$$

$$\mu = M_{Rc} (4.14) = 8.2924E+008$$

$$u = s_u (4.1) = 1.0408734E-005$$

Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.318426$

$$l_b = 300.00$$

$$l_d = 942.1341$$

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: $f_y = 655.5556$

Mean concrete strength: $f'_c = (f'_{c,jacket} * Area_{jacket} + f'_{c,core} * Area_{core}) / Area_{section} = 27.68182$, but $f_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 25.00$$

$$K_{tr} = 1.7174$$

$$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 257.6106$$

where A_{tr_x} , A_{tr_y} are the sum of the area of all stirrup legs along X and Y local axis

$$s = \text{Max}(s_{external}, s_{internal}) = 250.00$$

$$n = 24.00$$

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 998292.205$

Calculation of Shear Strength at edge 1, $V_{r1} = 998292.205$

$$V_{r1} = V_{Col} ((10.3), ASCE 41-17) = knl * V_{Col0}$$

$$V_{Col0} = 998292.205$$

$$knl = 1 \text{ (zero step-static loading)}$$

NOTE: In expression (10-3) ' $V_s = A_v * f_y * d / s$ ' is replaced by ' $V_s + f * V_f$ ' where V_f is the contribution of FRPs (11.3), ACI 440).

$$= 1 \text{ (normal-weight concrete)}$$

Mean concrete strength: $f_c' = (f_{c'}^{\text{jacket}} \cdot \text{Area}_{\text{jacket}} + f_{c'}^{\text{core}} \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 27.68182$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 4.00$

$\mu_u = 11.77537$

$V_u = 0.00051441$

$d = 0.8 \cdot h = 600.00$

$N_u = 16273.616$

$A_g = 300000.00$

From (11.5.4.8), ACI 318-14: $V_s = V_{s,\text{jacket}} + V_{s,\text{core}} = 881489.011$

where:

$V_{s,\text{jacket}} = V_{s,j1} + V_{s,j2} = 802851.456$

$V_{s,j1} = 523598.776$ is calculated for section web jacket, with:

$d = 600.00$

$A_v = 157079.633$

$f_y = 555.5556$

$s = 100.00$

$V_{s,j1}$ is multiplied by $\text{Col},j1 = 1.00$

$s/d = 0.16666667$

$V_{s,j2} = 279252.68$ is calculated for section flange jacket, with:

$d = 320.00$

$A_v = 157079.633$

$f_y = 555.5556$

$s = 100.00$

$V_{s,j2}$ is multiplied by $\text{Col},j2 = 1.00$

$s/d = 0.3125$

$V_{s,\text{core}} = V_{s,c1} + V_{s,c2} = 78637.555$

$V_{s,c1} = 78637.555$ is calculated for section web core, with:

$d = 440.00$

$A_v = 100530.965$

$f_y = 444.4444$

$s = 250.00$

$V_{s,c1}$ is multiplied by $\text{Col},c1 = 1.00$

$s/d = 0.56818182$

$V_{s,c2} = 0.00$ is calculated for section flange core, with:

$d = 160.00$

$A_v = 100530.965$

$f_y = 444.4444$

$s = 250.00$

$V_{s,c2}$ is multiplied by $\text{Col},c2 = 0.00$

$s/d = 1.5625$

V_f ((11-3)-(11.4), ACI 440) = 372533.843

$f = 0.95$, for fully-wrapped sections

$w_f/s_f = 1$ (FRP strips adjacent to one another).

In (11.3) $\sin \theta + \cos \theta$ is replaced with $(\cot \theta + \csc \theta) \sin \alpha$ which is more a generalised expression,

where θ is the angle of the crack direction (see KANEPE).

This later relation, considered as a function $V_f(\theta, \alpha)$, is implemented for every different fiber orientation α_i , as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.

orientation 1: $\theta = b1 + 90^\circ = 90.00$

$V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, \theta)|)$, with:

total thickness per orientation, $t_{f1} = N_L \cdot t / N_{\text{Dir}} = 1.016$

$d_{fv} = d$ (figure 11.2, ACI 440) = 707.00

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: $V_s + V_f \leq 838832.606$

$b_w = 400.00$

Calculation of Shear Strength at edge 2, $V_{r2} = 998292.205$

$V_{r2} = V_{\text{Col}}$ ((10.3), ASCE 41-17) = $k_{nl} \cdot V_{\text{Col}0}$

$V_{\text{Col}0} = 998292.205$

$k_{nl} = 1$ (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: $fc' = (fc'_{jacket} \cdot Area_{jacket} + fc'_{core} \cdot Area_{core}) / Area_{section} = 27.68182$, but $fc'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 4.00$

$\mu_u = 11.77482$

$V_u = 0.00051441$

$d = 0.8 \cdot h = 600.00$

$N_u = 16273.616$

$A_g = 300000.00$

From (11.5.4.8), ACI 318-14: $V_s = V_{s,jacket} + V_{s,core} = 881489.011$

where:

$V_{s,jacket} = V_{s,j1} + V_{s,j2} = 802851.456$

$V_{s,j1} = 523598.776$ is calculated for section web jacket, with:

$d = 600.00$

$A_v = 157079.633$

$f_y = 555.5556$

$s = 100.00$

$V_{s,j1}$ is multiplied by $Col,j1 = 1.00$

$s/d = 0.16666667$

$V_{s,j2} = 279252.68$ is calculated for section flange jacket, with:

$d = 320.00$

$A_v = 157079.633$

$f_y = 555.5556$

$s = 100.00$

$V_{s,j2}$ is multiplied by $Col,j2 = 1.00$

$s/d = 0.3125$

$V_{s,core} = V_{s,c1} + V_{s,c2} = 78637.555$

$V_{s,c1} = 78637.555$ is calculated for section web core, with:

$d = 440.00$

$A_v = 100530.965$

$f_y = 444.4444$

$s = 250.00$

$V_{s,c1}$ is multiplied by $Col,c1 = 1.00$

$s/d = 0.56818182$

$V_{s,c2} = 0.00$ is calculated for section flange core, with:

$d = 160.00$

$A_v = 100530.965$

$f_y = 444.4444$

$s = 250.00$

$V_{s,c2}$ is multiplied by $Col,c2 = 0.00$

$s/d = 1.5625$

V_f ((11-3)-(11.4), ACI 440) = 372533.843

$f = 0.95$, for fully-wrapped sections

$w_f/s_f = 1$ (FRP strips adjacent to one another).

In (11.3) $\sin \theta + \cos \theta$ is replaced with $(\cot \theta + \csc \theta) \sin \alpha$ which is more a generalised expression,

where θ is the angle of the crack direction (see KANEPE).

This later relation, considered as a function $V_f(\theta, \alpha)$, is implemented for every different fiber orientation α_i , as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.

orientation 1: $\theta = b1 + 90^\circ = 90.00$

$V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, \theta)|)$, with:

total thickness per orientation, $tf1 = NL \cdot t / NoDir = 1.016$

$dfv = d$ (figure 11.2, ACI 440) = 707.00

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: $V_s + V_f \leq 838832.606$

$bw = 400.00$

End Of Calculation of Shear Capacity ratio for element: column JLC1 of floor 1

At local axis: 3

Start Of Calculation of Shear Capacity ratio for element: column JLC1 of floor 1

At Shear local axis: 2
(Bending local axis: 3)
Section Type: rcjcs

Constant Properties

Knowledge Factor, $\gamma = 0.85$
Mean strength values are used for both shear and moment calculations.
Consequently:
Jacket
New material of Secondary Member: Concrete Strength, $f_c = f_{cm} = 33.00$
New material of Secondary Member: Steel Strength, $f_s = f_{sm} = 555.5556$
Concrete Elasticity, $E_c = 26999.444$
Steel Elasticity, $E_s = 200000.00$
Existing Column
Existing material of Secondary Member: Concrete Strength, $f_c = f_{cm} = 20.00$
Existing material of Secondary Member: Steel Strength, $f_s = f_{sm} = 444.4444$
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, $f_s = 1.25 \cdot f_{sm} = 694.4444$
Existing Column
Existing material: Steel Strength, $f_s = 1.25 \cdot f_{sm} = 555.5556$

Max Height, $H_{max} = 750.00$
Min Height, $H_{min} = 400.00$
Max Width, $W_{max} = 750.00$
Min Width, $W_{min} = 400.00$
Jacket Thickness, $t_j = 100.00$
Cover Thickness, $c = 25.00$
Mean Confinement Factor overall section = 1.03889
Element Length, $L = 3000.00$
Secondary Member
Ribbed Bars
Ductile Steel
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
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, $V_a = -0.00051441$
EDGE -B-
Shear Force, $V_b = 0.00051441$
BOTH EDGES
Axial Force, $F = -16273.616$
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: $A_{st} = 0.00$
-Compression: $A_{sc} = 5353.274$
Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension: $Asl,ten = 1137.257$
-Compression: $Asl,com = 2208.54$
-Middle: $Asl,mid = 2007.478$

Calculation of Shear Capacity ratio, $Ve/Vr = 0.55377356$

Member Controlled by Flexure ($Ve/Vr < 1$)

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $Ve = (Mpr1 + Mpr2)/ln = 552827.824$

with

$Mpr1 = \text{Max}(Mu1+, Mu1-) = 8.2924E+008$

$Mu1+ = 5.1260E+008$, is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination

$Mu1- = 8.2924E+008$, is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination

$Mpr2 = \text{Max}(Mu2+, Mu2-) = 8.2924E+008$

$Mu2+ = 5.1260E+008$, 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

$Mu2- = 8.2924E+008$, 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 u according to 4.1, Biskinis/Fardis 2013:

$u = 9.5578758E-006$

$Mu = 5.1260E+008$

with full section properties:

$b = 750.00$

$d = 707.00$

$d' = 43.00$

$v = 0.00093001$

$N = 16273.616$

$fc = 33.00$

$co (5A.5, TBDY) = 0.002$

Final value of cu : $cu^* = \text{shear_factor} * \text{Max}(cu, cc) = 0.01288354$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $cu = 0.01288354$

we ((5.4c), TBDY) = $ase * sh, \text{min} * fywe / fce + \text{Min}(fx, fy) = 0.05503171$

where $f = af * pf * ffe / fce$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$fx = 0.04286225$

Expression ((15B.6), TBDY) is modified as $af = 1 - (\text{Unconfined area}) / (\text{total area})$

$af = 0.31984848$

with Unconfined area = $((bmax - 2R)^2 + (hmax - 2R)^2) / 3 = 140733.333$

$bmax = 750.00$

$hmax = 750.00$

From EC8 A.4.4.3(6), $pf = 2tf / bw = 0.00508$

$bw = 400.00$

effective stress from (A.35), $ffe = 870.5244$

$fy = 0.04286225$

Expression ((15B.6), TBDY) is modified as $af = 1 - (\text{Unconfined area}) / (\text{total area})$

$af = 0.31984848$

with Unconfined area = $((bmax - 2R)^2 + (hmax - 2R)^2) / 3 = 140733.333$

$bmax = 750.00$

$hmax = 750.00$

From EC8 A.4.4.3(6), $pf = 2tf / bw = 0.00508$

$bw = 400.00$

effective stress from (A.35), $ffe = 870.5244$

$R = 40.00$

Effective FRP thickness, $tf = NL * t * \text{Cos}(b1) = 1.016$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u,f = 0.015$$

$$ase \text{ ((5.4d), TBDY)} = (ase1 * A_{ext} + ase2 * A_{int}) / A_{sec} = 0.45746528$$

$$ase1 = \text{Max}(((A_{conf,max1} - A_{noConf1}) / A_{conf,max1}) * (A_{conf,min1} / A_{conf,max1}), 0) = 0.45746528$$

The definitions of A_{noConf} , $A_{conf,min}$ and $A_{conf,max}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max1} = 353600.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{conf,min1} = 293525.00$ is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area $A_{conf,max1}$ by a length equal to half the clear spacing between external hoops.

$A_{noConf1} = 158733.333$ is the unconfined external core area which is equal to $b_i^2/6$ as defined at (A.2).

$$ase2 \text{ (>=ase1)} = \text{Max}(((A_{conf,max2} - A_{noConf2}) / A_{conf,max2}) * (A_{conf,min2} / A_{conf,max2}), 0) = 0.45746528$$

The definitions of A_{noConf} , $A_{conf,min}$ and $A_{conf,max}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max2} = 171264.00$ is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

$A_{conf,min2} = 54741.00$ is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area $A_{conf,max2}$ by a length equal to half the clear spacing between internal hoops.

$A_{noConf2} = 106242.667$ is the unconfined internal core area which is equal to $b_i^2/6$ as defined at (A.2).

$$psh_{,min} * F_{ywe} = \text{Min}(psh_{,x} * F_{ywe}, psh_{,y} * F_{ywe}) = 2.92621$$

Expression (5.4d) 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)

$$psh_{,x} * F_{ywe} = psh1 * F_{ywe1} + ps2 * F_{ywe2} = 2.92621$$

$$psh1 \text{ ((5.4d), TBDY)} = L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00367709$$

$$L_{stir1} \text{ (Length of stirrups along Y)} = 2060.00$$

$$A_{stir1} \text{ (stirrups area)} = 78.53982$$

$$psh2 \text{ (5.4d)} = L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00067082$$

$$L_{stir2} \text{ (Length of stirrups along Y)} = 1468.00$$

$$A_{stir2} \text{ (stirrups area)} = 50.26548$$

$$psh_{,y} * F_{ywe} = psh1 * F_{ywe1} + ps2 * F_{ywe2} = 2.92621$$

$$psh1 \text{ ((5.4d), TBDY)} = L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00367709$$

$$L_{stir1} \text{ (Length of stirrups along X)} = 2060.00$$

$$A_{stir1} \text{ (stirrups area)} = 78.53982$$

$$psh2 \text{ ((5.4d), TBDY)} = L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00067082$$

$$L_{stir2} \text{ (Length of stirrups along X)} = 1468.00$$

$$A_{stir2} \text{ (stirrups area)} = 50.26548$$

$$A_{sec} = 440000.00$$

$$s1 = 100.00$$

$$s2 = 250.00$$

$$f_{ywe1} = 694.4444$$

$$f_{ywe2} = 555.5556$$

$$f_{ce} = 33.00$$

$$\text{From ((5.A5), TBDY), TBDY: } cc = 0.00238888$$

$$c = \text{confinement factor} = 1.03889$$

$$y1 = 0.00145721$$

$$sh1 = 0.00466307$$

$$ft1 = 459.4373$$

$$fy1 = 382.8645$$

$$su1 = 0.00582756$$

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

$$l_o / l_{o,min} = l_b / d = 0.318426$$

$$su1 = 0.4 * esu1_{nominal} \text{ ((5.5), TBDY)} = 0.032$$

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 $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$, from 10.3.5, ASCE 41-17.

with $fs1 = (fs_{jacket} \cdot Asl_{ten,jacket} + fs_{core} \cdot Asl_{ten,core}) / Asl_{ten} = 382.8645$

with $Es1 = (Es_{jacket} \cdot Asl_{ten,jacket} + Es_{core} \cdot Asl_{ten,core}) / Asl_{ten} = 200000.00$

$y2 = 0.00145721$

$sh2 = 0.00466307$

$ft2 = 465.423$

$fy2 = 387.8525$

$su2 = 0.00582756$

using (30) in Biskinis/Fardis (2013) multiplied with $shear_factor$ and also multiplied by the $shear_factor$ according to 15.7.1.4, with $Shear_factor = 1.00$

$lo/lo_{ou,min} = lb/lb_{,min} = 0.318426$

$su2 = 0.4 \cdot esu2_nominal$ ((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 $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$, from 10.3.5, ASCE 41-17.

with $fs2 = (fs_{jacket} \cdot Asl_{com,jacket} + fs_{core} \cdot Asl_{com,core}) / Asl_{com} = 387.8525$

with $Es2 = (Es_{jacket} \cdot Asl_{com,jacket} + Es_{core} \cdot Asl_{com,core}) / Asl_{com} = 200000.00$

$yv = 0.00145721$

$shv = 0.00466307$

$ftv = 463.3885$

$fyv = 386.157$

$suv = 0.00582756$

using (30) in Biskinis/Fardis (2013) multiplied with $shear_factor$ and also multiplied by the $shear_factor$ according to 15.7.1.4, with $Shear_factor = 1.00$

$lo/lo_{ou,min} = lb/ld = 0.318426$

$suv = 0.4 \cdot esuv_nominal$ ((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 $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$, from 10.3.5, ASCE 41-17.

with $fsv = (fs_{jacket} \cdot Asl_{mid,jacket} + fs_{mid} \cdot Asl_{mid,core}) / Asl_{mid} = 386.157$

with $Es_v = (Es_{jacket} \cdot Asl_{mid,jacket} + Es_{mid} \cdot Asl_{mid,core}) / Asl_{mid} = 200000.00$

$1 = Asl_{ten} / (b \cdot d) \cdot (fs1 / fc) = 0.02488335$

$2 = Asl_{com} / (b \cdot d) \cdot (fs2 / fc) = 0.04895276$

$v = Asl_{mid} / (b \cdot d) \cdot (fsv / fc) = 0.04430167$

and confined core properties:

$b = 690.00$

$d = 677.00$

$d' = 13.00$

fcc (5A.2, TBDY) = 34.2833

cc (5A.5, TBDY) = 0.00238888

$c =$ confinement factor = 1.03889

$1 = Asl_{ten} / (b \cdot d) \cdot (fs1 / fc) = 0.02824566$

$2 = Asl_{com} / (b \cdot d) \cdot (fs2 / fc) = 0.05556741$

$v = Asl_{mid} / (b \cdot d) \cdot (fsv / fc) = 0.05028784$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < vs_{y2}$ - LHS eq.(4.5) is satisfied

--->

su (4.9) = 0.13760581

$Mu = MRc$ (4.14) = 5.1260E+008

$u = su$ (4.1) = 9.5578758E-006

Calculation of ratio lb/ld

Lap Length: $lb/ld = 0.318426$

$lb = 300.00$

$ld = 942.1341$

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: $f_y = 655.5556$

Mean concrete strength: $f_c' = (f_c'_{jacket} \cdot Area_{jacket} + f_c'_{core} \cdot Area_{core}) / Area_{section} = 27.68182$, 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 = 1.7174

$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 257.6106$

where A_{tr_x} , A_{tr_y} are the sum of the area of all stirrup legs along X and Y local axis

s = $\text{Max}(s_{external}, s_{internal}) = 250.00$

n = 24.00

Calculation of μ_1 -

Calculation of ultimate curvature μ according to 4.1, Biskinis/Fardis 2013:

$\mu = 1.0408734E-005$

$\mu_1 = 8.2924E+008$

with full section properties:

b = 400.00

d = 707.00

d' = 43.00

v = 0.00174378

N = 16273.616

$f_c = 33.00$

α (5A.5, TBDY) = 0.002

Final value of μ : $\mu^* = \text{shear_factor} \cdot \text{Max}(\mu, \mu_c) = 0.01288354$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $\mu_c = 0.01288354$

we ((5.4c), TBDY) = $\alpha \cdot s \cdot \text{min}(f_{ywe}/f_{ce} + \text{Min}(f_x, f_y)) = 0.05503171$

where $f = \alpha \cdot p_f \cdot f_{fe}/f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

 $f_x = 0.04286225$

Expression ((15B.6), TBDY) is modified as $\alpha_f = 1 - (\text{Unconfined area})/(\text{total area})$

$\alpha_f = 0.31984848$

with Unconfined area = $((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 140733.333$

$b_{max} = 750.00$

$h_{max} = 750.00$

From EC8 A.4.4.3(6), $p_f = 2t_f/b_w = 0.00508$

$b_w = 400.00$

effective stress from (A.35), $f_{f,e} = 870.5244$

 $f_y = 0.04286225$

Expression ((15B.6), TBDY) is modified as $\alpha_f = 1 - (\text{Unconfined area})/(\text{total area})$

$\alpha_f = 0.31984848$

with Unconfined area = $((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 140733.333$

$b_{max} = 750.00$

$h_{max} = 750.00$

From EC8 A.4.4.3(6), $p_f = 2t_f/b_w = 0.00508$

$b_w = 400.00$

effective stress from (A.35), $f_{f,e} = 870.5244$

R = 40.00

Effective FRP thickness, $t_f = N_L \cdot t \cdot \text{Cos}(b_1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{f} = 0.015$

ase ((5.4d), TBDY) = $(\text{ase}_1 \cdot A_{ext} + \text{ase}_2 \cdot A_{int}) / A_{sec} = 0.45746528$

$\text{ase}_1 = \text{Max}(((A_{conf,max1} - A_{noConf1}) / A_{conf,max1}) \cdot (A_{conf,min1} / A_{conf,max1}), 0) = 0.45746528$

The definitions of A_{noConf} , $A_{conf,min}$ and $A_{conf,max}$ are derived from generalization

of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max1} = 353600.00$ is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{conf,min1} = 293525.00$ is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area $A_{conf,max1}$ by a length equal to half the clear spacing between external hoops.

$A_{noConf1} = 158733.333$ is the unconfined external core area which is equal to $b_i^2/6$ as defined at (A.2).

$ase2 (>= ase1) = \text{Max}(((A_{conf,max2} - A_{noConf2})/A_{conf,max2}) * (A_{conf,min2}/A_{conf,max2}), 0) = 0.45746528$

The definitions of A_{noConf} , $A_{conf,min}$ and $A_{conf,max}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max2} = 171264.00$ is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

$A_{conf,min2} = 54741.00$ is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area $A_{conf,max2}$ by a length equal to half the clear spacing between internal hoops.

$A_{noConf2} = 106242.667$ is the unconfined internal core area which is equal to $b_i^2/6$ as defined at (A.2).

$p_{sh,min} * F_{ywe} = \text{Min}(p_{sh,x} * F_{ywe}, p_{sh,y} * F_{ywe}) = 2.92621$

Expression (5.4d) 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)

 $p_{sh,x} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{s2} * F_{ywe2} = 2.92621$

p_{sh1} ((5.4d), TBDY) = $L_{stir1} * A_{stir1} / (A_{sec} * s_1) = 0.00367709$

L_{stir1} (Length of stirrups along Y) = 2060.00

A_{stir1} (stirrups area) = 78.53982

p_{sh2} (5.4d) = $L_{stir2} * A_{stir2} / (A_{sec} * s_2) = 0.00067082$

L_{stir2} (Length of stirrups along Y) = 1468.00

A_{stir2} (stirrups area) = 50.26548

 $p_{sh,y} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{s2} * F_{ywe2} = 2.92621$

p_{sh1} ((5.4d), TBDY) = $L_{stir1} * A_{stir1} / (A_{sec} * s_1) = 0.00367709$

L_{stir1} (Length of stirrups along X) = 2060.00

A_{stir1} (stirrups area) = 78.53982

p_{sh2} ((5.4d), TBDY) = $L_{stir2} * A_{stir2} / (A_{sec} * s_2) = 0.00067082$

L_{stir2} (Length of stirrups along X) = 1468.00

A_{stir2} (stirrups area) = 50.26548

 $A_{sec} = 440000.00$

$s_1 = 100.00$

$s_2 = 250.00$

$f_{ywe1} = 694.4444$

$f_{ywe2} = 555.5556$

$f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY: $cc = 0.00238888$

$c = \text{confinement factor} = 1.03889$

$y_1 = 0.00145721$

$sh_1 = 0.00466307$

$ft_1 = 465.423$

$fy_1 = 387.8525$

$su_1 = 0.00582756$

using (30) in Biskinis/Fardis (2013) multiplied with $shear_factor$ and also multiplied by the $shear_factor$ according to 15.7.1.4, with $Shear_factor = 1.00$

$lo/lou,min = lb/ld = 0.318426$

$su_1 = 0.4 * esu1_nominal$ ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: $esu1_nominal = 0.08$,

For calculation of $esu1_nominal$ 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 $fs_1 = (fs_{jacket} * A_{sl,ten,jacket} + fs_{core} * A_{sl,ten,core}) / A_{sl,ten} = 387.8525$

with $Es_1 = (Es_{jacket} * A_{sl,ten,jacket} + Es_{core} * A_{sl,ten,core}) / A_{sl,ten} = 200000.00$

$y_2 = 0.00145721$

$sh_2 = 0.00466307$
 $ft_2 = 459.4373$
 $fy_2 = 382.8645$
 $su_2 = 0.00582756$
 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
 $lo/lo_{min} = lb/lb_{min} = 0.318426$
 $su_2 = 0.4 * esu_{2,nominal} ((5.5), TBDY) = 0.032$
 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 $fs_2 = (fs_{jacket} * Asl_{com,jacket} + fs_{core} * Asl_{com,core}) / Asl_{com} = 382.8645$
 with $Es_2 = (Es_{jacket} * Asl_{com,jacket} + Es_{core} * Asl_{com,core}) / Asl_{com} = 200000.00$
 $yv = 0.00145721$
 $shv = 0.00466307$
 $ftv = 463.3885$
 $fyv = 386.157$
 $suv = 0.00582756$
 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
 $lo/lo_{min} = lb/ld = 0.318426$
 $suv = 0.4 * esuv_{nominal} ((5.5), TBDY) = 0.032$
 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 $fsv = (fs_{jacket} * Asl_{mid,jacket} + fs_{mid} * Asl_{mid,core}) / Asl_{mid} = 386.157$
 with $Es_v = (Es_{jacket} * Asl_{mid,jacket} + Es_{mid} * Asl_{mid,core}) / Asl_{mid} = 200000.00$
 $1 = Asl_{ten} / (b * d) * (fs_1 / fc) = 0.09178643$
 $2 = Asl_{com} / (b * d) * (fs_2 / fc) = 0.04665628$
 $v = Asl_{mid} / (b * d) * (fsv / fc) = 0.08306563$

and confined core properties:

$b = 340.00$
 $d = 677.00$
 $d' = 13.00$
 $fcc (5A.2, TBDY) = 34.2833$
 $cc (5A.5, TBDY) = 0.00238888$
 $c = \text{confinement factor} = 1.03889$
 $1 = Asl_{ten} / (b * d) * (fs_1 / fc) = 0.11276915$
 $2 = Asl_{com} / (b * d) * (fs_2 / fc) = 0.05732208$
 $v = Asl_{mid} / (b * d) * (fsv / fc) = 0.10205474$

Case/Assumption: Unconfined full section - Steel rupture
 ' satisfies Eq. (4.3)

--->
 $v < v_{s,y_2}$ - LHS eq.(4.5) is satisfied
 --->
 $su (4.9) = 0.20810191$
 $Mu = MRc (4.14) = 8.2924E+008$
 $u = su (4.1) = 1.0408734E-005$

 Calculation of ratio lb/ld

 Lap Length: $lb/ld = 0.318426$
 $lb = 300.00$
 $ld = 942.1341$
 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: $fy = 655.5556$
 Mean concrete strength: $fc' = (fc'_{jacket} * Area_{jacket} + fc'_{core} * Area_{core}) / Area_{section} = 27.68182$, but $fc'^{0.5} <=$
 8.3 MPa (22.5.3.1, ACI 318-14)
 $t = 1.00$

s = 0.80
e = 1.00
cb = 25.00
Ktr = 1.7174
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) = 250.00
n = 24.00

Calculation of Mu2+

Calculation of ultimate curvature μ according to 4.1, Biskinis/Fardis 2013:

u = 9.5578758E-006
Mu = 5.1260E+008

with full section properties:

b = 750.00
d = 707.00
d' = 43.00
v = 0.00093001
N = 16273.616

fc = 33.00
co (5A.5, TBDY) = 0.002

Final value of c_u : $c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.01288354$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $c_u = 0.01288354$

w_e ((5.4c), TBDY) = $ase^* sh_{\min} * fy_{we}/f_{ce} + \text{Min}(f_x, f_y) = 0.05503171$

where $f = af * pf * f_{fe}/f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

 $f_x = 0.04286225$

Expression ((15B.6), TBDY) is modified as $af = 1 - (\text{Unconfined area})/(\text{total area})$

$af = 0.31984848$

with Unconfined area = $((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2)/3 = 140733.333$

$b_{\max} = 750.00$

$h_{\max} = 750.00$

From EC8 A.4.4.3(6), $pf = 2tf/bw = 0.00508$

$bw = 400.00$

effective stress from (A.35), $ff_e = 870.5244$

 $f_y = 0.04286225$

Expression ((15B.6), TBDY) is modified as $af = 1 - (\text{Unconfined area})/(\text{total area})$

$af = 0.31984848$

with Unconfined area = $((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2)/3 = 140733.333$

$b_{\max} = 750.00$

$h_{\max} = 750.00$

From EC8 A.4.4.3(6), $pf = 2tf/bw = 0.00508$

$bw = 400.00$

effective stress from (A.35), $ff_e = 870.5244$

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) = $(ase1 * A_{ext} + ase2 * A_{int})/A_{sec} = 0.45746528$

$ase1 = \text{Max}(((A_{conf,max1} - A_{noConf1})/A_{conf,max1}) * (A_{conf,min1}/A_{conf,max1}), 0) = 0.45746528$

The definitions of A_{noConf} , $A_{conf,min}$ and $A_{conf,max}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max1} = 353600.00$ is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

Aconf,min1 = 293525.00 is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area Aconf,max1 by a length equal to half the clear spacing between external hoops.

AnoConf1 = 158733.333 is the unconfined external core area which is equal to $b_i^2/6$ as defined at (A.2).
ase2 (\geq ase1) = $\text{Max}(((A_{\text{conf,max2}} - A_{\text{noConf2}})/A_{\text{conf,max2}}) * (A_{\text{conf,min2}}/A_{\text{conf,max2}}), 0) = 0.45746528$

The definitions of AnoConf, Aconf,min and Aconf,max are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

Aconf,max2 = 171264.00 is the confined core area at levels of member with hoops and is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

Aconf,min2 = 54741.00 is the confined core area at midway between the levels of hoops and is calculated by reducing all the dimensions of the area Aconf,max2 by a length equal to half the clear spacing between internal hoops.

AnoConf2 = 106242.667 is the unconfined internal core area which is equal to $b_i^2/6$ as defined at (A.2).
psh,min*Fywe = $\text{Min}(psh_x * Fywe, psh_y * Fywe) = 2.92621$

Expression (5.4d) 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 = 2.92621
psh1 ((5.4d), TBDY) = $L_{\text{stir1}} * A_{\text{stir1}} / (A_{\text{sec}} * s_1) = 0.00367709$

Lstir1 (Length of stirrups along Y) = 2060.00

Astir1 (stirrups area) = 78.53982

psh2 (5.4d) = $L_{\text{stir2}} * A_{\text{stir2}} / (A_{\text{sec}} * s_2) = 0.00067082$

Lstir2 (Length of stirrups along Y) = 1468.00

Astir2 (stirrups area) = 50.26548

psh_y*Fywe = psh1*Fywe1 + ps2*Fywe2 = 2.92621
psh1 ((5.4d), TBDY) = $L_{\text{stir1}} * A_{\text{stir1}} / (A_{\text{sec}} * s_1) = 0.00367709$

Lstir1 (Length of stirrups along X) = 2060.00

Astir1 (stirrups area) = 78.53982

psh2 ((5.4d), TBDY) = $L_{\text{stir2}} * A_{\text{stir2}} / (A_{\text{sec}} * s_2) = 0.00067082$

Lstir2 (Length of stirrups along X) = 1468.00

Astir2 (stirrups area) = 50.26548

Asec = 440000.00

s1 = 100.00

s2 = 250.00

fywe1 = 694.4444

fywe2 = 555.5556

fce = 33.00

From ((5.A5), TBDY), TBDY: cc = 0.00238888

c = confinement factor = 1.03889

y1 = 0.00145721

sh1 = 0.00466307

ft1 = 459.4373

fy1 = 382.8645

su1 = 0.00582756

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 = 0.318426

su1 = $0.4 * esu1_{\text{nominal}} ((5.5), \text{TBDY}) = 0.032$

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.

with fs1 = $(f_{s,jacket} * A_{s,t,jacket} + f_{s,core} * A_{s,t,core}) / A_{s,t} = 382.8645$

with Es1 = $(E_{s,jacket} * A_{s,t,jacket} + E_{s,core} * A_{s,t,core}) / A_{s,t} = 200000.00$

y2 = 0.00145721

sh2 = 0.00466307

ft2 = 465.423

fy2 = 387.8525

su2 = 0.00582756

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 = 0.318426

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 = 387.8525

with Es2 = (Es,jacket*Asl,com,jacket + Es,core*Asl,com,core)/Asl,com = 200000.00

yv = 0.00145721

shv = 0.00466307

ftv = 463.3885

fyv = 386.157

suv = 0.00582756

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 = 0.318426

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 = 386.157

with Esv = (Es,jacket*Asl,mid,jacket + Es,mid*Asl,mid,core)/Asl,mid = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.02488335

2 = Asl,com/(b*d)*(fs2/fc) = 0.04895276

v = Asl,mid/(b*d)*(fsv/fc) = 0.04430167

and confined core properties:

b = 690.00

d = 677.00

d' = 13.00

fcc (5A.2, TBDY) = 34.2833

cc (5A.5, TBDY) = 0.00238888

c = confinement factor = 1.03889

1 = Asl,ten/(b*d)*(fs1/fc) = 0.02824566

2 = Asl,com/(b*d)*(fs2/fc) = 0.05556741

v = Asl,mid/(b*d)*(fsv/fc) = 0.05028784

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

v < vs,y2 - LHS eq.(4.5) is satisfied

--->

su (4.9) = 0.13760581

Mu = MRc (4.14) = 5.1260E+008

u = su (4.1) = 9.5578758E-006

Calculation of ratio lb/ld

Lap Length: lb/ld = 0.318426

lb = 300.00

ld = 942.1341

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 = 655.5556

Mean concrete strength: fc' = (fc'_jacket*Area_jacket + fc'_core*Area_core)/Area_section = 27.68182, but $fc'^{0.5} <=$ 8.3 MPa (22.5.3.1, ACI 318-14)

t = 1.00

s = 0.80

e = 1.00

cb = 25.00

Ktr = 1.7174

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

$$s = \text{Max}(s_{\text{external}}, s_{\text{internal}}) = 250.00$$
$$n = 24.00$$

Calculation of μ_2 -

Calculation of ultimate curvature μ according to 4.1, Biskinis/Fardis 2013:

$$u = 1.0408734E-005$$

$$\mu = 8.2924E+008$$

with full section properties:

$$b = 400.00$$

$$d = 707.00$$

$$d' = 43.00$$

$$v = 0.00174378$$

$$N = 16273.616$$

$$f_c = 33.00$$

$$c_o \text{ (5A.5, TBDY)} = 0.002$$

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.01288354$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } c_u = 0.01288354$$

$$w_e \text{ ((5.4c), TBDY)} = a_{se} * s_{h,\text{min}} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.05503171$$

where $f = a_f * p_f * f_{fe}/f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.04286225$$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area})/(\text{total area})$

$$a_f = 0.31984848$$

$$\text{with Unconfined area} = ((b_{\text{max}} - 2R)^2 + (h_{\text{max}} - 2R)^2)/3 = 140733.333$$

$$b_{\text{max}} = 750.00$$

$$h_{\text{max}} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 870.5244$$

$$f_y = 0.04286225$$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area})/(\text{total area})$

$$a_f = 0.31984848$$

$$\text{with Unconfined area} = ((b_{\text{max}} - 2R)^2 + (h_{\text{max}} - 2R)^2)/3 = 140733.333$$

$$b_{\text{max}} = 750.00$$

$$h_{\text{max}} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 870.5244$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = NL * t * \text{Cos}(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{f} = 0.015$$

$$a_{se} \text{ ((5.4d), TBDY)} = (a_{se1} * A_{\text{ext}} + a_{se2} * A_{\text{int}})/A_{\text{sec}} = 0.45746528$$

$$a_{se1} = \text{Max}(((A_{\text{conf,max1}} - A_{\text{noConf1}})/A_{\text{conf,max1}}) * (A_{\text{conf,min1}}/A_{\text{conf,max1}}), 0) = 0.45746528$$

The definitions of A_{noConf} , $A_{\text{conf,min}}$ and $A_{\text{conf,max}}$ are derived from generalization of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{\text{conf,max1}} = 353600.00$ is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the external perimeter hoops.

$A_{\text{conf,min1}} = 293525.00$ is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area $A_{\text{conf,max1}}$ by a length

equal to half the clear spacing between external hoops.

$A_{\text{noConf1}} = 158733.333$ is the unconfined external core area which is equal to $b_i^2/6$ as defined at (A.2).

$$a_{se2} (>= a_{se1}) = \text{Max}(((A_{\text{conf,max2}} - A_{\text{noConf2}})/A_{\text{conf,max2}}) * (A_{\text{conf,min2}}/A_{\text{conf,max2}}), 0) = 0.45746528$$

The definitions of A_{noConf} , $A_{\text{conf,min}}$ and $A_{\text{conf,max}}$ are derived from generalization

of the rectangular sections confinement, which is expressed by (5.4d).

The generalization is done according to Mander, J., Priestley, M., and Park, R. (1988)

"Theoretical Stress-Strain Model for Confined Concrete."

J. Struct. Eng., 10.1061/(ASCE)0733-9445(1988)114:8(1804), 1804-1826.

$A_{conf,max2} = 171264.00$ is the confined core area at levels of member with hoops and

is calculated as the area of core enclosed by the center lines of the internal perimeter hoops.

$A_{conf,min2} = 54741.00$ is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area $A_{conf,max2}$ by a length

equal to half the clear spacing between internal hoops.

$A_{noConf2} = 106242.667$ is the unconfined internal core area which is equal to $b_i^2/6$ as defined at (A.2).

$p_{sh,min} * F_{ywe} = \text{Min}(p_{sh,x} * F_{ywe}, p_{sh,y} * F_{ywe}) = 2.92621$

Expression (5.4d) 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)

 $p_{sh,x} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{sh2} * F_{ywe2} = 2.92621$

p_{sh1} ((5.4d), TBDY) = $L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00367709$

L_{stir1} (Length of stirrups along Y) = 2060.00

A_{stir1} (stirrups area) = 78.53982

p_{sh2} (5.4d) = $L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00067082$

L_{stir2} (Length of stirrups along Y) = 1468.00

A_{stir2} (stirrups area) = 50.26548

 $p_{sh,y} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{sh2} * F_{ywe2} = 2.92621$

p_{sh1} ((5.4d), TBDY) = $L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00367709$

L_{stir1} (Length of stirrups along X) = 2060.00

A_{stir1} (stirrups area) = 78.53982

p_{sh2} ((5.4d), TBDY) = $L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00067082$

L_{stir2} (Length of stirrups along X) = 1468.00

A_{stir2} (stirrups area) = 50.26548

 $A_{sec} = 440000.00$

$s1 = 100.00$

$s2 = 250.00$

$f_{ywe1} = 694.4444$

$f_{ywe2} = 555.5556$

$f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY: $cc = 0.00238888$

$c =$ confinement factor = 1.03889

$y1 = 0.00145721$

$sh1 = 0.00466307$

$ft1 = 465.423$

$fy1 = 387.8525$

$su1 = 0.00582756$

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

$l_o/l_{ou,min} = l_b/l_d = 0.318426$

$su1 = 0.4 * esu1_{nominal}$ ((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 $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE 41-17.

with $fs1 = (f_{s,jacket} * A_{s1,ten,jacket} + f_{s,core} * A_{s1,ten,core}) / A_{s1,ten} = 387.8525$

with $Es1 = (E_{s,jacket} * A_{s1,ten,jacket} + E_{s,core} * A_{s1,ten,core}) / A_{s1,ten} = 200000.00$

$y2 = 0.00145721$

$sh2 = 0.00466307$

$ft2 = 459.4373$

$fy2 = 382.8645$

$su2 = 0.00582756$

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

$l_o/l_{ou,min} = l_b/l_{b,min} = 0.318426$

$su2 = 0.4 * esu2_{nominal}$ ((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.

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 $fs_2 = (fs_{jacket} \cdot Asl_{com,jacket} + fs_{core} \cdot Asl_{com,core}) / Asl_{com} = 382.8645$

with $Es_2 = (Es_{jacket} \cdot Asl_{com,jacket} + Es_{core} \cdot Asl_{com,core}) / Asl_{com} = 200000.00$

$yv = 0.00145721$

$shv = 0.00466307$

$ftv = 463.3885$

$fyv = 386.157$

$suv = 0.00582756$

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

$lo/lou_{min} = lb/ld = 0.318426$

$suv = 0.4 \cdot esuv_{nominal} ((5.5), TBDY) = 0.032$

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 $fsv = (fs_{jacket} \cdot Asl_{mid,jacket} + fs_{mid} \cdot Asl_{mid,core}) / Asl_{mid} = 386.157$

with $Esv = (Es_{jacket} \cdot Asl_{mid,jacket} + Es_{mid} \cdot Asl_{mid,core}) / Asl_{mid} = 200000.00$

$1 = Asl_{ten} / (b \cdot d) \cdot (fs_1 / fc) = 0.09178643$

$2 = Asl_{com} / (b \cdot d) \cdot (fs_2 / fc) = 0.04665628$

$v = Asl_{mid} / (b \cdot d) \cdot (fsv / fc) = 0.08306563$

and confined core properties:

$b = 340.00$

$d = 677.00$

$d' = 13.00$

fcc (5A.2, TBDY) = 34.2833

cc (5A.5, TBDY) = 0.00238888

c = confinement factor = 1.03889

$1 = Asl_{ten} / (b \cdot d) \cdot (fs_1 / fc) = 0.11276915$

$2 = Asl_{com} / (b \cdot d) \cdot (fs_2 / fc) = 0.05732208$

$v = Asl_{mid} / (b \cdot d) \cdot (fsv / fc) = 0.10205474$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < vs_{y2}$ - LHS eq.(4.5) is satisfied

--->

su (4.9) = 0.20810191

$Mu = MRc$ (4.14) = 8.2924E+008

$u = su$ (4.1) = 1.0408734E-005

Calculation of ratio lb/ld

Lap Length: $lb/ld = 0.318426$

$lb = 300.00$

$ld = 942.1341$

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: $fy = 655.5556$

Mean concrete strength: $fc' = (fc'_{jacket} \cdot Area_{jacket} + fc'_{core} \cdot Area_{core}) / Area_{section} = 27.68182$, but $fc'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 1.7174$

$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 257.6106$

where A_{tr_x}, A_{tr_y} are the sum of the area of all stirrup legs along X and Y loxal axis

$s = \text{Max}(s_{external}, s_{internal}) = 250.00$

$n = 24.00$

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 998292.205$

Calculation of Shear Strength at edge 1, $V_{r1} = 998292.205$

$V_{r1} = V_{Col} ((10.3), \text{ASCE } 41-17) = k_{nl} * V_{Col0}$

$V_{Col0} = 998292.205$

$k_{nl} = 1$ (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: $f_c' = (f_c'_{jacket} * \text{Area}_{jacket} + f_c'_{core} * \text{Area}_{core}) / \text{Area}_{section} = 27.68182$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 4.00$

$M_u = 11.78089$

$V_u = 0.00051441$

$d = 0.8 * h = 600.00$

$N_u = 16273.616$

$A_g = 300000.00$

From (11.5.4.8), ACI 318-14: $V_s = V_{sjacket} + V_{s,core} = 881489.011$

where:

$V_{sjacket} = V_{sj1} + V_{sj2} = 802851.456$

$V_{sj1} = 279252.68$ is calculated for section web jacket, with:

$d = 320.00$

$A_v = 157079.633$

$f_y = 555.5556$

$s = 100.00$

V_{sj1} is multiplied by $Col_{j1} = 1.00$

$s/d = 0.3125$

$V_{sj2} = 523598.776$ is calculated for section flange jacket, with:

$d = 600.00$

$A_v = 157079.633$

$f_y = 555.5556$

$s = 100.00$

V_{sj2} is multiplied by $Col_{j2} = 1.00$

$s/d = 0.16666667$

$V_{s,core} = V_{s,c1} + V_{s,c2} = 78637.555$

$V_{s,c1} = 0.00$ is calculated for section web core, with:

$d = 160.00$

$A_v = 100530.965$

$f_y = 444.4444$

$s = 250.00$

$V_{s,c1}$ is multiplied by $Col_{c1} = 0.00$

$s/d = 1.5625$

$V_{s,c2} = 78637.555$ is calculated for section flange core, with:

$d = 440.00$

$A_v = 100530.965$

$f_y = 444.4444$

$s = 250.00$

$V_{s,c2}$ is multiplied by $Col_{c2} = 1.00$

$s/d = 0.56818182$

$V_f ((11-3)-(11.4), \text{ACI } 440) = 372533.843$

$f = 0.95$, for fully-wrapped sections

$w_f/s_f = 1$ (FRP strips adjacent to one another).

In (11.3) $\sin \theta + \cos \theta$ is replaced with $(\cot \theta + \csc \theta) \sin \alpha$ which is more a generalised expression,

where θ is the angle of the crack direction (see KANEPE).

This later relation, considered as a function $V_f(\theta, \alpha)$, is implemented for every different fiber orientation α_i , as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.

orientation 1: $\theta = 45^\circ + 90^\circ = 135^\circ$

$V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, \theta)|)$, with:

total thickness per orientation, $t_{f1} = N_L * t / N_{oDir} = 1.016$

$d_{fv} = d$ (figure 11.2, ACI 440) = 707.00

$f_{fe} ((11-5), \text{ACI } 440) = 259.312$

$E_f = 64828.00$

$f_e = 0.004$, from (11.6a), ACI 440

with $f_u = 0.01$

From (11-11), ACI 440: $V_s + V_f \leq 838832.606$

bw = 400.00

Calculation of Shear Strength at edge 2, Vr2 = 998292.205

Vr2 = VCol ((10.3), ASCE 41-17) = knl*VCol0

VCol0 = 998292.205

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: $f_c' = (f_c'_{\text{jacket}} \cdot \text{Area}_{\text{jacket}} + f_c'_{\text{core}} \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 27.68182$, but $f_c'^{0.5} < = 8.3$ MPa (22.5.3.1, ACI 318-14)

M/Vd = 4.00

Mu = 11.78144

Vu = 0.00051441

d = 0.8*h = 600.00

Nu = 16273.616

Ag = 300000.00

From (11.5.4.8), ACI 318-14: Vs = Vs,jacket + Vs,core = 881489.011

where:

Vs,jacket = Vs,j1 + Vs,j2 = 802851.456

Vs,j1 = 279252.68 is calculated for section web jacket, with:

d = 320.00

Av = 157079.633

fy = 555.5556

s = 100.00

Vs,j1 is multiplied by Col,j1 = 1.00

s/d = 0.3125

Vs,j2 = 523598.776 is calculated for section flange jacket, with:

d = 600.00

Av = 157079.633

fy = 555.5556

s = 100.00

Vs,j2 is multiplied by Col,j2 = 1.00

s/d = 0.16666667

Vs,core = Vs,c1 + Vs,c2 = 78637.555

Vs,c1 = 0.00 is calculated for section web core, with:

d = 160.00

Av = 100530.965

fy = 444.4444

s = 250.00

Vs,c1 is multiplied by Col,c1 = 0.00

s/d = 1.5625

Vs,c2 = 78637.555 is calculated for section flange core, with:

d = 440.00

Av = 100530.965

fy = 444.4444

s = 250.00

Vs,c2 is multiplied by Col,c2 = 1.00

s/d = 0.56818182

Vf ((11-3)-(11.4), ACI 440) = 372533.843

f = 0.95, for fully-wrapped sections

wf/sf = 1 (FRP strips adjacent to one another).

In (11.3) $\sin \theta + \cos \theta$ is replaced with $(\cot \theta + \csc \theta) \sin \alpha$ which is more a generalised expression, where θ is the angle of the crack direction (see KANEPE).

This later relation, considered as a function $V_f(\theta, \alpha)$, is implemented for every different fiber orientation α_i , as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.

orientation 1: $\theta = b1 + 90^\circ = 90.00$

$V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, \theta)|)$, with:

total thickness per orientation, $t_{f1} = N_L * t / \text{NoDir} = 1.016$

$d_{fv} = d$ (figure 11.2, ACI 440) = 707.00

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: $V_s + V_f \leq 838832.606$
 $bw = 400.00$

End Of Calculation of Shear Capacity ratio for element: column JLC1 of floor 1
At local axis: 2

Start Of Calculation of Chord Rotation Capacity for element: column JLC1 of floor 1
At local axis: 3
Integration Section: (b)
Section Type: rcjls

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 Secondary Member: Concrete Strength, $f_c = f_{cm} = 33.00$
New material of Secondary Member: Steel Strength, $f_s = f_{sm} = 555.5556$
Concrete Elasticity, $E_c = 26999.444$
Steel Elasticity, $E_s = 200000.00$
Existing Column
Existing material of Secondary Member: Concrete Strength, $f_c = f_{cm} = 20.00$
Existing material of Secondary Member: Steel Strength, $f_s = f_{sm} = 444.4444$
Concrete Elasticity, $E_c = 21019.039$
Steel Elasticity, $E_s = 200000.00$
Max Height, $H_{max} = 750.00$
Min Height, $H_{min} = 400.00$
Max Width, $W_{max} = 750.00$
Min Width, $W_{min} = 400.00$
Jacket Thickness, $t_j = 100.00$
Cover Thickness, $c = 25.00$
Element Length, $L = 3000.00$
Secondary Member
Ribbed Bars
Ductile Steel
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
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, $M = 71505.406$
Shear Force, $V_2 = 6560.264$
Shear Force, $V_3 = -122.9023$
Axial Force, $F = -16937.611$
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: $A_{st} = 0.00$
-Compression: $A_{sc} = 5353.274$
Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension: $Asl,ten = 1137.257$

-Compression: $Asl,com = 2208.54$

-Middle: $Asl,mid = 2007.478$

Longitudinal External Reinforcement Area Distribution (in 3 divisions)

-Tension: $Asl,ten,jacket = 829.3805$

-Compression: $Asl,com,jacket = 1746.726$

-Middle: $Asl,mid,jacket = 1545.664$

Longitudinal Internal Reinforcement Area Distribution (in 3 divisions)

-Tension: $Asl,ten,core = 307.8761$

-Compression: $Asl,com,core = 461.8141$

-Middle: $Asl,mid,core = 461.8141$

Mean Diameter of Tension Reinforcement, $DbL = 16.80$

Existing component: From table 7-7, ASCE 41_17: Final chord rotation Capacity $u,R = u = 0.02574693$
 $u = y + p = 0.03029051$

- Calculation of y -

$y = (My * Ls / 3) / Eleff = 0.00029051$ ((4.29), Biskinis Phd)

$My = 4.2097E+008$

$Ls = M/V$ (with $Ls > 0.1 * L$ and $Ls < 2 * L$) = 300.00

From table 10.5, ASCE 41_17: $Eleff = factor * Ec * Ig = 1.4491E+014$

factor = 0.30

$Ag = 440000.00$

Mean concrete strength: $fc' = (fc'_{jacket} * Area_{jacket} + fc'_{core} * Area_{core}) / Area_{section} = 27.68182$

$N = 16937.611$

$Ec * Ig = Ec_{jacket} * Ig_{jacket} + Ec_{core} * Ig_{core} = 4.8303E+014$

Calculation of Yielding Moment My

Calculation of y and My according to Annex 7 -

Assuming neutral axis within flange ($y < t/d$, compression zone rectangular) with:

flange width, $b = 750.00$

web width, $bw = 400.00$

flange thickness, $t = 400.00$

$y = \text{Min}(y_{ten}, y_{com})$

$y_{ten} = 3.1431513E-006$

with ((10.1), ASCE 41-17) $fy = \text{Min}(fy, 1.25 * fy * (lb/d)^{2/3}) = 358.4764$

$d = 707.00$

$y = 0.19342282$

$A = 0.01018486$

$B = 0.00449527$

with $pt = 0.00671906$

$pc = 0.00416509$

$pv = 0.00378591$

$N = 16937.611$

$b = 750.00$

" = 0.06082037

$y_{comp} = 1.6462780E-005$

with $fc' (12.3, (ACI 440)) = 33.48734$

$fc = 33.00$

$fl = 0.49678681$

$b = b_{max} = 750.00$

$h = h_{max} = 750.00$

$Ag = 0.44$

$g = pt + pc + pv = 0.01009575$

$rc = 40.00$

$Ae / Ac = 0.31291181$

Effective FRP thickness, $tf = NL * t * \text{Cos}(b1) = 1.016$

effective strain from (12.5) and (12.12), $\epsilon_{fe} = 0.004$

$f_u = 0.01$

$E_f = 64828.00$

$E_c = 26999.444$

$y = 0.19181197$

$A = 0.01002422$

$B = 0.00440616$

with $E_s = 200000.00$

CONFIRMATION: $y = 0.19278073 < t/d$

Calculation of ratio l_b/l_d

Lap Length: $l_d/l_{d,min} = 0.39803249$

$l_b = 300.00$

$l_d = 753.7073$

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: $f_y = 524.4444$

Mean concrete strength: $f_c' = (f_c'_{jacket} \cdot Area_{jacket} + f_c'_{core} \cdot Area_{core}) / Area_{section} = 27.68182$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 1.7174$

$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 257.6106$

where A_{tr_x} , A_{tr_y} are the sum of the area of all stirrup legs along X and Y local axis

$s = \text{Max}(s_{external}, s_{internal}) = 250.00$

$n = 24.00$

- Calculation of p -

From table 10-8: $p = 0.03$

with:

- Columns controlled by inadequate development or splicing along the clear height because $l_b/l_d < 1$

shear control ratio $V_y E / V_{CoI} O E = 0.55377356$

$d = d_{external} = 707.00$

$s = s_{external} = 0.00$

- $t = s_1 + s_2 + 2 \cdot t_f / b_w \cdot (f_{fe} / f_s) = 0.00671906$

jacket: $s_1 = A_{v1} \cdot L_{stir1} / (s_1 \cdot A_g) = 0.00367709$

$A_{v1} = 78.53982$, is the area of every stirrup parallel to loading (shear) direction

$L_{stir1} = 2060.00$, is the total Length of all stirrups parallel to loading (shear) direction

$s_1 = 100.00$

core: $s_2 = A_{v2} \cdot L_{stir2} / (s_2 \cdot A_g) = 0.00067082$

$A_{v2} = 50.26548$, is the area of every stirrup parallel to loading (shear) direction

$L_{stir2} = 1468.00$, is the total Length of all stirrups parallel to loading (shear) direction

$s_2 = 250.00$

The term $2 \cdot t_f / b_w \cdot (f_{fe} / f_s)$ is implemented to account for FRP contribution

where $f = 2 \cdot t_f / b_w$ is FRP ratio (EC8 - 3, A.4.4.3(6)) and f_{fe} / f_s normalises f to steel strength

All these variables have already been given in Shear control ratio calculation.

For the normalisation f_s of jacket is used.

$NUD = 16937.611$

$A_g = 440000.00$

$f_c E = (f_c'_{jacket} \cdot Area_{jacket} + f_c'_{core} \cdot Area_{core}) / section_area = 27.68182$

$f_y E = (f_{y_ext_Long_Reinf} \cdot Area_{ext_Long_Reinf} + f_{y_int_Long_Reinf} \cdot Area_{int_Long_Reinf}) / Area_{Tot_Long_Rein} = 529.9948$

$f_y t E = (f_{y_ext_Trans_Reinf} \cdot s_1 + f_{y_int_Trans_Reinf} \cdot s_2) / (s_1 + s_2) = 538.4128$

$p_l = Area_{Tot_Long_Rein} / (b \cdot d) = 0.01009575$

$b = 750.00$

$d = 707.00$

$f_c E = 27.68182$

End Of Calculation of Chord Rotation Capacity for element: column JLC1 of floor 1

At local axis: 3
Integration Section: (b)
