

Detailed Member Calculations

Units: N&mm

Regulation: ASCE 41-17

Calculation No. 1

column C1, Floor 1

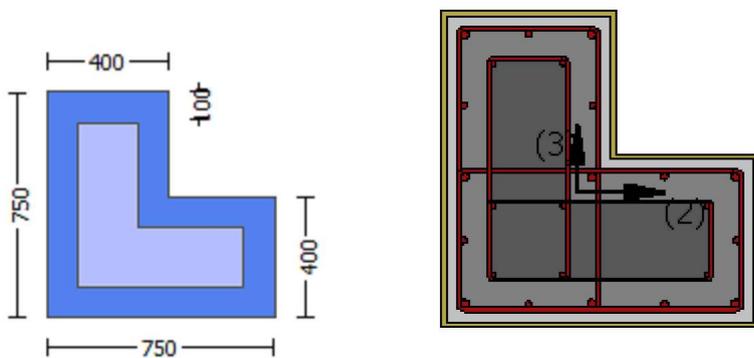
Limit State: Immediate Occupancy (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Shear capacity V_{Rd}

Edge: Start

Local Axis: (2)



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

At local axis: 2

Integration Section: (a)

Section Type: rcjlc

Constant Properties

Knowledge Factor, $\gamma = 0.90$

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

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

Consequently:

Jacket

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

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

Concrete Elasticity, $E_c = 26999.444$
 Steel Elasticity, $E_s = 200000.00$
 Existing Column
 New material of Secondary Member: Concrete Strength, $f_c = f_{c_lower_bound} = 25.00$
 New material of Secondary Member: Steel Strength, $f_s = f_{s_lower_bound} = 500.00$
 Concrete Elasticity, $E_c = 26999.444$
 Steel Elasticity, $E_s = 200000.00$
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 Note: Especially for the calculation of γ for displacement ductility demand,
 the expected (mean value) strengths are used (7.5.1.3, ASCE 41-17) because bending is considered as
 Deformation-Controlled Action (Table C7-1, ASCE 41-17).
 Jacket
 New material: Concrete Strength, $f_c = f_{cm} = 33.00$
 New material: Steel Strength, $f_s = f_{sm} = 555.56$
 Existing Column
 New material: Concrete Strength, $f_c = f_{cm} = 33.00$
 New material: Steel Strength, $f_s = f_{sm} = 555.56$
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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, $c = 25.00$
 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
 Adequate Lap Length ($l_o/l_{ou,min} = l_b/l_d >= 1$)
 FRP Wrapping Data
 Type: Carbon
 Cured laminate properties (design values)
 Thickness, $t = 1.016$
 Tensile Strength, $f_{fu} = 1055.00$
 Tensile Modulus, $E_f = 64828.00$
 Elongation, $e_{fu} = 0.01$
 Number of directions, $NoDir = 1$
 Fiber orientations, $bi: 0.00^\circ$
 Number of layers, $NL = 1$
 Radius of rounding corners, $R = 40.00$

 Stepwise Properties

EDGE -A-
 Bending Moment, $M_a = -1.8810E+007$
 Shear Force, $V_a = -6058.142$
 EDGE -B-
 Bending Moment, $M_b = 629358.106$
 Shear Force, $V_b = 6058.142$
 BOTH EDGES
 Axial Force, $F = -18615.215$
 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, $Db_{L,ten} = 16.80$

New component: From table 7-7, ASCE 41_17: Final Shear Capacity $V_R = 1.0 * V_n = 949014.707$

$$V_n \text{ ((10.3), ASCE 41-17)} = k_n \cdot V_{CoI} = 949014.707$$

$$V_{CoI} = 949014.707$$

$$k_n = 1.00$$

$$\text{displacement_ductility_demand} = 0.01509048$$

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

$$M/Vd = 4.00$$

$$\mu_u = 1.8810E+007$$

$$V_u = 6058.142$$

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

$$N_u = 18615.215$$

$$A_g = 300000.00$$

$$\text{From (11.5.4.8), ACI 318-14: } V_s = V_{s,jacket} + V_{s,core} = 811033.559$$

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 $Col_{j2} = 1.00$

$$s/d = 0.16666667$$

$$V_{s,core} = V_{s,c1} + V_{s,c2} = 88467.249$$

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

$$d = 160.00$$

$$A_v = 100530.965$$

$$f_y = 500.00$$

$$s = 250.00$$

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

$$s/d = 1.5625$$

$V_{s,c2} = 88467.249$ is calculated for section flange core, with:

$$d = 440.00$$

$$A_v = 100530.965$$

$$f_y = 500.00$$

$$s = 250.00$$

$V_{s,c2}$ 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 $(\cot \theta + \cot \alpha) \sin \alpha$ 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.

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

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

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

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

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

$$E_f = 64828.00$$

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

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

$$\text{From (11-11), ACI 440: } V_s + V_f \leq 797164.595$$

$$b_w = 400.00$$

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 = $6.6493790E-005$
 $y = (M_y * L_s / 3) / E_{eff} = 0.00440634$ ((4.29), Biskinis Phd))
 $M_y = 6.5012E+008$
 $L_s = M/V$ (with $L_s > 0.1 * L$ and $L_s < 2 * L$) = 3104.908
From table 10.5, ASCE 41_17: $E_{eff} = factor * E_c * I_g = 1.5270E+014$
factor = 0.30
 $A_g = 440000.00$
Mean concrete strength: $f'_c = (f'_{c_jacket} * Area_{jacket} + f'_{c_core} * Area_{core}) / Area_{section} = 33.00$
 $N = 18615.215$
 $E_c * I_g = E_{c_jacket} * I_{g_jacket} + E_{c_core} * I_{g_core} = 5.0901E+014$

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, $t = 400.00$

$y = \text{Min}(y_{ten}, y_{com})$
 $y_{ten} = 4.8677145E-006$
with $f_y = 555.56$
 $d = 707.00$
 $y = 0.19284589$
 $A = 0.01015895$
 $B = 0.00446935$
with $p_t = 0.00214476$
 $p_c = 0.00416509$
 $p_v = 0.00378591$
 $N = 18615.215$
 $b = 750.00$
" = 0.06082037
 $y_{comp} = 1.6459533E-005$
with f'_c (12.3, (ACI 440)) = 33.48734
 $f'_c = 33.00$
 $\beta_1 = 0.49678681$
 $b = b_{max} = 750.00$
 $h = h_{max} = 750.00$
 $A_g = 0.44$
 $g = p_t + p_c + p_v = 0.01009575$
 $rc = 40.00$
 $A_e / A_c = 0.31291181$
Effective FRP thickness, $t_f = NL * t * \text{Cos}(b_1) = 1.016$
effective strain from (12.5) and (12.12), $\epsilon_{fe} = 0.004$
 $f_u = 0.01$
 $E_f = 64828.00$
 $E_c = 26999.444$
 $y = 0.19184981$
 $A = 0.01001713$
 $B = 0.00440616$
with $E_s = 200000.00$
CONFIRMATION: $y = 0.19284589 < t/d$

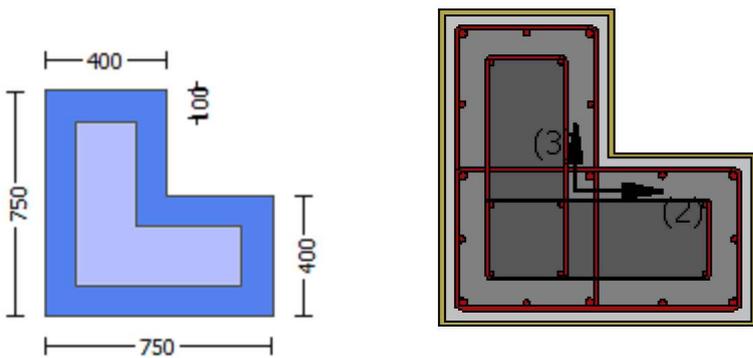
Calculation of ratio l_b/d

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

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: Immediate Occupancy (data interpolation between analysis steps 1 and 2)
 Analysis: Uniform +X
 Check: Chord rotation capacity (θ)
 Edge: Start
 Local Axis: (2)



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

Constant Properties

Knowledge Factor, $\gamma = 0.90$
 Mean strength values are used for both shear and moment calculations.
 Consequently:
 Jacket
 New material of Secondary Member: Concrete Strength, $f_c = f_{cm} = 33.00$
 New material of Secondary Member: Steel Strength, $f_s = f_{sm} = 555.56$
 Concrete Elasticity, $E_c = 26999.444$
 Steel Elasticity, $E_s = 200000.00$
 Existing Column
 New material of Secondary Member: Concrete Strength, $f_c = f_{cm} = 33.00$
 New material of Secondary Member: Steel Strength, $f_s = f_{sm} = 555.56$
 Concrete Elasticity, $E_c = 26999.444$
 Steel Elasticity, $E_s = 200000.00$

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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

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Jacket
New material: Steel Strength, fs = 1.25*fsm = 694.45
Existing Column
New material: Steel Strength, fs = 1.25*fsm = 694.45
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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
Adequate Lap Length (lo/lou,min>=1)
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
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Stepwise Properties
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At local axis: 3
EDGE -A-
Shear Force, Va = -0.00017144
EDGE -B-
Shear Force, Vb = 0.00017144
BOTH EDGES
Axial Force, F = -16273.607
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
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Calculation of Shear Capacity ratio , Ve/Vr = 1.05752
Member Controlled by Shear (Ve/Vr > 1)
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 Ve = (Mpr1 + Mpr2)/ln = 1.1525E+006
with
Mpr1 = Max(Mu1+ , Mu1-) = 1.7288E+009
Mu1+ = 1.1540E+009, 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- = 1.7288E+009, 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 = Max(Mu2+ , Mu2-) = 1.7288E+009
Mu2+ = 1.1540E+009, 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- = 1.7288E+009, is the ultimate moment strength at the edge 2 of the member in the opposite moment
direction which is defined for the the static loading combination

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Calculation of Mu1+

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

$$\mu = 5.0226943E-005$$

$$\text{Mu} = 1.1540E+009$$

with full section properties:

$$b = 750.00$$

$$d = 707.00$$

$$d' = 43.00$$

$$v = 0.00093001$$

$$N = 16273.607$$

$$f_c = 33.00$$

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

$$\text{Final value of } \mu: \mu^* = \text{shear_factor} * \text{Max}(\mu, c_o) = 0.01291652$$

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

$$\text{From (5.4b), TBDY: } \mu = 0.01291652$$

$$\mu_e ((5.4c), \text{TBDY}) = a_{se} * \text{sh}_{,\min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.05541928$$

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 $a_f = 1 - (\text{Unconfined area})/(\text{total area})$

$$a_f = 0.31984848$$

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

$$b_{\max} = 750.00$$

$$h_{\max} = 750.00$$

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

$$b_w = 400.00$$

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

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u_{f} = 0.015$$

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

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

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).

$$psh_{min} * F_{ywe} = \text{Min}(psh_x * F_{ywe}, psh_y * F_{ywe}) = 3.0194$$

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)

$$psh_x * F_{ywe} = psh1 * F_{ywe1} + ps2 * F_{ywe2} = 3.0194$$
$$psh1 \text{ ((5.4d), TBDY)} = L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00367709$$

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

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

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

$$psh_y * F_{ywe} = psh1 * F_{ywe1} + ps2 * F_{ywe2} = 3.0194$$
$$psh1 \text{ ((5.4d), TBDY)} = L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00367709$$

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

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

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

$$A_{sec} = 440000.00$$

$$s1 = 100.00$$

$$s2 = 250.00$$

$$fy_{we1} = 694.45$$

$$fy_{we2} = 694.45$$

$$f_{ce} = 33.00$$

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

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

$$y1 = 0.0025$$

$$sh1 = 0.008$$

$$ft1 = 833.34$$

$$fy1 = 694.45$$

$$su1 = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$$l_o/l_{ou,min} = l_b/l_d = 1.00$$

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

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

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

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

$$\text{with } fs1 = (f_{s,jacket} * A_{sl,ten,jacket} + f_{s,core} * A_{sl,ten,core}) / A_{sl,ten} = 694.45$$

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

$$y2 = 0.0025$$

$$sh2 = 0.008$$

$$ft2 = 833.34$$

$$fy2 = 694.45$$

$$su2 = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$$l_o/l_{ou,min} = l_b/l_{b,min} = 1.00$$

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

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

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

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

$$\text{with } fs2 = (f_{s,jacket} * A_{sl,com,jacket} + f_{s,core} * A_{sl,com,core}) / A_{sl,com} = 694.45$$

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

$$y_v = 0.0025$$

$$shv = 0.008$$

$$ftv = 833.34$$

$$fyv = 694.45$$

$$suv = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$lo/lou,min = lb/ld = 1.00$$

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

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.

$$\text{with } fsv = (fs,jacket * Asl,mid,jacket + fs,mid * Asl,mid,core) / Asl,mid = 694.45$$

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

$$1 = Asl,ten / (b * d) * (fs1 / fc) = 0.0451341$$

$$2 = Asl,com / (b * d) * (fs2 / fc) = 0.08764993$$

$$v = Asl,mid / (b * d) * (fsv / fc) = 0.07967042$$

and confined core properties:

$$b = 690.00$$

$$d = 677.00$$

$$d' = 13.00$$

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

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

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

$$1 = Asl,ten / (b * d) * (fs1 / fc) = 0.05123276$$

$$2 = Asl,com / (b * d) * (fs2 / fc) = 0.09949345$$

$$v = Asl,mid / (b * d) * (fsv / fc) = 0.09043572$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

$$su (4.9) = 0.09885678$$

$$Mu = MRc (4.14) = 1.1540E+009$$

$$u = su (4.1) = 5.0226943E-005$$

Calculation of ratio lb/ld

Adequate Lap Length: $lb/ld \geq 1$

Calculation of Mu1-

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

$$u = 6.4288704E-005$$

$$Mu = 1.7288E+009$$

with full section properties:

$$b = 400.00$$

$$d = 707.00$$

$$d' = 43.00$$

$$v = 0.00174378$$

$$N = 16273.607$$

$$fc = 33.00$$

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

$$\text{Final value of } cu: cu^* = \text{shear_factor} * \text{Max}(cu, cc) = 0.01291652$$

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

$$\text{From (5.4b), TBDY: } cu = 0.01291652$$

$$\text{we ((5.4c), TBDY) } = ase * sh,min * fywe / fce + \text{Min}(fx, fy) = 0.05541928$$

where $f = af * pf * ffe / fce$ 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, $t_f = NL * t * \cos(b_1) = 1.016$

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

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

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

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

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).

$$p_{sh,min} * F_{ywe} = \text{Min}(p_{sh,x} * F_{ywe}, p_{sh,y} * F_{ywe}) = 3.0194$$

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)

$$p_{sh,x} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{sh2} * F_{ywe2} = 3.0194$$

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

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

A_{stir1} (stirrups area) = 78.53982

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

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

A_{stir2} (stirrups area) = 50.26548

$$p_{sh,y} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{sh2} * F_{ywe2} = 3.0194$$

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

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

A_{stir1} (stirrups area) = 78.53982

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

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

Asec = 440000.00
s1 = 100.00
s2 = 250.00
fywe1 = 694.45
fywe2 = 694.45
fce = 33.00

From ((5.A.5), TBDY), TBDY: cc = 0.00238888
c = confinement factor = 1.03889

y1 = 0.0025
sh1 = 0.008
ft1 = 833.34
fy1 = 694.45
su1 = 0.032

using (30) in Biskinis/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 = 1.00

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

with fs1 = (fs,jacket*Asl,ten,jacket + fs,core*Asl,ten,core)/Asl,ten = 694.45

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

y2 = 0.0025
sh2 = 0.008
ft2 = 833.34
fy2 = 694.45
su2 = 0.032

using (30) in Biskinis/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 = 1.00

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

with fs2 = (fs,jacket*Asl,com,jacket + fs,core*Asl,com,core)/Asl,com = 694.45

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

yv = 0.0025
shv = 0.008
ftv = 833.34
fyv = 694.45
suv = 0.032

using (30) in Biskinis/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 = 1.00

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

with fsv = (fs,jacket*Asl,mid,jacket + fs,mid*Asl,mid,core)/Asl,mid = 694.45

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

1 = Asl,ten/(b*d)*(fs1/fc) = 0.16434361

2 = Asl,com/(b*d)*(fs2/fc) = 0.08462644

v = Asl,mid/(b*d)*(fsv/fc) = 0.14938203

and confined core properties:

b = 340.00
d = 677.00
d' = 13.00

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

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

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

$$1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.20191317$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.10397236$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.18353132$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

---->

$v < v_{s,y2}$ - LHS eq.(4.5) is not satisfied

---->

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

---->

$$s_u (4.8) = 0.29596233$$

$$M_u = M_{Rc} (4.15) = 1.7288E+009$$

$$u = s_u (4.1) = 6.4288704E-005$$

Calculation of ratio l_b/l_d

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

Calculation of M_{u2+}

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

$$u = 5.0226943E-005$$

$$M_u = 1.1540E+009$$

with full section properties:

$$b = 750.00$$

$$d = 707.00$$

$$d' = 43.00$$

$$v = 0.00093001$$

$$N = 16273.607$$

$$f_c = 33.00$$

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

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.01291652$$

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

$$\text{From (5.4b), TBDY: } c_u = 0.01291652$$

$$w_e ((5.4c), TBDY) = a_{se} * s_{h,min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.05541928$$

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 $a_f = 1 - (\text{Unconfined area})/(\text{total area})$

$$a_f = 0.31984848$$

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

$$b_{max} = 750.00$$

$$h_{max} = 750.00$$

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

$$b_w = 400.00$$

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

$$R = 40.00$$

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).

$p_{sh,min} * F_{ywe} = \text{Min}(p_{sh,x} * F_{ywe}, p_{sh,y} * F_{ywe}) = 3.0194$

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)

 $p_{sh,x} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{sh2} * F_{ywe2} = 3.0194$

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

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

 $p_{sh,y} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{sh2} * F_{ywe2} = 3.0194$

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

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

 $A_{sec} = 440000.00$

$s_1 = 100.00$

$s_2 = 250.00$

$f_{ywe1} = 694.45$

$f_{ywe2} = 694.45$

$f_{ce} = 33.00$

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

c = confinement factor = 1.03889

$y_1 = 0.0025$

$sh_1 = 0.008$

$ft_1 = 833.34$

$fy_1 = 694.45$

$su_1 = 0.032$

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

and also multiplied by the shear_factor according to 15.7.1.4, with

Shear_factor = 1.00

$l_o / l_{ou,min} = l_b / l_d = 1.00$

$su_1 = 0.4 * e_{su1,nominal}((5.5), TBDY) = 0.032$

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 $fs1 = (fs_{jacket} \cdot Asl_{ten,jacket} + fs_{core} \cdot Asl_{ten,core}) / Asl_{ten} = 694.45$

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

$y2 = 0.0025$

$sh2 = 0.008$

$ft2 = 833.34$

$fy2 = 694.45$

$su2 = 0.032$

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

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

$Shear_factor = 1.00$

$lo/lou, min = lb/lb, min = 1.00$

$su2 = 0.4 \cdot esu2_nominal$ ((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 $fs2 = (fs_{jacket} \cdot Asl_{com,jacket} + fs_{core} \cdot Asl_{com,core}) / Asl_{com} = 694.45$

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

$yv = 0.0025$

$shv = 0.008$

$ftv = 833.34$

$fyv = 694.45$

$su = 0.032$

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

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

$Shear_factor = 1.00$

$lo/lou, min = lb/ld = 1.00$

$su = 0.4 \cdot esuv_nominal$ ((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 $fsv = (fs_{jacket} \cdot Asl_{mid,jacket} + fs_{mid} \cdot Asl_{mid,core}) / Asl_{mid} = 694.45$

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

$1 = Asl_{ten} / (b \cdot d) \cdot (fs1 / fc) = 0.0451341$

$2 = Asl_{com} / (b \cdot d) \cdot (fs2 / fc) = 0.08764993$

$v = Asl_{mid} / (b \cdot d) \cdot (fsv / fc) = 0.07967042$

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

$1 = Asl_{ten} / (b \cdot d) \cdot (fs1 / fc) = 0.05123276$

$2 = Asl_{com} / (b \cdot d) \cdot (fs2 / fc) = 0.09949345$

$v = Asl_{mid} / (b \cdot d) \cdot (fsv / fc) = 0.09043572$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

su (4.9) = 0.09885678

$Mu = MRc$ (4.14) = 1.1540E+009

$u = su$ (4.1) = 5.0226943E-005

Calculation of ratio lb/ld

Adequate Lap Length: $lb/ld \geq 1$

Calculation of Mu2-

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

$$\mu = 6.4288704E-005$$

$$Mu = 1.7288E+009$$

with full section properties:

$$b = 400.00$$

$$d = 707.00$$

$$d' = 43.00$$

$$v = 0.00174378$$

$$N = 16273.607$$

$$f_c = 33.00$$

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

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.01291652$$

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

$$\text{From (5.4b), TBDY: } c_u = 0.01291652$$

$$w_e ((5.4c), TBDY) = a_{se} * s_{h, \min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.05541928$$

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.

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).

$$psh_{min} * F_{ywe} = \text{Min}(psh_x * F_{ywe}, psh_y * F_{ywe}) = 3.0194$$

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)

$$psh_x * F_{ywe} = psh1 * F_{ywe1} + ps2 * F_{ywe2} = 3.0194$$
$$psh1 \text{ ((5.4d), TBDY)} = L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00367709$$

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

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

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

$$psh_y * F_{ywe} = psh1 * F_{ywe1} + ps2 * F_{ywe2} = 3.0194$$
$$psh1 \text{ ((5.4d), TBDY)} = L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00367709$$

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

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

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

$$A_{sec} = 440000.00$$

$$s1 = 100.00$$

$$s2 = 250.00$$

$$fy_{we1} = 694.45$$

$$fy_{we2} = 694.45$$

$$f_{ce} = 33.00$$

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

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

$$y1 = 0.0025$$

$$sh1 = 0.008$$

$$ft1 = 833.34$$

$$fy1 = 694.45$$

$$su1 = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$$l_o/l_{o,min} = l_b/l_d = 1.00$$

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

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

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

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

$$\text{with } fs1 = (fs_{jacket} * A_{sl,ten,jacket} + fs_{core} * A_{sl,ten,core}) / A_{sl,ten} = 694.45$$

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

$$y2 = 0.0025$$

$$sh2 = 0.008$$

$$ft2 = 833.34$$

$$fy2 = 694.45$$

$$su2 = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$$l_o/l_{o,min} = l_b/l_{b,min} = 1.00$$

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

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

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

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

$$\text{with } fs2 = (fs_{jacket} * A_{sl,com,jacket} + fs_{core} * A_{sl,com,core}) / A_{sl,com} = 694.45$$

$$\text{with } Es2 = (Es_{jacket} * A_{sl,com,jacket} + Es_{core} * A_{sl,com,core}) / A_{sl,com} = 200000.00$$

$$y_v = 0.0025$$

$shv = 0.008$
 $ftv = 833.34$
 $fyv = 694.45$
 $suv = 0.032$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 $Shear_factor = 1.00$
 $lo/lou,min = lb/ld = 1.00$
 $suv = 0.4 * esuv_nominal ((5.5), TBDY) = 0.032$
 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 $fsv = (fs,jacket*Asl,mid,jacket + fs,mid*Asl,mid,core)/Asl,mid = 694.45$
 with $Esv = (Es,jacket*Asl,mid,jacket + Es,mid*Asl,mid,core)/Asl,mid = 200000.00$
 $1 = Asl,ten/(b*d)*(fs1/fc) = 0.16434361$
 $2 = Asl,com/(b*d)*(fs2/fc) = 0.08462644$
 $v = Asl,mid/(b*d)*(fsv/fc) = 0.14938203$

and confined core properties:

$b = 340.00$
 $d = 677.00$
 $d' = 13.00$
 $fcc (5A.2, TBDY) = 34.2833$
 $cc (5A.5, TBDY) = 0.00238888$
 $c = \text{confinement factor} = 1.03889$
 $1 = Asl,ten/(b*d)*(fs1/fc) = 0.20191317$
 $2 = Asl,com/(b*d)*(fs2/fc) = 0.10397236$
 $v = Asl,mid/(b*d)*(fsv/fc) = 0.18353132$

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

--->
 $v < vs,y2$ - LHS eq.(4.5) is not satisfied

--->
 $v < vs,c$ - RHS eq.(4.5) is satisfied

--->
 $su (4.8) = 0.29596233$
 $Mu = MRc (4.15) = 1.7288E+009$
 $u = su (4.1) = 6.4288704E-005$

 Calculation of ratio lb/ld

 Adequate Lap Length: $lb/ld \geq 1$

 Calculation of Shear Strength $Vr = Min(Vr1,Vr2) = 1.0898E+006$

 Calculation of Shear Strength at edge 1, $Vr1 = 1.0898E+006$

$Vr1 = VCol ((10.3), ASCE 41-17) = knl*VCol0$
 $VCol0 = 1.0898E+006$
 $knl = 1$ (zero step-static loading)

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

 $= 1$ (normal-weight concrete)
 Mean concrete strength: $fc' = (fc'_jacket*Area_jacket + fc'_core*Area_core)/Area_section = 33.00$, but $fc'^{0.5} \leq 8.3$
 MPa (22.5.3.1, ACI 318-14)
 $M/Vd = 4.00$
 $Mu = 1518.01$
 $Vu = 0.00017144$
 $d = 0.8*h = 600.00$
 $Nu = 16273.607$
 $Ag = 300000.00$

From (11.5.4.8), ACI 318-14: $V_s = V_{s,jacket} + V_{s,core} = 901155.609$

where:

$V_{s,jacket} = V_{s,j1} + V_{s,j2} = 802857.879$

$V_{s,j1} = 523602.964$ is calculated for section web jacket, with:

$d = 600.00$

$A_v = 157079.633$

$f_y = 555.56$

$s = 100.00$

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

$s/d = 0.16666667$

$V_{s,j2} = 279254.914$ is calculated for section flange jacket, with:

$d = 320.00$

$A_v = 157079.633$

$f_y = 555.56$

$s = 100.00$

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

$s/d = 0.3125$

$V_{s,core} = V_{s,c1} + V_{s,c2} = 98297.73$

$V_{s,c1} = 98297.73$ is calculated for section web core, with:

$d = 440.00$

$A_v = 100530.965$

$f_y = 555.56$

$s = 250.00$

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

$s/d = 0.56818182$

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

$d = 160.00$

$A_v = 100530.965$

$f_y = 555.56$

$s = 250.00$

$V_{s,c2}$ 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 $(\cot + \cot a)\sin a$ 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: $\theta = 90^\circ = 90.00$

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

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

$d_{fv} = d$ (figure 11.2, ACI 440) = 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: $V_s + V_f \leq 915872.391$

$b_w = 400.00$

Calculation of Shear Strength at edge 2, $V_{r2} = 1.0898E+006$

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

$V_{Col0} = 1.0898E+006$

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

$M / Vd = 4.00$

$\mu_u = 1518.01$

$V_u = 0.00017144$

$d = 0.8 \cdot h = 600.00$

$N_u = 16273.607$

Ag = 300000.00

From (11.5.4.8), ACI 318-14: $V_s = V_{s,jacket} + V_{s,core} = 901155.609$

where:

$V_{s,jacket} = V_{s,j1} + V_{s,j2} = 802857.879$

$V_{s,j1} = 523602.964$ is calculated for section web jacket, with:

d = 600.00

Av = 157079.633

fy = 555.56

s = 100.00

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

s/d = 0.16666667

$V_{s,j2} = 279254.914$ is calculated for section flange jacket, with:

d = 320.00

Av = 157079.633

fy = 555.56

s = 100.00

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

s/d = 0.3125

$V_{s,core} = V_{s,c1} + V_{s,c2} = 98297.73$

$V_{s,c1} = 98297.73$ is calculated for section web core, with:

d = 440.00

Av = 100530.965

fy = 555.56

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

Av = 100530.965

fy = 555.56

s = 250.00

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

s/d = 1.5625

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 Vf(θ , α), is implemented for every different fiber orientation ai, as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.

orientation 1: $\theta = 45^\circ$ and $\alpha = 90^\circ$

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: $V_s + V_f \leq 915872.391$

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: rcjlcs

Constant Properties

Knowledge Factor, $\phi = 0.90$

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

Consequently:

Jacket

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

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

Concrete Elasticity, $E_c = 26999.444$

Steel Elasticity, $E_s = 200000.00$

Existing Column

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

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

Concrete Elasticity, $E_c = 26999.444$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

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

Jacket

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

Existing Column

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

#####

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

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

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $e_{fu} = 0.01$

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

Fiber orientations, $b_i = 0.00^\circ$

Number of layers, $N_L = 1$

Radius of rounding corners, $R = 40.00$

Stepwise Properties

At local axis: 2

EDGE -A-

Shear Force, $V_a = -0.0001715$

EDGE -B-

Shear Force, $V_b = 0.0001715$

BOTH EDGES

Axial Force, $F = -16273.607$

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 , $V_e/V_r = 1.05752$

Member Controlled by Shear ($V_e/V_r > 1$)

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 1.1525E+006$
with

$M_{pr1} = \text{Max}(\mu_{1+}, \mu_{1-}) = 1.7288E+009$

$\mu_{1+} = 1.1540E+009$, 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

$\mu_{1-} = 1.7288E+009$, 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

$M_{pr2} = \text{Max}(\mu_{2+}, \mu_{2-}) = 1.7288E+009$

$\mu_{2+} = 1.1540E+009$, 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

$\mu_{2-} = 1.7288E+009$, 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:

$\mu = 5.0226943E-005$

$\mu_u = 1.1540E+009$

with full section properties:

$b = 750.00$

$d = 707.00$

$d' = 43.00$

$v = 0.00093001$

$N = 16273.607$

$f_c = 33.00$

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

Final value of μ_c : $\mu_c^* = \text{shear_factor} * \text{Max}(\mu_c, \mu_{cc}) = 0.01291652$

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

From (5.4b), TBDY: $\mu_c = 0.01291652$

μ_w ((5.4c), TBDY) = $\alpha s_e * \text{sh}_{\min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.05541928$

where $f = \alpha * p_f * f_{fe}/f_{ce}$ 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).
 $ase_2 (>= ase_1) = \text{Max}(((A_{conf,max2} - A_{noConf2})/A_{conf,max2}) * (A_{conf,min2}/A_{conf,max2}), 0) = 0.45746528$

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).
 $p_{sh,min} * F_{ywe} = \text{Min}(p_{sh,x} * F_{ywe}, p_{sh,y} * F_{ywe}) = 3.0194$

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)

 $p_{sh,x} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{s2} * F_{ywe2} = 3.0194$
 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

 $p_{sh,y} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{s2} * F_{ywe2} = 3.0194$
 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

 $A_{sec} = 440000.00$
 $s_1 = 100.00$
 $s_2 = 250.00$
 $f_{ywe1} = 694.45$
 $f_{ywe2} = 694.45$
 $f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY: $cc = 0.00238888$
 $c = \text{confinement factor} = 1.03889$

$y_1 = 0.0025$
 $sh_1 = 0.008$
 $ft_1 = 833.34$
 $fy_1 = 694.45$
 $su_1 = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$l_o/l_{ou,min} = l_b/l_d = 1.00$

$su_1 = 0.4 * esu_{1,nominal}$ ((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 $fs_1 = (f_{s,jacket} * A_{sl,ten,jacket} + f_{s,core} * A_{sl,ten,core}) / A_{sl,ten} = 694.45$

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

$y_2 = 0.0025$
 $sh_2 = 0.008$
 $ft_2 = 833.34$

$$f_y2 = 694.45$$

$$s_u2 = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$l_o/l_{o,u,min} = l_b/l_{b,min} = 1.00$$

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

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.

$$\text{with } f_{s2} = (f_{s,jacket} * A_{s1,com,jacket} + f_{s,core} * A_{s1,com,core}) / A_{s1,com} = 694.45$$

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

$$y_v = 0.0025$$

$$sh_v = 0.008$$

$$f_{tv} = 833.34$$

$$f_{yv} = 694.45$$

$$s_{uv} = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$l_o/l_{o,u,min} = l_b/l_d = 1.00$$

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

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, f_{tv}, 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.

$$\text{with } f_{sv} = (f_{s,jacket} * A_{s1,mid,jacket} + f_{s,mid} * A_{s1,mid,core}) / A_{s1,mid} = 694.45$$

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

$$1 = A_{s1,ten} / (b * d) * (f_{s1} / f_c) = 0.0451341$$

$$2 = A_{s1,com} / (b * d) * (f_{s2} / f_c) = 0.08764993$$

$$v = A_{s1,mid} / (b * d) * (f_{sv} / f_c) = 0.07967042$$

and confined core properties:

$$b = 690.00$$

$$d = 677.00$$

$$d' = 13.00$$

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

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

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

$$1 = A_{s1,ten} / (b * d) * (f_{s1} / f_c) = 0.05123276$$

$$2 = A_{s1,com} / (b * d) * (f_{s2} / f_c) = 0.09949345$$

$$v = A_{s1,mid} / (b * d) * (f_{sv} / f_c) = 0.09043572$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

$$s_u (4.9) = 0.09885678$$

$$M_u = M_{Rc} (4.14) = 1.1540E+009$$

$$u = s_u (4.1) = 5.0226943E-005$$

Calculation of ratio l_b/l_d

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

Calculation of M_{u1} -

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

$$u = 6.4288704E-005$$

$$M_u = 1.7288E+009$$

with full section properties:

$$b = 400.00$$

$$d = 707.00$$

$$d' = 43.00$$

$$v = 0.00174378$$

$$N = 16273.607$$

$$f_c = 33.00$$

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

$$\text{Final value of } \alpha: \alpha^* = \text{shear_factor} * \text{Max}(\alpha, \alpha_c) = 0.01291652$$

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

$$\text{From (5.4b), TBDY: } \alpha = 0.01291652$$

$$\text{we ((5.4c), TBDY) } = \alpha s_e * \text{sh}_{\min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.05541928$$

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

$$f_x = 0.04286225$$

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

$$\alpha_f = 0.31984848$$

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

$$b_{\max} = 750.00$$

$$h_{\max} = 750.00$$

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

$$b_w = 400.00$$

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

$$f_y = 0.04286225$$

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

$$\alpha_f = 0.31984848$$

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

$$b_{\max} = 750.00$$

$$h_{\max} = 750.00$$

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

$$b_w = 400.00$$

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

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$\alpha_s_e \text{ ((5.4d), TBDY) } = (\alpha_s e_1 * A_{\text{ext}} + \alpha_s e_2 * A_{\text{int}}) / A_{\text{sec}} = 0.45746528$$

$$\alpha_s e_1 = \text{Max}(((A_{\text{conf,max1}} - A_{\text{noConf1}}) / A_{\text{conf,max1}}) * (A_{\text{conf,min1}} / A_{\text{conf,max1}}), 0) = 0.45746528$$

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).

$$\alpha_s e_2 (> = \alpha_s e_1) = \text{Max}(((A_{\text{conf,max2}} - A_{\text{noConf2}}) / A_{\text{conf,max2}}) * (A_{\text{conf,min2}} / A_{\text{conf,max2}}), 0) = 0.45746528$$

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 $A_{\text{conf,max2}}$ 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).

$$p_{sh,\min} * f_{ywe} = \text{Min}(p_{sh,x} * f_{ywe}, p_{sh,y} * f_{ywe}) = 3.0194$$

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)

psh_x*Fywe = psh1*Fywe1+ps2*Fywe2 = 3.0194
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 = 3.0194
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 = 694.45
fywe2 = 694.45
fce = 33.00

From ((5.A5), TBDY), TBDY: cc = 0.00238888
c = confinement factor = 1.03889

y1 = 0.0025
sh1 = 0.008
ft1 = 833.34
fy1 = 694.45
su1 = 0.032

using (30) in Biskinis/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 = 1.00

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 = 694.45

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

y2 = 0.0025
sh2 = 0.008
ft2 = 833.34
fy2 = 694.45
su2 = 0.032

using (30) in Biskinis/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 = 1.00

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

From table 5A.1, TBDY: esu2_nominal = 0.08,

For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

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

with fs2 = (fs,jacket*Asl,com,jacket + fs,core*Asl,com,core)/Asl,com = 694.45

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

yv = 0.0025
shv = 0.008
ftv = 833.34
fyv = 694.45
suv = 0.032

using (30) in Biskinis/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 = 1.00

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 $fsv = (fs_jacket * Asl_mid_jacket + fs_mid * Asl_mid_core) / Asl_mid = 694.45$
 with $Esv = (Es_jacket * Asl_mid_jacket + Es_mid * Asl_mid_core) / Asl_mid = 200000.00$
 $1 = Asl_ten / (b * d) * (fs1 / fc) = 0.16434361$
 $2 = Asl_com / (b * d) * (fs2 / fc) = 0.08462644$
 $v = Asl_mid / (b * d) * (fsv / fc) = 0.14938203$

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
 $1 = Asl_ten / (b * d) * (fs1 / fc) = 0.20191317$
 $2 = Asl_com / (b * d) * (fs2 / fc) = 0.10397236$
 $v = Asl_mid / (b * d) * (fsv / fc) = 0.18353132$

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

---->
 $v < vs,y2$ - LHS eq.(4.5) is not satisfied

---->
 $v < vs,c$ - RHS eq.(4.5) is satisfied

---->
 su (4.8) = 0.29596233
 $Mu = MRc$ (4.15) = 1.7288E+009
 $u = su$ (4.1) = 6.4288704E-005

 Calculation of ratio lb/ld

 Adequate Lap Length: $lb/ld \geq 1$

 Calculation of $Mu2+$

 Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:
 $u = 5.0226943E-005$
 $Mu = 1.1540E+009$

 with full section properties:

$b = 750.00$
 $d = 707.00$
 $d' = 43.00$
 $v = 0.00093001$
 $N = 16273.607$

$fc = 33.00$
 co (5A.5, TBDY) = 0.002
 Final value of cu : $cu^* = shear_factor * Max(cu, cc) = 0.01291652$

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

From (5.4b), TBDY: $cu = 0.01291652$

we ((5.4c), TBDY) = $ase * sh_min * fywe / fce + Min(fx, fy) = 0.05541928$

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), $f_{f,e} = 870.5244$

fy = 0.04286225
Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area})/(\text{total area})$
af = 0.31984848
with Unconfined area = $((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2)/3 = 140733.333$
bmax = 750.00
hmax = 750.00
From EC8 A.4.4.3(6), $p_f = 2t_f/bw = 0.00508$
bw = 400.00
effective stress from (A.35), $f_{f,e} = 870.5244$

R = 40.00
Effective FRP thickness, $t_f = NL * t * \cos(b_1) = 1.016$
fu,f = 1055.00
Ef = 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).

$p_{sh,min} * F_{ywe} = \text{Min}(p_{sh,x} * F_{ywe}, p_{sh,y} * F_{ywe}) = 3.0194$

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)

$p_{sh,x} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{sh2} * F_{ywe2} = 3.0194$

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

$p_{sh,y} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{sh2} * F_{ywe2} = 3.0194$

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

$A_{sec} = 440000.00$

$s_1 = 100.00$

$s_2 = 250.00$

$f_{ywe1} = 694.45$

$$fy_{we2} = 694.45$$

$$f_{ce} = 33.00$$

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

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

$$y_1 = 0.0025$$

$$sh_1 = 0.008$$

$$ft_1 = 833.34$$

$$fy_1 = 694.45$$

$$su_1 = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$lo/lou, \min = lb/ld = 1.00$$

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

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

For calculation of $esu_{1, \text{nominal}}$ 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.

$$\text{with } fs_1 = (fs_{\text{jacket}} * Asl, \text{ten, jacket} + fs_{\text{core}} * Asl, \text{ten, core}) / Asl, \text{ten} = 694.45$$

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

$$y_2 = 0.0025$$

$$sh_2 = 0.008$$

$$ft_2 = 833.34$$

$$fy_2 = 694.45$$

$$su_2 = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$lo/lou, \min = lb/lb, \min = 1.00$$

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

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

For calculation of $esu_{2, \text{nominal}}$ 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.

$$\text{with } fs_2 = (fs_{\text{jacket}} * Asl, \text{com, jacket} + fs_{\text{core}} * Asl, \text{com, core}) / Asl, \text{com} = 694.45$$

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

$$y_v = 0.0025$$

$$sh_v = 0.008$$

$$ft_v = 833.34$$

$$fy_v = 694.45$$

$$su_v = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$lo/lou, \min = lb/ld = 1.00$$

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

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

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

For calculation of $esu_{v, \text{nominal}}$ and y_v, sh_v, ft_v, fy_v , it is considered
characteristic value $fsy_v = fs_v/1.2$, from table 5.1, TBDY.

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

$$\text{with } fs_v = (fs_{\text{jacket}} * Asl, \text{mid, jacket} + fs_{\text{mid}} * Asl, \text{mid, core}) / Asl, \text{mid} = 694.45$$

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

$$1 = Asl, \text{ten} / (b * d) * (fs_1 / f_c) = 0.0451341$$

$$2 = Asl, \text{com} / (b * d) * (fs_2 / f_c) = 0.08764993$$

$$v = Asl, \text{mid} / (b * d) * (fs_v / f_c) = 0.07967042$$

and confined core properties:

$$b = 690.00$$

$$d = 677.00$$

$$d' = 13.00$$

$$fcc (5A.2, \text{TBDY}) = 34.2833$$

$$cc (5A.5, \text{TBDY}) = 0.00238888$$

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

$$1 = Asl, \text{ten} / (b * d) * (fs_1 / f_c) = 0.05123276$$

$$2 = Asl, \text{com} / (b * d) * (fs_2 / f_c) = 0.09949345$$

$$v = Asl, \text{mid} / (b * d) * (fs_v / f_c) = 0.09043572$$

Case/Assumption: Unconfined full section - Steel rupture

satisfies Eq. (4.3)

--->

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

--->

$$s_u(4.9) = 0.09885678$$

$$\mu_u = M_{Rc}(4.14) = 1.1540E+009$$

$$u = s_u(4.1) = 5.0226943E-005$$

Calculation of ratio l_b/l_d

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

Calculation of μ_{u2}

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

$$u = 6.4288704E-005$$

$$\mu_u = 1.7288E+009$$

with full section properties:

$$b = 400.00$$

$$d = 707.00$$

$$d' = 43.00$$

$$v = 0.00174378$$

$$N = 16273.607$$

$$f_c = 33.00$$

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

$$\text{Final value of } \mu_u: \mu_u^* = \text{shear_factor} * \text{Max}(\mu_u, \mu_c) = 0.01291652$$

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

$$\text{From (5.4b), TBDY: } \mu_u = 0.01291652$$

$$\mu_{we}((5.4c), \text{TBDY}) = \alpha * \text{sh}_{\min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.05541928$$

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

$$f_x = 0.04286225$$

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

$$\alpha_f = 0.31984848$$

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

$$b_{\max} = 750.00$$

$$h_{\max} = 750.00$$

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

$$b_w = 400.00$$

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

$$f_y = 0.04286225$$

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

$$\alpha_f = 0.31984848$$

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

$$b_{\max} = 750.00$$

$$h_{\max} = 750.00$$

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

$$b_w = 400.00$$

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

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

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

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

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.

$A_{conf,max1} = 353600.00$ 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).
 $p_{sh,min} * F_{ywe} = \text{Min}(p_{sh,x} * F_{ywe}, p_{sh,y} * F_{ywe}) = 3.0194$

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)

 $p_{sh,x} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{s2} * F_{ywe2} = 3.0194$
 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

 $p_{sh,y} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{s2} * F_{ywe2} = 3.0194$
 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

 $A_{sec} = 440000.00$
 $s_1 = 100.00$
 $s_2 = 250.00$
 $f_{ywe1} = 694.45$
 $f_{ywe2} = 694.45$
 $f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY: $cc = 0.00238888$
 $c = \text{confinement factor} = 1.03889$

$y_1 = 0.0025$
 $sh_1 = 0.008$
 $ft_1 = 833.34$
 $fy_1 = 694.45$
 $su_1 = 0.032$

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

$l_o/l_{ou,min} = l_b/l_d = 1.00$

$su_1 = 0.4 * esu_{1,nominal}$ ((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 $fs_1 = (f_{s,jacket} * A_{s1,ten,jacket} + f_{s,core} * A_{s1,ten,core}) / A_{s1,ten} = 694.45$

with $Es_1 = (E_{s,jacket} * A_{s1,ten,jacket} + E_{s,core} * A_{s1,ten,core}) / A_{s1,ten} = 200000.00$

$y_2 = 0.0025$
 $sh_2 = 0.008$
 $ft_2 = 833.34$

$$f_y2 = 694.45$$

$$s_u2 = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$l_o/l_{o,u,min} = l_b/l_{b,min} = 1.00$$

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

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

For calculation of $e_{s_u2,nominal}$ and y_2 , sh_2, ft_2, f_y2 , it is considered
characteristic value $f_{s_y2} = f_{s2}/1.2$, 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.

$$\text{with } f_{s2} = (f_{s,jacket} * A_{s1,com,jacket} + f_{s,core} * A_{s1,com,core}) / A_{s1,com} = 694.45$$

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

$$y_v = 0.0025$$

$$sh_v = 0.008$$

$$f_{t_v} = 833.34$$

$$f_{y_v} = 694.45$$

$$s_{u_v} = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$l_o/l_{o,u,min} = l_b/l_d = 1.00$$

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

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

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

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

y_1 , sh_1, ft_1, f_y1 , are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE 41-17.

$$\text{with } f_{s_v} = (f_{s,jacket} * A_{s1,mid,jacket} + f_{s,mid} * A_{s1,mid,core}) / A_{s1,mid} = 694.45$$

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

$$1 = A_{s1,ten} / (b * d) * (f_{s1} / f_c) = 0.16434361$$

$$2 = A_{s1,com} / (b * d) * (f_{s2} / f_c) = 0.08462644$$

$$v = A_{s1,mid} / (b * d) * (f_{s_v} / f_c) = 0.14938203$$

and confined core properties:

$$b = 340.00$$

$$d = 677.00$$

$$d' = 13.00$$

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

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

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

$$1 = A_{s1,ten} / (b * d) * (f_{s1} / f_c) = 0.20191317$$

$$2 = A_{s1,com} / (b * d) * (f_{s2} / f_c) = 0.10397236$$

$$v = A_{s1,mid} / (b * d) * (f_{s_v} / f_c) = 0.18353132$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < v_{s,y2}$ - LHS eq.(4.5) is not satisfied

--->

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

--->

$$s_u (4.8) = 0.29596233$$

$$\mu_u = M_{Rc} (4.15) = 1.7288E+009$$

$$u = s_u (4.1) = 6.4288704E-005$$

Calculation of ratio l_b/l_d

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

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 1.0898E+006$

Calculation of Shear Strength at edge 1, $V_{r1} = 1.0898E+006$

$V_{r1} = V_{CoI} ((10.3), ASCE 41-17) = k_n l * V_{CoIO}$

$$V_{CoIO} = 1.0898E+006$$

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

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

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

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

$M/Vd = 4.00$

$M_u = 1518.777$

$V_u = 0.0001715$

$d = 0.8 \cdot h = 600.00$

$N_u = 16273.607$

$A_g = 300000.00$

From (11.5.4.8), ACI 318-14: $V_s = V_{s,jacket} + V_{s,core} = 901155.609$

where:

$V_{s,jacket} = V_{s,j1} + V_{s,j2} = 802857.879$

$V_{s,j1} = 279254.914$ is calculated for section web jacket, with:

$d = 320.00$

$A_v = 157079.633$

$f_y = 555.56$

$s = 100.00$

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

$s/d = 0.3125$

$V_{s,j2} = 523602.964$ is calculated for section flange jacket, with:

$d = 600.00$

$A_v = 157079.633$

$f_y = 555.56$

$s = 100.00$

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

$s/d = 0.16666667$

$V_{s,core} = V_{s,c1} + V_{s,c2} = 98297.73$

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

$d = 160.00$

$A_v = 100530.965$

$f_y = 555.56$

$s = 250.00$

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

$s/d = 1.5625$

$V_{s,c2} = 98297.73$ is calculated for section flange core, with:

$d = 440.00$

$A_v = 100530.965$

$f_y = 555.56$

$s = 250.00$

$V_{s,c2}$ 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: $\alpha = \beta_1 + 90^\circ = 90.00$

$V_f = \text{Min}(|V_f(45, \beta_1)|, |V_f(-45, \beta_1)|)$, 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: $V_s + V_f \leq 915872.391$

$b_w = 400.00$

Calculation of Shear Strength at edge 2, $V_{r2} = 1.0898E+006$

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

VCoIO = 1.0898E+006
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: $f_c' = (f_c'_{\text{jacket}} \cdot \text{Area}_{\text{jacket}} + f_c'_{\text{core}} \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 33.00$, but $f_c'^{0.5} \leq 8.3$
MPa (22.5.3.1, ACI 318-14)

$M/Vd = 4.00$

$M_u = 1518.777$

$V_u = 0.0001715$

$d = 0.8 \cdot h = 600.00$

$N_u = 16273.607$

$A_g = 300000.00$

From (11.5.4.8), ACI 318-14: $V_s = V_{s,\text{jacket}} + V_{s,\text{core}} = 901155.609$

where:

$V_{s,\text{jacket}} = V_{s,j1} + V_{s,j2} = 802857.879$

$V_{s,j1} = 279254.914$ is calculated for section web jacket, with:

$d = 320.00$

$A_v = 157079.633$

$f_y = 555.56$

$s = 100.00$

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

$s/d = 0.3125$

$V_{s,j2} = 523602.964$ is calculated for section flange jacket, with:

$d = 600.00$

$A_v = 157079.633$

$f_y = 555.56$

$s = 100.00$

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

$s/d = 0.16666667$

$V_{s,\text{core}} = V_{s,c1} + V_{s,c2} = 98297.73$

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

$d = 160.00$

$A_v = 100530.965$

$f_y = 555.56$

$s = 250.00$

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

$s/d = 1.5625$

$V_{s,c2} = 98297.73$ is calculated for section flange core, with:

$d = 440.00$

$A_v = 100530.965$

$f_y = 555.56$

$s = 250.00$

$V_{s,c2}$ 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 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: $\alpha = b1 + 90^\circ = 90.00$

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

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

$d_{fv} = d$ (figure 11.2, ACI 440) = 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: $V_s + V_f \leq 915872.391$

$b_w = 400.00$

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: (a)

Section Type: rcjlc

Constant Properties

Knowledge Factor, $\gamma = 0.90$

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

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

Consequently:

Jacket

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

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

Concrete Elasticity, $E_c = 26999.444$

Steel Elasticity, $E_s = 200000.00$

Existing Column

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

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

Concrete Elasticity, $E_c = 26999.444$

Steel Elasticity, $E_s = 200000.00$

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

Adequate Lap Length ($l_b/l_d > 1$)

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $e_{fu} = 0.01$

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

Fiber orientations, $b_i = 0.00^\circ$

Number of layers, $N_L = 1$

Radius of rounding corners, $R = 40.00$

Stepwise Properties

Bending Moment, $M = -399066.903$

Shear Force, $V_2 = -6058.142$

Shear Force, $V_3 = 163.9376$

Axial Force, $F = -18615.215$

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: $A_{sl,mid} = 2007.478$

Longitudinal External Reinforcement Area Distribution (in 3 divisions)

-Tension: $A_{sl,ten,jacket} = 829.3805$

-Compression: $A_{sl,com,jacket} = 1746.726$

-Middle: $A_{sl,mid,jacket} = 1545.664$

Longitudinal Internal Reinforcement Area Distribution (in 3 divisions)

-Tension: $A_{sl,ten,core} = 307.8761$

-Compression: $A_{sl,com,core} = 461.8141$

-Middle: $A_{sl,mid,core} = 461.8141$

Mean Diameter of Tension Reinforcement, $DbL = 16.80$

New component: From table 7-7, ASCE 41_17: Final chord rotation Capacity $u_R = 1.0^*$ $u = 0.00609608$

$u = y + p = 0.00609608$

- Calculation of y -

$y = (M_y * L_s / 3) / E_{eff} = 0.00345459$ ((4.29), Biskinis Phd)

$M_y = 6.5012E+008$

$L_s = M/V$ (with $L_s > 0.1 * L$ and $L_s < 2 * L$) = 2434.26

From table 10.5, ASCE 41_17: $E_{eff} = factor * E_c * I_g = 1.5270E+014$

factor = 0.30

$A_g = 440000.00$

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

$N = 18615.215$

$E_c * I_g = E_{c,jacket} * I_{g,jacket} + E_{c,core} * I_{g,core} = 5.0901E+014$

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, $t = 400.00$

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

$y_{ten} = 4.8677145E-006$

with $f_y = 555.56$

$d = 707.00$

$y = 0.19284589$

$A = 0.01015895$

$B = 0.00446935$

with $pt = 0.00671904$

$pc = 0.00416509$

$pv = 0.00378591$

$N = 18615.215$

$b = 750.00$

" = 0.06082037

$y_{comp} = 1.6459533E-005$

with fc^* (12.3, (ACI 440)) = 33.48734

$fc = 33.00$

$fl = 0.49678681$

$b = b_{max} = 750.00$

$h = h_{max} = 750.00$

$A_g = 0.44$

$g = pt + pc + pv = 0.01009575$

$rc = 40.00$

$A_e/A_c = 0.31291181$

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

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

$f_u = 0.01$

$E_f = 64828.00$

$E_c = 26999.444$

$y = 0.19184981$

$$A = 0.01001713$$

$$B = 0.00440616$$

$$\text{with } E_s = 200000.00$$

$$\text{CONFIRMATION: } y = 0.19284589 < t/d$$

Calculation of ratio l_b/d

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

- Calculation of p -

From table 10-8: $p = 0.00264149$

with:

- Columns not controlled by inadequate development or splicing along the clear height because $l_b/d \geq 1$
shear control ratio $V_y E / V_{Co} I_{OE} = 1.05752$

$$d = d_{\text{external}} = 707.00$$

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

- $t = s_1 + s_2 + 2 \cdot t_f / b_w \cdot (f_{fe} / f_s) = 0.00671904$

$$\text{jacket: } s_1 = A_{v1} \cdot L_{\text{stir}1} / (s_1 \cdot A_g) = 0.00367709$$

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

$L_{\text{stir}1} = 2060.00$, is the total Length of all stirrups parallel to loading (shear) direction

$$s_1 = 100.00$$

$$\text{core: } s_2 = A_{v2} \cdot L_{\text{stir}2} / (s_2 \cdot A_g) = 0.00067082$$

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

$L_{\text{stir}2} = 1468.00$, 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.

$$N_{UD} = 18615.215$$

$$A_g = 440000.00$$

$$f_{cE} = (f_{c_{\text{jacket}}} \cdot \text{Area}_{\text{jacket}} + f_{c_{\text{core}}} \cdot \text{Area}_{\text{core}}) / \text{section_area} = 33.00$$

$$f_{yE} = (f_{y_{\text{ext_Long_Reinf}}} \cdot \text{Area}_{\text{ext_Long_Reinf}} + f_{y_{\text{int_Long_Reinf}}} \cdot \text{Area}_{\text{int_Long_Reinf}}) / \text{Area}_{\text{Tot_Long_Rein}} = 555.56$$

$$f_{ytE} = (f_{y_{\text{ext_Trans_Reinf}}} \cdot s_1 + f_{y_{\text{int_Trans_Reinf}}} \cdot s_2) / (s_1 + s_2) = 555.56$$

$$p_l = \text{Area}_{\text{Tot_Long_Rein}} / (b \cdot d) = 0.01009575$$

$$b = 750.00$$

$$d = 707.00$$

$$f_{cE} = 33.00$$

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

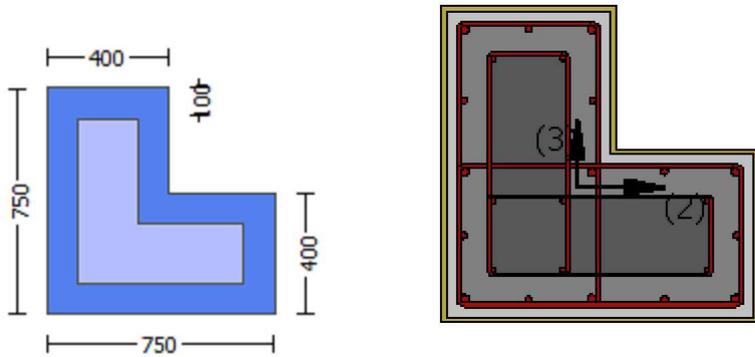
Limit State: Immediate Occupancy (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Shear capacity VRd

Edge: Start

Local Axis: (3)



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

At local axis: 3

Integration Section: (a)

Section Type: rcjlc

Constant Properties

Knowledge Factor, $\gamma = 0.90$

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

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

Consequently:

Jacket

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

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

Concrete Elasticity, $E_c = 26999.444$

Steel Elasticity, $E_s = 200000.00$

Existing Column

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

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

Concrete Elasticity, $E_c = 26999.444$

Steel Elasticity, $E_s = 200000.00$

#####

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

Jacket

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

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

Existing Column

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

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

#####

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

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

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $e_{fu} = 0.01$

Number of directions, $NoDir = 1$

Fiber orientations, $b_i = 0.00^\circ$

Number of layers, $NL = 1$

Radius of rounding corners, $R = 40.00$

Stepwise Properties

EDGE -A-

Bending Moment, $M_a = -399066.903$

Shear Force, $V_a = 163.9376$

EDGE -B-

Bending Moment, $M_b = -90444.323$

Shear Force, $V_b = -163.9376$

BOTH EDGES

Axial Force, $F = -18615.215$

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: $A_{sl,com} = 2208.54$

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

Mean Diameter of Tension Reinforcement, $Db_{L,ten} = 16.80$

New component: From table 7-7, ASCE 41_17: Final Shear Capacity $V_R = 1.0 \cdot V_n = 949014.707$

V_n ((10.3), ASCE 41-17) = $k_n \cdot V_{CoIO} = 949014.707$

$V_{CoI} = 949014.707$

$k_n = 1.00$

displacement_ductility_demand = 0.0073234

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

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

= 1 (normal-weight concrete)

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

$M/Vd = 4.00$

$M_u = 399066.903$

$V_u = 163.9376$

$d = 0.8 \cdot h = 600.00$

$N_u = 18615.215$

$A_g = 300000.00$

From (11.5.4.8), ACI 318-14: $V_s = V_{sjacket} + V_{s,core} = 811033.559$

where:

$V_{sjacket} = V_{sj1} + V_{sj2} = 722566.31$

$V_{sj1} = 471238.898$ 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

$$s/d = 0.3125$$

$$V_{s,core} = V_{s,c1} + V_{s,c2} = 88467.249$$

V_{s,c1} = 88467.249 is calculated for section web core, with:

$$d = 440.00$$

$$A_v = 100530.965$$

$$f_y = 500.00$$

$$s = 250.00$$

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:

$$d = 160.00$$

$$A_v = 100530.965$$

$$f_y = 500.00$$

$$s = 250.00$$

V_{s,c2} is multiplied by Col_{c2} = 0.00

$$s/d = 1.5625$$

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

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

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.

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

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

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

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

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

$$E_f = 64828.00$$

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

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

$$\text{From (11-11), ACI 440: } V_s + V_f \leq 797164.595$$

$$b_w = 400.00$$

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 $\theta = 2.5299333E-005$

$$y = (M_y * L_s / 3) / E_{eff} = 0.00345459 \text{ ((4.29), Biskinis Phd)}$$

$$M_y = 6.5012E+008$$

$$L_s = M/V \text{ (with } L_s > 0.1 * L \text{ and } L_s < 2 * L) = 2434.26$$

$$\text{From table 10.5, ASCE 41_17: } E_{eff} = \text{factor} * E_c * I_g = 1.5270E+014$$

$$\text{factor} = 0.30$$

$$A_g = 440000.00$$

$$\text{Mean concrete strength: } f'_c = (f'_{c_jacket} * \text{Area}_{jacket} + f'_{c_core} * \text{Area}_{core}) / \text{Area}_{section} = 33.00$$

$$N = 18615.215$$

$$E_c * I_g = E_{c_jacket} * I_{g_jacket} + E_{c_core} * I_{g_core} = 5.0901E+014$$

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, bw = 400.00
flange thickness, t = 400.00

y = Min(y_ten, y_com)
y_ten = 4.8677145E-006
with fy = 555.56
d = 707.00
y = 0.19284589
A = 0.01015895
B = 0.00446935
with pt = 0.00214476
pc = 0.00416509
pv = 0.00378591
N = 18615.215
b = 750.00
" = 0.06082037
y_comp = 1.6459533E-005
with fc* (12.3, (ACI 440)) = 33.48734
fc = 33.00
fl = 0.49678681
b = bmax = 750.00
h = hmax = 750.00
Ag = 0.44
g = pt + pc + pv = 0.01009575
rc = 40.00
Ae/Ac = 0.31291181
Effective FRP thickness, tf = NL*t*Cos(b1) = 1.016
effective strain from (12.5) and (12.12), efe = 0.004
fu = 0.01
Ef = 64828.00
Ec = 26999.444
y = 0.19184981
A = 0.01001713
B = 0.00440616
with Es = 200000.00
CONFIRMATION: y = 0.19284589 < t/d

Calculation of ratio lb/d

Adequate Lap Length: lb/d >= 1

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

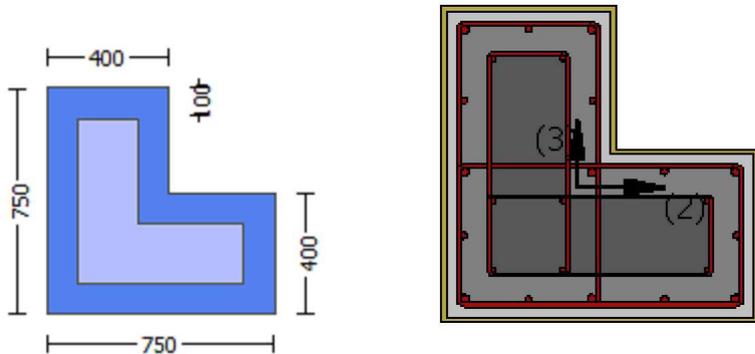
Limit State: Immediate Occupancy (data interpolation between analysis steps 1 and 2)

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: rcjlcs

Constant Properties

Knowledge Factor, $\gamma = 0.90$

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

Consequently:

Jacket

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

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

Concrete Elasticity, $E_c = 26999.444$

Steel Elasticity, $E_s = 200000.00$

Existing Column

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

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

Concrete Elasticity, $E_c = 26999.444$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

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

Jacket

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

Existing Column

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

#####

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
Adequate Lap Length ($l_o/l_{ou, \min} \geq 1$)
FRP Wrapping Data
Type: Carbon
Cured laminate properties (design values)
Thickness, $t = 1.016$
Tensile Strength, $f_{fu} = 1055.00$
Tensile Modulus, $E_f = 64828.00$
Elongation, $\epsilon_{fu} = 0.01$
Number of directions, $N_{oDir} = 1$
Fiber orientations, $b_i: 0.00^\circ$
Number of layers, $N_L = 1$
Radius of rounding corners, $R = 40.00$

Stepwise Properties

At local axis: 3
EDGE -A-
Shear Force, $V_a = -0.00017144$
EDGE -B-
Shear Force, $V_b = 0.00017144$
BOTH EDGES
Axial Force, $F = -16273.607$
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, $V_e/V_r = 1.05752$
Member Controlled by Shear ($V_e/V_r > 1$)
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 1.1525E+006$
with
 $M_{pr1} = \text{Max}(\mu_{u1+}, \mu_{u1-}) = 1.7288E+009$
 $\mu_{u1+} = 1.1540E+009$, is the ultimate moment strength at the edge 1 of the member in the actual moment direction
which is defined for the static loading combination
 $\mu_{u1-} = 1.7288E+009$, is the ultimate moment strength at the edge 1 of the member in the opposite moment
direction which is defined for the static loading combination
 $M_{pr2} = \text{Max}(\mu_{u2+}, \mu_{u2-}) = 1.7288E+009$
 $\mu_{u2+} = 1.1540E+009$, is the ultimate moment strength at the edge 2 of the member in the actual moment direction
which is defined for the the static loading combination
 $\mu_{u2-} = 1.7288E+009$, 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_{u1+}

Calculation of ultimate curvature ϕ_u according to 4.1, Biskinis/Fardis 2013:
 $\phi_u = 5.0226943E-005$
 $M_u = 1.1540E+009$

with full section properties:

$b = 750.00$
 $d = 707.00$
 $d' = 43.00$
 $v = 0.00093001$
 $N = 16273.607$
 $f_c = 33.00$

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

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.01291652$$

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

$$\text{From (5.4b), TBDY: } c_u = 0.01291652$$

$$w_e ((5.4c), TBDY) = a_{se} * s_{h,min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.05541928$$

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 $a_f = 1 - (\text{Unconfined area})/(\text{total area})$

$$a_f = 0.31984848$$

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

$$b_{max} = 750.00$$

$$h_{max} = 750.00$$

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

$$b_w = 400.00$$

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

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u_{f} = 0.015$$

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

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

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).

$$p_{sh,min} * F_{ywe} = \text{Min}(p_{sh,x} * F_{ywe}, p_{sh,y} * F_{ywe}) = 3.0194$$

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)

$$p_{sh,x} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{sh2} * F_{ywe2} = 3.0194$$

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

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

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

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

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

Astir2 (stirrups area) = 50.26548

psh_y*Fywe = psh₁*Fywe₁+ps₂*Fywe₂ = 3.0194
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 = 694.45

fywe₂ = 694.45

fce = 33.00

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

c = confinement factor = 1.03889

y₁ = 0.0025

sh₁ = 0.008

ft₁ = 833.34

fy₁ = 694.45

su₁ = 0.032

using (30) in Biskinis/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 = 1.00

su₁ = 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 y₁, sh₁,ft₁,fy₁, it is considered
characteristic value fsy₁ = fs₁/1.2, from table 5.1, TBDY.

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

with fs₁ = (fs,jacket*Asl,ten,jacket + fs,core*Asl,ten,core)/Asl,ten = 694.45

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

y₂ = 0.0025

sh₂ = 0.008

ft₂ = 833.34

fy₂ = 694.45

su₂ = 0.032

using (30) in Biskinis/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 = 1.00

su₂ = 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 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 Min(1,1.25*(lb/ld)^{2/3}), from 10.3.5, ASCE 41-17.

with fs₂ = (fs,jacket*Asl,com,jacket + fs,core*Asl,com,core)/Asl,com = 694.45

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

y_v = 0.0025

sh_v = 0.008

ft_v = 833.34

fy_v = 694.45

suv = 0.032

using (30) in Biskinis/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 = 1.00

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

From table 5A.1, TBDY: esuv_nominal = 0.08,

considering characteristic value fsy_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 fsy_v = fs_v/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 fs_v = (fs,jacket*Asl,mid,jacket + fs,mid*Asl,mid,core)/Asl,mid = 694.45

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

$$1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.0451341$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.08764993$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.07967042$$

and confined core properties:

$$b = 690.00$$

$$d = 677.00$$

$$d' = 13.00$$

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

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

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

$$1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.05123276$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.09949345$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.09043572$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

$$s_u (4.9) = 0.09885678$$

$$\mu_u = M_{Rc} (4.14) = 1.1540E+009$$

$$u = s_u (4.1) = 5.0226943E-005$$

 Calculation of ratio l_b/d

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

 Calculation of μ_{u1} -

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

$$u = 6.4288704E-005$$

$$\mu_u = 1.7288E+009$$

 with full section properties:

$$b = 400.00$$

$$d = 707.00$$

$$d' = 43.00$$

$$v = 0.00174378$$

$$N = 16273.607$$

$$f_c = 33.00$$

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

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.01291652$$

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

$$\text{From (5.4b), TBDY: } c_u = 0.01291652$$

$$w_e ((5.4c), TBDY) = a_{se} * s_{h,min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.05541928$$

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 $a_f = 1 - (\text{Unconfined area})/(\text{total area})$

$$a_f = 0.31984848$$

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

$$b_{max} = 750.00$$

$$h_{max} = 750.00$$

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).

$p_{sh,min} * F_{ywe} = \text{Min}(p_{sh,x} * F_{ywe}, p_{sh,y} * F_{ywe}) = 3.0194$

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)

$p_{sh,x} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{sh2} * F_{ywe2} = 3.0194$

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

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

$p_{sh,y} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{sh2} * F_{ywe2} = 3.0194$

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

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

$A_{sec} = 440000.00$

$s1 = 100.00$

$s2 = 250.00$

$f_{ywe1} = 694.45$

$f_{ywe2} = 694.45$

$f_{ce} = 33.00$

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

$c =$ confinement factor = 1.03889

$y1 = 0.0025$

$sh1 = 0.008$

$ft1 = 833.34$

$fy1 = 694.45$

$su1 = 0.032$

using (30) in Biskinis/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 = 1.00

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 = 694.45

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

y2 = 0.0025

sh2 = 0.008

ft2 = 833.34

fy2 = 694.45

su2 = 0.032

using (30) in Biskinis/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 = 1.00

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 = 694.45

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

yv = 0.0025

shv = 0.008

ftv = 833.34

fyv = 694.45

suv = 0.032

using (30) in Biskinis/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 = 1.00

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 = 694.45

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

1 = Asl,ten/(b*d)*(fs1/fc) = 0.16434361

2 = Asl,com/(b*d)*(fs2/fc) = 0.08462644

v = Asl,mid/(b*d)*(fsv/fc) = 0.14938203

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) = 0.20191317

2 = Asl,com/(b*d)*(fs2/fc) = 0.10397236

v = Asl,mid/(b*d)*(fsv/fc) = 0.18353132

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

v < vs,y2 - LHS eq.(4.5) is not satisfied

--->

v < vs,c - RHS eq.(4.5) is satisfied

--->

su (4.8) = 0.29596233

Mu = MRc (4.15) = 1.7288E+009

u = su (4.1) = 6.4288704E-005

Calculation of ratio l_b/d

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

Calculation of μ_{2+}

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

$$\mu = 5.0226943E-005$$

$$\mu_{2+} = 1.1540E+009$$

with full section properties:

$$b = 750.00$$

$$d = 707.00$$

$$d' = 43.00$$

$$v = 0.00093001$$

$$N = 16273.607$$

$$f_c = 33.00$$

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

$$\text{Final value of } \mu_{cu}^* = \text{shear_factor} * \text{Max}(\mu_{cu}, \mu_{cc}) = 0.01291652$$

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

$$\text{From (5.4b), TBDY: } \mu_{cu} = 0.01291652$$

$$\mu_{we} \text{ (5.4c), TBDY} = a_{se} * s_{h,min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.05541928$$

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.

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).
 $psh_{min} * F_{ywe} = \text{Min}(psh_x * F_{ywe}, psh_y * F_{ywe}) = 3.0194$

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)

 $psh_x * F_{ywe} = psh_1 * F_{ywe1} + ps_2 * F_{ywe2} = 3.0194$
 psh_1 ((5.4d), TBDY) = $L_{stir1} * A_{stir1} / (A_{sec} * s_1) = 0.00367709$
Lstir1 (Length of stirrups along Y) = 2060.00
Astir1 (stirrups area) = 78.53982
 psh_2 (5.4d) = $L_{stir2} * A_{stir2} / (A_{sec} * s_2) = 0.00067082$
Lstir2 (Length of stirrups along Y) = 1468.00
Astir2 (stirrups area) = 50.26548

 $psh_y * F_{ywe} = psh_1 * F_{ywe1} + ps_2 * F_{ywe2} = 3.0194$
 psh_1 ((5.4d), TBDY) = $L_{stir1} * A_{stir1} / (A_{sec} * s_1) = 0.00367709$
Lstir1 (Length of stirrups along X) = 2060.00
Astir1 (stirrups area) = 78.53982
 psh_2 ((5.4d), TBDY) = $L_{stir2} * A_{stir2} / (A_{sec} * s_2) = 0.00067082$
Lstir2 (Length of stirrups along X) = 1468.00
Astir2 (stirrups area) = 50.26548

Asec = 440000.00

s1 = 100.00

s2 = 250.00

fywe1 = 694.45

fywe2 = 694.45

fce = 33.00

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

c = confinement factor = 1.03889

y1 = 0.0025

sh1 = 0.008

ft1 = 833.34

fy1 = 694.45

su1 = 0.032

using (30) in Biskinis/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 = 1.00

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 = $(f_{s,jacket} * A_{s,ten,jacket} + f_{s,core} * A_{s,ten,core}) / A_{s,ten} = 694.45$

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

y2 = 0.0025

sh2 = 0.008

ft2 = 833.34

fy2 = 694.45

su2 = 0.032

using (30) in Biskinis/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 = 1.00

su2 = $0.4 * esu2_{nominal}$ ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: $es_{u2_nominal} = 0.08$,

For calculation of $es_{u2_nominal}$ and y_2, sh_2, ft_2, fy_2 , it is considered characteristic value $fs_{y2} = fs_2/1.2$, from table 5.1, TBDY.

y_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 $fs_2 = (fs_{jacket} \cdot Asl_{com,jacket} + fs_{core} \cdot Asl_{com,core}) / Asl_{com} = 694.45$

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

$y_v = 0.0025$

$sh_v = 0.008$

$ft_v = 833.34$

$fy_v = 694.45$

$suv = 0.032$

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

and also multiplied by the shear_factor according to 15.7.1.4, with

Shear_factor = 1.00

$lo/lo_{u,min} = lb/d = 1.00$

$suv = 0.4 \cdot es_{uv_nominal} ((5.5), TBDY) = 0.032$

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

with $fs_v = (fs_{jacket} \cdot Asl_{mid,jacket} + fs_{mid} \cdot Asl_{mid,core}) / Asl_{mid} = 694.45$

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

$1 = Asl_{ten} / (b \cdot d) \cdot (fs_1 / fc) = 0.0451341$

$2 = Asl_{com} / (b \cdot d) \cdot (fs_2 / fc) = 0.08764993$

$v = Asl_{mid} / (b \cdot d) \cdot (fs_v / fc) = 0.07967042$

and confined core properties:

$b = 690.00$

$d = 677.00$

$d' = 13.00$

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

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

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

$1 = Asl_{ten} / (b \cdot d) \cdot (fs_1 / fc) = 0.05123276$

$2 = Asl_{com} / (b \cdot d) \cdot (fs_2 / fc) = 0.09949345$

$v = Asl_{mid} / (b \cdot d) \cdot (fs_v / fc) = 0.09043572$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

$su (4.9) = 0.09885678$

$Mu = MRc (4.14) = 1.1540E+009$

$u = su (4.1) = 5.0226943E-005$

Calculation of ratio lb/d

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

Calculation of Mu_2 -

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

$u = 6.4288704E-005$

$Mu = 1.7288E+009$

with full section properties:

$b = 400.00$

$d = 707.00$

$d' = 43.00$

$v = 0.00174378$

$N = 16273.607$

$fc = 33.00$

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

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.01291652$$

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

$$\text{From (5.4b), TBDY: } c_u = 0.01291652$$

$$w_e ((5.4c), TBDY) = a_{se} * s_{h,min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.05541928$$

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 $a_f = 1 - (\text{Unconfined area})/(\text{total area})$

$$a_f = 0.31984848$$

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

$$b_{max} = 750.00$$

$$h_{max} = 750.00$$

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

$$b_w = 400.00$$

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

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

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

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

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).

$$p_{sh,min} * F_{ywe} = \text{Min}(p_{sh,x} * F_{ywe}, p_{sh,y} * F_{ywe}) = 3.0194$$

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)

$$p_{sh,x} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{sh2} * F_{ywe2} = 3.0194$$

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

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

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

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

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

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

$$\begin{aligned} \text{psh}_y * \text{Fywe} &= \text{psh}_1 * \text{Fywe}_1 + \text{ps}_2 * \text{Fywe}_2 = 3.0194 \\ \text{psh}_1 ((5.4d), \text{TBDY}) &= \text{Lstir}_1 * \text{Astir}_1 / (\text{Asec} * \text{s}_1) = 0.00367709 \\ \text{Lstir}_1 (\text{Length of stirrups along X}) &= 2060.00 \\ \text{Astir}_1 (\text{stirrups area}) &= 78.53982 \\ \text{psh}_2 ((5.4d), \text{TBDY}) &= \text{Lstir}_2 * \text{Astir}_2 / (\text{Asec} * \text{s}_2) = 0.00067082 \\ \text{Lstir}_2 (\text{Length of stirrups along X}) &= 1468.00 \\ \text{Astir}_2 (\text{stirrups area}) &= 50.26548 \end{aligned}$$

$$\text{Asec} = 440000.00$$

$$\text{s}_1 = 100.00$$

$$\text{s}_2 = 250.00$$

$$\text{fywe}_1 = 694.45$$

$$\text{fywe}_2 = 694.45$$

$$\text{fce} = 33.00$$

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

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

$$\text{y}_1 = 0.0025$$

$$\text{sh}_1 = 0.008$$

$$\text{ft}_1 = 833.34$$

$$\text{fy}_1 = 694.45$$

$$\text{su}_1 = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$\text{lo/lou, min} = \text{lb/ld} = 1.00$$

$$\text{su}_1 = 0.4 * \text{esu}_1 \text{ nominal } ((5.5), \text{TBDY}) = 0.032$$

$$\text{From table 5A.1, TBDY: } \text{esu}_1 \text{ nominal} = 0.08,$$

For calculation of esu1_nominal and y1, sh1, ft1, fy1, it is considered
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

$$\text{y}_1, \text{sh}_1, \text{ft}_1, \text{fy}_1, \text{ are also multiplied by } \text{Min}(1, 1.25 * (\text{lb/ld})^{2/3}), \text{ from 10.3.5, ASCE 41-17.}$$

$$\text{with } \text{fs}_1 = (\text{fs}_{\text{jacket}} * \text{Asl}_{\text{ten, jacket}} + \text{fs}_{\text{core}} * \text{Asl}_{\text{ten, core}}) / \text{Asl}_{\text{ten}} = 694.45$$

$$\text{with } \text{Es}_1 = (\text{Es}_{\text{jacket}} * \text{Asl}_{\text{ten, jacket}} + \text{Es}_{\text{core}} * \text{Asl}_{\text{ten, core}}) / \text{Asl}_{\text{ten}} = 200000.00$$

$$\text{y}_2 = 0.0025$$

$$\text{sh}_2 = 0.008$$

$$\text{ft}_2 = 833.34$$

$$\text{fy}_2 = 694.45$$

$$\text{su}_2 = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$\text{lo/lou, min} = \text{lb/lb, min} = 1.00$$

$$\text{su}_2 = 0.4 * \text{esu}_2 \text{ nominal } ((5.5), \text{TBDY}) = 0.032$$

$$\text{From table 5A.1, TBDY: } \text{esu}_2 \text{ nominal} = 0.08,$$

For calculation of esu2_nominal and y2, sh2, ft2, fy2, it is considered
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

$$\text{y}_2, \text{sh}_2, \text{ft}_2, \text{fy}_2, \text{ are also multiplied by } \text{Min}(1, 1.25 * (\text{lb/ld})^{2/3}), \text{ from 10.3.5, ASCE 41-17.}$$

$$\text{with } \text{fs}_2 = (\text{fs}_{\text{jacket}} * \text{Asl}_{\text{com, jacket}} + \text{fs}_{\text{core}} * \text{Asl}_{\text{com, core}}) / \text{Asl}_{\text{com}} = 694.45$$

$$\text{with } \text{Es}_2 = (\text{Es}_{\text{jacket}} * \text{Asl}_{\text{com, jacket}} + \text{Es}_{\text{core}} * \text{Asl}_{\text{com, core}}) / \text{Asl}_{\text{com}} = 200000.00$$

$$\text{y}_v = 0.0025$$

$$\text{sh}_v = 0.008$$

$$\text{ft}_v = 833.34$$

$$\text{fy}_v = 694.45$$

$$\text{suv} = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$\text{lo/lou, min} = \text{lb/ld} = 1.00$$

$$\text{suv} = 0.4 * \text{esuv}_v \text{ nominal } ((5.5), \text{TBDY}) = 0.032$$

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

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.

$$\text{y}_v, \text{sh}_v, \text{ft}_v, \text{fy}_v, \text{ are also multiplied by } \text{Min}(1, 1.25 * (\text{lb/ld})^{2/3}), \text{ from 10.3.5, ASCE 41-17.}$$

$$\text{with } \text{fs}_v = (\text{fs}_{\text{jacket}} * \text{Asl}_{\text{mid, jacket}} + \text{fs}_{\text{mid}} * \text{Asl}_{\text{mid, core}}) / \text{Asl}_{\text{mid}} = 694.45$$

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

$$1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.16434361$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.08462644$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.14938203$$

and confined core properties:

$$b = 340.00$$

$$d = 677.00$$

$$d' = 13.00$$

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

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

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

$$1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.20191317$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.10397236$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.18353132$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < v_{s,y2}$ - LHS eq.(4.5) is not satisfied

--->

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

--->

$$s_u (4.8) = 0.29596233$$

$$M_u = M_{Rc} (4.15) = 1.7288E+009$$

$$u = s_u (4.1) = 6.4288704E-005$$

Calculation of ratio l_b/l_d

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

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 1.0898E+006$

Calculation of Shear Strength at edge 1, $V_{r1} = 1.0898E+006$

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

$$V_{Col0} = 1.0898E+006$$

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

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)

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

$$M/Vd = 4.00$$

$$M_u = 1518.01$$

$$V_u = 0.00017144$$

$$d = 0.8 * h = 600.00$$

$$N_u = 16273.607$$

$$A_g = 300000.00$$

$$\text{From (11.5.4.8), ACI 318-14: } V_s = V_{sjacket} + V_{s,core} = 901155.609$$

where:

$$V_{sjacket} = V_{sj1} + V_{sj2} = 802857.879$$

$V_{sj1} = 523602.964$ is calculated for section web jacket, with:

$$d = 600.00$$

$$A_v = 157079.633$$

$$f_y = 555.56$$

$$s = 100.00$$

V_{sj1} is multiplied by $Col,j1 = 1.00$

$$s/d = 0.16666667$$

$V_{sj2} = 279254.914$ is calculated for section flange jacket, with:

$$d = 320.00$$

$$A_v = 157079.633$$

$$f_y = 555.56$$

$$s = 100.00$$

V_{sj2} is multiplied by $Col,j2 = 1.00$

$$s/d = 0.3125$$

$$V_{s,core} = V_{s,c1} + V_{s,c2} = 98297.73$$

$V_{s,c1} = 98297.73$ is calculated for section web core, with:

$$d = 440.00$$

$$A_v = 100530.965$$

$$f_y = 555.56$$

$$s = 250.00$$

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

$$s/d = 0.56818182$$

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

$$d = 160.00$$

$$A_v = 100530.965$$

$$f_y = 555.56$$

$$s = 250.00$$

$V_{s,c2}$ 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) $\sin + \cos$ 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: $\theta = 45^\circ$

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

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

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

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

$$E_f = 64828.00$$

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

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

$$\text{From (11-11), ACI 440: } V_s + V_f \leq 915872.391$$

$$b_w = 400.00$$

Calculation of Shear Strength at edge 2, $V_{r2} = 1.0898E+006$

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

$$V_{Col0} = 1.0898E+006$$

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

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

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

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

$$M/Vd = 4.00$$

$$\mu_u = 1518.01$$

$$V_u = 0.00017144$$

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

$$N_u = 16273.607$$

$$A_g = 300000.00$$

$$\text{From (11.5.4.8), ACI 318-14: } V_s = V_{s,jacket} + V_{s,core} = 901155.609$$

where:

$$V_{s,jacket} = V_{s,j1} + V_{s,j2} = 802857.879$$

$V_{s,j1} = 523602.964$ is calculated for section web jacket, with:

$$d = 600.00$$

$$A_v = 157079.633$$

$$f_y = 555.56$$

$$s = 100.00$$

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

$$s/d = 0.16666667$$

$V_{s,j2} = 279254.914$ is calculated for section flange jacket, with:

$$d = 320.00$$

$$A_v = 157079.633$$

$$f_y = 555.56$$

$$s = 100.00$$

V_{s,j2} is multiplied by Col,j2 = 1.00
s/d = 0.3125

V_{s,core} = V_{s,c1} + V_{s,c2} = 98297.73

V_{s,c1} = 98297.73 is calculated for section web core, with:
d = 440.00

A_v = 100530.965

f_y = 555.56

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 = 555.56

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

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

In (11.3) sin + cos is replaced with (cot + cota)sinα 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(α, a_i), is implemented for every different fiber orientation a_i,
as well as for 2 crack directions, α = 45° and α = -45° to take into consideration the cyclic seismic loading.

orientation 1: α = b1 + 90° = 90.00

V_f = Min(|V_f(45, a₁)|, |V_f(-45, a₁)|), with:

total thickness per orientation, t_{f1} = NL*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 <= 915872.391

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, k = 0.90

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

Consequently:

Jacket

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

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

Concrete Elasticity, E_c = 26999.444

Steel Elasticity, E_s = 200000.00

Existing Column

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

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

Concrete Elasticity, E_c = 26999.444

Steel Elasticity, E_s = 200000.00

#####

Note: Especially for the calculation of moment strengths,

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

Jacket

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

Existing Column

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

#####

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

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

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $\epsilon_{fu} = 0.01$

Number of directions, $NoDir = 1$

Fiber orientations, $b_i = 0.00^\circ$

Number of layers, $NL = 1$

Radius of rounding corners, $R = 40.00$

Stepwise Properties

At local axis: 2

EDGE -A-

Shear Force, $V_a = -0.0001715$

EDGE -B-

Shear Force, $V_b = 0.0001715$

BOTH EDGES

Axial Force, $F = -16273.607$

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: $A_{sl,mid} = 2007.478$

Calculation of Shear Capacity ratio , $V_e/V_r = 1.05752$

Member Controlled by Shear ($V_e/V_r > 1$)

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 1.1525E+006$

with

$M_{pr1} = \text{Max}(M_{u1+}, M_{u1-}) = 1.7288E+009$

$M_{u1+} = 1.1540E+009$, 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

$M_{u1-} = 1.7288E+009$, 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

$M_{pr2} = \text{Max}(M_{u2+}, M_{u2-}) = 1.7288E+009$

$M_{u2+} = 1.1540E+009$, 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

$M_{u2-} = 1.7288E+009$, 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:

$$u = 5.0226943E-005$$

$$\mu = 1.1540E+009$$

with full section properties:

$$b = 750.00$$

$$d = 707.00$$

$$d' = 43.00$$

$$v = 0.00093001$$

$$N = 16273.607$$

$$f_c = 33.00$$

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

$$\text{Final value of } \phi_u: \phi_u = \text{shear_factor} * \text{Max}(\phi_{cu}, \phi_{cc}) = 0.01291652$$

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

$$\text{From (5.4b), TBDY: } \phi_{cu} = 0.01291652$$

$$\phi_{cc} \text{ ((5.4c), TBDY) } = a_{se} * \text{sh}_{, \text{min}} * f_{ywe} / f_{ce} + \text{Min}(\phi_{fx}, \phi_{fy}) = 0.05541928$$

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

$$\phi_{fx} = 0.04286225$$

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

$$a_f = 0.31984848$$

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

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

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

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

$$b_w = 400.00$$

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

$$\phi_{fy} = 0.04286225$$

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.

$A_{\text{conf,max2}} = 171264.00$ 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.

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).
 $psh,min*Fywe = \text{Min}(psh,x*Fywe, psh,y*Fywe) = 3.0194$

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)

 $psh_x*Fywe = psh1*Fywe1 + ps2*Fywe2 = 3.0194$
 $psh1$ ((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

 $psh_y*Fywe = psh1*Fywe1 + ps2*Fywe2 = 3.0194$
 $psh1$ ((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 = 694.45
fywe2 = 694.45
fce = 33.00

From ((5.A5), TBDY), TBDY: cc = 0.00238888
c = confinement factor = 1.03889

y1 = 0.0025
sh1 = 0.008
ft1 = 833.34
fy1 = 694.45
su1 = 0.032

using (30) in Biskinis/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 = 1.00

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 $fs1 = (fs,jacket*Asl,ten,jacket + fs,core*Asl,ten,core)/Asl,ten = 694.45$

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

y2 = 0.0025
sh2 = 0.008
ft2 = 833.34
fy2 = 694.45
su2 = 0.032

using (30) in Biskinis/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 = 1.00

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

From table 5A.1, TBDY: esu2_nominal = 0.08,

For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered characteristic value $fsy2 = fs2/1.2$, from table 5.1, TBDY.

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

with $fs2 = (fs,jacket*Asl,com,jacket + fs,core*Asl,com,core)/Asl,com = 694.45$

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

yv = 0.0025
shv = 0.008
ftv = 833.34

$f_{yv} = 694.45$
 $s_{uv} = 0.032$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $l_o/l_{ou,min} = l_b/l_d = 1.00$
 $s_{uv} = 0.4 * e_{suv_nominal} ((5.5), TBDY) = 0.032$
 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 $f_{sv} = (f_{s,jacket} * A_{s,mid,jacket} + f_{s,mid} * A_{s,mid,core}) / A_{s,mid} = 694.45$
 with $E_{sv} = (E_{s,jacket} * A_{s,mid,jacket} + E_{s,mid} * A_{s,mid,core}) / A_{s,mid} = 200000.00$
 $1 = A_{s,ten} / (b * d) * (f_{s1} / f_c) = 0.0451341$
 $2 = A_{s,com} / (b * d) * (f_{s2} / f_c) = 0.08764993$
 $v = A_{s,mid} / (b * d) * (f_{sv} / f_c) = 0.07967042$
 and confined core properties:
 $b = 690.00$
 $d = 677.00$
 $d' = 13.00$
 $f_{cc} (5A.2, TBDY) = 34.2833$
 $cc (5A.5, TBDY) = 0.00238888$
 $c = \text{confinement factor} = 1.03889$
 $1 = A_{s,ten} / (b * d) * (f_{s1} / f_c) = 0.05123276$
 $2 = A_{s,com} / (b * d) * (f_{s2} / f_c) = 0.09949345$
 $v = A_{s,mid} / (b * d) * (f_{sv} / f_c) = 0.09043572$
 Case/Assumption: Unconfined full section - Steel rupture
 ' satisfies Eq. (4.3)

--->
 $v < v_{s,y2}$ - LHS eq.(4.5) is satisfied
 --->
 $su (4.9) = 0.09885678$
 $Mu = MRc (4.14) = 1.1540E+009$
 $u = su (4.1) = 5.0226943E-005$

 Calculation of ratio l_b/l_d

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

 Calculation of Mu_1 -

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

$u = 6.4288704E-005$
 $Mu = 1.7288E+009$

 with full section properties:

$b = 400.00$
 $d = 707.00$
 $d' = 43.00$
 $v = 0.00174378$
 $N = 16273.607$
 $f_c = 33.00$
 $co (5A.5, TBDY) = 0.002$
 Final value of cu : $cu^* = \text{shear_factor} * \text{Max}(cu, cc) = 0.01291652$
 The Shear_factor is considered equal to 1 (pure moment strength)
 From (5.4b), TBDY: $cu = 0.01291652$
 $we ((5.4c), TBDY) = a_s * sh_{,min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.05541928$
 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 $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$af = 0.31984848$$

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

$$b_{\max} = 750.00$$

$$h_{\max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } pf = 2tf/bw = 0.00508$$

$$bw = 400.00$$

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

$$f_y = 0.04286225$$

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

$$af = 0.31984848$$

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

$$b_{\max} = 750.00$$

$$h_{\max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } pf = 2tf/bw = 0.00508$$

$$bw = 400.00$$

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

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

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

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

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).

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

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).

$$psh_{,min} * F_{ywe} = \text{Min}(psh_{,x} * F_{ywe}, psh_{,y} * F_{ywe}) = 3.0194$$

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)

$$psh_{,x} * F_{ywe} = psh1 * F_{ywe1} + ps2 * F_{ywe2} = 3.0194$$

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

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

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

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

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

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

$$psh_{,y} * F_{ywe} = psh1 * F_{ywe1} + ps2 * F_{ywe2} = 3.0194$$

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

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

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

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

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

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

Asec = 440000.00

s1 = 100.00

s2 = 250.00

fywe1 = 694.45

fywe2 = 694.45

fce = 33.00

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

c = confinement factor = 1.03889

y1 = 0.0025

sh1 = 0.008

ft1 = 833.34

fy1 = 694.45

su1 = 0.032

using (30) in Biskinis/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 = 1.00

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 = (fsjacket*Asl,ten,jacket + fs,core*Asl,ten,core)/Asl,ten = 694.45

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

y2 = 0.0025

sh2 = 0.008

ft2 = 833.34

fy2 = 694.45

su2 = 0.032

using (30) in Biskinis/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 = 1.00

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 = (fsjacket*Asl,com,jacket + fs,core*Asl,com,core)/Asl,com = 694.45

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

yv = 0.0025

shv = 0.008

ftv = 833.34

fyv = 694.45

suv = 0.032

using (30) in Biskinis/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 = 1.00

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 = (fsjacket*Asl,mid,jacket + fs,mid*Asl,mid,core)/Asl,mid = 694.45

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

1 = Asl,ten/(b*d)*(fs1/fc) = 0.16434361

2 = Asl,com/(b*d)*(fs2/fc) = 0.08462644

v = Asl,mid/(b*d)*(fsv/fc) = 0.14938203

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 = $Asl_{ten}/(b*d)*(fs1/fc) = 0.20191317$

2 = $Asl_{com}/(b*d)*(fs2/fc) = 0.10397236$

v = $Asl_{mid}/(b*d)*(fsv/fc) = 0.18353132$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

v < $v_{s,y2}$ - LHS eq.(4.5) is not satisfied

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

su (4.8) = 0.29596233

Mu = MRc (4.15) = 1.7288E+009

u = su (4.1) = 6.4288704E-005

Calculation of ratio lb/l_d

Adequate Lap Length: lb/l_d >= 1

Calculation of Mu₂₊

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

u = 5.0226943E-005

Mu = 1.1540E+009

with full section properties:

b = 750.00

d = 707.00

d' = 43.00

v = 0.00093001

N = 16273.607

fc = 33.00

co (5A.5, TBDY) = 0.002

Final value of cu: cu* = shear_factor * Max(cu, cc) = 0.01291652

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

From (5.4b), TBDY: cu = 0.01291652

we ((5.4c), TBDY) = ase* sh,min*fywe/fce+ Min(fx, fy) = 0.05541928

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), ffe = 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), ffe = 870.5244

R = 40.00

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

fu,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).

$$p_{sh,min} * F_{ywe} = \text{Min}(p_{sh,x} * F_{ywe}, p_{sh,y} * F_{ywe}) = 3.0194$$

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)

$$p_{sh,x} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{sh2} * F_{ywe2} = 3.0194$$

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

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

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

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

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

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

$$p_{sh,y} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{sh2} * F_{ywe2} = 3.0194$$

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

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

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

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

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

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

$$A_{sec} = 440000.00$$

$$s1 = 100.00$$

$$s2 = 250.00$$

$$f_{ywe1} = 694.45$$

$$f_{ywe2} = 694.45$$

$$f_{ce} = 33.00$$

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

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

$$y1 = 0.0025$$

$$sh1 = 0.008$$

$$ft1 = 833.34$$

$$fy1 = 694.45$$

$$su1 = 0.032$$

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

and also multiplied by the shear_factor according to 15.7.1.4, with

Shear_factor = 1.00

$$l_o / l_{ou,min} = l_b / l_d = 1.00$$

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

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

For calculation of $esu1_{nominal}$ and $y1$, $sh1$, $ft1$, $fy1$, it is considered

characteristic value $f_{sy1} = f_{s1}/1.2$, 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 $f_{s1} = (f_{s,jacket} \cdot A_{s,ten,jacket} + f_{s,core} \cdot A_{s,ten,core})/A_{s,ten} = 694.45$

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

$y_2 = 0.0025$

$sh_2 = 0.008$

$ft_2 = 833.34$

$fy_2 = 694.45$

$su_2 = 0.032$

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

and also multiplied by the shear_factor according to 15.7.1.4, with

Shear_factor = 1.00

$l_o/l_{o,min} = l_b/l_{b,min} = 1.00$

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

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 $f_{s2} = (f_{s,jacket} \cdot A_{s,com,jacket} + f_{s,core} \cdot A_{s,com,core})/A_{s,com} = 694.45$

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

$y_v = 0.0025$

$sh_v = 0.008$

$ft_v = 833.34$

$fy_v = 694.45$

$su_v = 0.032$

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

and also multiplied by the shear_factor according to 15.7.1.4, with

Shear_factor = 1.00

$l_o/l_{o,min} = l_b/l_d = 1.00$

$su_v = 0.4 \cdot esu_{v,nominal} ((5.5), TBDY) = 0.032$

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 $f_{sv} = (f_{s,jacket} \cdot A_{s,mid,jacket} + f_{s,mid} \cdot A_{s,mid,core})/A_{s,mid} = 694.45$

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

$1 = A_{s,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.0451341$

$2 = A_{s,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.08764993$

$v = A_{s,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.07967042$

and confined core properties:

$b = 690.00$

$d = 677.00$

$d' = 13.00$

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

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

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

$1 = A_{s,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.05123276$

$2 = A_{s,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.09949345$

$v = A_{s,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.09043572$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

---->

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

---->

$su (4.9) = 0.09885678$

$Mu = MRc (4.14) = 1.1540E+009$

$u = su (4.1) = 5.0226943E-005$

Calculation of ratio l_b/l_d

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

Calculation of Mu_2 -

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

$$u = 6.4288704E-005$$

$$\mu = 1.7288E+009$$

with full section properties:

$$b = 400.00$$

$$d = 707.00$$

$$d' = 43.00$$

$$v = 0.00174378$$

$$N = 16273.607$$

$$f_c = 33.00$$

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

$$\text{Final value of } \phi_u: \phi_u = \text{shear_factor} * \text{Max}(\phi_{cu}, \phi_{cc}) = 0.01291652$$

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

$$\text{From (5.4b), TBDY: } \phi_{cu} = 0.01291652$$

$$\phi_{we} ((5.4c), TBDY) = \alpha_{se} * \text{sh}_{, \text{min}} * f_{ywe} / f_{ce} + \text{Min}(\phi_{fx}, \phi_{fy}) = 0.05541928$$

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

$$\phi_{fx} = 0.04286225$$

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

$$\alpha_f = 0.31984848$$

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

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

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

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

$$b_w = 400.00$$

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

$$\phi_{fy} = 0.04286225$$

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

$$\alpha_f = 0.31984848$$

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

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

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

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

$$b_w = 400.00$$

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

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

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

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

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., 10.1061/(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).

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

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.

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).
 $psh,min*Fywe = \text{Min}(psh,x*Fywe, psh,y*Fywe) = 3.0194$

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)

 $psh_x*Fywe = psh1*Fywe1 + ps2*Fywe2 = 3.0194$
 $psh1$ ((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

 $psh_y*Fywe = psh1*Fywe1 + ps2*Fywe2 = 3.0194$
 $psh1$ ((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 = 694.45
fywe2 = 694.45
fce = 33.00

From ((5.A5), TBDY), TBDY: cc = 0.00238888
c = confinement factor = 1.03889

y1 = 0.0025
sh1 = 0.008
ft1 = 833.34
fy1 = 694.45
su1 = 0.032

using (30) in Biskinis/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 = 1.00

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 $fs1 = (fs,jacket*Asl,ten,jacket + fs,core*Asl,ten,core)/Asl,ten = 694.45$

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

y2 = 0.0025
sh2 = 0.008
ft2 = 833.34
fy2 = 694.45
su2 = 0.032

using (30) in Biskinis/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 = 1.00

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

From table 5A.1, TBDY: esu2_nominal = 0.08,

For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered characteristic value $fsy2 = fs2/1.2$, from table 5.1, TBDY.

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

with $fs2 = (fs,jacket*Asl,com,jacket + fs,core*Asl,com,core)/Asl,com = 694.45$

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

yv = 0.0025
shv = 0.008
ftv = 833.34

$f_{yv} = 694.45$
 $s_{uv} = 0.032$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $l_o/l_{ou,min} = l_b/l_d = 1.00$
 $s_{uv} = 0.4 * e_{suv_nominal} ((5.5), TBDY) = 0.032$
 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 $f_{sv} = (f_{s,jacket} * A_{s,mid,jacket} + f_{s,mid} * A_{s,mid,core}) / A_{s,mid} = 694.45$
 with $E_{sv} = (E_{s,jacket} * A_{s,mid,jacket} + E_{s,mid} * A_{s,mid,core}) / A_{s,mid} = 200000.00$
 $1 = A_{s,ten} / (b * d) * (f_{s1} / f_c) = 0.16434361$
 $2 = A_{s,com} / (b * d) * (f_{s2} / f_c) = 0.08462644$
 $v = A_{s,mid} / (b * d) * (f_{sv} / f_c) = 0.14938203$

and confined core properties:

$b = 340.00$
 $d = 677.00$
 $d' = 13.00$
 $f_{cc} (5A.2, TBDY) = 34.2833$
 $cc (5A.5, TBDY) = 0.00238888$
 $c = \text{confinement factor} = 1.03889$
 $1 = A_{s,ten} / (b * d) * (f_{s1} / f_c) = 0.20191317$
 $2 = A_{s,com} / (b * d) * (f_{s2} / f_c) = 0.10397236$
 $v = A_{s,mid} / (b * d) * (f_{sv} / f_c) = 0.18353132$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

---->

$v < v_{s,y2}$ - LHS eq.(4.5) is not satisfied

---->

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

---->

$su (4.8) = 0.29596233$

$\mu = MR_c (4.15) = 1.7288E+009$

$u = su (4.1) = 6.4288704E-005$

 Calculation of ratio l_b/l_d

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

 Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 1.0898E+006$

 Calculation of Shear Strength at edge 1, $V_{r1} = 1.0898E+006$

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

$V_{Co10} = 1.0898E+006$

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

$M/Vd = 4.00$

$\mu_u = 1518.777$

$V_u = 0.0001715$

$d = 0.8 * h = 600.00$

$N_u = 16273.607$

$A_g = 300000.00$

From (11.5.4.8), ACI 318-14: $V_s = V_{s,jacket} + V_{s,core} = 901155.609$

where:

$$V_{s,jacket} = V_{s,j1} + V_{s,j2} = 802857.879$$

$V_{s,j1} = 279254.914$ is calculated for section web jacket, with:

$$d = 320.00$$

$$A_v = 157079.633$$

$$f_y = 555.56$$

$$s = 100.00$$

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

$$s/d = 0.3125$$

$V_{s,j2} = 523602.964$ is calculated for section flange jacket, with:

$$d = 600.00$$

$$A_v = 157079.633$$

$$f_y = 555.56$$

$$s = 100.00$$

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

$$s/d = 0.16666667$$

$$V_{s,core} = V_{s,c1} + V_{s,c2} = 98297.73$$

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

$$d = 160.00$$

$$A_v = 100530.965$$

$$f_y = 555.56$$

$$s = 250.00$$

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

$$s/d = 1.5625$$

$V_{s,c2} = 98297.73$ is calculated for section flange core, with:

$$d = 440.00$$

$$A_v = 100530.965$$

$$f_y = 555.56$$

$$s = 250.00$$

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

$$s/d = 0.56818182$$

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

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

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

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

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

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

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

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

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

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

$$E_f = 64828.00$$

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

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

From (11-11), ACI 440: $V_s + V_f \leq 915872.391$

$$bw = 400.00$$

Calculation of Shear Strength at edge 2, $V_{r2} = 1.0898E+006$

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

$$V_{Col0} = 1.0898E+006$$

$knl = 1$ (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: $f_c' = (f_c'_{jacket} * Area_{jacket} + f_c'_{core} * Area_{core}) / Area_{section} = 33.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$$M/Vd = 4.00$$

$$\mu_u = 1518.777$$

$$V_u = 0.0001715$$

$$d = 0.8 * h = 600.00$$

$$N_u = 16273.607$$

$$A_g = 300000.00$$

From (11.5.4.8), ACI 318-14: $V_s = V_{s,jacket} + V_{s,core} = 901155.609$

where:

$$V_{s,jacket} = V_{s,j1} + V_{s,j2} = 802857.879$$

$V_{s,j1} = 279254.914$ is calculated for section web jacket, with:

$$d = 320.00$$

$$A_v = 157079.633$$

$$f_y = 555.56$$

$$s = 100.00$$

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

$$s/d = 0.3125$$

$V_{s,j2} = 523602.964$ is calculated for section flange jacket, with:

$$d = 600.00$$

$$A_v = 157079.633$$

$$f_y = 555.56$$

$$s = 100.00$$

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

$$s/d = 0.16666667$$

$$V_{s,core} = V_{s,c1} + V_{s,c2} = 98297.73$$

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

$$d = 160.00$$

$$A_v = 100530.965$$

$$f_y = 555.56$$

$$s = 250.00$$

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

$$s/d = 1.5625$$

$V_{s,c2} = 98297.73$ is calculated for section flange core, with:

$$d = 440.00$$

$$A_v = 100530.965$$

$$f_y = 555.56$$

$$s = 250.00$$

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

$$s/d = 0.56818182$$

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

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

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

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

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

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

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

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

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

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

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

$$E_f = 64828.00$$

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

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

$$\text{From (11-11), ACI 440: } V_s + V_f \leq 915872.391$$

$$b_w = 400.00$$

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: rcjlc

Constant Properties

Knowledge Factor, $\gamma = 0.90$

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

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

Consequently:

Jacket

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

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

Concrete Elasticity, $E_c = 26999.444$

Steel Elasticity, $E_s = 200000.00$

Existing Column

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

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

Concrete Elasticity, $E_c = 26999.444$

Steel Elasticity, $E_s = 200000.00$

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

Adequate Lap Length ($l_b/d > 1$)

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $e_{fu} = 0.01$

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

Fiber orientations, $b_i = 0.00^\circ$

Number of layers, $N_L = 1$

Radius of rounding corners, $R = 40.00$

Stepwise Properties

Bending Moment, $M = -1.8810E+007$

Shear Force, $V_2 = -6058.142$

Shear Force, $V_3 = 163.9376$

Axial Force, $F = -18615.215$

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: $A_{sl,mid} = 2007.478$

Longitudinal External Reinforcement Area Distribution (in 3 divisions)

-Tension: $A_{sl,ten,jacket} = 829.3805$

-Compression: $A_{sl,com,jacket} = 1746.726$

-Middle: $A_{sl,mid,jacket} = 1545.664$

Longitudinal Internal Reinforcement Area Distribution (in 3 divisions)

-Tension: $A_{sl,ten,core} = 307.8761$

-Compression: $A_{sl,com,core} = 461.8141$

-Middle: $A_{sl,mid,core} = 461.8141$

Mean Diameter of Tension Reinforcement, $DbL = 16.80$

New component: From table 7-7, ASCE 41_17: Final chord rotation Capacity $u_{,R} = 1.0^*$ $u = 0.00704783$

$u = y + p = 0.00704783$

- Calculation of y -

$y = (M_y * L_s / 3) / E_{eff} = 0.00440634$ ((4.29), Biskinis Phd)
 $M_y = 6.5012E+008$
 $L_s = M/V$ (with $L_s > 0.1 * L$ and $L_s < 2 * L$) = 3104.908
 From table 10.5, ASCE 41_17: $E_{eff} = factor * E_c * I_g = 1.5270E+014$
 $factor = 0.30$
 $A_g = 440000.00$
 Mean concrete strength: $f_c' = (f_c'_{jacket} * Area_{jacket} + f_c'_{core} * Area_{core}) / Area_{section} = 33.00$
 $N = 18615.215$
 $E_c * I_g = E_c_{jacket} * I_{g,jacket} + E_c_{core} * I_{g,core} = 5.0901E+014$

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, $t = 400.00$

$y = \text{Min}(y_{ten}, y_{com})$
 $y_{ten} = 4.8677145E-006$
 with $f_y = 555.56$
 $d = 707.00$
 $y = 0.19284589$
 $A = 0.01015895$
 $B = 0.00446935$
 with $p_t = 0.00671904$
 $p_c = 0.00416509$
 $p_v = 0.00378591$
 $N = 18615.215$
 $b = 750.00$
 $" = 0.06082037$
 $y_{comp} = 1.6459533E-005$
 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), $\epsilon_{fe} = 0.004$
 $f_u = 0.01$
 $E_f = 64828.00$
 $E_c = 26999.444$
 $y = 0.19184981$
 $A = 0.01001713$
 $B = 0.00440616$
 with $E_s = 200000.00$
 CONFIRMATION: $y = 0.19284589 < t/d$

Calculation of ratio l_b/d

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

- Calculation of p -

From table 10-8: $p = 0.00264149$

with:

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

shear control ratio $V_{yE}/V_{CoI0E} = 1.05752$

$d = d_{\text{external}} = 707.00$

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

$t = s_1 + s_2 + 2 \cdot t_f / b_w \cdot (f_{fe} / f_s) = 0.00671904$

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

$s_1 = 100.00$

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.

$N_{UD} = 18615.215$

$A_g = 440000.00$

$f_{cE} = (f_{c_jacket} \cdot \text{Area_jacket} + f_{c_core} \cdot \text{Area_core}) / \text{section_area} = 33.00$

$f_{yE} = (f_{y_ext_Long_Reinf} \cdot \text{Area_ext_Long_Reinf} + f_{y_int_Long_Reinf} \cdot \text{Area_int_Long_Reinf}) / \text{Area_Tot_Long_Rein} = 555.56$

$f_{yE} = (f_{y_ext_Trans_Reinf} \cdot s_1 + f_{y_int_Trans_Reinf} \cdot s_2) / (s_1 + s_2) = 555.56$

$\rho_l = \text{Area_Tot_Long_Rein} / (b \cdot d) = 0.01009575$

$b = 750.00$

$d = 707.00$

$f_{cE} = 33.00$

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

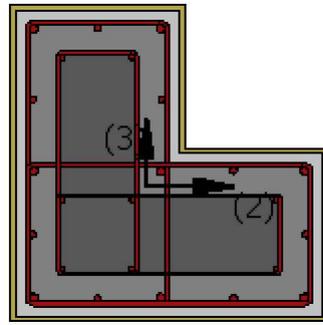
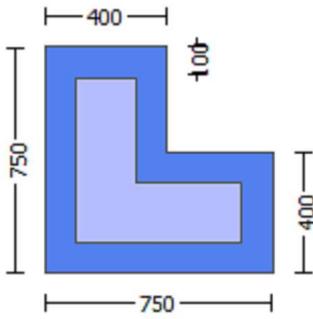
Limit State: Immediate Occupancy (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Shear capacity V_{Rd}

Edge: End

Local Axis: (2)



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

At local axis: 2

Integration Section: (b)

Section Type: rcjlcs

Constant Properties

Knowledge Factor, $\gamma = 0.90$

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

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

Consequently:

Jacket

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

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

Concrete Elasticity, $E_c = 26999.444$

Steel Elasticity, $E_s = 200000.00$

Existing Column

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

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

Concrete Elasticity, $E_c = 26999.444$

Steel Elasticity, $E_s = 200000.00$

#####

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

Jacket

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

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

Existing Column

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

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

#####

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

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

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $e_{fu} = 0.01$

Number of directions, NoDir = 1
Fiber orientations, bi: 0.00°
Number of layers, NL = 1
Radius of rounding corners, R = 40.00

Stepwise Properties

EDGE -A-
Bending Moment, Ma = -1.8810E+007
Shear Force, Va = -6058.142
EDGE -B-
Bending Moment, Mb = 629358.106
Shear Force, Vb = 6058.142
BOTH EDGES
Axial Force, F = -18615.215
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

New component: From table 7-7, ASCE 41_17: Final Shear Capacity VR = 1.0*Vn = 1.1009E+006
Vn ((10.3), ASCE 41-17) = knl*VColO = 1.1009E+006
VCol = 1.1009E+006
knl = 1.00
displacement_ductility_demand = 0.04639374

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

= 1 (normal-weight concrete)
Mean concrete strength: fc' = (fc'_jacket*Area_jacket + fc'_core*Area_core)/Area_section = 25.00, but fc'^0.5 <= 8.3
MPa (22.5.3.1, ACI 318-14)
M/Vd = 2.00
Mu = 629358.106
Vu = 6058.142
d = 0.8*h = 600.00
Nu = 18615.215
Ag = 300000.00
From (11.5.4.8), ACI 318-14: Vs = Vs,jacket + Vs,core = 811033.559
where:
Vs,jacket = Vs,j1 + Vs,j2 = 722566.31
Vs,j1 = 251327.412 is calculated for section web jacket, with:
d = 320.00
Av = 157079.633
fy = 500.00
s = 100.00
Vs,j1 is multiplied by Col,j1 = 1.00
s/d = 0.3125
Vs,j2 = 471238.898 is calculated for section flange jacket, with:
d = 600.00
Av = 157079.633
fy = 500.00
s = 100.00
Vs,j2 is multiplied by Col,j2 = 1.00
s/d = 0.16666667
Vs,core = Vs,c1 + Vs,c2 = 88467.249
Vs,c1 = 0.00 is calculated for section web core, with:
d = 160.00
Av = 100530.965

$f_y = 500.00$
 $s = 250.00$
 $V_{s,c1}$ is multiplied by $Col,c1 = 0.00$
 $s/d = 1.5625$
 $V_{s,c2} = 88467.249$ is calculated for section flange core, with:
 $d = 440.00$
 $A_v = 100530.965$
 $f_y = 500.00$
 $s = 250.00$

$V_{s,c2}$ 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
 $wf/sf = 1$ (FRP strips adjacent to one another).

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

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

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

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

total thickness per orientation, $tf1 = NL * t / \text{NoDir} = 1.016$

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

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

$E_f = 64828.00$

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

with $f_u = 0.01$

From (11-11), ACI 440: $V_s + V_f \leq 797164.595$

$bw = 400.00$

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 $\theta = 1.9751951E-005$

$y = (M_y * L_s / 3) / E_{eff} = 0.00042575$ ((4.29), Biskinis Phd)

$M_y = 6.5012E+008$

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

From table 10.5, ASCE 41_17: $E_{eff} = \text{factor} * E_c * I_g = 1.5270E+014$

factor = 0.30

$A_g = 440000.00$

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

$N = 18615.215$

$E_c * I_g = E_{c,jacket} * I_{g,jacket} + E_{c,core} * I_{g,core} = 5.0901E+014$

Calculation of Yielding Moment M_y

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

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

flange width, $b = 750.00$

web width, $bw = 400.00$

flange thickness, $t = 400.00$

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

$y_{ten} = 4.8677145E-006$

with $f_y = 555.56$

$d = 707.00$

$y = 0.19284589$

$A = 0.01015895$

$B = 0.00446935$

with $pt = 0.00214476$

$pc = 0.00416509$

pv = 0.00378591
N = 18615.215
b = 750.00
" = 0.06082037
y_comp = 1.6459533E-005
with fc* (12.3, (ACI 440)) = 33.48734
fc = 33.00
fl = 0.49678681
b = bmax = 750.00
h = hmax = 750.00
Ag = 0.44
g = pt + pc + pv = 0.01009575
rc = 40.00
Ae/Ac = 0.31291181
Effective FRP thickness, tf = NL*t*Cos(b1) = 1.016
effective strain from (12.5) and (12.12), efe = 0.004
fu = 0.01
Ef = 64828.00
Ec = 26999.444
y = 0.19184981
A = 0.01001713
B = 0.00440616
with Es = 200000.00
CONFIRMATION: y = 0.19284589 < t/d

Calculation of ratio lb/d

Adequate Lap Length: lb/d >= 1

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

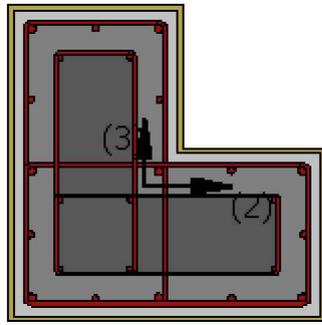
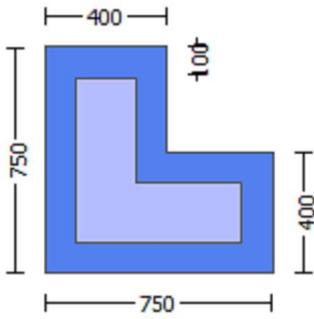
Limit State: Immediate Occupancy (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity (u)

Edge: End

Local Axis: (2)



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

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

Constant Properties

Knowledge Factor, $\gamma = 0.90$

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

Consequently:

Jacket

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

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

Concrete Elasticity, $E_c = 26999.444$

Steel Elasticity, $E_s = 200000.00$

Existing Column

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

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

Concrete Elasticity, $E_c = 26999.444$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

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

Jacket

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

Existing Column

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

#####

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

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

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $\epsilon_{fu} = 0.01$

Number of directions, $NoDir = 1$

Fiber orientations, $b_i = 0.00^\circ$

Number of layers, $NL = 1$

Radius of rounding corners, $R = 40.00$

Stepwise Properties

At local axis: 3

EDGE -A-

Shear Force, $V_a = -0.00017144$

EDGE -B-

Shear Force, $V_b = 0.00017144$

BOTH EDGES

Axial Force, $F = -16273.607$

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: $As_{mid} = 2007.478$

Calculation of Shear Capacity ratio, $V_e/V_r = 1.05752$

Member Controlled by Shear ($V_e/V_r > 1$)

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 1.1525E+006$

with

$M_{pr1} = \text{Max}(Mu_{1+}, Mu_{1-}) = 1.7288E+009$

$Mu_{1+} = 1.1540E+009$, 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

$Mu_{1-} = 1.7288E+009$, 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

$M_{pr2} = \text{Max}(Mu_{2+}, Mu_{2-}) = 1.7288E+009$

$Mu_{2+} = 1.1540E+009$, 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

$Mu_{2-} = 1.7288E+009$, 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:

$\phi_u = 5.0226943E-005$

$M_u = 1.1540E+009$

with full section properties:

$b = 750.00$

$d = 707.00$

$d' = 43.00$

$v = 0.00093001$

$N = 16273.607$

$f_c = 33.00$

ω (5A.5, TBDY) = 0.002

Final value of ϕ_u : $\phi_u^* = \text{shear_factor} * \text{Max}(\phi_u, \phi_c) = 0.01291652$

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

From (5.4b), TBDY: $\phi_u = 0.01291652$

ω_e ((5.4c), TBDY) = $\omega_e * \text{sh}_{\min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.05541928$

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

$f_x = 0.04286225$

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

$a_f = 0.31984848$

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), $pf = 2tf/bw = 0.00508$
 $bw = 400.00$
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, $tf = NL*tf*Cos(b1) = 1.016$
 $f_{u,f} = 1055.00$
 $E_f = 64828.00$
 $u_{,f} = 0.015$

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).

$psh_{,min} * F_{ywe} = \text{Min}(psh_x * F_{ywe}, psh_y * F_{ywe}) = 3.0194$

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)

$psh_x * F_{ywe} = psh1 * F_{ywe1} + ps2 * F_{ywe2} = 3.0194$
 $psh1$ ((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

$psh_y * F_{ywe} = psh1 * F_{ywe1} + ps2 * F_{ywe2} = 3.0194$
 $psh1$ ((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

$A_{sec} = 440000.00$
 $s1 = 100.00$
 $s2 = 250.00$

fywe1 = 694.45
fywe2 = 694.45
fce = 33.00

From ((5.A.5), TBDY), TBDY: cc = 0.00238888
c = confinement factor = 1.03889

y1 = 0.0025
sh1 = 0.008
ft1 = 833.34
fy1 = 694.45
su1 = 0.032

using (30) in Biskinis/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 = 1.00

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 = 694.45

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

y2 = 0.0025
sh2 = 0.008
ft2 = 833.34
fy2 = 694.45
su2 = 0.032

using (30) in Biskinis/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 = 1.00

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 = 694.45

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

yv = 0.0025
shv = 0.008
ftv = 833.34
fyv = 694.45
suv = 0.032

using (30) in Biskinis/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 = 1.00

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 = 694.45

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

1 = Asl,ten/(b*d)*(fs1/fc) = 0.0451341

2 = Asl,com/(b*d)*(fs2/fc) = 0.08764993

v = Asl,mid/(b*d)*(fsv/fc) = 0.07967042

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) = 0.05123276

2 = Asl,com/(b*d)*(fs2/fc) = 0.09949345

v = Asl,mid/(b*d)*(fsv/fc) = 0.09043572

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

--->
v < vs,y2 - LHS eq.(4.5) is satisfied
--->
su (4.9) = 0.09885678
Mu = MRc (4.14) = 1.1540E+009
u = su (4.1) = 5.0226943E-005

Calculation of ratio lb/d

Adequate Lap Length: lb/d >= 1

Calculation of Mu1-

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:
u = 6.4288704E-005
Mu = 1.7288E+009

with full section properties:

b = 400.00
d = 707.00
d' = 43.00
v = 0.00174378
N = 16273.607
fc = 33.00
co (5A.5, TBDY) = 0.002
Final value of cu: cu* = shear_factor * Max(cu, cc) = 0.01291652
The Shear_factor is considered equal to 1 (pure moment strength)
From (5.4b), TBDY: cu = 0.01291652
we ((5.4c), TBDY) = ase* sh,min*fywe/fce+Min(fx, fy) = 0.05541928
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 = 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.

$A_{conf,max1} = 353600.00$ 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).
 $psh_{min} * F_{ywe} = \text{Min}(psh_x * F_{ywe}, psh_y * F_{ywe}) = 3.0194$

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)

 $psh_x * F_{ywe} = psh1 * F_{ywe1} + ps2 * F_{ywe2} = 3.0194$

$psh1$ ((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

 $psh_y * F_{ywe} = psh1 * F_{ywe1} + ps2 * F_{ywe2} = 3.0194$

$psh1$ ((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

 $A_{sec} = 440000.00$

$s1 = 100.00$

$s2 = 250.00$

$f_{ywe1} = 694.45$

$f_{ywe2} = 694.45$

$f_{ce} = 33.00$

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

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

$y1 = 0.0025$

$sh1 = 0.008$

$ft1 = 833.34$

$fy1 = 694.45$

$su1 = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with $shear_factor$ and also multiplied by the $shear_factor$ according to 15.7.1.4, with $Shear_factor = 1.00$

$lo/lo_{u,min} = l_b/l_d = 1.00$

$su1 = 0.4 * esu1_nominal$ ((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 $fs1 = (f_{s,jacket} * A_{s1,ten,jacket} + f_{s,core} * A_{s1,ten,core}) / A_{s1,ten} = 694.45$

with $Es1 = (E_{s,jacket} * A_{s1,ten,jacket} + E_{s,core} * A_{s1,ten,core}) / A_{s1,ten} = 200000.00$

$y2 = 0.0025$

$sh2 = 0.008$

$$ft2 = 833.34$$

$$fy2 = 694.45$$

$$su2 = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$lo/lo_{u,min} = lb/lb_{u,min} = 1.00$$

$$su2 = 0.4 * esu2_{nominal} ((5.5), TBDY) = 0.032$$

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.

$$\text{with } fs2 = (fs_{jacket} * A_{sl,com,jacket} + fs_{core} * A_{sl,com,core}) / A_{sl,com} = 694.45$$

$$\text{with } Es2 = (Es_{jacket} * A_{sl,com,jacket} + Es_{core} * A_{sl,com,core}) / A_{sl,com} = 200000.00$$

$$yv = 0.0025$$

$$shv = 0.008$$

$$ftv = 833.34$$

$$fyv = 694.45$$

$$suv = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$lo/lo_{u,min} = lb/ld = 1.00$$

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

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.

$$\text{with } fsv = (fs_{jacket} * A_{sl,mid,jacket} + fs_{mid} * A_{sl,mid,core}) / A_{sl,mid} = 694.45$$

$$\text{with } Esv = (Es_{jacket} * A_{sl,mid,jacket} + Es_{mid} * A_{sl,mid,core}) / A_{sl,mid} = 200000.00$$

$$1 = A_{sl,ten} / (b * d) * (fs1 / fc) = 0.16434361$$

$$2 = A_{sl,com} / (b * d) * (fs2 / fc) = 0.08462644$$

$$v = A_{sl,mid} / (b * d) * (fsv / fc) = 0.14938203$$

and confined core properties:

$$b = 340.00$$

$$d = 677.00$$

$$d' = 13.00$$

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

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

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

$$1 = A_{sl,ten} / (b * d) * (fs1 / fc) = 0.20191317$$

$$2 = A_{sl,com} / (b * d) * (fs2 / fc) = 0.10397236$$

$$v = A_{sl,mid} / (b * d) * (fsv / fc) = 0.18353132$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

---->

$v < vs,y2$ - LHS eq.(4.5) is not satisfied

---->

$v < vs,c$ - RHS eq.(4.5) is satisfied

---->

$$su (4.8) = 0.29596233$$

$$Mu = MRc (4.15) = 1.7288E+009$$

$$u = su (4.1) = 6.4288704E-005$$

Calculation of ratio lb/ld

Adequate Lap Length: $lb/ld \geq 1$

Calculation of $Mu2+$

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

u = 5.0226943E-005
Mu = 1.1540E+009

with full section properties:

b = 750.00
d = 707.00
d' = 43.00
v = 0.00093001
N = 16273.607
fc = 33.00
co (5A.5, TBDY) = 0.002

Final value of cu: $cu^* = \text{shear_factor} * \text{Max}(cu, cc) = 0.01291652$

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

From (5.4b), TBDY: $cu = 0.01291652$

w_e ((5.4c), TBDY) = $ase * sh, \min * fy_{we} / f_{ce} + \text{Min}(f_x, f_y) = 0.05541928$

where $f = af * pf * ff_e / f_{ce}$ 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.

$A_{conf,min1} = 293525.00$ 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).

$$psh_{min} * Fy_{we} = \text{Min}(psh_x * Fy_{we}, psh_y * Fy_{we}) = 3.0194$$

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)

$$psh_x * Fy_{we} = psh1 * Fy_{we1} + ps2 * Fy_{we2} = 3.0194$$

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

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

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

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

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

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

$$psh_y * Fy_{we} = psh1 * Fy_{we1} + ps2 * Fy_{we2} = 3.0194$$

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

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

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

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

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

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

$$Asec = 440000.00$$

$$s1 = 100.00$$

$$s2 = 250.00$$

$$fy_{we1} = 694.45$$

$$fy_{we2} = 694.45$$

$$f_{ce} = 33.00$$

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

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

$$y1 = 0.0025$$

$$sh1 = 0.008$$

$$ft1 = 833.34$$

$$fy1 = 694.45$$

$$su1 = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$$lo/lou_{min} = lb/ld = 1.00$$

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

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

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

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

$$\text{with } fs1 = (fs_{jacket} * Asl_{ten,jacket} + fs_{core} * Asl_{ten,core}) / Asl_{ten} = 694.45$$

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

$$y2 = 0.0025$$

$$sh2 = 0.008$$

$$ft2 = 833.34$$

$$fy2 = 694.45$$

$$su2 = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$$lo/lou_{min} = lb/lb_{min} = 1.00$$

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

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

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

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

$$\text{with } fs2 = (fs_{jacket} * Asl_{com,jacket} + fs_{core} * Asl_{com,core}) / Asl_{com} = 694.45$$

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

$$y_v = 0.0025$$

$$sh_v = 0.008$$

$$ft_v = 833.34$$

$$fy_v = 694.45$$

$$su_v = 0.032$$

using (30) in Biskinis/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 = 1.00

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 = (fsjacket*Asl,mid,jacket + fs,mid*Asl,mid,core)/Asl,mid = 694.45

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

1 = Asl,ten/(b*d)*(fs1/fc) = 0.0451341

2 = Asl,com/(b*d)*(fs2/fc) = 0.08764993

v = Asl,mid/(b*d)*(fsv/fc) = 0.07967042

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) = 0.05123276

2 = Asl,com/(b*d)*(fs2/fc) = 0.09949345

v = Asl,mid/(b*d)*(fsv/fc) = 0.09043572

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

---->

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

---->

su (4.9) = 0.09885678

Mu = MRc (4.14) = 1.1540E+009

u = su (4.1) = 5.0226943E-005

Calculation of ratio lb/d

Adequate Lap Length: lb/d >= 1

Calculation of Mu2-

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

u = 6.4288704E-005

Mu = 1.7288E+009

with full section properties:

b = 400.00

d = 707.00

d' = 43.00

v = 0.00174378

N = 16273.607

fc = 33.00

co (5A.5, TBDY) = 0.002

Final value of cu: cu* = shear_factor * Max(cu, cc) = 0.01291652

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

From (5.4b), TBDY: cu = 0.01291652

we ((5.4c), TBDY) = ase* sh,min*fywe/fce+Min(fx, fy) = 0.05541928

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 $af = 1 - (\text{Unconfined area})/(\text{total area})$
 $af = 0.31984848$
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, $tf = NL \cdot t \cdot \cos(b1) = 1.016$
 $fu,f = 1055.00$
 $Ef = 64828.00$
 $u,f = 0.015$

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

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

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).

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

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).

$psh_{min} \cdot F_{ywe} = \text{Min}(psh_x \cdot F_{ywe}, psh_y \cdot F_{ywe}) = 3.0194$

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)

$psh_x \cdot F_{ywe} = psh1 \cdot F_{ywe1} + ps2 \cdot F_{ywe2} = 3.0194$
 $psh1$ ((5.4d), TBDY) = $L_{stir1} \cdot A_{stir1}/(A_{sec} \cdot s1) = 0.00367709$
 L_{stir1} (Length of stirrups along Y) = 2060.00
 A_{stir1} (stirrups area) = 78.53982
 $psh2$ (5.4d) = $L_{stir2} \cdot A_{stir2}/(A_{sec} \cdot s2) = 0.00067082$
 L_{stir2} (Length of stirrups along Y) = 1468.00
 A_{stir2} (stirrups area) = 50.26548

$psh_y \cdot F_{ywe} = psh1 \cdot F_{ywe1} + ps2 \cdot F_{ywe2} = 3.0194$
 $psh1$ ((5.4d), TBDY) = $L_{stir1} \cdot A_{stir1}/(A_{sec} \cdot s1) = 0.00367709$
 L_{stir1} (Length of stirrups along X) = 2060.00
 A_{stir1} (stirrups area) = 78.53982
 $psh2$ ((5.4d), TBDY) = $L_{stir2} \cdot A_{stir2}/(A_{sec} \cdot s2) = 0.00067082$
 L_{stir2} (Length of stirrups along X) = 1468.00
 A_{stir2} (stirrups area) = 50.26548

$A_{sec} = 440000.00$
 $s1 = 100.00$
 $s2 = 250.00$

fywe1 = 694.45
fywe2 = 694.45
fce = 33.00

From ((5.A.5), TBDY), TBDY: cc = 0.00238888
c = confinement factor = 1.03889

y1 = 0.0025
sh1 = 0.008
ft1 = 833.34
fy1 = 694.45
su1 = 0.032

using (30) in Biskinis/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 = 1.00

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 = 694.45

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

y2 = 0.0025
sh2 = 0.008
ft2 = 833.34
fy2 = 694.45
su2 = 0.032

using (30) in Biskinis/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 = 1.00

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 = 694.45

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

yv = 0.0025
shv = 0.008
ftv = 833.34
fyv = 694.45
suv = 0.032

using (30) in Biskinis/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 = 1.00

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 = 694.45

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

1 = Asl,ten/(b*d)*(fs1/fc) = 0.16434361

2 = Asl,com/(b*d)*(fs2/fc) = 0.08462644

v = Asl,mid/(b*d)*(fsv/fc) = 0.14938203

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) = 0.20191317

2 = Asl,com/(b*d)*(fs2/fc) = 0.10397236

v = Asl,mid/(b*d)*(fsv/fc) = 0.18353132

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

--->
 $v < v_{s,y2}$ - LHS eq.(4.5) is not satisfied
--->
 $v < v_{s,c}$ - RHS eq.(4.5) is satisfied
--->

s_u (4.8) = 0.29596233
 $M_u = MR_c$ (4.15) = 1.7288E+009
 $u = s_u$ (4.1) = 6.4288704E-005

Calculation of ratio l_b/d

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

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 1.0898E+006$

Calculation of Shear Strength at edge 1, $V_{r1} = 1.0898E+006$
 $V_{r1} = V_{Col}$ ((10.3), ASCE 41-17) = $k_{nl} * V_{Col0}$
 $V_{Col0} = 1.0898E+006$
 $k_{nl} = 1$ (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: $f_c' = (f_c'_{jacket} * Area_{jacket} + f_c'_{core} * Area_{core}) / Area_{section} = 33.00$, but $f_c'^{0.5} \leq 8.3$
MPa (22.5.3.1, ACI 318-14)

$M/d = 4.00$
 $M_u = 1518.01$
 $V_u = 0.00017144$
 $d = 0.8 * h = 600.00$
 $N_u = 16273.607$
 $A_g = 300000.00$
From (11.5.4.8), ACI 318-14: $V_s = V_{s,jacket} + V_{s,core} = 901155.609$

where:
 $V_{s,jacket} = V_{s,j1} + V_{s,j2} = 802857.879$
 $V_{s,j1} = 523602.964$ is calculated for section web jacket, with:
 $d = 600.00$
 $A_v = 157079.633$
 $f_y = 555.56$
 $s = 100.00$

$V_{s,j1}$ is multiplied by $Col,j1 = 1.00$
 $s/d = 0.16666667$
 $V_{s,j2} = 279254.914$ is calculated for section flange jacket, with:
 $d = 320.00$
 $A_v = 157079.633$
 $f_y = 555.56$
 $s = 100.00$

$V_{s,j2}$ is multiplied by $Col,j2 = 1.00$
 $s/d = 0.3125$
 $V_{s,core} = V_{s,c1} + V_{s,c2} = 98297.73$
 $V_{s,c1} = 98297.73$ is calculated for section web core, with:
 $d = 440.00$
 $A_v = 100530.965$
 $f_y = 555.56$
 $s = 250.00$

$V_{s,c1}$ is multiplied by $Col,c1 = 1.00$
 $s/d = 0.56818182$
 $V_{s,c2} = 0.00$ is calculated for section flange core, with:
 $d = 160.00$
 $A_v = 100530.965$
 $f_y = 555.56$

$s = 250.00$
 $V_{s,c2}$ 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
 $wf/sf = 1$ (FRP strips adjacent to one another).
 \ln (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: $\alpha_1 = \alpha_1 + 90^\circ = 90.00$
 $V_f = \text{Min}(|V_f(45, \alpha_1)|, |V_f(-45, \alpha_1)|)$, with:
 total thickness per orientation, $t_{f1} = NL \cdot t / \text{NoDir} = 1.016$
 $d_{fv} = d$ (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: $V_s + V_f \leq 915872.391$
 $bw = 400.00$

 Calculation of Shear Strength at edge 2, $V_{r2} = 1.0898E+006$
 $V_{r2} = V_{Col}$ ((10.3), ASCE 41-17) = $k_{nl} \cdot V_{Col0}$
 $V_{Col0} = 1.0898E+006$
 $k_{nl} = 1$ (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).

 $\alpha = 1$ (normal-weight concrete)
 Mean concrete strength: $f'_c = (f'_{c,jacket} \cdot Area_{jacket} + f'_{c,core} \cdot Area_{core}) / Area_{section} = 33.00$, but $f'_c^{0.5} \leq 8.3$
 MPa (22.5.3.1, ACI 318-14)
 $M/Vd = 4.00$
 $M_u = 1518.01$
 $V_u = 0.00017144$
 $d = 0.8 \cdot h = 600.00$
 $N_u = 16273.607$
 $A_g = 300000.00$
 From (11.5.4.8), ACI 318-14: $V_s = V_{s,jacket} + V_{s,core} = 901155.609$
 where:
 $V_{s,jacket} = V_{s,j1} + V_{s,j2} = 802857.879$
 $V_{s,j1} = 523602.964$ is calculated for section web jacket, with:
 $d = 600.00$
 $A_v = 157079.633$
 $f_y = 555.56$
 $s = 100.00$
 $V_{s,j1}$ is multiplied by $Col,j1 = 1.00$
 $s/d = 0.16666667$
 $V_{s,j2} = 279254.914$ is calculated for section flange jacket, with:
 $d = 320.00$
 $A_v = 157079.633$
 $f_y = 555.56$
 $s = 100.00$
 $V_{s,j2}$ is multiplied by $Col,j2 = 1.00$
 $s/d = 0.3125$
 $V_{s,core} = V_{s,c1} + V_{s,c2} = 98297.73$
 $V_{s,c1} = 98297.73$ is calculated for section web core, with:
 $d = 440.00$
 $A_v = 100530.965$
 $f_y = 555.56$
 $s = 250.00$
 $V_{s,c1}$ is multiplied by $Col,c1 = 1.00$
 $s/d = 0.56818182$
 $V_{s,c2} = 0.00$ is calculated for section flange core, with:
 $d = 160.00$
 $A_v = 100530.965$

$f_y = 555.56$

$s = 250.00$

$V_{s,c2}$ 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

$wf/sf = 1$ (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 $V_f(\theta, a)$, is implemented for every different fiber orientation a_i , as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.

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

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

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

$d_{fv} = d$ (figure 11.2, ACI 440) = 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: $V_s + V_f \leq 915872.391$

$bw = 400.00$

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, $\gamma = 0.90$

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

Consequently:

Jacket

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

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

Concrete Elasticity, $E_c = 26999.444$

Steel Elasticity, $E_s = 200000.00$

Existing Column

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

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

Concrete Elasticity, $E_c = 26999.444$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

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

Jacket

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

Existing Column

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

#####

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
Adequate Lap Length ($l_o/l_{ou}, \min \geq 1$)
FRP Wrapping Data
Type: Carbon
Cured laminate properties (design values)
Thickness, $t = 1.016$
Tensile Strength, $f_{fu} = 1055.00$
Tensile Modulus, $E_f = 64828.00$
Elongation, $e_{fu} = 0.01$
Number of directions, $NoDir = 1$
Fiber orientations, $bi = 0.00^\circ$
Number of layers, $NL = 1$
Radius of rounding corners, $R = 40.00$

Stepwise Properties

At local axis: 2
EDGE -A-
Shear Force, $V_a = -0.0001715$
EDGE -B-
Shear Force, $V_b = 0.0001715$
BOTH EDGES
Axial Force, $F = -16273.607$
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: $As_{c,mid} = 2007.478$

Calculation of Shear Capacity ratio, $V_e/V_r = 1.05752$
Member Controlled by Shear ($V_e/V_r > 1$)
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 1.1525E+006$
with
 $M_{pr1} = \text{Max}(Mu_{1+}, Mu_{1-}) = 1.7288E+009$
 $Mu_{1+} = 1.1540E+009$, 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
 $Mu_{1-} = 1.7288E+009$, 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
 $M_{pr2} = \text{Max}(Mu_{2+}, Mu_{2-}) = 1.7288E+009$
 $Mu_{2+} = 1.1540E+009$, 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
 $Mu_{2-} = 1.7288E+009$, 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:
 $\phi_u = 5.0226943E-005$
 $M_u = 1.1540E+009$

with full section properties:

$b = 750.00$
 $d = 707.00$
 $d' = 43.00$
 $v = 0.00093001$
 $N = 16273.607$

$$f_c = 33.00$$

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

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.01291652$$

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

$$\text{From (5.4b), TBDY: } c_u = 0.01291652$$

$$\text{we ((5.4c), TBDY) } = a_{se} * s_{h,\min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.05541928$$

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 $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.31984848$$

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

$$b_{\max} = 750.00$$

$$h_{\max} = 750.00$$

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

$$b_w = 400.00$$

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

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

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

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

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.

$A_{\text{conf,min2}} = 54741.00$ 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).

$$p_{sh,\min} * F_{ywe} = \text{Min}(p_{sh,x} * F_{ywe}, p_{sh,y} * F_{ywe}) = 3.0194$$

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)

$$p_{sh,x} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{sh2} * F_{ywe2} = 3.0194$$

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

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

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

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

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

psh_y*Fywe = psh₁*Fywe₁+ps₂*Fywe₂ = 3.0194
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 = 694.45
fywe₂ = 694.45
fce = 33.00

From ((5.A5), TBDY), TBDY: cc = 0.00238888
c = confinement factor = 1.03889

y₁ = 0.0025
sh₁ = 0.008
ft₁ = 833.34
fy₁ = 694.45
su₁ = 0.032

using (30) in Biskinis/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 = 1.00

su₁ = 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 y₁, sh₁,ft₁,fy₁, it is considered
characteristic value fsy₁ = fs₁/1.2, from table 5.1, TBDY.

y₁, sh₁,ft₁,fy₁, are also multiplied by Min(1,1.25*(lb/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} = 694.45

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

y₂ = 0.0025
sh₂ = 0.008
ft₂ = 833.34
fy₂ = 694.45
su₂ = 0.032

using (30) in Biskinis/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} = 1.00

su₂ = 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 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 Min(1,1.25*(lb/l_d)^{2/3}), from 10.3.5, ASCE 41-17.

with fs₂ = (fs_{jacket}*Asl_{com,jacket} + fs_{core}*Asl_{com,core})/Asl_{com} = 694.45

with Es₂ = (Es_{jacket}*Asl_{com,jacket} + Es_{core}*Asl_{com,core})/Asl_{com} = 200000.00

y_v = 0.0025
sh_v = 0.008
ft_v = 833.34
fy_v = 694.45
su_v = 0.032

using (30) in Biskinis/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 = 1.00

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

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

considering characteristic value fsy_v = 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 fsy_v = fs_v/1.2, from table 5.1, TBDY.

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

with fs_v = (fs_{jacket}*Asl_{mid,jacket} + fs_{mid}*Asl_{mid,core})/Asl_{mid} = 694.45

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

$$1 = A_{sl,ten} / (b \cdot d) \cdot (f_{s1} / f_c) = 0.0451341$$

$$2 = A_{sl,com} / (b \cdot d) \cdot (f_{s2} / f_c) = 0.08764993$$

$$v = A_{sl,mid} / (b \cdot d) \cdot (f_{sv} / f_c) = 0.07967042$$

and confined core properties:

$$b = 690.00$$

$$d = 677.00$$

$$d' = 13.00$$

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

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

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

$$1 = A_{sl,ten} / (b \cdot d) \cdot (f_{s1} / f_c) = 0.05123276$$

$$2 = A_{sl,com} / (b \cdot d) \cdot (f_{s2} / f_c) = 0.09949345$$

$$v = A_{sl,mid} / (b \cdot d) \cdot (f_{sv} / f_c) = 0.09043572$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

$$s_u (4.9) = 0.09885678$$

$$\mu_u = M_{Rc} (4.14) = 1.1540E+009$$

$$u = s_u (4.1) = 5.0226943E-005$$

Calculation of ratio l_b/d

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

Calculation of μ_{u1} -

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

$$u = 6.4288704E-005$$

$$\mu_u = 1.7288E+009$$

with full section properties:

$$b = 400.00$$

$$d = 707.00$$

$$d' = 43.00$$

$$v = 0.00174378$$

$$N = 16273.607$$

$$f_c = 33.00$$

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

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} \cdot \text{Max}(c_u, c_c) = 0.01291652$$

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

$$\text{From (5.4b), TBDY: } c_u = 0.01291652$$

$$w_e ((5.4c), TBDY) = a_{se} \cdot s_{h,min} \cdot f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.05541928$$

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 $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.31984848$$

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

$$b_{max} = 750.00$$

$$h_{max} = 750.00$$

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

$$b_w = 400.00$$

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

$$f_y = 0.04286225$$

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

$$a_f = 0.31984848$$

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

$$b_{max} = 750.00$$

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).

$p_{sh,min} * F_{ywe} = \text{Min}(p_{sh,x} * F_{ywe}, p_{sh,y} * F_{ywe}) = 3.0194$

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)

$p_{sh,x} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{sh2} * F_{ywe2} = 3.0194$

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

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

$p_{sh,y} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{sh2} * F_{ywe2} = 3.0194$

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

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

$A_{sec} = 440000.00$

$s1 = 100.00$

$s2 = 250.00$

$f_{ywe1} = 694.45$

$f_{ywe2} = 694.45$

$f_{ce} = 33.00$

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

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

$y1 = 0.0025$

$sh1 = 0.008$

$ft1 = 833.34$

$fy1 = 694.45$

su1 = 0.032

using (30) in Biskinis/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 = 1.00

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

From table 5A.1, TBDY: esu1_nominal = 0.08,

For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

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

with fs1 = (fs,jacket*Asl,ten,jacket + fs,core*Asl,ten,core)/Asl,ten = 694.45

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

y2 = 0.0025

sh2 = 0.008

ft2 = 833.34

fy2 = 694.45

su2 = 0.032

using (30) in Biskinis/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 = 1.00

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 = 694.45

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

yv = 0.0025

shv = 0.008

ftv = 833.34

fyv = 694.45

suv = 0.032

using (30) in Biskinis/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 = 1.00

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 = 694.45

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

1 = Asl,ten/(b*d)*(fs1/fc) = 0.16434361

2 = Asl,com/(b*d)*(fs2/fc) = 0.08462644

v = Asl,mid/(b*d)*(fsv/fc) = 0.14938203

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) = 0.20191317

2 = Asl,com/(b*d)*(fs2/fc) = 0.10397236

v = Asl,mid/(b*d)*(fsv/fc) = 0.18353132

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

---->

v < vs,y2 - LHS eq.(4.5) is not satisfied

---->

v < vs,c - RHS eq.(4.5) is satisfied

---->

su (4.8) = 0.29596233

Mu = MRc (4.15) = 1.7288E+009

$$u = s_u(4.1) = 6.4288704E-005$$

Calculation of ratio l_b/d

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

Calculation of μ_{2+}

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

$$u = 5.0226943E-005$$

$$\mu = 1.1540E+009$$

with full section properties:

$$b = 750.00$$

$$d = 707.00$$

$$d' = 43.00$$

$$v = 0.00093001$$

$$N = 16273.607$$

$$f_c = 33.00$$

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

$$\text{Final value of } \mu: \mu^* = \text{shear_factor} * \text{Max}(\mu_c, \mu_{cc}) = 0.01291652$$

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

$$\text{From (5.4b), TBDY: } \mu_c = 0.01291652$$

$$\mu_{cc} \text{ ((5.4c), TBDY) } = a_{se} * s_{h,min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.05541928$$

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 $a_f = 1 - (\text{Unconfined area})/(\text{total area})$

$$a_f = 0.31984848$$

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

$$b_{max} = 750.00$$

$$h_{max} = 750.00$$

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

$$b_w = 400.00$$

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

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

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

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

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.

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 = $\text{Min}(psh_x * Fywe, psh_y * Fywe) = 3.0194$

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 = 3.0194

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 = 3.0194

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 = 694.45

fywe2 = 694.45

fce = 33.00

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

c = confinement factor = 1.03889

y1 = 0.0025

sh1 = 0.008

ft1 = 833.34

fy1 = 694.45

su1 = 0.032

using (30) in Biskinis/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 = 1.00

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 = $(f_{s,\text{jacket}} * A_{s1,\text{ten,jacket}} + f_{s,\text{core}} * A_{s1,\text{ten,core}}) / A_{s1,\text{ten}} = 694.45$

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 = 0.0025

sh2 = 0.008

ft2 = 833.34

fy2 = 694.45

su2 = 0.032

using (30) in Biskinis/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 = 1.00

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

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

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

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

$$\text{with } fs_2 = (fs_{jacket} * Asl_{,com,jacket} + fs_{core} * Asl_{,com,core}) / Asl_{,com} = 694.45$$

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

$$y_v = 0.0025$$

$$sh_v = 0.008$$

$$ft_v = 833.34$$

$$fy_v = 694.45$$

$$suv = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$$lo/lo_{u,min} = lb/ld = 1.00$$

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

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

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

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

$$\text{with } fs_v = (fs_{jacket} * Asl_{,mid,jacket} + fs_{mid} * Asl_{,mid,core}) / Asl_{,mid} = 694.45$$

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

$$1 = Asl_{,ten} / (b * d) * (fs_1 / fc) = 0.0451341$$

$$2 = Asl_{,com} / (b * d) * (fs_2 / fc) = 0.08764993$$

$$v = Asl_{,mid} / (b * d) * (fs_v / fc) = 0.07967042$$

and confined core properties:

$$b = 690.00$$

$$d = 677.00$$

$$d' = 13.00$$

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

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

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

$$1 = Asl_{,ten} / (b * d) * (fs_1 / fc) = 0.05123276$$

$$2 = Asl_{,com} / (b * d) * (fs_2 / fc) = 0.09949345$$

$$v = Asl_{,mid} / (b * d) * (fs_v / fc) = 0.09043572$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

$$su (4.9) = 0.09885678$$

$$\mu_u = MRc (4.14) = 1.1540E+009$$

$$u = su (4.1) = 5.0226943E-005$$

Calculation of ratio lb/ld

Adequate Lap Length: $lb/ld \geq 1$

Calculation of μ_u -

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

$$u = 6.4288704E-005$$

$$\mu_u = 1.7288E+009$$

with full section properties:

$$b = 400.00$$

$$d = 707.00$$

$$d' = 43.00$$

$$v = 0.00174378$$

$$N = 16273.607$$

$$f_c = 33.00$$

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

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.01291652$$

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

$$\text{From (5.4b), TBDY: } c_u = 0.01291652$$

$$\text{we ((5.4c), TBDY)} = a_{se} * s_{h,\min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.05541928$$

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 $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.31984848$$

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

$$b_{\max} = 750.00$$

$$h_{\max} = 750.00$$

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

$$b_w = 400.00$$

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

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

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

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

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.

$A_{\text{conf,min2}} = 54741.00$ 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).

$$p_{sh,\min} * F_{ywe} = \text{Min}(p_{sh,x} * F_{ywe}, p_{sh,y} * F_{ywe}) = 3.0194$$

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)

$$p_{sh,x} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{sh2} * F_{ywe2} = 3.0194$$

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

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

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

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

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

psh_y*Fywe = psh₁*Fywe₁+ps₂*Fywe₂ = 3.0194
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 = 694.45
fywe₂ = 694.45
fce = 33.00

From ((5.A5), TBDY), TBDY: cc = 0.00238888
c = confinement factor = 1.03889

y₁ = 0.0025
sh₁ = 0.008
ft₁ = 833.34
fy₁ = 694.45
su₁ = 0.032

using (30) in Biskinis/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 = 1.00

su₁ = 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 y₁, sh₁,ft₁,fy₁, it is considered
characteristic value fsy₁ = fs₁/1.2, from table 5.1, TBDY.

y₁, sh₁,ft₁,fy₁, are also multiplied by Min(1,1.25*(lb/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} = 694.45

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

y₂ = 0.0025
sh₂ = 0.008
ft₂ = 833.34
fy₂ = 694.45
su₂ = 0.032

using (30) in Biskinis/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} = 1.00

su₂ = 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 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 Min(1,1.25*(lb/l_d)^{2/3}), from 10.3.5, ASCE 41-17.

with fs₂ = (fs_{jacket}*Asl_{com,jacket} + fs_{core}*Asl_{com,core})/Asl_{com} = 694.45

with Es₂ = (Es_{jacket}*Asl_{com,jacket} + Es_{core}*Asl_{com,core})/Asl_{com} = 200000.00

y_v = 0.0025
sh_v = 0.008
ft_v = 833.34
fy_v = 694.45
su_v = 0.032

using (30) in Biskinis/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 = 1.00

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

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

considering characteristic value fsy_v = 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 fsy_v = fs_v/1.2, from table 5.1, TBDY.

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

with fs_v = (fs_{jacket}*Asl_{mid,jacket} + fs_{mid}*Asl_{mid,core})/Asl_{mid} = 694.45

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

$$1 = A_{sl,ten} / (b \cdot d) \cdot (f_{s1} / f_c) = 0.16434361$$

$$2 = A_{sl,com} / (b \cdot d) \cdot (f_{s2} / f_c) = 0.08462644$$

$$v = A_{sl,mid} / (b \cdot d) \cdot (f_{sv} / f_c) = 0.14938203$$

and confined core properties:

$$b = 340.00$$

$$d = 677.00$$

$$d' = 13.00$$

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

$$c_c (5A.5, \text{TBDY}) = 0.00238888$$

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

$$1 = A_{sl,ten} / (b \cdot d) \cdot (f_{s1} / f_c) = 0.20191317$$

$$2 = A_{sl,com} / (b \cdot d) \cdot (f_{s2} / f_c) = 0.10397236$$

$$v = A_{sl,mid} / (b \cdot d) \cdot (f_{sv} / f_c) = 0.18353132$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < v_{s,y2}$ - LHS eq.(4.5) is not satisfied

--->

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

--->

$$s_u (4.8) = 0.29596233$$

$$\mu_u = M_{Rc} (4.15) = 1.7288E+009$$

$$u = s_u (4.1) = 6.4288704E-005$$

Calculation of ratio l_b/d

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

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 1.0898E+006$

Calculation of Shear Strength at edge 1, $V_{r1} = 1.0898E+006$

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

$$V_{Co10} = 1.0898E+006$$

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

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

= 1 (normal-weight concrete)

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

$$M/d = 4.00$$

$$\mu_u = 1518.777$$

$$V_u = 0.0001715$$

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

$$N_u = 16273.607$$

$$A_g = 300000.00$$

$$\text{From (11.5.4.8), ACI 318-14: } V_s = V_{s,jacket} + V_{s,core} = 901155.609$$

where:

$$V_{s,jacket} = V_{s,j1} + V_{s,j2} = 802857.879$$

$V_{s,j1} = 279254.914$ is calculated for section web jacket, with:

$$d = 320.00$$

$$A_v = 157079.633$$

$$f_y = 555.56$$

$$s = 100.00$$

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

$$s/d = 0.3125$$

$V_{s,j2} = 523602.964$ is calculated for section flange jacket, with:

$$d = 600.00$$

$$A_v = 157079.633$$

$$f_y = 555.56$$

$$s = 100.00$$

$V_{s,j2}$ is multiplied by $Col,j2 = 1.00$
 $s/d = 0.16666667$

$V_{s,core} = V_{s,c1} + V_{s,c2} = 98297.73$

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

$d = 160.00$

$A_v = 100530.965$

$f_y = 555.56$

$s = 250.00$

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

$s/d = 1.5625$

$V_{s,c2} = 98297.73$ is calculated for section flange core, with:

$d = 440.00$

$A_v = 100530.965$

$f_y = 555.56$

$s = 250.00$

$V_{s,c2}$ 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 a is the angle of the crack direction (see KANEPE).

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

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

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

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

$d_{fv} = d$ (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: $V_s + V_f \leq 915872.391$

$b_w = 400.00$

Calculation of Shear Strength at edge 2, $V_{r2} = 1.0898E+006$

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

$V_{Col0} = 1.0898E+006$

$k_{nl} = 1$ (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: $f'_c = (f'_{c,jacket} * Area_{jacket} + f'_{c,core} * Area_{core}) / Area_{section} = 33.00$, but $f'_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 4.00$

$\mu_u = 1518.777$

$\nu_u = 0.0001715$

$d = 0.8 * h = 600.00$

$N_u = 16273.607$

$A_g = 300000.00$

From (11.5.4.8), ACI 318-14: $V_s = V_{s,jacket} + V_{s,core} = 901155.609$

where:

$V_{s,jacket} = V_{s,j1} + V_{s,j2} = 802857.879$

$V_{s,j1} = 279254.914$ is calculated for section web jacket, with:

$d = 320.00$

$A_v = 157079.633$

$f_y = 555.56$

$s = 100.00$

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

$s/d = 0.3125$

$V_{s,j2} = 523602.964$ is calculated for section flange jacket, with:

$d = 600.00$

$A_v = 157079.633$

$f_y = 555.56$

$s = 100.00$
 $V_{s,j2}$ is multiplied by $Col,j2 = 1.00$
 $s/d = 0.16666667$
 $V_{s,core} = V_{s,c1} + V_{s,c2} = 98297.73$
 $V_{s,c1} = 0.00$ is calculated for section web core, with:
 $d = 160.00$
 $A_v = 100530.965$
 $f_y = 555.56$
 $s = 250.00$
 $V_{s,c1}$ is multiplied by $Col,c1 = 0.00$
 $s/d = 1.5625$
 $V_{s,c2} = 98297.73$ is calculated for section flange core, with:
 $d = 440.00$
 $A_v = 100530.965$
 $f_y = 555.56$
 $s = 250.00$
 $V_{s,c2}$ 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).
 $\ln(11.3) \sin + \cos$ 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, $tf1 = NL * t / NoDir = 1.016$
 $dfv = d$ (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: $V_s + V_f \leq 915872.391$
 $bw = 400.00$

 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, $\gamma = 0.90$
 Chord Rotation is generally considered as Deformation-Controlled Action according to Table C7-1, ASCE 41-17.
 Mean strengths are used for Deformation-Controlled Actions according to 7.5.1.3, ASCE 41-17
 Consequently:
 Jacket
 New material of Secondary Member: Concrete Strength, $f_c = f_{cm} = 33.00$
 New material of Secondary Member: Steel Strength, $f_s = f_{sm} = 555.56$
 Concrete Elasticity, $E_c = 26999.444$
 Steel Elasticity, $E_s = 200000.00$
 Existing Column
 New material of Secondary Member: Concrete Strength, $f_c = f_{cm} = 33.00$
 New material of Secondary Member: Steel Strength, $f_s = f_{sm} = 555.56$
 Concrete Elasticity, $E_c = 26999.444$
 Steel Elasticity, $E_s = 200000.00$
 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
 Adequate Lap Length ($l_b/d >= 1$)
 FRP Wrapping Data
 Type: Carbon
 Cured laminate properties (design values)
 Thickness, $t = 1.016$
 Tensile Strength, $f_{fu} = 1055.00$
 Tensile Modulus, $E_f = 64828.00$
 Elongation, $e_{fu} = 0.01$
 Number of directions, $NoDir = 1$
 Fiber orientations, $bi: 0.00^\circ$
 Number of layers, $NL = 1$
 Radius of rounding corners, $R = 40.00$

 Stepwise Properties

Bending Moment, $M = -90444.323$
 Shear Force, $V_2 = 6058.142$
 Shear Force, $V_3 = -163.9376$
 Axial Force, $F = -18615.215$
 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, $Db_L = 16.80$

 New component: From table 7-7, ASCE 41_17: Final chord rotation Capacity $u_{,R} = 1.0^*$ $u = 0.00342444$
 $u = y + p = 0.00342444$

 - Calculation of y -

$y = (M_y * L_s / 3) / E_{eff} = 0.00078295$ ((4.29), Biskinis Phd))
 $M_y = 6.5012E+008$
 $L_s = M/V$ (with $L_s > 0.1 * L$ and $L_s < 2 * L$) = 551.6996
 From table 10.5, ASCE 41_17: $E_{eff} = factor * E_c * I_g = 1.5270E+014$
 $factor = 0.30$
 $A_g = 440000.00$
 Mean concrete strength: $fc' = (fc'_{jacket} * Area_{jacket} + fc'_{core} * Area_{core}) / Area_{section} = 33.00$
 $N = 18615.215$
 $E_c * I_g = E_c * I_{g,jacket} + E_c * I_{g,core} = 5.0901E+014$

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, $t = 400.00$

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

$$y_{\text{ten}} = 4.8677145\text{E-}006$$

with $f_y = 555.56$

$$d = 707.00$$

$$y = 0.19284589$$

$$A = 0.01015895$$

$$B = 0.00446935$$

$$\text{with } p_t = 0.00671904$$

$$p_c = 0.00416509$$

$$p_v = 0.00378591$$

$$N = 18615.215$$

$$b = 750.00$$

$$\rho = 0.06082037$$

$$y_{\text{comp}} = 1.6459533\text{E-}005$$

with f_c^* (12.3, (ACI 440)) = 33.48734

$$f_c = 33.00$$

$$f_l = 0.49678681$$

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

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

$$A_g = 0.44$$

$$g = p_t + p_c + p_v = 0.01009575$$

$$r_c = 40.00$$

$$A_e/A_c = 0.31291181$$

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

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

$$f_u = 0.01$$

$$E_f = 64828.00$$

$$E_c = 26999.444$$

$$y = 0.19184981$$

$$A = 0.01001713$$

$$B = 0.00440616$$

$$\text{with } E_s = 200000.00$$

CONFIRMATION: $y = 0.19284589 < t/d$

Calculation of ratio l_b/d

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

- Calculation of p -

From table 10-8: $p = 0.00264149$

with:

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

shear control ratio $V_y E / V_{CoI} E = 1.05752$

$$d = d_{\text{external}} = 707.00$$

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

$$t = s_1 + s_2 + 2 \cdot t_f / b_w \cdot (f_{fe} / f_s) = 0.00671904$$

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

$A_{v1} = 78.53982$, 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.

$$N_{UD} = 18615.215$$

$$A_g = 440000.00$$

$$f_{cE} = (f_{c_jacket} \cdot Area_jacket + f_{c_core} \cdot Area_core) / section_area = 33.00$$

$$f_{yE} = (f_{y_ext_Long_Reinf} \cdot Area_ext_Long_Reinf + f_{y_int_Long_Reinf} \cdot Area_int_Long_Reinf) / Area_Tot_Long_Rein = 555.56$$

$$f_{yE} = (f_{y_ext_Trans_Reinf} \cdot s_1 + f_{y_int_Trans_Reinf} \cdot s_2) / (s_1 + s_2) = 555.56$$

$$\rho_l = Area_Tot_Long_Rein / (b \cdot d) = 0.01009575$$

$$b = 750.00$$

$$d = 707.00$$

$$f_{cE} = 33.00$$

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

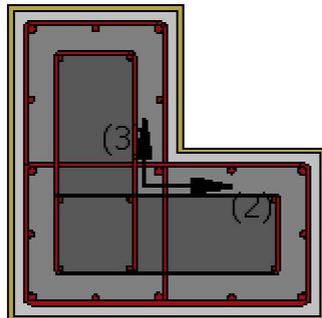
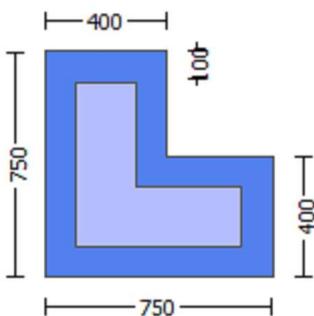
Limit State: Immediate Occupancy (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Shear capacity V_{Rd}

Edge: End

Local Axis: (3)



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

At local axis: 3

Integration Section: (b)

Section Type: rcjlc

Constant Properties

Knowledge Factor, $\gamma = 0.90$
Member Shear Force is generally considered as Force-Controlled Action according to Table C7-1, ASCE 41-17.
Lower-bound strengths are used for Force-Controlled Actions according to 7.5.1.3, ASCE 41-17

Consequently:

Jacket

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

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

Concrete Elasticity, $E_c = 26999.444$

Steel Elasticity, $E_s = 200000.00$

Existing Column

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

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

Concrete Elasticity, $E_c = 26999.444$

Steel Elasticity, $E_s = 200000.00$

#####

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

Jacket

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

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

Existing Column

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

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

#####

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

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

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $\epsilon_{fu} = 0.01$

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, $M_a = -399066.903$

Shear Force, $V_a = 163.9376$

EDGE -B-

Bending Moment, $M_b = -90444.323$

Shear Force, $V_b = -163.9376$

BOTH EDGES

Axial Force, $F = -18615.215$

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: Asl,mid = 2007.478

Mean Diameter of Tension Reinforcement, DbL,ten = 16.80

New component: From table 7-7, ASCE 41_17: Final Shear Capacity VR = 1.0*Vn = 1.1009E+006

Vn ((10.3), ASCE 41-17) = knl*VCol0 = 1.1009E+006

VCol = 1.1009E+006

knl = 1.00

displacement_ductility_demand = 1.0335237E-005

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

= 1 (normal-weight concrete)

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

M/Vd = 2.00

Mu = 90444.323

Vu = 163.9376

d = 0.8*h = 600.00

Nu = 18615.215

Ag = 300000.00

From (11.5.4.8), ACI 318-14: Vs = Vs,jacket + Vs,core = 811033.559

where:

Vs,jacket = Vs,j1 + Vs,j2 = 722566.31

Vs,j1 = 471238.898 is calculated for section web jacket, with:

d = 600.00

Av = 157079.633

fy = 500.00

s = 100.00

Vs,j1 is multiplied by Col,j1 = 1.00

s/d = 0.16666667

Vs,j2 = 251327.412 is calculated for section flange jacket, with:

d = 320.00

Av = 157079.633

fy = 500.00

s = 100.00

Vs,j2 is multiplied by Col,j2 = 1.00

s/d = 0.3125

Vs,core = Vs,c1 + Vs,c2 = 88467.249

Vs,c1 = 88467.249 is calculated for section web core, with:

d = 440.00

Av = 100530.965

fy = 500.00

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 = 500.00

s = 250.00

Vs,c2 is multiplied by Col,c2 = 0.00

s/d = 1.5625

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

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

orientation 1: 1 = b1 + 90° = 90.00

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

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

dfv = d (figure 11.2, ACI 440) = 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 <= 797164.595
bw = 400.00

displacement_ductility_demand is calculated as ϕ_y

- Calculation of ϕ_y for END B -
for rotation axis 2 and integ. section (b)

From analysis, chord rotation = 8.0919355E-009
 $y = (M_y \cdot L_s / 3) / E_{\text{eff}} = 0.00078295$ ((4.29), Biskinis Phd)
My = 6.5012E+008
Ls = M/V (with Ls > 0.1*L and Ls < 2*L) = 551.6996
From table 10.5, ASCE 41_17: $E_{\text{eff}} = \text{factor} \cdot E_c \cdot I_g = 1.5270E+014$
factor = 0.30
Ag = 440000.00
Mean concrete strength: $f_c' = (f_c'_{\text{jacket}} \cdot \text{Area}_{\text{jacket}} + f_c'_{\text{core}} \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 33.00$
N = 18615.215
 $E_c \cdot I_g = E_{c_{\text{jacket}}} \cdot I_{g_{\text{jacket}}} + E_{c_{\text{core}}} \cdot I_{g_{\text{core}}} = 5.0901E+014$

Calculation of Yielding Moment My

Calculation of ϕ_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

$y = \text{Min}(y_{\text{ten}}, y_{\text{com}})$
 $y_{\text{ten}} = 4.8677145E-006$
with fy = 555.56
d = 707.00
y = 0.19284589
A = 0.01015895
B = 0.00446935
with pt = 0.00214476
pc = 0.00416509
pv = 0.00378591
N = 18615.215
b = 750.00
" = 0.06082037
 $y_{\text{comp}} = 1.6459533E-005$
with f_c^* (12.3, (ACI 440)) = 33.48734
fc = 33.00
fl = 0.49678681
b = bmax = 750.00
h = hmax = 750.00
Ag = 0.44
g = pt + pc + pv = 0.01009575
rc = 40.00
Ae/Ac = 0.31291181
Effective FRP thickness, $t_f = N \cdot L \cdot \text{Cos}(b1) = 1.016$
effective strain from (12.5) and (12.12), efe = 0.004
fu = 0.01
Ef = 64828.00
Ec = 26999.444
y = 0.19184981
A = 0.01001713
B = 0.00440616

with $E_s = 200000.00$

CONFIRMATION: $y = 0.19284589 < t/d$

Calculation of ratio I_b/I_d

Adequate Lap Length: $I_b/I_d \geq 1$

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

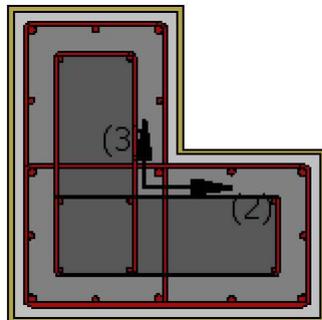
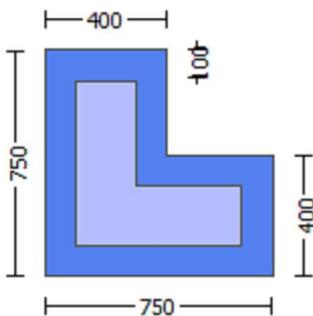
Limit State: Immediate Occupancy (data interpolation between analysis steps 1 and 2)

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: rcjlc

Constant Properties

Knowledge Factor, $\gamma = 0.90$

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

Consequently:

Jacket

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

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

Concrete Elasticity, $E_c = 26999.444$

Steel Elasticity, $E_s = 200000.00$

Existing Column

```

: New material of Secondary Member: Concrete Strength,  $f_c = f_{cm} = 33.00$ 
: New material of Secondary Member: Steel Strength,  $f_s = f_{sm} = 555.56$ 
: Concrete Elasticity,  $E_c = 26999.444$ 
: Steel Elasticity,  $E_s = 200000.00$ 
: #####
: Note: Especially for the calculation of moment strengths,
: the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14
: Jacket
: New material: Steel Strength,  $f_s = 1.25 \cdot f_{sm} = 694.45$ 
: Existing Column
: New material: Steel Strength,  $f_s = 1.25 \cdot f_{sm} = 694.45$ 
: #####
: 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
: Adequate Lap Length ( $l_o/l_{ou, min} >= 1$ )
: FRP Wrapping Data
: Type: Carbon
: Cured laminate properties (design values)
: Thickness,  $t = 1.016$ 
: Tensile Strength,  $f_{fu} = 1055.00$ 
: Tensile Modulus,  $E_f = 64828.00$ 
: Elongation,  $e_{fu} = 0.01$ 
: Number of directions,  $N_{oDir} = 1$ 
: Fiber orientations,  $b_i = 0.00^\circ$ 
: Number of layers,  $N_L = 1$ 
: Radius of rounding corners,  $R = 40.00$ 
: -----
: Stepwise Properties
: -----
: At local axis: 3
: EDGE -A-
: Shear Force,  $V_a = -0.00017144$ 
: EDGE -B-
: Shear Force,  $V_b = 0.00017144$ 
: BOTH EDGES
: Axial Force,  $F = -16273.607$ 
: 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,  $V_e/V_r = 1.05752$ 
: Member Controlled by Shear ( $V_e/V_r > 1$ )
: Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 1.1525E+006$ 
: with
:  $M_{pr1} = \text{Max}(M_{u1+}, M_{u1-}) = 1.7288E+009$ 
:    $M_{u1+} = 1.1540E+009$ , 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
:    $M_{u1-} = 1.7288E+009$ , 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

$$M_{pr2} = \text{Max}(M_{u2+}, M_{u2-}) = 1.7288E+009$$

$M_{u2+} = 1.1540E+009$, 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

$M_{u2-} = 1.7288E+009$, 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:

$$\phi_u = 5.0226943E-005$$

$$M_u = 1.1540E+009$$

with full section properties:

$$b = 750.00$$

$$d = 707.00$$

$$d' = 43.00$$

$$v = 0.00093001$$

$$N = 16273.607$$

$$f_c = 33.00$$

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

$$\text{Final value of } \phi_{cu}^* = \text{shear_factor} * \text{Max}(\phi_{cu}, \phi_{cc}) = 0.01291652$$

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

$$\text{From (5.4b), TBDY: } \phi_{cu} = 0.01291652$$

$$\omega_e \text{ ((5.4c), TBDY)} = a_{se} * \text{sh}_{,\min} * f_{ywe} / f_{ce} + \text{Min}(\phi_{fx}, \phi_{fy}) = 0.05541928$$

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

$$\phi_{fx} = 0.04286225$$

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

$$a_f = 0.31984848$$

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

$$b_{\max} = 750.00$$

$$h_{\max} = 750.00$$

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

$$b_w = 400.00$$

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

$$\phi_{fy} = 0.04286225$$

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.

AnoConf1 = 158733.333 is the unconfined external core area which is equal to $bi^2/6$ 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).
 $psh,min * Fywe = \text{Min}(psh,x * Fywe, psh,y * Fywe) = 3.0194$

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)

 $psh,x * Fywe = psh1 * Fywe1 + ps2 * Fywe2 = 3.0194$
 $psh1 \text{ ((5.4d), TBDY)} = Lstir1 * Astir1 / (Asec * s1) = 0.00367709$
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

 $psh,y * Fywe = psh1 * Fywe1 + ps2 * Fywe2 = 3.0194$
 $psh1 \text{ ((5.4d), TBDY)} = Lstir1 * Astir1 / (Asec * s1) = 0.00367709$
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 = 694.45

fywe2 = 694.45

fce = 33.00

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

c = confinement factor = 1.03889

y1 = 0.0025

sh1 = 0.008

ft1 = 833.34

fy1 = 694.45

su1 = 0.032

using (30) in Biskinis/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 = 1.00

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 = 694.45

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

y2 = 0.0025

sh2 = 0.008

ft2 = 833.34

fy2 = 694.45

su2 = 0.032

using (30) in Biskinis/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 = 1.00

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 $fs2 = (fs_jacket \cdot Asl,com,jacket + fs_core \cdot Asl,com,core) / Asl,com = 694.45$

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

$yv = 0.0025$

$shv = 0.008$

$ftv = 833.34$

$fyv = 694.45$

$suv = 0.032$

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

and also multiplied by the $shear_factor$ according to 15.7.1.4, with $Shear_factor = 1.00$

$lo/lo, min = lb/ld = 1.00$

$suv = 0.4 \cdot esuv_nominal$ ((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 $fsv = (fs_jacket \cdot Asl,mid,jacket + fs_mid \cdot Asl,mid,core) / Asl,mid = 694.45$

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

$1 = Asl,ten / (b \cdot d) \cdot (fs1 / fc) = 0.0451341$

$2 = Asl,com / (b \cdot d) \cdot (fs2 / fc) = 0.08764993$

$v = Asl,mid / (b \cdot d) \cdot (fsv / fc) = 0.07967042$

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

$1 = Asl,ten / (b \cdot d) \cdot (fs1 / fc) = 0.05123276$

$2 = Asl,com / (b \cdot d) \cdot (fs2 / fc) = 0.09949345$

$v = Asl,mid / (b \cdot d) \cdot (fsv / fc) = 0.09043572$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

su (4.9) = 0.09885678

$Mu = MRc$ (4.14) = 1.1540E+009

$u = su$ (4.1) = 5.0226943E-005

Calculation of ratio lb/ld

Adequate Lap Length: $lb/ld \geq 1$

Calculation of $Mu1$ -

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

$u = 6.4288704E-005$

$Mu = 1.7288E+009$

with full section properties:

$b = 400.00$

$d = 707.00$

$d' = 43.00$

$v = 0.00174378$

$N = 16273.607$

$fc = 33.00$

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

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.01291652$$

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

$$\text{From (5.4b), TBDY: } c_u = 0.01291652$$

$$w_e ((5.4c), TBDY) = a_{se} * s_{h,min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.05541928$$

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 $a_f = 1 - (\text{Unconfined area})/(\text{total area})$

$$a_f = 0.31984848$$

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

$$b_{max} = 750.00$$

$$h_{max} = 750.00$$

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

$$b_w = 400.00$$

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

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

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

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

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).

$$p_{sh,min} * F_{ywe} = \text{Min}(p_{sh,x} * F_{ywe}, p_{sh,y} * F_{ywe}) = 3.0194$$

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)

$$p_{sh,x} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{sh2} * F_{ywe2} = 3.0194$$

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

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

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

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

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

Astir2 (stirrups area) = 50.26548

psh_y*Fywe = psh₁*Fywe₁+ps₂*Fywe₂ = 3.0194
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 = 694.45

fywe₂ = 694.45

fce = 33.00

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

c = confinement factor = 1.03889

y₁ = 0.0025

sh₁ = 0.008

ft₁ = 833.34

fy₁ = 694.45

su₁ = 0.032

using (30) in Biskinis/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 = 1.00

su₁ = 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 y₁, sh₁,ft₁,fy₁, it is considered
characteristic value fsy₁ = fs₁/1.2, from table 5.1, TBDY.

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

with fs₁ = (fs,jacket*Asl,ten,jacket + fs,core*Asl,ten,core)/Asl,ten = 694.45

with Es₁ = (Es,jacket*Asl,ten,jacket + Es,core*Asl,ten,core)/Asl,ten = 200000.00

y₂ = 0.0025

sh₂ = 0.008

ft₂ = 833.34

fy₂ = 694.45

su₂ = 0.032

using (30) in Biskinis/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 = 1.00

su₂ = 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 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 Min(1,1.25*(lb/ld)^{2/3}), from 10.3.5, ASCE 41-17.

with fs₂ = (fs,jacket*Asl,com,jacket + fs,core*Asl,com,core)/Asl,com = 694.45

with Es₂ = (Es,jacket*Asl,com,jacket + Es,core*Asl,com,core)/Asl,com = 200000.00

y_v = 0.0025

sh_v = 0.008

ft_v = 833.34

fy_v = 694.45

suv = 0.032

using (30) in Biskinis/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 = 1.00

suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esuv_nominal = 0.08,

considering characteristic value fsy_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 fsy_v = fs_v/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 fs_v = (fs,jacket*Asl,mid,jacket + fs,mid*Asl,mid,core)/Asl,mid = 694.45

with Es_v = (Es,jacket*Asl,mid,jacket + Es,mid*Asl,mid,core)/Asl,mid = 200000.00

$$1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.16434361$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.08462644$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.14938203$$

and confined core properties:

$$b = 340.00$$

$$d = 677.00$$

$$d' = 13.00$$

$$f_{cc} (5A.2, TBDY) = 34.2833$$

$$c_c (5A.5, TBDY) = 0.00238888$$

$$c = \text{confinement factor} = 1.03889$$

$$1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.20191317$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.10397236$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.18353132$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < v_{s,y2}$ - LHS eq.(4.5) is not satisfied

--->

$v < v_{s,c}$ - RHS eq.(4.5) is satisfied

--->

$$s_u (4.8) = 0.29596233$$

$$\mu_u = M_{Rc} (4.15) = 1.7288E+009$$

$$u = s_u (4.1) = 6.4288704E-005$$

Calculation of ratio l_b/l_d

Adequate Lap Length: $l_b/l_d \geq 1$

Calculation of μ_{u2+}

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

$$u = 5.0226943E-005$$

$$\mu_u = 1.1540E+009$$

with full section properties:

$$b = 750.00$$

$$d = 707.00$$

$$d' = 43.00$$

$$v = 0.00093001$$

$$N = 16273.607$$

$$f_c = 33.00$$

$$c_c (5A.5, TBDY) = 0.002$$

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.01291652$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } c_u = 0.01291652$$

$$w_e ((5.4c), TBDY) = a_{se} * s_{h,min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.05541928$$

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 $a_f = 1 - (\text{Unconfined area})/(\text{total area})$

$$a_f = 0.31984848$$

$$\text{with Unconfined area} = ((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 140733.333$$

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, $tf = NL*t*Cos(b1) = 1.016$
 $f_{u,f} = 1055.00$
 $E_f = 64828.00$
 $u_{,f} = 0.015$

$ase((5.4d), TBDY) = (ase1*A_{ext} + ase2*A_{int})/A_{sec} = 0.45746528$

$ase1 = Max(((A_{conf,max1} - A_{noConf1})/A_{conf,max1}) * (A_{conf,min1}/A_{conf,max1}), 0) = 0.45746528$

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).

$ase2 (>= ase1) = Max(((A_{conf,max2} - A_{noConf2})/A_{conf,max2}) * (A_{conf,min2}/A_{conf,max2}), 0) = 0.45746528$

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).

$psh_{,min} * F_{ywe} = Min(psh_{,x} * F_{ywe}, psh_{,y} * F_{ywe}) = 3.0194$

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)

$psh_{,x} * F_{ywe} = psh1 * F_{ywe1} + ps2 * F_{ywe2} = 3.0194$

$psh1((5.4d), TBDY) = L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00367709$

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

$psh_{,y} * F_{ywe} = psh1 * F_{ywe1} + ps2 * F_{ywe2} = 3.0194$

$psh1((5.4d), TBDY) = L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00367709$

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

$A_{sec} = 440000.00$

$s1 = 100.00$

$s2 = 250.00$

$f_{ywe1} = 694.45$

$f_{ywe2} = 694.45$

$f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY: $cc = 0.00238888$

$c =$ confinement factor = 1.03889

$y1 = 0.0025$

$sh1 = 0.008$

$ft1 = 833.34$

$f_{y1} = 694.45$
 $s_{u1} = 0.032$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $l_o/l_{ou,min} = l_b/l_d = 1.00$
 $s_{u1} = 0.4 * e_{s1_nominal} ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $e_{s1_nominal} = 0.08$,
 For calculation of $e_{s1_nominal}$ and y_1, sh_1, ft_1, f_{y1} , it is considered
 characteristic value $f_{s1} = f_{s1}/1.2$, 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 $f_{s1} = (f_{s,jacket} * A_{s1,ten,jacket} + f_{s,core} * A_{s1,ten,core}) / A_{s1,ten} = 694.45$
 with $E_{s1} = (E_{s,jacket} * A_{s1,ten,jacket} + E_{s,core} * A_{s1,ten,core}) / A_{s1,ten} = 200000.00$
 $y_2 = 0.0025$
 $sh_2 = 0.008$
 $ft_2 = 833.34$
 $f_{y2} = 694.45$
 $s_{u2} = 0.032$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $l_o/l_{ou,min} = l_b/l_{b,min} = 1.00$
 $s_{u2} = 0.4 * e_{s2_nominal} ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $e_{s2_nominal} = 0.08$,
 For calculation of $e_{s2_nominal}$ and y_2, sh_2, ft_2, f_{y2} , it is considered
 characteristic value $f_{s2} = f_{s2}/1.2$, from table 5.1, TBDY.
 y_2, sh_2, ft_2, f_{y2} , are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE 41-17.
 with $f_{s2} = (f_{s,jacket} * A_{s2,com,jacket} + f_{s,core} * A_{s2,com,core}) / A_{s2,com} = 694.45$
 with $E_{s2} = (E_{s,jacket} * A_{s2,com,jacket} + E_{s,core} * A_{s2,com,core}) / A_{s2,com} = 200000.00$
 $y_v = 0.0025$
 $sh_v = 0.008$
 $ft_v = 833.34$
 $f_{y_v} = 694.45$
 $s_{u_v} = 0.032$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $l_o/l_{ou,min} = l_b/l_d = 1.00$
 $s_{u_v} = 0.4 * e_{s_{u_v_nominal}} ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $e_{s_{u_v_nominal}} = 0.08$,
 considering characteristic value $f_{s_{u_v}} = f_{s_{u_v}}/1.2$, 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 $f_{s_{u_v}} = f_{s_{u_v}}/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, f_{y1} , are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE 41-17.
 with $f_{s_{u_v}} = (f_{s,jacket} * A_{s_{u_v},mid,jacket} + f_{s,mid} * A_{s_{u_v},mid,core}) / A_{s_{u_v},mid} = 694.45$
 with $E_{s_{u_v}} = (E_{s,jacket} * A_{s_{u_v},mid,jacket} + E_{s,mid} * A_{s_{u_v},mid,core}) / A_{s_{u_v},mid} = 200000.00$
 $1 = A_{s1,ten} / (b * d) * (f_{s1} / f_c) = 0.0451341$
 $2 = A_{s2,com} / (b * d) * (f_{s2} / f_c) = 0.08764993$
 $v = A_{s_{u_v},mid} / (b * d) * (f_{s_{u_v}} / f_c) = 0.07967042$
 and confined core properties:
 $b = 690.00$
 $d = 677.00$
 $d' = 13.00$
 $f_{cc} (5A.2, TBDY) = 34.2833$
 $cc (5A.5, TBDY) = 0.00238888$
 $c = \text{confinement factor} = 1.03889$
 $1 = A_{s1,ten} / (b * d) * (f_{s1} / f_c) = 0.05123276$
 $2 = A_{s2,com} / (b * d) * (f_{s2} / f_c) = 0.09949345$
 $v = A_{s_{u_v},mid} / (b * d) * (f_{s_{u_v}} / f_c) = 0.09043572$
 Case/Assumption: Unconfined full section - Steel rupture
 ' satisfies Eq. (4.3)
 --->
 $v < v_{s,y2}$ - LHS eq.(4.5) is satisfied
 --->
 $s_u (4.9) = 0.09885678$
 $M_u = M_{Rc} (4.14) = 1.1540E+009$
 $u = s_u (4.1) = 5.0226943E-005$

Calculation of ratio l_b/d

Adequate Lap Length: $l_b/d \geq 1$

Calculation of μ_2

Calculation of ultimate curvature μ according to 4.1, Biskinis/Fardis 2013:

$$\mu = 6.4288704E-005$$

$$\mu_2 = 1.7288E+009$$

with full section properties:

$$b = 400.00$$

$$d = 707.00$$

$$d' = 43.00$$

$$v = 0.00174378$$

$$N = 16273.607$$

$$f_c = 33.00$$

$$\alpha (5A.5, \text{TBDY}) = 0.002$$

$$\text{Final value of } \mu_2: \mu_2^* = \text{shear_factor} * \text{Max}(\mu_2, \mu_c) = 0.01291652$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \mu_2 = 0.01291652$$

$$\mu_2 \text{ (5.4c), TBDY} = \alpha * \text{sh}_{\min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.05541928$$

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 $\alpha_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$\alpha_f = 0.31984848$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 140733.333$$

$$b_{\max} = 750.00$$

$$h_{\max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } \rho_f = 2t_f / b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 870.5244$$

$$f_y = 0.04286225$$

Expression ((15B.6), TBDY) is modified as $\alpha_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$\alpha_f = 0.31984848$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 140733.333$$

$$b_{\max} = 750.00$$

$$h_{\max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } \rho_f = 2t_f / b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 870.5244$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L * t * \text{Cos}(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$\mu_{u,f} = 0.015$$

$$\alpha_{se} \text{ ((5.4d), TBDY)} = (\alpha_{se1} * A_{ext} + \alpha_{se2} * A_{int}) / A_{sec} = 0.45746528$$

$$\alpha_{se1} = \text{Max}(((A_{conf,max1} - A_{noConf1}) / A_{conf,max1}) * (A_{conf,min1} / A_{conf,max1}), 0) = 0.45746528$$

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.

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).
 $psh_{,min} * Fy_{we} = \text{Min}(psh_x * Fy_{we}, psh_y * Fy_{we}) = 3.0194$

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)

 $psh_x * Fy_{we} = psh_1 * Fy_{we1} + ps_2 * Fy_{we2} = 3.0194$
 $psh_1 \text{ ((5.4d), TBDY)} = L_{stir1} * Astir1 / (A_{sec} * s_1) = 0.00367709$
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

 $psh_y * Fy_{we} = psh_1 * Fy_{we1} + ps_2 * Fy_{we2} = 3.0194$
 $psh_1 \text{ ((5.4d), TBDY)} = L_{stir1} * Astir1 / (A_{sec} * s_1) = 0.00367709$
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 = 694.45

fywe2 = 694.45

fce = 33.00

From ((5.A.5), TBDY), TBDY: cc = 0.00238888

c = confinement factor = 1.03889

y1 = 0.0025

sh1 = 0.008

ft1 = 833.34

fy1 = 694.45

su1 = 0.032

using (30) in Biskinis/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 = 1.00

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,tен,jacket + fs,core * Asl,tен,core) / Asl,tен = 694.45

with Es1 = (Es,jacket * Asl,tен,jacket + Es,core * Asl,tен,core) / Asl,tен = 200000.00

y2 = 0.0025

sh2 = 0.008

ft2 = 833.34

fy2 = 694.45

su2 = 0.032

using (30) in Biskinis/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 = 1.00

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 $Min(1, 1.25 \cdot (lb/ld)^{2/3})$, from 10.3.5, ASCE 41-17.

with $fs2 = (fs_jacket \cdot Asl_com_jacket + fs_core \cdot Asl_com_core) / Asl_com = 694.45$

with $Es2 = (Es_jacket \cdot Asl_com_jacket + Es_core \cdot Asl_com_core) / Asl_com = 200000.00$

$yv = 0.0025$

$shv = 0.008$

$ftv = 833.34$

$fyv = 694.45$

$suv = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with $shear_factor$

and also multiplied by the $shear_factor$ according to 15.7.1.4, with $Shear_factor = 1.00$

$lo/lo_{ou,min} = lb/ld = 1.00$

$suv = 0.4 \cdot esuv_nominal$ ((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 $fsv = (fs_jacket \cdot Asl_mid_jacket + fs_mid \cdot Asl_mid_core) / Asl_mid = 694.45$

with $Es_{v} = (Es_jacket \cdot Asl_mid_jacket + Es_mid \cdot Asl_mid_core) / Asl_mid = 200000.00$

$1 = Asl_ten / (b \cdot d) \cdot (fs1 / fc) = 0.16434361$

$2 = Asl_com / (b \cdot d) \cdot (fs2 / fc) = 0.08462644$

$v = Asl_mid / (b \cdot d) \cdot (fsv / fc) = 0.14938203$

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

$1 = Asl_ten / (b \cdot d) \cdot (fs1 / fc) = 0.20191317$

$2 = Asl_com / (b \cdot d) \cdot (fs2 / fc) = 0.10397236$

$v = Asl_mid / (b \cdot d) \cdot (fsv / fc) = 0.18353132$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < v_{s,y2}$ - LHS eq.(4.5) is not satisfied

--->

$v < v_{s,c}$ - RHS eq.(4.5) is satisfied

--->

su (4.8) = 0.29596233

$Mu = MRc$ (4.15) = 1.7288E+009

$u = su$ (4.1) = 6.4288704E-005

Calculation of ratio lb/ld

Adequate Lap Length: $lb/ld \geq 1$

Calculation of Shear Strength $Vr = Min(Vr1, Vr2) = 1.0898E+006$

Calculation of Shear Strength at edge 1, $Vr1 = 1.0898E+006$

$Vr1 = VCol$ ((10.3), ASCE 41-17) = $knl \cdot VCol0$

$VCol0 = 1.0898E+006$

$knl = 1$ (zero step-static loading)

NOTE: In expression (10-3) ' $Vs = Av \cdot fy \cdot d / s$ ' is replaced by ' $Vs + f \cdot Vf$ '
where Vf is the contribution of FRPs (11.3), ACI 440).

= 1 (normal-weight concrete)

Mean concrete strength: $fc' = (fc'_{jacket} \cdot Area_{jacket} + fc'_{core} \cdot Area_{core}) / Area_{section} = 33.00$, but $fc'^{0.5} \leq 8.3$

MPa (22.5.3.1, ACI 318-14)

$$M/Vd = 4.00$$

$$\mu_u = 1518.01$$

$$V_u = 0.00017144$$

$$d = 0.8 \cdot h = 600.00$$

$$N_u = 16273.607$$

$$A_g = 300000.00$$

$$\text{From (11.5.4.8), ACI 318-14: } V_s = V_{s,jacket} + V_{s,core} = 901155.609$$

where:

$$V_{s,jacket} = V_{s,j1} + V_{s,j2} = 802857.879$$

$V_{s,j1} = 523602.964$ is calculated for section web jacket, with:

$$d = 600.00$$

$$A_v = 157079.633$$

$$f_y = 555.56$$

$$s = 100.00$$

$V_{s,j1}$ is multiplied by $Col,j1 = 1.00$

$$s/d = 0.16666667$$

$V_{s,j2} = 279254.914$ is calculated for section flange jacket, with:

$$d = 320.00$$

$$A_v = 157079.633$$

$$f_y = 555.56$$

$$s = 100.00$$

$V_{s,j2}$ is multiplied by $Col,j2 = 1.00$

$$s/d = 0.3125$$

$$V_{s,core} = V_{s,c1} + V_{s,c2} = 98297.73$$

$V_{s,c1} = 98297.73$ is calculated for section web core, with:

$$d = 440.00$$

$$A_v = 100530.965$$

$$f_y = 555.56$$

$$s = 250.00$$

$V_{s,c1}$ is multiplied by $Col,c1 = 1.00$

$$s/d = 0.56818182$$

$V_{s,c2} = 0.00$ is calculated for section flange core, with:

$$d = 160.00$$

$$A_v = 100530.965$$

$$f_y = 555.56$$

$$s = 250.00$$

$V_{s,c2}$ 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) $\sin \alpha + \cos \alpha$ is replaced with $(\cot \alpha + \cot \alpha) \sin \alpha$ which is more a generalised expression, where α is the angle of the crack direction (see KANEPE).

This later relation, considered as a function $V_f(\alpha, a_1)$, 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.

$$\text{orientation 1: } \alpha = b_1 + 90^\circ = 90.00$$

$$V_f = \text{Min}(|V_f(45, a_1)|, |V_f(-45, a_1)|), \text{ with:}$$

$$\text{total thickness per orientation, } t_{f1} = NL \cdot t / \text{NoDir} = 1.016$$

$$d_{fv} = d \text{ (figure 11.2, ACI 440)} = 707.00$$

$$f_{fe} \text{ ((11-5), ACI 440)} = 259.312$$

$$E_f = 64828.00$$

$$f_e = 0.004, \text{ from (11.6a), ACI 440}$$

$$\text{with } f_u = 0.01$$

$$\text{From (11-11), ACI 440: } V_s + V_f \leq 915872.391$$

$$b_w = 400.00$$

Calculation of Shear Strength at edge 2, $V_{r2} = 1.0898E+006$

$$V_{r2} = V_{Col} \text{ ((10.3), ASCE 41-17)} = k_{nl} \cdot V_{Col0}$$

$$V_{Col0} = 1.0898E+006$$

$$k_{nl} = 1 \text{ (zero step-static loading)}$$

NOTE: In expression (10-3) ' $V_s = A_v \cdot f_y \cdot d / s$ ' is replaced by ' $V_s + f \cdot V_f$ ' where V_f is the contribution of FRPs (11.3), ACI 440).

$$= 1 \text{ (normal-weight concrete)}$$

Mean concrete strength: $f_c' = (f_c'_{jacket} \cdot Area_{jacket} + f_c'_{core} \cdot Area_{core}) / Area_{section} = 33.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 4.00$

$\mu_u = 1518.01$

$V_u = 0.00017144$

$d = 0.8 \cdot h = 600.00$

$N_u = 16273.607$

$A_g = 300000.00$

From (11.5.4.8), ACI 318-14: $V_s = V_{sjacket} + V_{s,core} = 901155.609$

where:

$V_{sjacket} = V_{sj1} + V_{sj2} = 802857.879$

$V_{sj1} = 523602.964$ is calculated for section web jacket, with:

$d = 600.00$

$A_v = 157079.633$

$f_y = 555.56$

$s = 100.00$

V_{sj1} is multiplied by $Col,j1 = 1.00$

$s/d = 0.16666667$

$V_{sj2} = 279254.914$ is calculated for section flange jacket, with:

$d = 320.00$

$A_v = 157079.633$

$f_y = 555.56$

$s = 100.00$

V_{sj2} is multiplied by $Col,j2 = 1.00$

$s/d = 0.3125$

$V_{s,core} = V_{s,c1} + V_{s,c2} = 98297.73$

$V_{s,c1} = 98297.73$ is calculated for section web core, with:

$d = 440.00$

$A_v = 100530.965$

$f_y = 555.56$

$s = 250.00$

$V_{s,c1}$ is multiplied by $Col,c1 = 1.00$

$s/d = 0.56818182$

$V_{s,c2} = 0.00$ is calculated for section flange core, with:

$d = 160.00$

$A_v = 100530.965$

$f_y = 555.56$

$s = 250.00$

$V_{s,c2}$ 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: $\theta = 45^\circ + 90^\circ = 135^\circ$

$V_f = \text{Min}(|V_f(45, \alpha)|, |V_f(-45, \alpha)|)$, with:

total thickness per orientation, $t_{f1} = N_L \cdot t / N_{oDir} = 1.016$

$d_{fv} = d$ (figure 11.2, ACI 440) = 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: $V_s + V_f \leq 915872.391$

$b_w = 400.00$

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: rjIcs

Constant Properties

Knowledge Factor, $\gamma = 0.90$

Mean strength values are used for both shear and moment calculations.

Consequently:

Jacket

New material of Secondary Member: Concrete Strength, $f_c = f_{cm} = 33.00$

New material of Secondary Member: Steel Strength, $f_s = f_{sm} = 555.56$

Concrete Elasticity, $E_c = 26999.444$

Steel Elasticity, $E_s = 200000.00$

Existing Column

New material of Secondary Member: Concrete Strength, $f_c = f_{cm} = 33.00$

New material of Secondary Member: Steel Strength, $f_s = f_{sm} = 555.56$

Concrete Elasticity, $E_c = 26999.444$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14

Jacket

New material: Steel Strength, $f_s = 1.25 \cdot f_{sm} = 694.45$

Existing Column

New material: Steel Strength, $f_s = 1.25 \cdot f_{sm} = 694.45$

#####

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

Adequate Lap Length ($l_o/l_{ou, min} > 1$)

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $e_{fu} = 0.01$

Number of directions, $N_{oDir} = 1$

Fiber orientations, $b_i = 0.00^\circ$

Number of layers, $N_L = 1$

Radius of rounding corners, $R = 40.00$

Stepwise Properties

At local axis: 2

EDGE -A-

Shear Force, $V_a = -0.0001715$

EDGE -B-

Shear Force, $V_b = 0.0001715$

BOTH EDGES

Axial Force, $F = -16273.607$

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: Asl,com = 2208.54
-Middle: Asl,mid = 2007.478

Calculation of Shear Capacity ratio , $V_e/V_r = 1.05752$

Member Controlled by Shear ($V_e/V_r > 1$)

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 1.1525E+006$

with

$M_{pr1} = \text{Max}(M_{u1+}, M_{u1-}) = 1.7288E+009$

$M_{u1+} = 1.1540E+009$, 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

$M_{u1-} = 1.7288E+009$, 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

$M_{pr2} = \text{Max}(M_{u2+}, M_{u2-}) = 1.7288E+009$

$M_{u2+} = 1.1540E+009$, 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

$M_{u2-} = 1.7288E+009$, 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:

$\phi_u = 5.0226943E-005$

$M_u = 1.1540E+009$

with full section properties:

$b = 750.00$

$d = 707.00$

$d' = 43.00$

$v = 0.00093001$

$N = 16273.607$

$f_c = 33.00$

$\phi_{co} (5A.5, TBDY) = 0.002$

Final value of ϕ_{cu} : $\phi_{cu}^* = \text{shear_factor} * \text{Max}(\phi_{cu}, \phi_{cc}) = 0.01291652$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $\phi_{cu} = 0.01291652$

$\phi_{we} ((5.4c), TBDY) = a_{se} * \phi_{sh, \min} * f_{ywe} / f_{ce} + \text{Min}(\phi_{fx}, \phi_{fy}) = 0.05541928$

where $\phi_f = a_f * \phi_{pf} * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$\phi_{fx} = 0.04286225$

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), $\phi_{pf} = 2t_f / b_w = 0.00508$

$b_w = 400.00$

effective stress from (A.35), $f_{fe} = 870.5244$

$\phi_{fy} = 0.04286225$

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), $\phi_{pf} = 2t_f / b_w = 0.00508$

$b_w = 400.00$

effective stress from (A.35), $f_{fe} = 870.5244$

$R = 40.00$

Effective FRP thickness, $t_f = N L * t * \text{Cos}(b_1) = 1.016$

$f_{u,f} = 1055.00$

$$E_f = 64828.00$$

$$u, f = 0.015$$

$$ase \text{ ((5.4d), TBDY)} = (ase1 * A_{ext} + ase2 * A_{int}) / A_{sec} = 0.45746528$$

$$ase1 = \text{Max}(((A_{conf,max1} - A_{noConf1}) / A_{conf,max1}) * (A_{conf,min1} / A_{conf,max1}), 0) = 0.45746528$$

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).

$$p_{sh,min} * F_{ywe} = \text{Min}(p_{sh,x} * F_{ywe}, p_{sh,y} * F_{ywe}) = 3.0194$$

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)

$$p_{sh,x} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{sh2} * F_{ywe2} = 3.0194$$

$$p_{sh1} \text{ ((5.4d), TBDY)} = L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00367709$$

$$L_{stir1} \text{ (Length of stirrups along Y)} = 2060.00$$

$$A_{stir1} \text{ (stirrups area)} = 78.53982$$

$$p_{sh2} \text{ (5.4d)} = L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00067082$$

$$L_{stir2} \text{ (Length of stirrups along Y)} = 1468.00$$

$$A_{stir2} \text{ (stirrups area)} = 50.26548$$

$$p_{sh,y} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{sh2} * F_{ywe2} = 3.0194$$

$$p_{sh1} \text{ ((5.4d), TBDY)} = L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00367709$$

$$L_{stir1} \text{ (Length of stirrups along X)} = 2060.00$$

$$A_{stir1} \text{ (stirrups area)} = 78.53982$$

$$p_{sh2} \text{ ((5.4d), TBDY)} = L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00067082$$

$$L_{stir2} \text{ (Length of stirrups along X)} = 1468.00$$

$$A_{stir2} \text{ (stirrups area)} = 50.26548$$

$$A_{sec} = 440000.00$$

$$s1 = 100.00$$

$$s2 = 250.00$$

$$f_{ywe1} = 694.45$$

$$f_{ywe2} = 694.45$$

$$f_{ce} = 33.00$$

$$\text{From ((5.A5), TBDY), TBDY: } c_c = 0.00238888$$

$$c = \text{confinement factor} = 1.03889$$

$$y1 = 0.0025$$

$$sh1 = 0.008$$

$$ft1 = 833.34$$

$$fy1 = 694.45$$

$$su1 = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor

and also multiplied by the shear_factor according to 15.7.1.4, with

Shear_factor = 1.00

$$l_o / l_{ou,min} = l_b / l_d = 1.00$$

$$su1 = 0.4 * esu1_{nominal} \text{ ((5.5), TBDY)} = 0.032$$

From table 5A.1, TBDY: $esu1_{nominal} = 0.08$,

For calculation of $esu1_{nominal}$ and $y1$, $sh1$, $ft1$, $fy1$, it is considered

characteristic value $f_{s1} = f_s/1.2$, 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 $f_{s1} = (f_{s,jacket} \cdot A_{s,ten,jacket} + f_{s,core} \cdot A_{s,ten,core}) / A_{s,ten} = 694.45$

with $E_{s1} = (E_{s,jacket} \cdot A_{s,ten,jacket} + E_{s,core} \cdot A_{s,ten,core}) / A_{s,ten} = 200000.00$

$y_2 = 0.0025$

$sh_2 = 0.008$

$ft_2 = 833.34$

$fy_2 = 694.45$

$su_2 = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor

and also multiplied by the shear_factor according to 15.7.1.4, with

Shear_factor = 1.00

$l_o/l_{o,min} = l_b/l_{b,min} = 1.00$

$su_2 = 0.4 \cdot esu_{2,nominal} ((5.5), TBDY) = 0.032$

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 $f_{s2} = f_s/1.2$, 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 $f_{s2} = (f_{s,jacket} \cdot A_{s,com,jacket} + f_{s,core} \cdot A_{s,com,core}) / A_{s,com} = 694.45$

with $E_{s2} = (E_{s,jacket} \cdot A_{s,com,jacket} + E_{s,core} \cdot A_{s,com,core}) / A_{s,com} = 200000.00$

$y_v = 0.0025$

$sh_v = 0.008$

$ft_v = 833.34$

$fy_v = 694.45$

$su_v = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor

and also multiplied by the shear_factor according to 15.7.1.4, with

Shear_factor = 1.00

$l_o/l_{o,min} = l_b/l_d = 1.00$

$su_v = 0.4 \cdot esuv_{nominal} ((5.5), TBDY) = 0.032$

From table 5A.1, TBDY: $esuv_{nominal} = 0.08$,

considering characteristic value $f_{sv} = f_s/1.2$, from table 5.1, TBDY

For calculation of $esuv_{nominal}$ and y_v, sh_v, ft_v, fy_v , it is considered

characteristic value $f_{sv} = f_s/1.2$, 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 $f_{sv} = (f_{s,jacket} \cdot A_{s,mid,jacket} + f_{s,mid} \cdot A_{s,mid,core}) / A_{s,mid} = 694.45$

with $E_{sv} = (E_{s,jacket} \cdot A_{s,mid,jacket} + E_{s,mid} \cdot A_{s,mid,core}) / A_{s,mid} = 200000.00$

$1 = A_{s,ten} / (b \cdot d) \cdot (f_{s1} / f_c) = 0.0451341$

$2 = A_{s,com} / (b \cdot d) \cdot (f_{s2} / f_c) = 0.08764993$

$v = A_{s,mid} / (b \cdot d) \cdot (f_{sv} / f_c) = 0.07967042$

and confined core properties:

$b = 690.00$

$d = 677.00$

$d' = 13.00$

$f_{cc} (5A.2, TBDY) = 34.2833$

$cc (5A.5, TBDY) = 0.00238888$

$c = \text{confinement factor} = 1.03889$

$1 = A_{s,ten} / (b \cdot d) \cdot (f_{s1} / f_c) = 0.05123276$

$2 = A_{s,com} / (b \cdot d) \cdot (f_{s2} / f_c) = 0.09949345$

$v = A_{s,mid} / (b \cdot d) \cdot (f_{sv} / f_c) = 0.09043572$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

---->

$v < v_s, y_2$ - LHS eq.(4.5) is satisfied

---->

$su (4.9) = 0.09885678$

$Mu = MRc (4.14) = 1.1540E+009$

$u = su (4.1) = 5.0226943E-005$

Calculation of ratio l_b/l_d

Adequate Lap Length: $l_b/l_d \geq 1$

Calculation of Mu_1 -

Calculation of ultimate curvature ϕ_u according to 4.1, Biskinis/Fardis 2013:

$$u = 6.4288704E-005$$

$$\mu = 1.7288E+009$$

with full section properties:

$$b = 400.00$$

$$d = 707.00$$

$$d' = 43.00$$

$$v = 0.00174378$$

$$N = 16273.607$$

$$f_c = 33.00$$

$$\alpha_{co} (5A.5, TBDY) = 0.002$$

$$\text{Final value of } \phi_u: \phi_u = \text{shear_factor} * \text{Max}(\phi_{cu}, \phi_{cc}) = 0.01291652$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \phi_{cu} = 0.01291652$$

$$\phi_{cc} ((5.4c), TBDY) = \alpha_{ase} * \text{sh}_{,\min} * f_{ywe} / f_{ce} + \text{Min}(\phi_{fx}, \phi_{fy}) = 0.05541928$$

where $\phi_{fx} = \alpha_{af} * \rho_f * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$\phi_{fx} = 0.04286225$$

Expression ((15B.6), TBDY) is modified as $\alpha_{af} = 1 - (\text{Unconfined area}) / (\text{total area})$

$$\alpha_{af} = 0.31984848$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 140733.333$$

$$b_{\max} = 750.00$$

$$h_{\max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } \rho_f = 2t_f / b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{fe} = 870.5244$$

$$\phi_{fy} = 0.04286225$$

Expression ((15B.6), TBDY) is modified as $\alpha_{af} = 1 - (\text{Unconfined area}) / (\text{total area})$

$$\alpha_{af} = 0.31984848$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 140733.333$$

$$b_{\max} = 750.00$$

$$h_{\max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } \rho_f = 2t_f / b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{fe} = 870.5244$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L * t * \text{Cos}(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$\alpha_{ase} ((5.4d), TBDY) = (\alpha_{ase1} * A_{ext} + \alpha_{ase2} * A_{int}) / A_{sec} = 0.45746528$$

$$\alpha_{ase1} = \text{Max}(((A_{\text{conf,max1}} - A_{\text{noConf1}}) / A_{\text{conf,max1}}) * (A_{\text{conf,min1}} / A_{\text{conf,max1}}), 0) = 0.45746528$$

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).

$$\alpha_{ase2} (\geq \alpha_{ase1}) = \text{Max}(((A_{\text{conf,max2}} - A_{\text{noConf2}}) / A_{\text{conf,max2}}) * (A_{\text{conf,min2}} / A_{\text{conf,max2}}), 0) = 0.45746528$$

The definitions of 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.

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).
 $psh,min*Fywe = \text{Min}(psh,x*Fywe, psh,y*Fywe) = 3.0194$

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)

 $psh_x*Fywe = psh1*Fywe1 + ps2*Fywe2 = 3.0194$
 $psh1$ ((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

 $psh_y*Fywe = psh1*Fywe1 + ps2*Fywe2 = 3.0194$
 $psh1$ ((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 = 694.45
fywe2 = 694.45
fce = 33.00

From ((5.A5), TBDY), TBDY: cc = 0.00238888
c = confinement factor = 1.03889

y1 = 0.0025
sh1 = 0.008
ft1 = 833.34
fy1 = 694.45
su1 = 0.032

using (30) in Biskinis/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 = 1.00

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 $fs1 = (fs,jacket*Asl,ten,jacket + fs,core*Asl,ten,core)/Asl,ten = 694.45$

with $Es1 = (Es,jacket*Asl,ten,jacket + Es,core*Asl,ten,core)/Asl,ten = 200000.00$

y2 = 0.0025
sh2 = 0.008
ft2 = 833.34
fy2 = 694.45
su2 = 0.032

using (30) in Biskinis/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 = 1.00

su2 = $0.4*esu2_nominal$ ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu2_nominal = 0.08,

For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered characteristic value $fsy2 = fs2/1.2$, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25*(lb/ld)^{2/3})$, from 10.3.5, ASCE 41-17.

with $fs2 = (fs,jacket*Asl,com,jacket + fs,core*Asl,com,core)/Asl,com = 694.45$

with $Es2 = (Es,jacket*Asl,com,jacket + Es,core*Asl,com,core)/Asl,com = 200000.00$

yv = 0.0025
shv = 0.008
ftv = 833.34

$f_{yv} = 694.45$
 $s_{uv} = 0.032$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $l_o/l_{ou,min} = l_b/l_d = 1.00$
 $s_{uv} = 0.4 * e_{suv_nominal} ((5.5), TBDY) = 0.032$
 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 $f_{sv} = (f_{s,jacket} * A_{s,mid,jacket} + f_{s,mid} * A_{s,mid,core}) / A_{s,mid} = 694.45$
 with $E_{sv} = (E_{s,jacket} * A_{s,mid,jacket} + E_{s,mid} * A_{s,mid,core}) / A_{s,mid} = 200000.00$
 $1 = A_{s,ten} / (b * d) * (f_{s1} / f_c) = 0.16434361$
 $2 = A_{s,com} / (b * d) * (f_{s2} / f_c) = 0.08462644$
 $v = A_{s,mid} / (b * d) * (f_{sv} / f_c) = 0.14938203$
 and confined core properties:
 $b = 340.00$
 $d = 677.00$
 $d' = 13.00$
 $f_{cc} (5A.2, TBDY) = 34.2833$
 $cc (5A.5, TBDY) = 0.00238888$
 $c = \text{confinement factor} = 1.03889$
 $1 = A_{s,ten} / (b * d) * (f_{s1} / f_c) = 0.20191317$
 $2 = A_{s,com} / (b * d) * (f_{s2} / f_c) = 0.10397236$
 $v = A_{s,mid} / (b * d) * (f_{sv} / f_c) = 0.18353132$
 Case/Assumption: Unconfined full section - Steel rupture
 ' satisfies Eq. (4.3)

--->
 $v < v_{s,y2}$ - LHS eq.(4.5) is not satisfied
 --->
 $v < v_{s,c}$ - RHS eq.(4.5) is satisfied
 --->
 $su (4.8) = 0.29596233$
 $Mu = MRc (4.15) = 1.7288E+009$
 $u = su (4.1) = 6.4288704E-005$

 Calculation of ratio l_b/l_d

 Adequate Lap Length: $l_b/l_d \geq 1$

 Calculation of Mu_{2+}

 Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

$u = 5.0226943E-005$
 $Mu = 1.1540E+009$

 with full section properties:

$b = 750.00$
 $d = 707.00$
 $d' = 43.00$
 $v = 0.00093001$
 $N = 16273.607$
 $f_c = 33.00$
 $co (5A.5, TBDY) = 0.002$
 Final value of cu : $cu^* = \text{shear_factor} * \text{Max}(cu, cc) = 0.01291652$
 The Shear_factor is considered equal to 1 (pure moment strength)
 From (5.4b), TBDY: $cu = 0.01291652$
 $w_e ((5.4c), TBDY) = a_{se} * sh_{,min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.05541928$
 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, $t_f = N_L * t * \cos(b_1) = 1.016$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

a_{se} ((5.4d), TBDY) = $(a_{se1} * A_{ext} + a_{se2} * A_{int})/A_{sec} = 0.45746528$

$$a_{se1} = \text{Max}(((A_{conf,max1} - A_{noConf1})/A_{conf,max1}) * (A_{conf,min1}/A_{conf,max1}), 0) = 0.45746528$$

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).

$$p_{sh,min} * F_{ywe} = \text{Min}(p_{sh,x} * F_{ywe}, p_{sh,y} * F_{ywe}) = 3.0194$$

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)

$$p_{sh,x} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{sh2} * F_{ywe2} = 3.0194$$

$$p_{sh1} \text{ ((5.4d), TBDY)} = L_{stir1} * A_{stir1} / (A_{sec} * s_1) = 0.00367709$$

$$L_{stir1} \text{ (Length of stirrups along Y)} = 2060.00$$

$$A_{stir1} \text{ (stirrups area)} = 78.53982$$

$$p_{sh2} \text{ (5.4d)} = L_{stir2} * A_{stir2} / (A_{sec} * s_2) = 0.00067082$$

$$L_{stir2} \text{ (Length of stirrups along Y)} = 1468.00$$

$$A_{stir2} \text{ (stirrups area)} = 50.26548$$

$$p_{sh,y} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{sh2} * F_{ywe2} = 3.0194$$

$$p_{sh1} \text{ ((5.4d), TBDY)} = L_{stir1} * A_{stir1} / (A_{sec} * s_1) = 0.00367709$$

$$L_{stir1} \text{ (Length of stirrups along X)} = 2060.00$$

$$A_{stir1} \text{ (stirrups area)} = 78.53982$$

$$p_{sh2} \text{ ((5.4d), TBDY)} = L_{stir2} * A_{stir2} / (A_{sec} * s_2) = 0.00067082$$

Lstir2 (Length of stirrups along X) = 1468.00
Astir2 (stirrups area) = 50.26548

Asec = 440000.00
s1 = 100.00
s2 = 250.00
fywe1 = 694.45
fywe2 = 694.45
fce = 33.00

From ((5.A.5), TBDY), TBDY: cc = 0.00238888
c = confinement factor = 1.03889

y1 = 0.0025
sh1 = 0.008
ft1 = 833.34
fy1 = 694.45
su1 = 0.032

using (30) in Biskinis/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 = 1.00

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 $\text{Min}(1, 1.25 \cdot (lb/lb)^{2/3})$, from 10.3.5, ASCE 41-17.

with fs1 = (fs,jacket*Asl,ten,jacket + fs,core*Asl,ten,core)/Asl,ten = 694.45

with Es1 = (Es,jacket*Asl,ten,jacket + Es,core*Asl,ten,core)/Asl,ten = 200000.00

y2 = 0.0025
sh2 = 0.008
ft2 = 833.34
fy2 = 694.45
su2 = 0.032

using (30) in Biskinis/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 = 1.00

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 $\text{Min}(1, 1.25 \cdot (lb/lb)^{2/3})$, from 10.3.5, ASCE 41-17.

with fs2 = (fs,jacket*Asl,com,jacket + fs,core*Asl,com,core)/Asl,com = 694.45

with Es2 = (Es,jacket*Asl,com,jacket + Es,core*Asl,com,core)/Asl,com = 200000.00

yv = 0.0025
shv = 0.008
ftv = 833.34
fyv = 694.45
suv = 0.032

using (30) in Biskinis/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 = 1.00

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 $\text{Min}(1, 1.25 \cdot (lb/lb)^{2/3})$, from 10.3.5, ASCE 41-17.

with fsv = (fs,jacket*Asl,mid,jacket + fs,mid*Asl,mid,core)/Asl,mid = 694.45

with Esv = (Es,jacket*Asl,mid,jacket + Es,mid*Asl,mid,core)/Asl,mid = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.0451341

2 = Asl,com/(b*d)*(fs2/fc) = 0.08764993

v = Asl,mid/(b*d)*(fsv/fc) = 0.07967042

and confined core properties:

b = 690.00
d = 677.00
d' = 13.00

$$f_{cc} (5A.2, TBDY) = 34.2833$$

$$c_c (5A.5, TBDY) = 0.00238888$$

$$c = \text{confinement factor} = 1.03889$$

$$1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.05123276$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.09949345$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.09043572$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

---->

$v < v_{s,y2}$ - LHS eq.(4.5) is satisfied

---->

$$s_u (4.9) = 0.09885678$$

$$\mu_u = M_{Rc} (4.14) = 1.1540E+009$$

$$u = s_u (4.1) = 5.0226943E-005$$

Calculation of ratio l_b/l_d

Adequate Lap Length: $l_b/l_d \geq 1$

Calculation of μ_{u2} -

Calculation of ultimate curvature μ_u according to 4.1, Biskinis/Fardis 2013:

$$u = 6.4288704E-005$$

$$\mu_u = 1.7288E+009$$

with full section properties:

$$b = 400.00$$

$$d = 707.00$$

$$d' = 43.00$$

$$v = 0.00174378$$

$$N = 16273.607$$

$$f_c = 33.00$$

$$c_c (5A.5, TBDY) = 0.002$$

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.01291652$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } c_u = 0.01291652$$

$$w_e ((5.4c), TBDY) = a_{se} * s_{h,min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.05541928$$

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 $a_f = 1 - (\text{Unconfined area})/(\text{total area})$

$$a_f = 0.31984848$$

$$\text{with Unconfined area} = ((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 140733.333$$

$$b_{max} = 750.00$$

$$h_{max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{fe} = 870.5244$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L * t * \text{Cos}(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u, f = 0.015$$

$$ase \text{ ((5.4d), TBDY)} = (ase1 * A_{ext} + ase2 * A_{int}) / A_{sec} = 0.45746528$$

$$ase1 = \text{Max}(((A_{conf,max1} - A_{noConf1}) / A_{conf,max1}) * (A_{conf,min1} / A_{conf,max1}), 0) = 0.45746528$$

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).

$$p_{sh,min} * F_{ywe} = \text{Min}(p_{sh,x} * F_{ywe}, p_{sh,y} * F_{ywe}) = 3.0194$$

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)

$$p_{sh,x} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{sh2} * F_{ywe2} = 3.0194$$

$$p_{sh1} \text{ ((5.4d), TBDY)} = L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00367709$$

$$L_{stir1} \text{ (Length of stirrups along Y)} = 2060.00$$

$$A_{stir1} \text{ (stirrups area)} = 78.53982$$

$$p_{sh2} \text{ (5.4d)} = L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00067082$$

$$L_{stir2} \text{ (Length of stirrups along Y)} = 1468.00$$

$$A_{stir2} \text{ (stirrups area)} = 50.26548$$

$$p_{sh,y} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{sh2} * F_{ywe2} = 3.0194$$

$$p_{sh1} \text{ ((5.4d), TBDY)} = L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00367709$$

$$L_{stir1} \text{ (Length of stirrups along X)} = 2060.00$$

$$A_{stir1} \text{ (stirrups area)} = 78.53982$$

$$p_{sh2} \text{ ((5.4d), TBDY)} = L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00067082$$

$$L_{stir2} \text{ (Length of stirrups along X)} = 1468.00$$

$$A_{stir2} \text{ (stirrups area)} = 50.26548$$

$$A_{sec} = 440000.00$$

$$s1 = 100.00$$

$$s2 = 250.00$$

$$f_{ywe1} = 694.45$$

$$f_{ywe2} = 694.45$$

$$f_{ce} = 33.00$$

$$\text{From ((5.A5), TBDY), TBDY: } c_c = 0.00238888$$

$$c = \text{confinement factor} = 1.03889$$

$$y1 = 0.0025$$

$$sh1 = 0.008$$

$$ft1 = 833.34$$

$$fy1 = 694.45$$

$$su1 = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor

and also multiplied by the shear_factor according to 15.7.1.4, with

Shear_factor = 1.00

$$l_o / l_{ou,min} = l_b / l_d = 1.00$$

$$su1 = 0.4 * esu1_{nominal} \text{ ((5.5), TBDY)} = 0.032$$

From table 5A.1, TBDY: $esu1_{nominal} = 0.08$,

For calculation of $esu1_{nominal}$ and $y1$, $sh1$, $ft1$, $fy1$, it is considered

characteristic value $f_{sy1} = f_{s1}/1.2$, 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 $f_{s1} = (f_{s,jacket} \cdot A_{s,ten,jacket} + f_{s,core} \cdot A_{s,ten,core})/A_{s,ten} = 694.45$

with $E_{s1} = (E_{s,jacket} \cdot A_{s,ten,jacket} + E_{s,core} \cdot A_{s,ten,core})/A_{s,ten} = 200000.00$

$y_2 = 0.0025$

$sh_2 = 0.008$

$ft_2 = 833.34$

$fy_2 = 694.45$

$su_2 = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor

and also multiplied by the shear_factor according to 15.7.1.4, with

Shear_factor = 1.00

$l_o/l_{o,min} = l_b/l_{d,min} = 1.00$

$su_2 = 0.4 \cdot esu_{2,nominal} ((5.5), TBDY) = 0.032$

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 $f_{s2} = (f_{s,jacket} \cdot A_{s,com,jacket} + f_{s,core} \cdot A_{s,com,core})/A_{s,com} = 694.45$

with $E_{s2} = (E_{s,jacket} \cdot A_{s,com,jacket} + E_{s,core} \cdot A_{s,com,core})/A_{s,com} = 200000.00$

$y_v = 0.0025$

$sh_v = 0.008$

$ft_v = 833.34$

$fy_v = 694.45$

$su_v = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor

and also multiplied by the shear_factor according to 15.7.1.4, with

Shear_factor = 1.00

$l_o/l_{o,min} = l_b/l_d = 1.00$

$su_v = 0.4 \cdot esuv_{nominal} ((5.5), TBDY) = 0.032$

From table 5A.1, TBDY: $esuv_{nominal} = 0.08$,

considering characteristic value $f_{syv} = f_{sv}/1.2$, from table 5.1, TBDY

For calculation of $esuv_{nominal}$ and y_v, sh_v, ft_v, fy_v , it is considered

characteristic value $f_{syv} = f_{sv}/1.2$, 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 $f_{sv} = (f_{s,jacket} \cdot A_{s,mid,jacket} + f_{s,mid} \cdot A_{s,mid,core})/A_{s,mid} = 694.45$

with $E_{sv} = (E_{s,jacket} \cdot A_{s,mid,jacket} + E_{s,mid} \cdot A_{s,mid,core})/A_{s,mid} = 200000.00$

$1 = A_{s,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.16434361$

$2 = A_{s,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.08462644$

$v = A_{s,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.14938203$

and confined core properties:

$b = 340.00$

$d = 677.00$

$d' = 13.00$

$f_{cc} (5A.2, TBDY) = 34.2833$

$cc (5A.5, TBDY) = 0.00238888$

$c = \text{confinement factor} = 1.03889$

$1 = A_{s,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.20191317$

$2 = A_{s,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.10397236$

$v = A_{s,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.18353132$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

---->

$v < v_{s,y2}$ - LHS eq.(4.5) is not satisfied

---->

$v < v_{s,c}$ - RHS eq.(4.5) is satisfied

---->

$su (4.8) = 0.29596233$

$Mu = MRc (4.15) = 1.7288E+009$

$u = su (4.1) = 6.4288704E-005$

Calculation of ratio l_b/l_d

Adequate Lap Length: $l_b/l_d \geq 1$

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 1.0898\text{E}+006$

Calculation of Shear Strength at edge 1, $V_{r1} = 1.0898\text{E}+006$

$V_{r1} = V_{\text{Col}} ((10.3), \text{ASCE } 41-17) = k_{nl} * V_{\text{Col}0}$

$V_{\text{Col}0} = 1.0898\text{E}+006$

$k_{nl} = 1$ (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: $f_c' = (f_c'_{\text{jacket}} * \text{Area}_{\text{jacket}} + f_c'_{\text{core}} * \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 33.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 4.00$

$\mu_u = 1518.777$

$V_u = 0.0001715$

$d = 0.8 * h = 600.00$

$N_u = 16273.607$

$A_g = 300000.00$

From (11.5.4.8), ACI 318-14: $V_s = V_{s,\text{jacket}} + V_{s,\text{core}} = 901155.609$

where:

$V_{s,\text{jacket}} = V_{s,j1} + V_{s,j2} = 802857.879$

$V_{s,j1} = 279254.914$ is calculated for section web jacket, with:

$d = 320.00$

$A_v = 157079.633$

$f_y = 555.56$

$s = 100.00$

$V_{s,j1}$ is multiplied by $\text{Col},j1 = 1.00$

$s/d = 0.3125$

$V_{s,j2} = 523602.964$ is calculated for section flange jacket, with:

$d = 600.00$

$A_v = 157079.633$

$f_y = 555.56$

$s = 100.00$

$V_{s,j2}$ is multiplied by $\text{Col},j2 = 1.00$

$s/d = 0.16666667$

$V_{s,\text{core}} = V_{s,c1} + V_{s,c2} = 98297.73$

$V_{s,c1} = 0.00$ is calculated for section web core, with:

$d = 160.00$

$A_v = 100530.965$

$f_y = 555.56$

$s = 250.00$

$V_{s,c1}$ is multiplied by $\text{Col},c1 = 0.00$

$s/d = 1.5625$

$V_{s,c2} = 98297.73$ is calculated for section flange core, with:

$d = 440.00$

$A_v = 100530.965$

$f_y = 555.56$

$s = 250.00$

$V_{s,c2}$ 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 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, $t_{f1} = N_L * t / \text{NoDir} = 1.016$

$d_{fv} = d$ (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: $V_s + V_f \leq 915872.391$

$bw = 400.00$

Calculation of Shear Strength at edge 2, $V_{r2} = 1.0898E+006$

$V_{r2} = V_{Col} ((10.3), ASCE 41-17) = knl * V_{Col0}$

$V_{Col0} = 1.0898E+006$

$knl = 1$ (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: $f_c' = (f_c'_{jacket} * Area_{jacket} + f_c'_{core} * Area_{core}) / Area_{section} = 33.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 4.00$

$\mu_u = 1518.777$

$V_u = 0.0001715$

$d = 0.8 * h = 600.00$

$N_u = 16273.607$

$A_g = 300000.00$

From (11.5.4.8), ACI 318-14: $V_s = V_{s,jacket} + V_{s,core} = 901155.609$

where:

$V_{s,jacket} = V_{s,j1} + V_{s,j2} = 802857.879$

$V_{s,j1} = 279254.914$ is calculated for section web jacket, with:

$d = 320.00$

$A_v = 157079.633$

$f_y = 555.56$

$s = 100.00$

$V_{s,j1}$ is multiplied by $Col,j1 = 1.00$

$s/d = 0.3125$

$V_{s,j2} = 523602.964$ is calculated for section flange jacket, with:

$d = 600.00$

$A_v = 157079.633$

$f_y = 555.56$

$s = 100.00$

$V_{s,j2}$ is multiplied by $Col,j2 = 1.00$

$s/d = 0.16666667$

$V_{s,core} = V_{s,c1} + V_{s,c2} = 98297.73$

$V_{s,c1} = 0.00$ is calculated for section web core, with:

$d = 160.00$

$A_v = 100530.965$

$f_y = 555.56$

$s = 250.00$

$V_{s,c1}$ is multiplied by $Col,c1 = 0.00$

$s/d = 1.5625$

$V_{s,c2} = 98297.73$ is calculated for section flange core, with:

$d = 440.00$

$A_v = 100530.965$

$f_y = 555.56$

$s = 250.00$

$V_{s,c2}$ 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 $V_f(,)$, is implemented for every different fiber orientation a_i , as well as for 2 crack directions, $a = 45^\circ$ and $a = -45^\circ$ to take into consideration the cyclic seismic loading.

orientation 1: $\theta = b1 + 90^\circ = 90.00$

$V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, \theta)|)$, with:

total thickness per orientation, $t_{f1} = NL * t / \text{NoDir} = 1.016$

$d_{fv} = d$ (figure 11.2, ACI 440) = 707.00

$f_{fe} ((11-5), ACI 440) = 259.312$

$E_f = 64828.00$

fe = 0.004, from (11.6a), ACI 440
with fu = 0.01
From (11-11), ACI 440: Vs + Vf <= 915872.391
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, = 0.90
Chord Rotation is generally considered as Deformation-Controlled Action according to Table C7-1, ASCE 41-17.
Mean strengths are used for Deformation-Controlled Actions according to 7.5.1.3, ASCE 41-17
Consequently:
Jacket
New material of Secondary Member: Concrete Strength, fc = fcm = 33.00
New material of Secondary Member: Steel Strength, fs = fsm = 555.56
Concrete Elasticity, Ec = 26999.444
Steel Elasticity, Es = 200000.00
Existing Column
New material of Secondary Member: Concrete Strength, fc = fcm = 33.00
New material of Secondary Member: Steel Strength, fs = fsm = 555.56
Concrete Elasticity, Ec = 26999.444
Steel Elasticity, Es = 200000.00
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
Adequate Lap Length (lb/ld >= 1)
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

Bending Moment, M = 629358.106
Shear Force, V2 = 6058.142
Shear Force, V3 = -163.9376
Axial Force, F = -18615.215
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: Aslt = 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, $DbL = 16.80$

New component: From table 7-7, ASCE 41_17: Final chord rotation Capacity $u_{,R} = 1.0^*$ $u = 0.00306724$

$u = y + p = 0.00306724$

- Calculation of y -

$y = (My * Ls / 3) / Eleff = 0.00042575$ ((4.29), Biskinis Phd))

$My = 6.5012E+008$

$Ls = M/V$ (with $Ls > 0.1 * L$ and $Ls < 2 * L$) = 300.00

From table 10.5, ASCE 41_17: $Eleff = factor * Ec * Ig = 1.5270E+014$

$factor = 0.30$

$Ag = 440000.00$

Mean concrete strength: $fc' = (fc'_{jacket} * Area_{jacket} + fc'_{core} * Area_{core}) / Area_{section} = 33.00$

$N = 18615.215$

$Ec * Ig = Ec_{jacket} * Ig_{jacket} + Ec_{core} * Ig_{core} = 5.0901E+014$

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, $t = 400.00$

$y = \text{Min}(y_{ten}, y_{com})$

$y_{ten} = 4.8677145E-006$

with $fy = 555.56$

$d = 707.00$

$y = 0.19284589$

$A = 0.01015895$

$B = 0.00446935$

with $pt = 0.00671904$

$pc = 0.00416509$

$pv = 0.00378591$

$N = 18615.215$

$b = 750.00$

$" = 0.06082037$

$y_{comp} = 1.6459533E-005$

with $fc' (12.3, (ACI 440)) = 33.48734$

$fc = 33.00$

$fl = 0.49678681$

$b = b_{max} = 750.00$

$h = h_{max} = 750.00$

$Ag = 0.44$

$g = pt + pc + pv = 0.01009575$

$rc = 40.00$

$$A_e/A_c = 0.31291181$$

$$\text{Effective FRP thickness, } t_f = NL * t * \cos(b1) = 1.016$$

$$\text{effective strain from (12.5) and (12.12), } e_{fe} = 0.004$$

$$f_u = 0.01$$

$$E_f = 64828.00$$

$$E_c = 26999.444$$

$$y = 0.19184981$$

$$A = 0.01001713$$

$$B = 0.00440616$$

$$\text{with } E_s = 200000.00$$

$$\text{CONFIRMATION: } y = 0.19284589 < t/d$$

Calculation of ratio l_b/d

Adequate Lap Length: $l_b/d \geq 1$

- Calculation of p -

From table 10-8: $p = 0.00264149$

with:

- Columns not controlled by inadequate development or splicing along the clear height because $l_b/d \geq 1$

$$\text{shear control ratio } V_y E / V_{Co} I_{OE} = 1.05752$$

$$d = d_{\text{external}} = 707.00$$

$$s = s_{\text{external}} = 0.00$$

$$- t = s_1 + s_2 + 2 * t_f / b_w * (f_{fe} / f_s) = 0.00671904$$

$$\text{jacket: } s_1 = A_{v1} * L_{\text{stir1}} / (s_1 * A_g) = 0.00367709$$

$A_{v1} = 78.53982$, 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.

$$N_{UD} = 18615.215$$

$$A_g = 440000.00$$

$$f_{cE} = (f_{c_jacket} * \text{Area}_{\text{jacket}} + f_{c_core} * \text{Area}_{\text{core}}) / \text{section_area} = 33.00$$

$$f_{yIE} = (f_{y_ext_Long_Reinf} * \text{Area}_{\text{ext_Long_Reinf}} + f_{y_int_Long_Reinf} * \text{Area}_{\text{int_Long_Reinf}}) / \text{Area}_{\text{Tot_Long_Rein}} =$$

$$555.56$$

$$f_{ytE} = (f_{y_ext_Trans_Reinf} * s_1 + f_{y_int_Trans_Reinf} * s_2) / (s_1 + s_2) = 555.56$$

$$p_l = \text{Area}_{\text{Tot_Long_Rein}} / (b * d) = 0.01009575$$

$$b = 750.00$$

$$d = 707.00$$

$$f_{cE} = 33.00$$

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

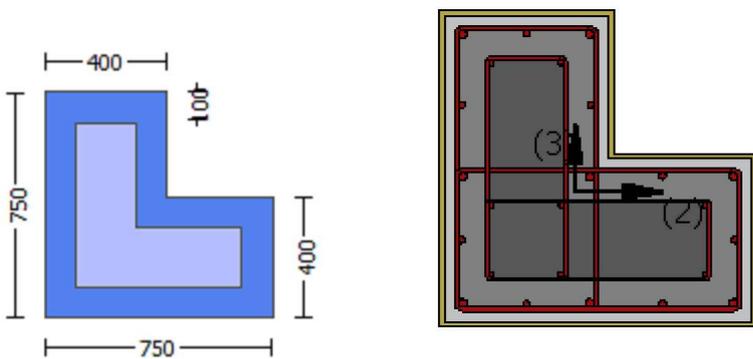
Limit State: Collapse Prevention (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Shear capacity VRd

Edge: Start

Local Axis: (2)



Start Of Calculation of Shear Capacity for element: column JLC1 of floor 1

At local axis: 2

Integration Section: (a)

Section Type: rcjlcs

Constant Properties

Knowledge Factor, $\gamma = 0.90$

Member Shear Force is generally considered as Force-Controlled Action according to Table C7-1, ASCE 41-17.

Lower-bound strengths are used for Force-Controlled Actions according to 7.5.1.3, ASCE 41-17

Consequently:

Jacket

New material of Secondary Member: Concrete Strength, $f_c = f_{c_lower_bound} = 25.00$

New material of Secondary Member: Steel Strength, $f_s = f_{s_lower_bound} = 500.00$

Concrete Elasticity, $E_c = 26999.444$

Steel Elasticity, $E_s = 200000.00$

Existing Column

New material of Secondary Member: Concrete Strength, $f_c = f_{c_lower_bound} = 25.00$

New material of Secondary Member: Steel Strength, $f_s = f_{s_lower_bound} = 500.00$

Concrete Elasticity, $E_c = 26999.444$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of γ for displacement ductility demand, the expected (mean value) strengths are used (7.5.1.3, ASCE 41-17) because bending is considered as Deformation-Controlled Action (Table C7-1, ASCE 41-17).

Jacket

New material: Concrete Strength, $f_c = f_{cm} = 33.00$

New material: Steel Strength, $f_s = f_{sm} = 555.56$

Existing Column

New material: Concrete Strength, $f_c = f_{cm} = 33.00$

New material: Steel Strength, $f_s = f_{sm} = 555.56$

#####

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
Adequate Lap Length ($l_o/l_{o,u,min} = l_b/l_d >= 1$)
FRP Wrapping Data
Type: Carbon
Cured laminate properties (design values)
Thickness, t = 1.016
Tensile Strength, $f_{fu} = 1055.00$
Tensile Modulus, $E_f = 64828.00$
Elongation, $e_{fu} = 0.01$
Number of directions, 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, $M_a = -1.5109E+007$
Shear Force, $V_a = -4866.131$
EDGE -B-
Bending Moment, $M_b = 505225.544$
Shear Force, $V_b = 4866.131$
BOTH EDGES
Axial Force, $F = -18154.476$
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, $Db_{L,ten} = 16.80$

New component: From table 7-7, ASCE 41_17: Final Shear Capacity $V_R = 1.0*V_n = 948969.187$
 $V_n ((10.3), ASCE 41-17) = k_n l * V_{CoI0} = 948969.187$
 $V_{CoI} = 948969.187$
 $k_n l = 1.00$
 $displacement_ductility_demand = 0.0121236$

NOTE: In expression (10-3) ' $V_s = A_v * f_y * d / s$ ' is replaced by ' $V_s + f * V_f$ '
where V_f is the contribution of FRPs (11.3), ACI 440).

= 1 (normal-weight concrete)
Mean concrete strength: $f'_c = (f'_c_jacket * Area_jacket + f'_c_core * Area_core) / Area_section = 25.00$, but $f'_c^{0.5} <= 8.3$
MPa (22.5.3.1, ACI 318-14)
 $M / Vd = 4.00$
 $M_u = 1.5109E+007$
 $V_u = 4866.131$
 $d = 0.8 * h = 600.00$
 $N_u = 18154.476$
 $A_g = 300000.00$
From (11.5.4.8), ACI 318-14: $V_s = V_{s,jacket} + V_{s,core} = 811033.559$

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 $Col,j2 = 1.00$

$$s/d = 0.16666667$$

$$V_{s,core} = V_{s,c1} + V_{s,c2} = 88467.249$$

$V_{s,c1} = 0.00$ is calculated for section web core, with:

$$d = 160.00$$

$$A_v = 100530.965$$

$$f_y = 500.00$$

$$s = 250.00$$

$V_{s,c1}$ is multiplied by $Col,c1 = 0.00$

$$s/d = 1.5625$$

$V_{s,c2} = 88467.249$ is calculated for section flange core, with:

$$d = 440.00$$

$$A_v = 100530.965$$

$$f_y = 500.00$$

$$s = 250.00$$

$V_{s,c2}$ is multiplied by $Col,c2 = 1.00$

$$s/d = 0.56818182$$

$$V_f((11-3)-(11.4), ACI 440) = 372533.843$$

$$f = 0.95, \text{ for fully-wrapped sections}$$

$w_f/s_f = 1$ (FRP strips adjacent to one another).

In (11.3) $\sin + \cos$ is replaced with $(\cot + \cot a)\sin a$ which is more a generalised expression,

where α is the angle of the crack direction (see KANEPE).

This later relation, considered as a function $V_f(\alpha)$, is implemented for every different fiber orientation α_i , as well as for 2 crack directions, $\alpha = 45^\circ$ and $\alpha = -45^\circ$ to take into consideration the cyclic seismic loading.

$$\text{orientation 1: } \alpha = b1 + 90^\circ = 90.00$$

$$V_f = \text{Min}(|V_f(45, \alpha)|, |V_f(-45, \alpha)|), \text{ with:}$$

$$\text{total thickness per orientation, } t_{f1} = NL * t / \text{NoDir} = 1.016$$

$$d_{fv} = d \text{ (figure 11.2, ACI 440)} = 707.00$$

$$f_{fe}((11-5), ACI 440) = 259.312$$

$$E_f = 64828.00$$

$$f_e = 0.004, \text{ from (11.6a), ACI 440}$$

$$\text{with } f_u = 0.01$$

$$\text{From (11-11), ACI 440: } V_s + V_f \leq 797164.595$$

$$b_w = 400.00$$

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 $\theta = 5.3408269E-005$

$$y = (M_y * L_s / 3) / E_{eff} = 0.00440532 \text{ ((4.29), Biskinis Phd)}$$

$$M_y = 6.4998E+008$$

$$L_s = M/V \text{ (with } L_s > 0.1 * L \text{ and } L_s < 2 * L) = 3104.846$$

$$\text{From table 10.5, ASCE 41_17: } E_{eff} = \text{factor} * E_c * I_g = 1.5270E+014$$

$$\text{factor} = 0.30$$

$$A_g = 440000.00$$

$$\text{Mean concrete strength: } f_c' = (f_c'_{jacket} * \text{Area}_{jacket} + f_c'_{core} * \text{Area}_{core}) / \text{Area}_{section} = 33.00$$

$$N = 18154.476$$

$$E_c * I_g = E_c * I_{g,jacket} + E_c * I_{g,core} = 5.0901E+014$$

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, $t = 400.00$

$y = \text{Min}(y_{\text{ten}}, y_{\text{com}})$

$y_{\text{ten}} = 4.8675041\text{E-}006$

with $f_y = 555.56$

$d = 707.00$

$y = 0.19281101$

$A = 0.01015738$

$B = 0.00446779$

with $p_t = 0.00214476$

$p_c = 0.00416509$

$p_v = 0.00378591$

$N = 18154.476$

$b = 750.00$

" = 0.06082037

$y_{\text{comp}} = 1.6460425\text{E-}005$

with f_c^* (12.3, (ACI 440)) = 33.48734

$f_c = 33.00$

$f_l = 0.49678681$

$b = b_{\text{max}} = 750.00$

$h = h_{\text{max}} = 750.00$

$A_g = 0.44$

$g = p_t + p_c + p_v = 0.01009575$

$r_c = 40.00$

$A_e/A_c = 0.31291181$

Effective FRP thickness, $t_f = NL*t*\text{Cos}(b1) = 1.016$

effective strain from (12.5) and (12.12), $e_{fe} = 0.004$

$f_u = 0.01$

$E_f = 64828.00$

$E_c = 26999.444$

$y = 0.19183941$

$A = 0.01001908$

$B = 0.00440616$

with $E_s = 200000.00$

CONFIRMATION: $y = 0.19281101 < t/d$

Calculation of ratio l_b/d

Adequate Lap Length: $l_b/d \geq 1$

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

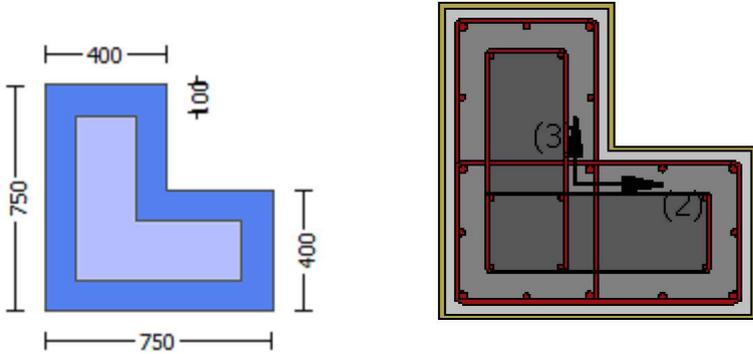
Limit State: Collapse Prevention (data interpolation between analysis steps 1 and 2)

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: rcjlcs

Constant Properties

Knowledge Factor, $\gamma = 0.90$

Mean strength values are used for both shear and moment calculations.

Consequently:

Jacket

New material of Secondary Member: Concrete Strength, $f_c = f_{cm} = 33.00$

New material of Secondary Member: Steel Strength, $f_s = f_{sm} = 555.56$

Concrete Elasticity, $E_c = 26999.444$

Steel Elasticity, $E_s = 200000.00$

Existing Column

New material of Secondary Member: Concrete Strength, $f_c = f_{cm} = 33.00$

New material of Secondary Member: Steel Strength, $f_s = f_{sm} = 555.56$

Concrete Elasticity, $E_c = 26999.444$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14

Jacket

New material: Steel Strength, $f_s = 1.25 \cdot f_{sm} = 694.45$

Existing Column

New material: Steel Strength, $f_s = 1.25 \cdot f_{sm} = 694.45$

#####

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
Adequate Lap Length ($l_o/l_{ou}, \min \geq 1$)
FRP Wrapping Data
Type: Carbon
Cured laminate properties (design values)
Thickness, $t = 1.016$
Tensile Strength, $f_{fu} = 1055.00$
Tensile Modulus, $E_f = 64828.00$
Elongation, $e_{fu} = 0.01$
Number of directions, $N_{oDir} = 1$
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, $V_a = -0.00017144$
EDGE -B-
Shear Force, $V_b = 0.00017144$
BOTH EDGES
Axial Force, $F = -16273.607$
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, $V_e/V_r = 1.05752$
Member Controlled by Shear ($V_e/V_r > 1$)
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 1.1525E+006$
with
 $M_{pr1} = \text{Max}(\mu_{u1+}, \mu_{u1-}) = 1.7288E+009$
 $\mu_{u1+} = 1.1540E+009$, is the ultimate moment strength at the edge 1 of the member in the actual moment direction
which is defined for the static loading combination
 $\mu_{u1-} = 1.7288E+009$, is the ultimate moment strength at the edge 1 of the member in the opposite moment
direction which is defined for the static loading combination
 $M_{pr2} = \text{Max}(\mu_{u2+}, \mu_{u2-}) = 1.7288E+009$
 $\mu_{u2+} = 1.1540E+009$, is the ultimate moment strength at the edge 2 of the member in the actual moment direction
which is defined for the the static loading combination
 $\mu_{u2-} = 1.7288E+009$, 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_{u1+}

Calculation of ultimate curvature ϕ_u according to 4.1, Biskinis/Fardis 2013:
 $\phi_u = 5.0226943E-005$
 $M_u = 1.1540E+009$

with full section properties:

$b = 750.00$
 $d = 707.00$
 $d' = 43.00$
 $v = 0.00093001$
 $N = 16273.607$
 $f_c = 33.00$

$$c_o (5A.5, TBDY) = 0.002$$

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.01291652$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } c_u = 0.01291652$$

$$\text{we ((5.4c), TBDY) } = a_{se} * s_{h,min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.05541928$$

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 $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.31984848$$

$$\text{with Unconfined area} = ((b_{max} - 2R)^2 + (h_{max} - 2R)^2) / 3 = 140733.333$$

$$b_{max} = 750.00$$

$$h_{max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 870.5244$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N_L * t * \text{Cos}(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$a_{se} ((5.4d), TBDY) = (a_{se1} * A_{ext} + a_{se2} * A_{int}) / A_{sec} = 0.45746528$$

$$a_{se1} = \text{Max}(((A_{conf,max1} - A_{noConf1}) / A_{conf,max1}) * (A_{conf,min1} / A_{conf,max1}), 0) = 0.45746528$$

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).

$$p_{sh,min} * F_{ywe} = \text{Min}(p_{sh,x} * F_{ywe}, p_{sh,y} * F_{ywe}) = 3.0194$$

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)

$$p_{sh,x} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{sh2} * F_{ywe2} = 3.0194$$

$$p_{sh1} ((5.4d), TBDY) = L_{stir1} * A_{stir1} / (A_{sec} * s_1) = 0.00367709$$

$$L_{stir1} (\text{Length of stirrups along } Y) = 2060.00$$

$$A_{stir1} (\text{stirrups area}) = 78.53982$$

$$p_{sh2} (5.4d) = L_{stir2} * A_{stir2} / (A_{sec} * s_2) = 0.00067082$$

$$L_{stir2} (\text{Length of stirrups along } Y) = 1468.00$$

$$\text{Astir2 (stirrups area)} = 50.26548$$

$$\text{psh}_y * \text{Fywe} = \text{psh}_1 * \text{Fywe}_1 + \text{ps}_2 * \text{Fywe}_2 = 3.0194$$

$$\text{psh}_1 ((5.4d), \text{TBDY}) = \text{Lstir}_1 * \text{Astir}_1 / (\text{Asec} * \text{s}_1) = 0.00367709$$

$$\text{Lstir}_1 (\text{Length of stirrups along X}) = 2060.00$$

$$\text{Astir}_1 (\text{stirrups area}) = 78.53982$$

$$\text{psh}_2 ((5.4d), \text{TBDY}) = \text{Lstir}_2 * \text{Astir}_2 / (\text{Asec} * \text{s}_2) = 0.00067082$$

$$\text{Lstir}_2 (\text{Length of stirrups along X}) = 1468.00$$

$$\text{Astir}_2 (\text{stirrups area}) = 50.26548$$

$$\text{Asec} = 440000.00$$

$$\text{s}_1 = 100.00$$

$$\text{s}_2 = 250.00$$

$$\text{fywe}_1 = 694.45$$

$$\text{fywe}_2 = 694.45$$

$$\text{fce} = 33.00$$

$$\text{From } ((5.A.5), \text{TBDY}), \text{TBDY: } \text{cc} = 0.00238888$$

$$\text{c} = \text{confinement factor} = 1.03889$$

$$\text{y}_1 = 0.0025$$

$$\text{sh}_1 = 0.008$$

$$\text{ft}_1 = 833.34$$

$$\text{fy}_1 = 694.45$$

$$\text{su}_1 = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$\text{lo/lou, min} = \text{lb/ld} = 1.00$$

$$\text{su}_1 = 0.4 * \text{esu}_1 \text{ nominal } ((5.5), \text{TBDY}) = 0.032$$

$$\text{From table 5A.1, TBDY: } \text{esu}_1 \text{ nominal} = 0.08,$$

For calculation of esu1_nominal and y1, sh1, ft1, fy1, it is considered
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

$$\text{y}_1, \text{sh}_1, \text{ft}_1, \text{fy}_1, \text{ are also multiplied by } \text{Min}(1, 1.25 * (\text{lb/ld})^{2/3}), \text{ from 10.3.5, ASCE 41-17.}$$

$$\text{with } \text{fs}_1 = (\text{fs}_{\text{jacket}} * \text{Asl}_{\text{ten, jacket}} + \text{fs}_{\text{core}} * \text{Asl}_{\text{ten, core}}) / \text{Asl}_{\text{ten}} = 694.45$$

$$\text{with } \text{Es}_1 = (\text{Es}_{\text{jacket}} * \text{Asl}_{\text{ten, jacket}} + \text{Es}_{\text{core}} * \text{Asl}_{\text{ten, core}}) / \text{Asl}_{\text{ten}} = 200000.00$$

$$\text{y}_2 = 0.0025$$

$$\text{sh}_2 = 0.008$$

$$\text{ft}_2 = 833.34$$

$$\text{fy}_2 = 694.45$$

$$\text{su}_2 = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$\text{lo/lou, min} = \text{lb/lb, min} = 1.00$$

$$\text{su}_2 = 0.4 * \text{esu}_2 \text{ nominal } ((5.5), \text{TBDY}) = 0.032$$

$$\text{From table 5A.1, TBDY: } \text{esu}_2 \text{ nominal} = 0.08,$$

For calculation of esu2_nominal and y2, sh2, ft2, fy2, it is considered
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

$$\text{y}_2, \text{sh}_2, \text{ft}_2, \text{fy}_2, \text{ are also multiplied by } \text{Min}(1, 1.25 * (\text{lb/ld})^{2/3}), \text{ from 10.3.5, ASCE 41-17.}$$

$$\text{with } \text{fs}_2 = (\text{fs}_{\text{jacket}} * \text{Asl}_{\text{com, jacket}} + \text{fs}_{\text{core}} * \text{Asl}_{\text{com, core}}) / \text{Asl}_{\text{com}} = 694.45$$

$$\text{with } \text{Es}_2 = (\text{Es}_{\text{jacket}} * \text{Asl}_{\text{com, jacket}} + \text{Es}_{\text{core}} * \text{Asl}_{\text{com, core}}) / \text{Asl}_{\text{com}} = 200000.00$$

$$\text{y}_v = 0.0025$$

$$\text{sh}_v = 0.008$$

$$\text{ft}_v = 833.34$$

$$\text{fy}_v = 694.45$$

$$\text{suv} = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$\text{lo/lou, min} = \text{lb/ld} = 1.00$$

$$\text{suv} = 0.4 * \text{esuv}_v \text{ nominal } ((5.5), \text{TBDY}) = 0.032$$

$$\text{From table 5A.1, TBDY: } \text{esuv}_v \text{ nominal} = 0.08,$$

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.

$$\text{y}_v, \text{sh}_v, \text{ft}_v, \text{fy}_v, \text{ are also multiplied by } \text{Min}(1, 1.25 * (\text{lb/ld})^{2/3}), \text{ from 10.3.5, ASCE 41-17.}$$

$$\text{with } \text{fs}_v = (\text{fs}_{\text{jacket}} * \text{Asl}_{\text{mid, jacket}} + \text{fs}_{\text{mid}} * \text{Asl}_{\text{mid, core}}) / \text{Asl}_{\text{mid}} = 694.45$$

$$\text{with } \text{Esv} = (\text{Es}_{\text{jacket}} * \text{Asl}_{\text{mid, jacket}} + \text{Es}_{\text{mid}} * \text{Asl}_{\text{mid, core}}) / \text{Asl}_{\text{mid}} = 200000.00$$

$$1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.0451341$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.08764993$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.07967042$$

and confined core properties:

$$b = 690.00$$

$$d = 677.00$$

$$d' = 13.00$$

$$f_{cc} (5A.2, TBDY) = 34.2833$$

$$c_c (5A.5, TBDY) = 0.00238888$$

$$c = \text{confinement factor} = 1.03889$$

$$1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.05123276$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.09949345$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.09043572$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < v_{s,y2}$ - LHS eq.(4.5) is satisfied

--->

$$s_u (4.9) = 0.09885678$$

$$\mu_u = M_{Rc} (4.14) = 1.1540E+009$$

$$u = s_u (4.1) = 5.0226943E-005$$

 Calculation of ratio l_b/d

 Adequate Lap Length: $l_b/d \geq 1$

 Calculation of μ_{u1} -

 Calculation of ultimate curvature μ_u according to 4.1, Biskinis/Fardis 2013:

$$u = 6.4288704E-005$$

$$\mu_u = 1.7288E+009$$

 with full section properties:

$$b = 400.00$$

$$d = 707.00$$

$$d' = 43.00$$

$$v = 0.00174378$$

$$N = 16273.607$$

$$f_c = 33.00$$

$$c_c (5A.5, TBDY) = 0.002$$

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.01291652$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } c_u = 0.01291652$$

$$w_e ((5.4c), TBDY) = a_{se} * s_{h,min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.05541928$$

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 $a_f = 1 - (\text{Unconfined area})/(\text{total area})$

$$a_f = 0.31984848$$

$$\text{with Unconfined area} = ((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 140733.333$$

$$b_{max} = 750.00$$

$$h_{max} = 750.00$$

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, $tf = NL*t*Cos(b1) = 1.016$

$f_u,f = 1055.00$

$E_f = 64828.00$

$u,f = 0.015$

$ase((5.4d), TBDY) = (ase1*Aext+ase2*Aint)/Asec = 0.45746528$

$ase1 = Max(((Aconf,max1-AnoConf1)/Aconf,max1)*(Aconf,min1/Aconf,max1),0) = 0.45746528$

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 $bi^2/6$ 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 $bi^2/6$ as defined at (A.2).

$psh,min*Fywe = Min(psh,x*Fywe, psh,y*Fywe) = 3.0194$

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)

$psh_x*Fywe = psh1*Fywe1+ps2*Fywe2 = 3.0194$

$psh1((5.4d), TBDY) = Lstir1*Astir1/(Asec*s1) = 0.00367709$

$Lstir1$ (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

$psh_y*Fywe = psh1*Fywe1+ps2*Fywe2 = 3.0194$

$psh1((5.4d), TBDY) = Lstir1*Astir1/(Asec*s1) = 0.00367709$

$Lstir1$ (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

$Asec = 440000.00$

$s1 = 100.00$

$s2 = 250.00$

$fywe1 = 694.45$

$fywe2 = 694.45$

$fce = 33.00$

From ((5.A5), TBDY), TBDY: $cc = 0.00238888$

$c =$ confinement factor = 1.03889

$y1 = 0.0025$

$sh1 = 0.008$

$ft1 = 833.34$

$fy1 = 694.45$

$su1 = 0.032$

using (30) in Biskinis/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 = 1.00

su1 = 0.4*esu1_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu1_nominal = 0.08,

For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/d)^ 2/3), from 10.3.5, ASCE 41-17.

with fs1 = (fs,jacket*Asl,ten,jacket + fs,core*Asl,ten,core)/Asl,ten = 694.45

with Es1 = (Es,jacket*Asl,ten,jacket + Es,core*Asl,ten,core)/Asl,ten = 200000.00

y2 = 0.0025

sh2 = 0.008

ft2 = 833.34

fy2 = 694.45

su2 = 0.032

using (30) in Biskinis/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 = 1.00

su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu2_nominal = 0.08,

For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/d)^ 2/3), from 10.3.5, ASCE 41-17.

with fs2 = (fs,jacket*Asl,com,jacket + fs,core*Asl,com,core)/Asl,com = 694.45

with Es2 = (Es,jacket*Asl,com,jacket + Es,core*Asl,com,core)/Asl,com = 200000.00

yv = 0.0025

shv = 0.008

ftv = 833.34

fyv = 694.45

suv = 0.032

using (30) in Biskinis/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 = 1.00

suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esuv_nominal = 0.08,

considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY
For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered
characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/d)^ 2/3), from 10.3.5, ASCE 41-17.

with fsv = (fs,jacket*Asl,mid,jacket + fs,mid*Asl,mid,core)/Asl,mid = 694.45

with Esv = (Es,jacket*Asl,mid,jacket + Es,mid*Asl,mid,core)/Asl,mid = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.16434361

2 = Asl,com/(b*d)*(fs2/fc) = 0.08462644

v = Asl,mid/(b*d)*(fsv/fc) = 0.14938203

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) = 0.20191317

2 = Asl,com/(b*d)*(fs2/fc) = 0.10397236

v = Asl,mid/(b*d)*(fsv/fc) = 0.18353132

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

v < vs,y2 - LHS eq.(4.5) is not satisfied

--->

v < vs,c - RHS eq.(4.5) is satisfied

--->

su (4.8) = 0.29596233

Mu = MRc (4.15) = 1.7288E+009

u = su (4.1) = 6.4288704E-005

Calculation of ratio l_b/d

Adequate Lap Length: $l_b/d \geq 1$

Calculation of μ_{2+}

Calculation of ultimate curvature μ according to 4.1, Biskinis/Fardis 2013:

$\mu = 5.0226943E-005$

$\mu_{2+} = 1.1540E+009$

with full section properties:

$b = 750.00$

$d = 707.00$

$d' = 43.00$

$v = 0.00093001$

$N = 16273.607$

$f_c = 33.00$

ω (5A.5, TBDY) = 0.002

Final value of μ_{cu} : $\mu_{cu}^* = \text{shear_factor} * \text{Max}(\mu_{cu}, \mu_{cc}) = 0.01291652$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $\mu_{cu} = 0.01291652$

ω_{we} ((5.4c), TBDY) = $\omega_{se} * \text{sh}_{,min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.05541928$

where $f = \omega_{pf} * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$f_x = 0.04286225$

Expression ((15B.6), TBDY) is modified as $\omega_{af} = 1 - (\text{Unconfined area}) / (\text{total area})$

$\omega_{af} = 0.31984848$

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), $\omega_{pf} = 2t_f / b_w = 0.00508$

$b_w = 400.00$

effective stress from (A.35), $f_{fe} = 870.5244$

$f_y = 0.04286225$

Expression ((15B.6), TBDY) is modified as $\omega_{af} = 1 - (\text{Unconfined area}) / (\text{total area})$

$\omega_{af} = 0.31984848$

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), $\omega_{pf} = 2t_f / b_w = 0.00508$

$b_w = 400.00$

effective stress from (A.35), $f_{fe} = 870.5244$

$R = 40.00$

Effective FRP thickness, $t_f = N L * t * \text{Cos}(b_1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$\omega_{u,f} = 0.015$

ω_{ase} ((5.4d), TBDY) = $(\omega_{ase1} * A_{ext} + \omega_{ase2} * A_{int}) / A_{sec} = 0.45746528$

$\omega_{ase1} = \text{Max}(((A_{conf,max1} - A_{noConf1}) / A_{conf,max1}) * (A_{conf,min1} / A_{conf,max1}), 0) = 0.45746528$

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.

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).

$psh_{,min} * Fy_{we} = \text{Min}(psh_x * Fy_{we}, psh_y * Fy_{we}) = 3.0194$

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)

 $psh_x * Fy_{we} = psh_1 * Fy_{we1} + ps_2 * Fy_{we2} = 3.0194$

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

 $psh_y * Fy_{we} = psh_1 * Fy_{we1} + ps_2 * Fy_{we2} = 3.0194$

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

 $A_{sec} = 440000.00$

$s_1 = 100.00$

$s_2 = 250.00$

$fy_{we1} = 694.45$

$fy_{we2} = 694.45$

$f_{ce} = 33.00$

From ((5.A.5), TBDY), TBDY: $cc = 0.00238888$

$c =$ confinement factor = 1.03889

$y_1 = 0.0025$

$sh_1 = 0.008$

$ft_1 = 833.34$

$fy_1 = 694.45$

$su_1 = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with

Shear_factor = 1.00

$l_o/l_{o,min} = l_b/l_d = 1.00$

$su_1 = 0.4 * esu_{1,nominal}$ ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: $esu_{1,nominal} = 0.08$,

For calculation of $esu_{1,nominal}$ and y_1, sh_1, ft_1, fy_1 , it is considered characteristic value $fs_1 = f_s/1.2$, 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 $fs_1 = (f_{s,jacket} * A_{s,ten,jacket} + f_{s,core} * A_{s,ten,core}) / A_{s,ten} = 694.45$

with $Es_1 = (E_{s,jacket} * A_{s,ten,jacket} + E_{s,core} * A_{s,ten,core}) / A_{s,ten} = 200000.00$

$y_2 = 0.0025$

$sh_2 = 0.008$

$ft_2 = 833.34$

$fy_2 = 694.45$

$su_2 = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with

Shear_factor = 1.00

$l_o/l_{o,min} = l_b/l_{b,min} = 1.00$

$su_2 = 0.4 * esu_{2,nominal}$ ((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 $fs2 = (fs_jacket \cdot Asl,com,jacket + fs_core \cdot Asl,com,core) / Asl,com = 694.45$

with $Es2 = (Es_jacket \cdot Asl,com,jacket + Es_core \cdot Asl,com,core) / Asl,com = 200000.00$

$yv = 0.0025$

$shv = 0.008$

$ftv = 833.34$

$fyv = 694.45$

$suv = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with $shear_factor$

and also multiplied by the $shear_factor$ according to 15.7.1.4, with $Shear_factor = 1.00$

$lo/lo, min = lb/ld = 1.00$

$suv = 0.4 \cdot esuv_nominal$ ((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 $fsv = (fs_jacket \cdot Asl,mid,jacket + fs_mid \cdot Asl,mid,core) / Asl,mid = 694.45$

with $Esv = (Es_jacket \cdot Asl,mid,jacket + Es_mid \cdot Asl,mid,core) / Asl,mid = 200000.00$

$1 = Asl,ten / (b \cdot d) \cdot (fs1 / fc) = 0.0451341$

$2 = Asl,com / (b \cdot d) \cdot (fs2 / fc) = 0.08764993$

$v = Asl,mid / (b \cdot d) \cdot (fsv / fc) = 0.07967042$

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

$1 = Asl,ten / (b \cdot d) \cdot (fs1 / fc) = 0.05123276$

$2 = Asl,com / (b \cdot d) \cdot (fs2 / fc) = 0.09949345$

$v = Asl,mid / (b \cdot d) \cdot (fsv / fc) = 0.09043572$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < vs,y2$ - LHS eq.(4.5) is satisfied

--->

su (4.9) = 0.09885678

$Mu = MRc$ (4.14) = 1.1540E+009

$u = su$ (4.1) = 5.0226943E-005

Calculation of ratio lb/ld

Adequate Lap Length: $lb/ld \geq 1$

Calculation of $Mu2$ -

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

$u = 6.4288704E-005$

$Mu = 1.7288E+009$

with full section properties:

$b = 400.00$

$d = 707.00$

$d' = 43.00$

$v = 0.00174378$

$N = 16273.607$

$fc = 33.00$

$$c_o (5A.5, TBDY) = 0.002$$

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.01291652$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } c_u = 0.01291652$$

$$\text{we ((5.4c), TBDY) } = a_{se} * s_{h,min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.05541928$$

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 $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.31984848$$

$$\text{with Unconfined area} = ((b_{max} - 2R)^2 + (h_{max} - 2R)^2) / 3 = 140733.333$$

$$b_{max} = 750.00$$

$$h_{max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 870.5244$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N_L * t * \text{Cos}(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$a_{se} ((5.4d), TBDY) = (a_{se1} * A_{ext} + a_{se2} * A_{int}) / A_{sec} = 0.45746528$$

$$a_{se1} = \text{Max}(((A_{conf,max1} - A_{noConf1}) / A_{conf,max1}) * (A_{conf,min1} / A_{conf,max1}), 0) = 0.45746528$$

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).

$$p_{sh,min} * F_{ywe} = \text{Min}(p_{sh,x} * F_{ywe}, p_{sh,y} * F_{ywe}) = 3.0194$$

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)

$$p_{sh,x} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{sh2} * F_{ywe2} = 3.0194$$

$$p_{sh1} ((5.4d), TBDY) = L_{stir1} * A_{stir1} / (A_{sec} * s_1) = 0.00367709$$

$$L_{stir1} (\text{Length of stirrups along } Y) = 2060.00$$

$$A_{stir1} (\text{stirrups area}) = 78.53982$$

$$p_{sh2} (5.4d) = L_{stir2} * A_{stir2} / (A_{sec} * s_2) = 0.00067082$$

$$L_{stir2} (\text{Length of stirrups along } Y) = 1468.00$$

$$\text{Astir2 (stirrups area)} = 50.26548$$

$$\text{psh}_y * \text{Fywe} = \text{psh}_1 * \text{Fywe}_1 + \text{ps}_2 * \text{Fywe}_2 = 3.0194$$

$$\text{psh}_1 ((5.4d), \text{TBDY}) = \text{Lstir}_1 * \text{Astir}_1 / (\text{Asec} * \text{s}_1) = 0.00367709$$

$$\text{Lstir}_1 (\text{Length of stirrups along X}) = 2060.00$$

$$\text{Astir}_1 (\text{stirrups area}) = 78.53982$$

$$\text{psh}_2 ((5.4d), \text{TBDY}) = \text{Lstir}_2 * \text{Astir}_2 / (\text{Asec} * \text{s}_2) = 0.00067082$$

$$\text{Lstir}_2 (\text{Length of stirrups along X}) = 1468.00$$

$$\text{Astir}_2 (\text{stirrups area}) = 50.26548$$

$$\text{Asec} = 440000.00$$

$$\text{s}_1 = 100.00$$

$$\text{s}_2 = 250.00$$

$$\text{fywe}_1 = 694.45$$

$$\text{fywe}_2 = 694.45$$

$$\text{fce} = 33.00$$

$$\text{From } ((5.A.5), \text{TBDY}), \text{TBDY: } \text{cc} = 0.00238888$$

$$\text{c} = \text{confinement factor} = 1.03889$$

$$\text{y}_1 = 0.0025$$

$$\text{sh}_1 = 0.008$$

$$\text{ft}_1 = 833.34$$

$$\text{fy}_1 = 694.45$$

$$\text{su}_1 = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$\text{lo/lou,min} = \text{lb/ld} = 1.00$$

$$\text{su}_1 = 0.4 * \text{esu}_1 \text{nominal } ((5.5), \text{TBDY}) = 0.032$$

$$\text{From table 5A.1, TBDY: } \text{esu}_1 \text{nominal} = 0.08,$$

For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

$$\text{y}_1, \text{sh}_1, \text{ft}_1, \text{fy}_1, \text{ are also multiplied by } \text{Min}(1, 1.25 * (\text{lb/ld})^{2/3}), \text{ from 10.3.5, ASCE 41-17.}$$

$$\text{with } \text{fs}_1 = (\text{fs,jacket} * \text{Asl,ten,jacket} + \text{fs,core} * \text{Asl,ten,core}) / \text{Asl,ten} = 694.45$$

$$\text{with } \text{Es}_1 = (\text{Es,jacket} * \text{Asl,ten,jacket} + \text{Es,core} * \text{Asl,ten,core}) / \text{Asl,ten} = 200000.00$$

$$\text{y}_2 = 0.0025$$

$$\text{sh}_2 = 0.008$$

$$\text{ft}_2 = 833.34$$

$$\text{fy}_2 = 694.45$$

$$\text{su}_2 = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$\text{lo/lou,min} = \text{lb/lb,min} = 1.00$$

$$\text{su}_2 = 0.4 * \text{esu}_2 \text{nominal } ((5.5), \text{TBDY}) = 0.032$$

$$\text{From table 5A.1, TBDY: } \text{esu}_2 \text{nominal} = 0.08,$$

For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

$$\text{y}_2, \text{sh}_2, \text{ft}_2, \text{fy}_2, \text{ are also multiplied by } \text{Min}(1, 1.25 * (\text{lb/ld})^{2/3}), \text{ from 10.3.5, ASCE 41-17.}$$

$$\text{with } \text{fs}_2 = (\text{fs,jacket} * \text{Asl,com,jacket} + \text{fs,core} * \text{Asl,com,core}) / \text{Asl,com} = 694.45$$

$$\text{with } \text{Es}_2 = (\text{Es,jacket} * \text{Asl,com,jacket} + \text{Es,core} * \text{Asl,com,core}) / \text{Asl,com} = 200000.00$$

$$\text{y}_v = 0.0025$$

$$\text{sh}_v = 0.008$$

$$\text{ft}_v = 833.34$$

$$\text{fy}_v = 694.45$$

$$\text{suv} = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$\text{lo/lou,min} = \text{lb/ld} = 1.00$$

$$\text{suv} = 0.4 * \text{esuv}_v \text{nominal } ((5.5), \text{TBDY}) = 0.032$$

$$\text{From table 5A.1, TBDY: } \text{esuv}_v \text{nominal} = 0.08,$$

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.

$$\text{y}_v, \text{sh}_v, \text{ft}_v, \text{fy}_v, \text{ are also multiplied by } \text{Min}(1, 1.25 * (\text{lb/ld})^{2/3}), \text{ from 10.3.5, ASCE 41-17.}$$

$$\text{with } \text{fs}_v = (\text{fs,jacket} * \text{Asl,mid,jacket} + \text{fs,mid} * \text{Asl,mid,core}) / \text{Asl,mid} = 694.45$$

$$\text{with } \text{Esv} = (\text{Es,jacket} * \text{Asl,mid,jacket} + \text{Es,mid} * \text{Asl,mid,core}) / \text{Asl,mid} = 200000.00$$

$$1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.16434361$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.08462644$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.14938203$$

and confined core properties:

$$b = 340.00$$

$$d = 677.00$$

$$d' = 13.00$$

$$f_{cc} (5A.2, TBDY) = 34.2833$$

$$c_c (5A.5, TBDY) = 0.00238888$$

$$c = \text{confinement factor} = 1.03889$$

$$1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.20191317$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.10397236$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.18353132$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < v_{s,y2}$ - LHS eq.(4.5) is not satisfied

--->

$v < v_{s,c}$ - RHS eq.(4.5) is satisfied

--->

$$s_u (4.8) = 0.29596233$$

$$M_u = M_{Rc} (4.15) = 1.7288E+009$$

$$u = s_u (4.1) = 6.4288704E-005$$

Calculation of ratio l_b/l_d

Adequate Lap Length: $l_b/l_d \geq 1$

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 1.0898E+006$

Calculation of Shear Strength at edge 1, $V_{r1} = 1.0898E+006$

$$V_{r1} = V_{Col} ((10.3), ASCE 41-17) = k_{nl} * V_{Col0}$$

$$V_{Col0} = 1.0898E+006$$

$$k_{nl} = 1 \text{ (zero step-static loading)}$$

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)

$$\text{Mean concrete strength: } f_c' = (f_c'_{jacket} * \text{Area}_{jacket} + f_c'_{core} * \text{Area}_{core}) / \text{Area}_{section} = 33.00, \text{ but } f_c'^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

$$M/Vd = 4.00$$

$$M_u = 1518.01$$

$$V_u = 0.00017144$$

$$d = 0.8 * h = 600.00$$

$$N_u = 16273.607$$

$$A_g = 300000.00$$

$$\text{From (11.5.4.8), ACI 318-14: } V_s = V_{sjacket} + V_{s,core} = 901155.609$$

where:

$$V_{sjacket} = V_{sj1} + V_{sj2} = 802857.879$$

$V_{sj1} = 523602.964$ is calculated for section web jacket, with:

$$d = 600.00$$

$$A_v = 157079.633$$

$$f_y = 555.56$$

$$s = 100.00$$

V_{sj1} is multiplied by $Col_{j1} = 1.00$

$$s/d = 0.16666667$$

$V_{sj2} = 279254.914$ is calculated for section flange jacket, with:

$$d = 320.00$$

$$A_v = 157079.633$$

$$f_y = 555.56$$

$$s = 100.00$$

V_{sj2} is multiplied by $Col_{j2} = 1.00$

$s/d = 0.3125$
 $V_{s,core} = V_{s,c1} + V_{s,c2} = 98297.73$
 $V_{s,c1} = 98297.73$ is calculated for section web core, with:
 $d = 440.00$
 $A_v = 100530.965$
 $f_y = 555.56$
 $s = 250.00$
 $V_{s,c1}$ is multiplied by $Col,c1 = 1.00$
 $s/d = 0.56818182$
 $V_{s,c2} = 0.00$ is calculated for section flange core, with:
 $d = 160.00$
 $A_v = 100530.965$
 $f_y = 555.56$
 $s = 250.00$
 $V_{s,c2}$ 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
 $wf/sf = 1$ (FRP strips adjacent to one another).
 \ln (11.3) $\sin + \cos$ is replaced with $(\cot + \cot a)\sin a$ which is more a generalised expression,
 where 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: $\theta = 45^\circ$
 $V_f = \text{Min}(|V_f(45^\circ)|, |V_f(-45^\circ)|)$, 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: $V_s + V_f \leq 915872.391$
 $b_w = 400.00$

Calculation of Shear Strength at edge 2, $V_{r2} = 1.0898E+006$
 $V_{r2} = V_{Col}$ ((10.3), ASCE 41-17) = $k_n l \cdot V_{Col0}$
 $V_{Col0} = 1.0898E+006$
 $k_n l = 1$ (zero step-static loading)

NOTE: In expression (10-3) ' $V_s = A_v \cdot f_y \cdot d / s$ ' is replaced by ' $V_s + f \cdot V_f$ '
 where V_f is the contribution of FRPs (11.3), ACI 440).

$\lambda = 1$ (normal-weight concrete)
 Mean concrete strength: $f_c' = (f_c'_{jacket} \cdot Area_{jacket} + f_c'_{core} \cdot Area_{core}) / Area_{section} = 33.00$, but $f_c'^{0.5} \leq 8.3$
 MPa (22.5.3.1, ACI 318-14)
 $M/Vd = 4.00$
 $\mu_u = 1518.01$
 $\nu_u = 0.00017144$
 $d = 0.8 \cdot h = 600.00$
 $N_u = 16273.607$
 $A_g = 300000.00$
 From (11.5.4.8), ACI 318-14: $V_s = V_{s,jacket} + V_{s,core} = 901155.609$
 where:
 $V_{s,jacket} = V_{s,j1} + V_{s,j2} = 802857.879$
 $V_{s,j1} = 523602.964$ is calculated for section web jacket, with:
 $d = 600.00$
 $A_v = 157079.633$
 $f_y = 555.56$
 $s = 100.00$
 $V_{s,j1}$ is multiplied by $Col,j1 = 1.00$
 $s/d = 0.16666667$
 $V_{s,j2} = 279254.914$ is calculated for section flange jacket, with:
 $d = 320.00$
 $A_v = 157079.633$
 $f_y = 555.56$
 $s = 100.00$

V_{s,j2} is multiplied by Col,j2 = 1.00
s/d = 0.3125

V_{s,core} = V_{s,c1} + V_{s,c2} = 98297.73

V_{s,c1} = 98297.73 is calculated for section web core, with:
d = 440.00

A_v = 100530.965
f_y = 555.56
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 = 555.56
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

wf/sf = 1 (FRP strips adjacent to one another).

In (11.3) sin + cos is replaced with (cot + cota)sinα 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(α, a_i), is implemented for every different fiber orientation a_i,
as well as for 2 crack directions, α = 45° and α = -45° to take into consideration the cyclic seismic loading.

orientation 1: α = b1 + 90° = 90.00

V_f = Min(|V_f(45, a₁)|, |V_f(-45, a₁)|), with:

total thickness per orientation, t_{f1} = NL*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 ≤ 915872.391

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, k = 0.90

Mean strength values are used for both shear and moment calculations.

Consequently:

Jacket

New material of Secondary Member: Concrete Strength, f_c = f_{cm} = 33.00

New material of Secondary Member: Steel Strength, f_s = f_{sm} = 555.56

Concrete Elasticity, E_c = 26999.444

Steel Elasticity, E_s = 200000.00

Existing Column

New material of Secondary Member: Concrete Strength, f_c = f_{cm} = 33.00

New material of Secondary Member: Steel Strength, f_s = f_{sm} = 555.56

Concrete Elasticity, E_c = 26999.444

Steel Elasticity, E_s = 200000.00

#####

Note: Especially for the calculation of moment strengths,

the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14

Jacket

New material: Steel Strength, f_s = 1.25*f_{sm} = 694.45

Existing Column

New material: Steel Strength, $f_s = 1.25 \cdot f_{sm} = 694.45$

#####

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

Adequate Lap Length ($l_o/l_{ou,min} > 1$)

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $e_{fu} = 0.01$

Number of directions, $NoDir = 1$

Fiber orientations, $b_i = 0.00^\circ$

Number of layers, $NL = 1$

Radius of rounding corners, $R = 40.00$

Stepwise Properties

At local axis: 2

EDGE -A-

Shear Force, $V_a = -0.0001715$

EDGE -B-

Shear Force, $V_b = 0.0001715$

BOTH EDGES

Axial Force, $F = -16273.607$

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 , $V_e/V_r = 1.05752$

Member Controlled by Shear ($V_e/V_r > 1$)

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 1.1525E+006$

with

$M_{pr1} = \text{Max}(\mu_{1+}, \mu_{1-}) = 1.7288E+009$

$\mu_{1+} = 1.1540E+009$, 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

$\mu_{1-} = 1.7288E+009$, 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

$M_{pr2} = \text{Max}(\mu_{2+}, \mu_{2-}) = 1.7288E+009$

$\mu_{2+} = 1.1540E+009$, 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

$\mu_{2-} = 1.7288E+009$, 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 ϕ_u according to 4.1, Biskinis/Fardis 2013:

$$u = 5.0226943E-005$$

$$\mu = 1.1540E+009$$

with full section properties:

$$b = 750.00$$

$$d = 707.00$$

$$d' = 43.00$$

$$v = 0.00093001$$

$$N = 16273.607$$

$$f_c = 33.00$$

$$\alpha (5A.5, \text{TBDY}) = 0.002$$

$$\text{Final value of } \phi_u: \phi_u = \text{shear_factor} * \text{Max}(\phi_{cu}, \phi_{cc}) = 0.01291652$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \phi_{cu} = 0.01291652$$

$$\phi_{cc} \text{ ((5.4c), TBDY) } = \alpha * \text{sh}_{,\min} * f_{ywe} / f_{ce} + \text{Min}(\phi_{fx}, \phi_{fy}) = 0.05541928$$

where $\phi_{fx} = \alpha * \rho_f * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$\phi_{fx} = 0.04286225$$

Expression ((15B.6), TBDY) is modified as $\alpha_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$\alpha_f = 0.31984848$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 140733.333$$

$$b_{\max} = 750.00$$

$$h_{\max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } \rho_f = 2t_f / b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{fe} = 870.5244$$

$$\phi_{fy} = 0.04286225$$

Expression ((15B.6), TBDY) is modified as $\alpha_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$\alpha_f = 0.31984848$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 140733.333$$

$$b_{\max} = 750.00$$

$$h_{\max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } \rho_f = 2t_f / b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{fe} = 870.5244$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L * t * \text{Cos}(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$\alpha_{se} \text{ ((5.4d), TBDY) } = (\alpha_{se1} * A_{ext} + \alpha_{se2} * A_{int}) / A_{sec} = 0.45746528$$

$$\alpha_{se1} = \text{Max}(((A_{conf,max1} - A_{noConf1}) / A_{conf,max1}) * (A_{conf,min1} / A_{conf,max1}), 0) = 0.45746528$$

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).

$$\alpha_{se2} (\geq \alpha_{se1}) = \text{Max}(((A_{conf,max2} - A_{noConf2}) / A_{conf,max2}) * (A_{conf,min2} / A_{conf,max2}), 0) = 0.45746528$$

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.

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).
 $psh,min*Fywe = \text{Min}(psh,x*Fywe, psh,y*Fywe) = 3.0194$

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)

 $psh_x*Fywe = psh1*Fywe1 + ps2*Fywe2 = 3.0194$
 $psh1$ ((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

 $psh_y*Fywe = psh1*Fywe1 + ps2*Fywe2 = 3.0194$
 $psh1$ ((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 = 694.45
fywe2 = 694.45
fce = 33.00

From ((5.A5), TBDY), TBDY: cc = 0.00238888
c = confinement factor = 1.03889

y1 = 0.0025
sh1 = 0.008
ft1 = 833.34
fy1 = 694.45
su1 = 0.032

using (30) in Biskinis/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 = 1.00

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 $fs1 = (fs,jacket*Asl,ten,jacket + fs,core*Asl,ten,core)/Asl,ten = 694.45$

with $Es1 = (Es,jacket*Asl,ten,jacket + Es,core*Asl,ten,core)/Asl,ten = 200000.00$

y2 = 0.0025
sh2 = 0.008
ft2 = 833.34
fy2 = 694.45
su2 = 0.032

using (30) in Biskinis/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 = 1.00

su2 = $0.4*esu2_nominal$ ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu2_nominal = 0.08,

For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered characteristic value $fsy2 = fs2/1.2$, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25*(lb/ld)^{2/3})$, from 10.3.5, ASCE 41-17.

with $fs2 = (fs,jacket*Asl,com,jacket + fs,core*Asl,com,core)/Asl,com = 694.45$

with $Es2 = (Es,jacket*Asl,com,jacket + Es,core*Asl,com,core)/Asl,com = 200000.00$

yv = 0.0025
shv = 0.008
ftv = 833.34

$f_{yv} = 694.45$
 $s_{uv} = 0.032$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $l_o/l_{ou,min} = l_b/l_d = 1.00$
 $s_{uv} = 0.4 * e_{suv_nominal} ((5.5), TBDY) = 0.032$
 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 $f_{sv} = (f_{s,jacket} * A_{s,mid,jacket} + f_{s,mid} * A_{s,mid,core}) / A_{s,mid} = 694.45$
 with $E_{sv} = (E_{s,jacket} * A_{s,mid,jacket} + E_{s,mid} * A_{s,mid,core}) / A_{s,mid} = 200000.00$
 $1 = A_{s,ten} / (b * d) * (f_{s1} / f_c) = 0.0451341$
 $2 = A_{s,com} / (b * d) * (f_{s2} / f_c) = 0.08764993$
 $v = A_{s,mid} / (b * d) * (f_{sv} / f_c) = 0.07967042$
 and confined core properties:
 $b = 690.00$
 $d = 677.00$
 $d' = 13.00$
 $f_{cc} (5A.2, TBDY) = 34.2833$
 $cc (5A.5, TBDY) = 0.00238888$
 $c = \text{confinement factor} = 1.03889$
 $1 = A_{s,ten} / (b * d) * (f_{s1} / f_c) = 0.05123276$
 $2 = A_{s,com} / (b * d) * (f_{s2} / f_c) = 0.09949345$
 $v = A_{s,mid} / (b * d) * (f_{sv} / f_c) = 0.09043572$
 Case/Assumption: Unconfined full section - Steel rupture
 ' satisfies Eq. (4.3)

--->
 $v < v_{s,y2}$ - LHS eq.(4.5) is satisfied
 --->
 $su (4.9) = 0.09885678$
 $Mu = MRc (4.14) = 1.1540E+009$
 $u = su (4.1) = 5.0226943E-005$

 Calculation of ratio l_b/l_d

Adequate Lap Length: $l_b/l_d \geq 1$

Calculation of Mu_1 -

 Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

$u = 6.4288704E-005$
 $Mu = 1.7288E+009$

 with full section properties:

$b = 400.00$
 $d = 707.00$
 $d' = 43.00$
 $v = 0.00174378$
 $N = 16273.607$
 $f_c = 33.00$
 $co (5A.5, TBDY) = 0.002$
 Final value of cu : $cu^* = \text{shear_factor} * \text{Max}(cu, cc) = 0.01291652$
 The Shear_factor is considered equal to 1 (pure moment strength)
 From (5.4b), TBDY: $cu = 0.01291652$
 $we ((5.4c), TBDY) = a_s * sh_{,min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.05541928$
 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 $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

af = 0.31984848
with Unconfined area = $((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 140733.333$
bmax = 750.00
hmax = 750.00
From EC8 A.4.4.3(6), pf = $2t_f/b_w = 0.00508$
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 = $((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 140733.333$
bmax = 750.00
hmax = 750.00
From EC8 A.4.4.3(6), pf = $2t_f/b_w = 0.00508$
bw = 400.00
effective stress from (A.35), ff,e = 870.5244

R = 40.00
Effective FRP thickness, tf = $NL*t*\text{Cos}(b_1) = 1.016$
fu,f = 1055.00
Ef = 64828.00
u,f = 0.015

ase ((5.4d), TBDY) = $(ase_1*A_{ext} + ase_2*A_{int})/A_{sec} = 0.45746528$

ase1 = $\text{Max}(((A_{conf,max1} - A_{noConf1})/A_{conf,max1}) * (A_{conf,min1}/A_{conf,max1}), 0) = 0.45746528$

The definitions of 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 ($\geq ase_1$) = $\text{Max}(((A_{conf,max2} - A_{noConf2})/A_{conf,max2}) * (A_{conf,min2}/A_{conf,max2}), 0) = 0.45746528$

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*Fywe = $\text{Min}(psh_x*Fywe, psh_y*Fywe) = 3.0194$

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 = $psh_1*Fywe_1 + ps_2*Fywe_2 = 3.0194$
psh1 ((5.4d), TBDY) = $L_{stir1}*A_{stir1}/(A_{sec}*s_1) = 0.00367709$
Lstir1 (Length of stirrups along Y) = 2060.00
Astir1 (stirrups area) = 78.53982
psh2 ((5.4d), TBDY) = $L_{stir2}*A_{stir2}/(A_{sec}*s_2) = 0.00067082$
Lstir2 (Length of stirrups along Y) = 1468.00
Astir2 (stirrups area) = 50.26548

psh_y*Fywe = $psh_1*Fywe_1 + ps_2*Fywe_2 = 3.0194$
psh1 ((5.4d), TBDY) = $L_{stir1}*A_{stir1}/(A_{sec}*s_1) = 0.00367709$
Lstir1 (Length of stirrups along X) = 2060.00
Astir1 (stirrups area) = 78.53982
psh2 ((5.4d), TBDY) = $L_{stir2}*A_{stir2}/(A_{sec}*s_2) = 0.00067082$
Lstir2 (Length of stirrups along X) = 1468.00
Astir2 (stirrups area) = 50.26548

Asec = 440000.00

s1 = 100.00

s2 = 250.00

fywe1 = 694.45

fywe2 = 694.45

fce = 33.00

From ((5.A.5), TBDY), TBDY: cc = 0.00238888

c = confinement factor = 1.03889

y1 = 0.0025

sh1 = 0.008

ft1 = 833.34

fy1 = 694.45

su1 = 0.032

using (30) in Biskinis/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 = 1.00

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 = (fsjacket*Asl,ten,jacket + fs,core*Asl,ten,core)/Asl,ten = 694.45

with Es1 = (Es,jacket*Asl,ten,jacket + Es,core*Asl,ten,core)/Asl,ten = 200000.00

y2 = 0.0025

sh2 = 0.008

ft2 = 833.34

fy2 = 694.45

su2 = 0.032

using (30) in Biskinis/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 = 1.00

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 = (fsjacket*Asl,com,jacket + fs,core*Asl,com,core)/Asl,com = 694.45

with Es2 = (Es,jacket*Asl,com,jacket + Es,core*Asl,com,core)/Asl,com = 200000.00

yv = 0.0025

shv = 0.008

ftv = 833.34

fyv = 694.45

suv = 0.032

using (30) in Biskinis/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 = 1.00

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 = 694.45

with Esv = (Es,jacket*Asl,mid,jacket + Es,mid*Asl,mid,core)/Asl,mid = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.16434361

2 = Asl,com/(b*d)*(fs2/fc) = 0.08462644

v = Asl,mid/(b*d)*(fsv/fc) = 0.14938203

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 = $Asl_{ten}/(b*d)*(fs1/fc) = 0.20191317$

2 = $Asl_{com}/(b*d)*(fs2/fc) = 0.10397236$

v = $Asl_{mid}/(b*d)*(fsv/fc) = 0.18353132$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

v < $v_{s,y2}$ - LHS eq.(4.5) is not satisfied

v < $v_{s,c}$ - RHS eq.(4.5) is satisfied

su (4.8) = 0.29596233

Mu = MRc (4.15) = 1.7288E+009

u = su (4.1) = 6.4288704E-005

Calculation of ratio lb/l_d

Adequate Lap Length: lb/l_d >= 1

Calculation of Mu₂₊

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

u = 5.0226943E-005

Mu = 1.1540E+009

with full section properties:

b = 750.00

d = 707.00

d' = 43.00

v = 0.00093001

N = 16273.607

fc = 33.00

co (5A.5, TBDY) = 0.002

Final value of cu: cu* = shear_factor * Max(cu, cc) = 0.01291652

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: cu = 0.01291652

we ((5.4c), TBDY) = ase* sh,min*fywe/fce+Min(fx, fy) = 0.05541928

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), ffe = 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), ffe = 870.5244

R = 40.00

Effective FRP thickness, tf = NL*t*Cos(b1) = 1.016

fu,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).

$$p_{sh,min} * F_{ywe} = \text{Min}(p_{sh,x} * F_{ywe}, p_{sh,y} * F_{ywe}) = 3.0194$$

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)

$$p_{sh,x} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{sh2} * F_{ywe2} = 3.0194$$

$$p_{sh1} \text{ ((5.4d), TBDY)} = L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00367709$$

$$L_{stir1} \text{ (Length of stirrups along Y)} = 2060.00$$

$$A_{stir1} \text{ (stirrups area)} = 78.53982$$

$$p_{sh2} \text{ (5.4d)} = L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00067082$$

$$L_{stir2} \text{ (Length of stirrups along Y)} = 1468.00$$

$$A_{stir2} \text{ (stirrups area)} = 50.26548$$

$$p_{sh,y} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{sh2} * F_{ywe2} = 3.0194$$

$$p_{sh1} \text{ ((5.4d), TBDY)} = L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00367709$$

$$L_{stir1} \text{ (Length of stirrups along X)} = 2060.00$$

$$A_{stir1} \text{ (stirrups area)} = 78.53982$$

$$p_{sh2} \text{ ((5.4d), TBDY)} = L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00067082$$

$$L_{stir2} \text{ (Length of stirrups along X)} = 1468.00$$

$$A_{stir2} \text{ (stirrups area)} = 50.26548$$

$$A_{sec} = 440000.00$$

$$s1 = 100.00$$

$$s2 = 250.00$$

$$f_{ywe1} = 694.45$$

$$f_{ywe2} = 694.45$$

$$f_{ce} = 33.00$$

$$\text{From ((5.A5), TBDY), TBDY: } c_c = 0.00238888$$

$$c = \text{confinement factor} = 1.03889$$

$$y1 = 0.0025$$

$$sh1 = 0.008$$

$$ft1 = 833.34$$

$$fy1 = 694.45$$

$$su1 = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$$l_o / l_{ou,min} = l_b / l_d = 1.00$$

$$su1 = 0.4 * esu1_{nominal} \text{ ((5.5), TBDY)} = 0.032$$

$$\text{From table 5A.1, TBDY: } esu1_{nominal} = 0.08,$$

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 $f_{s1} = (f_{s,jacket} \cdot A_{s,ten,jacket} + f_{s,core} \cdot A_{s,ten,core})/A_{s,ten} = 694.45$

with $E_{s1} = (E_{s,jacket} \cdot A_{s,ten,jacket} + E_{s,core} \cdot A_{s,ten,core})/A_{s,ten} = 200000.00$

$y_2 = 0.0025$

$sh_2 = 0.008$

$ft_2 = 833.34$

$fy_2 = 694.45$

$su_2 = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor

and also multiplied by the shear_factor according to 15.7.1.4, with

Shear_factor = 1.00

$l_o/l_{o,min} = l_b/l_{b,min} = 1.00$

$su_2 = 0.4 \cdot esu_{2,nominal} ((5.5), TBDY) = 0.032$

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 $f_{s2} = (f_{s,jacket} \cdot A_{s,com,jacket} + f_{s,core} \cdot A_{s,com,core})/A_{s,com} = 694.45$

with $E_{s2} = (E_{s,jacket} \cdot A_{s,com,jacket} + E_{s,core} \cdot A_{s,com,core})/A_{s,com} = 200000.00$

$y_v = 0.0025$

$sh_v = 0.008$

$ft_v = 833.34$

$fy_v = 694.45$

$su_v = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor

and also multiplied by the shear_factor according to 15.7.1.4, with

Shear_factor = 1.00

$l_o/l_{o,min} = l_b/l_d = 1.00$

$su_v = 0.4 \cdot esuv_{nominal} ((5.5), TBDY) = 0.032$

From table 5A.1, TBDY: $esuv_{nominal} = 0.08$,

considering characteristic value $f_{syv} = f_{sv}/1.2$, from table 5.1, TBDY

For calculation of $esuv_{nominal}$ and y_v, sh_v, ft_v, fy_v , it is considered

characteristic value $f_{syv} = f_{sv}/1.2$, 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 $f_{sv} = (f_{s,jacket} \cdot A_{s,mid,jacket} + f_{s,mid} \cdot A_{s,mid,core})/A_{s,mid} = 694.45$

with $E_{sv} = (E_{s,jacket} \cdot A_{s,mid,jacket} + E_{s,mid} \cdot A_{s,mid,core})/A_{s,mid} = 200000.00$

$1 = A_{s,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.0451341$

$2 = A_{s,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.08764993$

$v = A_{s,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.07967042$

and confined core properties:

$b = 690.00$

$d = 677.00$

$d' = 13.00$

$f_{cc} (5A.2, TBDY) = 34.2833$

$cc (5A.5, TBDY) = 0.00238888$

$c = \text{confinement factor} = 1.03889$

$1 = A_{s,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.05123276$

$2 = A_{s,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.09949345$

$v = A_{s,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.09043572$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

---->

$v < v_{s,y2}$ - LHS eq.(4.5) is satisfied

---->

$su (4.9) = 0.09885678$

$Mu = MRc (4.14) = 1.1540E+009$

$u = su (4.1) = 5.0226943E-005$

Calculation of ratio l_b/l_d

Adequate Lap Length: $l_b/l_d \geq 1$

Calculation of Mu_2 -

Calculation of ultimate curvature ϕ_u according to 4.1, Biskinis/Fardis 2013:

$$u = 6.4288704E-005$$

$$\mu = 1.7288E+009$$

with full section properties:

$$b = 400.00$$

$$d = 707.00$$

$$d' = 43.00$$

$$v = 0.00174378$$

$$N = 16273.607$$

$$f_c = 33.00$$

$$\alpha_{co} (5A.5, TBDY) = 0.002$$

$$\text{Final value of } \phi_u: \phi_u = \text{shear_factor} * \text{Max}(\phi_{cu}, \phi_{cc}) = 0.01291652$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \phi_{cu} = 0.01291652$$

$$\phi_{we} ((5.4c), TBDY) = \alpha_{se} * \text{sh}_{, \text{min}} * f_{ywe} / f_{ce} + \text{Min}(\phi_{fx}, \phi_{fy}) = 0.05541928$$

where $\phi_f = \alpha_f * \rho_f * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$\phi_{fx} = 0.04286225$$

Expression ((15B.6), TBDY) is modified as $\alpha_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$\alpha_f = 0.31984848$$

$$\text{with Unconfined area} = ((b_{\text{max}} - 2R)^2 + (h_{\text{max}} - 2R)^2) / 3 = 140733.333$$

$$b_{\text{max}} = 750.00$$

$$h_{\text{max}} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } \rho_f = 2t_f / b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 870.5244$$

$$\phi_{fy} = 0.04286225$$

Expression ((15B.6), TBDY) is modified as $\alpha_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$\alpha_f = 0.31984848$$

$$\text{with Unconfined area} = ((b_{\text{max}} - 2R)^2 + (h_{\text{max}} - 2R)^2) / 3 = 140733.333$$

$$b_{\text{max}} = 750.00$$

$$h_{\text{max}} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } \rho_f = 2t_f / b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 870.5244$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L * t * \text{Cos}(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$\alpha_{se} ((5.4d), TBDY) = (\alpha_{se1} * A_{\text{ext}} + \alpha_{se2} * A_{\text{int}}) / A_{\text{sec}} = 0.45746528$$

$$\alpha_{se1} = \text{Max}(((A_{\text{conf,max1}} - A_{\text{noConf1}}) / A_{\text{conf,max1}}) * (A_{\text{conf,min1}} / A_{\text{conf,max1}}), 0) = 0.45746528$$

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.

$A_{\text{conf,min1}} = 293525.00$ 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).

$$\alpha_{se2} (\geq \alpha_{se1}) = \text{Max}(((A_{\text{conf,max2}} - A_{\text{noConf2}}) / A_{\text{conf,max2}}) * (A_{\text{conf,min2}} / A_{\text{conf,max2}}), 0) = 0.45746528$$

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.

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).
 $psh,min*Fywe = \text{Min}(psh,x*Fywe, psh,y*Fywe) = 3.0194$

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)

 $psh_x*Fywe = psh1*Fywe1 + ps2*Fywe2 = 3.0194$
 $psh1$ ((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

 $psh_y*Fywe = psh1*Fywe1 + ps2*Fywe2 = 3.0194$
 $psh1$ ((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 = 694.45
fywe2 = 694.45
fce = 33.00

From ((5.A5), TBDY), TBDY: cc = 0.00238888
c = confinement factor = 1.03889

y1 = 0.0025
sh1 = 0.008
ft1 = 833.34
fy1 = 694.45
su1 = 0.032

using (30) in Biskinis/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 = 1.00

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 $fs1 = (fs,jacket*Asl,ten,jacket + fs,core*Asl,ten,core)/Asl,ten = 694.45$

with $Es1 = (Es,jacket*Asl,ten,jacket + Es,core*Asl,ten,core)/Asl,ten = 200000.00$

y2 = 0.0025
sh2 = 0.008
ft2 = 833.34
fy2 = 694.45
su2 = 0.032

using (30) in Biskinis/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 = 1.00

su2 = $0.4*esu2_nominal$ ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu2_nominal = 0.08,

For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered characteristic value $fsy2 = fs2/1.2$, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25*(lb/ld)^{2/3})$, from 10.3.5, ASCE 41-17.

with $fs2 = (fs,jacket*Asl,com,jacket + fs,core*Asl,com,core)/Asl,com = 694.45$

with $Es2 = (Es,jacket*Asl,com,jacket + Es,core*Asl,com,core)/Asl,com = 200000.00$

yv = 0.0025
shv = 0.008
ftv = 833.34

$f_{yv} = 694.45$
 $s_{uv} = 0.032$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $l_o/l_{ou,min} = l_b/l_d = 1.00$
 $s_{uv} = 0.4 * e_{suv_nominal} ((5.5), TBDY) = 0.032$
 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 $f_{sv} = (f_{s,jacket} * A_{sl,mid,jacket} + f_{s,mid} * A_{sl,mid,core}) / A_{sl,mid} = 694.45$
 with $E_{sv} = (E_{s,jacket} * A_{sl,mid,jacket} + E_{s,mid} * A_{sl,mid,core}) / A_{sl,mid} = 200000.00$
 $1 = A_{sl,ten} / (b * d) * (f_{s1} / f_c) = 0.16434361$
 $2 = A_{sl,com} / (b * d) * (f_{s2} / f_c) = 0.08462644$
 $v = A_{sl,mid} / (b * d) * (f_{sv} / f_c) = 0.14938203$

and confined core properties:

$b = 340.00$
 $d = 677.00$
 $d' = 13.00$
 $f_{cc} (5A.2, TBDY) = 34.2833$
 $cc (5A.5, TBDY) = 0.00238888$
 $c = \text{confinement factor} = 1.03889$
 $1 = A_{sl,ten} / (b * d) * (f_{s1} / f_c) = 0.20191317$
 $2 = A_{sl,com} / (b * d) * (f_{s2} / f_c) = 0.10397236$
 $v = A_{sl,mid} / (b * d) * (f_{sv} / f_c) = 0.18353132$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

$v < v_{s,y2}$ - LHS eq.(4.5) is not satisfied

$v < v_{s,c}$ - RHS eq.(4.5) is satisfied

$su (4.8) = 0.29596233$

$Mu = MRc (4.15) = 1.7288E+009$

$u = su (4.1) = 6.4288704E-005$

 Calculation of ratio l_b/l_d

Adequate Lap Length: $l_b/l_d \geq 1$

 Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 1.0898E+006$

 Calculation of Shear Strength at edge 1, $V_{r1} = 1.0898E+006$

$V_{r1} = V_{Col} ((10.3), ASCE 41-17) = k_{nl} * V_{Col0}$

$V_{Col0} = 1.0898E+006$

$k_{nl} = 1$ (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: $f'_c = (f'_{c,jacket} * Area_{jacket} + f'_{c,core} * Area_{core}) / Area_{section} = 33.00$, but $f_c^{0.5} \leq 8.3$
 MPa (22.5.3.1, ACI 318-14)

$M/Vd = 4.00$

$Mu = 1518.777$

$Vu = 0.0001715$

$d = 0.8 * h = 600.00$

$Nu = 16273.607$

$Ag = 300000.00$

From (11.5.4.8), ACI 318-14: $V_s = V_{s,jacket} + V_{s,core} = 901155.609$

where:

$$V_{s,jacket} = V_{s,j1} + V_{s,j2} = 802857.879$$

$V_{s,j1} = 279254.914$ is calculated for section web jacket, with:

$$d = 320.00$$

$$A_v = 157079.633$$

$$f_y = 555.56$$

$$s = 100.00$$

$V_{s,j1}$ is multiplied by $Col,j1 = 1.00$

$$s/d = 0.3125$$

$V_{s,j2} = 523602.964$ is calculated for section flange jacket, with:

$$d = 600.00$$

$$A_v = 157079.633$$

$$f_y = 555.56$$

$$s = 100.00$$

$V_{s,j2}$ is multiplied by $Col,j2 = 1.00$

$$s/d = 0.16666667$$

$$V_{s,core} = V_{s,c1} + V_{s,c2} = 98297.73$$

$V_{s,c1} = 0.00$ is calculated for section web core, with:

$$d = 160.00$$

$$A_v = 100530.965$$

$$f_y = 555.56$$

$$s = 250.00$$

$V_{s,c1}$ is multiplied by $Col,c1 = 0.00$

$$s/d = 1.5625$$

$V_{s,c2} = 98297.73$ is calculated for section flange core, with:

$$d = 440.00$$

$$A_v = 100530.965$$

$$f_y = 555.56$$

$$s = 250.00$$

$V_{s,c2}$ is multiplied by $Col,c2 = 1.00$

$$s/d = 0.56818182$$

$V_f ((11-3)-(11.4), ACI 440) = 372533.843$

$$f = 0.95, \text{ for fully-wrapped sections}$$

$w_f/s_f = 1$ (FRP strips adjacent to one another).

In (11.3) $\sin + \cos$ is replaced with $(\cot + \cot a) \sin a$ which is more a generalised expression, where α is the angle of the crack direction (see KANEPE).

This later relation, considered as a function $V_f(\alpha, a_1)$, 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: $\alpha = b_1 + 90^\circ = 90.00$

$V_f = \text{Min}(|V_f(45, \alpha_1)|, |V_f(-45, \alpha_1)|)$, with:

total thickness per orientation, $tf_1 = NL * t / NoDir = 1.016$

$df_v = d$ (figure 11.2, ACI 440) = 707.00

$ffe ((11-5), ACI 440) = 259.312$

$$E_f = 64828.00$$

$$f_e = 0.004, \text{ from (11.6a), ACI 440}$$

$$\text{with } f_u = 0.01$$

From (11-11), ACI 440: $V_s + V_f \leq 915872.391$

$$bw = 400.00$$

Calculation of Shear Strength at edge 2, $V_{r2} = 1.0898E+006$

$V_{r2} = V_{Col} ((10.3), ASCE 41-17) = knl * V_{Col0}$

$$V_{Col0} = 1.0898E+006$$

$knl = 1$ (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: $f_c' = (f_c'_{jacket} * Area_{jacket} + f_c'_{core} * Area_{core}) / Area_{section} = 33.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$$M/Vd = 4.00$$

$$Mu = 1518.777$$

$$Vu = 0.0001715$$

$$d = 0.8 * h = 600.00$$

$$Nu = 16273.607$$

$$Ag = 300000.00$$

From (11.5.4.8), ACI 318-14: $V_s = V_{s,jacket} + V_{s,core} = 901155.609$

where:

$$V_{s,jacket} = V_{s,j1} + V_{s,j2} = 802857.879$$

$V_{s,j1} = 279254.914$ is calculated for section web jacket, with:

$$d = 320.00$$

$$A_v = 157079.633$$

$$f_y = 555.56$$

$$s = 100.00$$

$V_{s,j1}$ is multiplied by $Col,j1 = 1.00$

$$s/d = 0.3125$$

$V_{s,j2} = 523602.964$ is calculated for section flange jacket, with:

$$d = 600.00$$

$$A_v = 157079.633$$

$$f_y = 555.56$$

$$s = 100.00$$

$V_{s,j2}$ is multiplied by $Col,j2 = 1.00$

$$s/d = 0.16666667$$

$$V_{s,core} = V_{s,c1} + V_{s,c2} = 98297.73$$

$V_{s,c1} = 0.00$ is calculated for section web core, with:

$$d = 160.00$$

$$A_v = 100530.965$$

$$f_y = 555.56$$

$$s = 250.00$$

$V_{s,c1}$ is multiplied by $Col,c1 = 0.00$

$$s/d = 1.5625$$

$V_{s,c2} = 98297.73$ is calculated for section flange core, with:

$$d = 440.00$$

$$A_v = 100530.965$$

$$f_y = 555.56$$

$$s = 250.00$$

$V_{s,c2}$ is multiplied by $Col,c2 = 1.00$

$$s/d = 0.56818182$$

$$V_f((11-3)-(11.4), ACI 440) = 372533.843$$

$$f = 0.95, \text{ for fully-wrapped sections}$$

$w_f/s_f = 1$ (FRP strips adjacent to one another).

In (11.3) $\sin + \cos$ is replaced with $(\cot + \cot a)\sin a$ which is more a generalised expression,

where a is the angle of the crack direction (see KANEPE).

This later relation, considered as a function $V_f(\theta, a)$, is implemented for every different fiber orientation a_i , as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.

$$\text{orientation 1: } \theta = b1 + 90^\circ = 90.00$$

$$V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, a1)|), \text{ with:}$$

$$\text{total thickness per orientation, } t_{f1} = NL * t / \text{NoDir} = 1.016$$

$$d_{fv} = d \text{ (figure 11.2, ACI 440)} = 707.00$$

$$f_{fe}((11-5), ACI 440) = 259.312$$

$$E_f = 64828.00$$

$$f_e = 0.004, \text{ from (11.6a), ACI 440}$$

$$\text{with } f_u = 0.01$$

$$\text{From (11-11), ACI 440: } V_s + V_f \leq 915872.391$$

$$b_w = 400.00$$

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: (a)

Section Type: rcjlc

Constant Properties

Knowledge Factor, $\gamma = 0.90$

Chord Rotation is generally considered as Deformation-Controlled Action according to Table C7-1, ASCE 41-17.

Mean strengths are used for Deformation-Controlled Actions according to 7.5.1.3, ASCE 41-17

Consequently:

Jacket

New material of Secondary Member: Concrete Strength, $f_c = f_{cm} = 33.00$

New material of Secondary Member: Steel Strength, $f_s = f_{sm} = 555.56$

Concrete Elasticity, $E_c = 26999.444$

Steel Elasticity, $E_s = 200000.00$

Existing Column

New material of Secondary Member: Concrete Strength, $f_c = f_{cm} = 33.00$

New material of Secondary Member: Steel Strength, $f_s = f_{sm} = 555.56$

Concrete Elasticity, $E_c = 26999.444$

Steel Elasticity, $E_s = 200000.00$

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

Adequate Lap Length ($l_b/l_d > 1$)

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $e_{fu} = 0.01$

Number of directions, $N_{oDir} = 1$

Fiber orientations, $b_i = 0.00^\circ$

Number of layers, $N_L = 1$

Radius of rounding corners, $R = 40.00$

Stepwise Properties

Bending Moment, $M = -320844.41$

Shear Force, $V_2 = -4866.131$

Shear Force, $V_3 = 131.6809$

Axial Force, $F = -18154.476$

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: $A_{sl,mid} = 2007.478$

Longitudinal External Reinforcement Area Distribution (in 3 divisions)

-Tension: $A_{sl,ten,jacket} = 829.3805$

-Compression: $A_{sl,com,jacket} = 1746.726$

-Middle: $A_{sl,mid,jacket} = 1545.664$

Longitudinal Internal Reinforcement Area Distribution (in 3 divisions)

-Tension: $A_{sl,ten,core} = 307.8761$

-Compression: $A_{sl,com,core} = 461.8141$

-Middle: $A_{sl,mid,core} = 461.8141$

Mean Diameter of Tension Reinforcement, $DbL = 16.80$

New component: From table 7-7, ASCE 41_17: Final chord rotation Capacity $u_{,R} = 1.0^*$ $u = 0.05378656$

$u = y + p = 0.05378656$

- Calculation of y -

$y = (M_y * L_s / 3) / E_{eff} = 0.00345707$ ((4.29), Biskinis Phd)
 $M_y = 6.4998E+008$
 $L_s = M/V$ (with $L_s > 0.1 * L$ and $L_s < 2 * L$) = 2436.529
 From table 10.5, ASCE 41_17: $E_{eff} = factor * E_c * I_g = 1.5270E+014$
 $factor = 0.30$
 $A_g = 440000.00$
 Mean concrete strength: $f_c' = (f_c'_{jacket} * Area_{jacket} + f_c'_{core} * Area_{core}) / Area_{section} = 33.00$
 $N = 18154.476$
 $E_c * I_g = E_c_{jacket} * I_{g_{jacket}} + E_c_{core} * I_{g_{core}} = 5.0901E+014$

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, $t = 400.00$

$y = \text{Min}(y_{ten}, y_{com})$
 $y_{ten} = 4.8675041E-006$
 with $f_y = 555.56$
 $d = 707.00$
 $y = 0.19281101$
 $A = 0.01015738$
 $B = 0.00446779$
 with $p_t = 0.00671904$
 $p_c = 0.00416509$
 $p_v = 0.00378591$
 $N = 18154.476$
 $b = 750.00$
 $" = 0.06082037$
 $y_{comp} = 1.6460425E-005$
 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), $\epsilon_{fe} = 0.004$
 $f_u = 0.01$
 $E_f = 64828.00$
 $E_c = 26999.444$
 $y = 0.19183941$
 $A = 0.01001908$
 $B = 0.00440616$
 with $E_s = 200000.00$
 CONFIRMATION: $y = 0.19281101 < t/d$

Calculation of ratio l_b/d

Adequate Lap Length: $l_b/d \geq 1$

- Calculation of p -

From table 10-8: $p = 0.05032949$

with:

- Columns not controlled by inadequate development or splicing along the clear height because $l_b/d \geq 1$

shear control ratio $V_{yE}/V_{CoI0E} = 1.05752$

$d = d_{\text{external}} = 707.00$

$s = s_{\text{external}} = 0.00$

$t = s_1 + s_2 + 2 \cdot t_f / b_w \cdot (f_{fe}/f_s) = 0.00671904$

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

$s_1 = 100.00$

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.

$N_{UD} = 18154.476$

$A_g = 440000.00$

$f_{cE} = (f_{c_jacket} \cdot \text{Area_jacket} + f_{c_core} \cdot \text{Area_core}) / \text{section_area} = 33.00$

$f_{yIE} = (f_{y_ext_Long_Reinf} \cdot \text{Area_ext_Long_Reinf} + f_{y_int_Long_Reinf} \cdot \text{Area_int_Long_Reinf}) / \text{Area_Tot_Long_Rein} = 555.56$

$f_{yIE} = (f_{y_ext_Trans_Reinf} \cdot s_1 + f_{y_int_Trans_Reinf} \cdot s_2) / (s_1 + s_2) = 555.56$

$\rho_l = \text{Area_Tot_Long_Rein} / (b \cdot d) = 0.01009575$

$b = 750.00$

$d = 707.00$

$f_{cE} = 33.00$

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

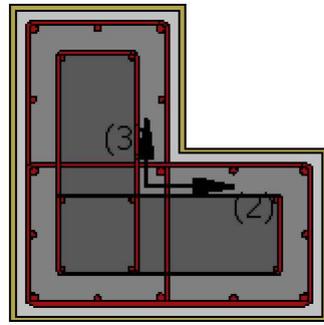
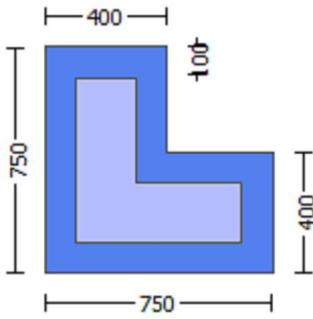
Limit State: Collapse Prevention (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Shear capacity V_{Rd}

Edge: Start

Local Axis: (3)



Start Of Calculation of Shear Capacity for element: column JLC1 of floor 1

At local axis: 3

Integration Section: (a)

Section Type: rcjlcs

Constant Properties

Knowledge Factor, $\gamma = 0.90$

Member Shear Force is generally considered as Force-Controlled Action according to Table C7-1, ASCE 41-17.

Lower-bound strengths are used for Force-Controlled Actions according to 7.5.1.3, ASCE 41-17

Consequently:

Jacket

New material of Secondary Member: Concrete Strength, $f_c = f_{c_lower_bound} = 25.00$

New material of Secondary Member: Steel Strength, $f_s = f_{s_lower_bound} = 500.00$

Concrete Elasticity, $E_c = 26999.444$

Steel Elasticity, $E_s = 200000.00$

Existing Column

New material of Secondary Member: Concrete Strength, $f_c = f_{c_lower_bound} = 25.00$

New material of Secondary Member: Steel Strength, $f_s = f_{s_lower_bound} = 500.00$

Concrete Elasticity, $E_c = 26999.444$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of γ for displacement ductility demand, the expected (mean value) strengths are used (7.5.1.3, ASCE 41-17) because bending is considered as Deformation-Controlled Action (Table C7-1, ASCE 41-17).

Jacket

New material: Concrete Strength, $f_c = f_{cm} = 33.00$

New material: Steel Strength, $f_s = f_{sm} = 555.56$

Existing Column

New material: Concrete Strength, $f_c = f_{cm} = 33.00$

New material: Steel Strength, $f_s = f_{sm} = 555.56$

#####

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

Adequate Lap Length ($l_o/l_{ou,min} = l_b/l_d \geq 1$)

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $e_{fu} = 0.01$

Number of directions, NoDir = 1
Fiber orientations, bi: 0.00°
Number of layers, NL = 1
Radius of rounding corners, R = 40.00

Stepwise Properties

EDGE -A-
Bending Moment, Ma = -320844.41
Shear Force, Va = 131.6809
EDGE -B-
Bending Moment, Mb = -72349.636
Shear Force, Vb = -131.6809
BOTH EDGES
Axial Force, F = -18154.476
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: Asl,t = 0.00
-Compression: Asl,c = 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

New component: From table 7-7, ASCE 41_17: Final Shear Capacity VR = 1.0*Vn = 948969.187
Vn ((10.3), ASCE 41-17) = knl*VColO = 948969.187
VCol = 948969.187
knl = 1.00
displacement_ductility_demand = 0.00587761

NOTE: In expression (10-3) 'Vs = Av*fy*d/s' is replaced by 'Vs+ f*VF'
where Vf is the contribution of FRPs (11.3), ACI 440).

= 1 (normal-weight concrete)
Mean concrete strength: fc' = (fc'_jacket*Area_jacket + fc'_core*Area_core)/Area_section = 25.00, but fc'^0.5 <= 8.3
MPa (22.5.3.1, ACI 318-14)
M/Vd = 4.00
Mu = 320844.41
Vu = 131.6809
d = 0.8*h = 600.00
Nu = 18154.476
Ag = 300000.00
From (11.5.4.8), ACI 318-14: Vs = Vs,jacket + Vs,core = 811033.559
where:
Vs,jacket = Vs,j1 + Vs,j2 = 722566.31
Vs,j1 = 471238.898 is calculated for section web jacket, with:
d = 600.00
Av = 157079.633
fy = 500.00
s = 100.00
Vs,j1 is multiplied by Col,j1 = 1.00
s/d = 0.16666667
Vs,j2 = 251327.412 is calculated for section flange jacket, with:
d = 320.00
Av = 157079.633
fy = 500.00
s = 100.00
Vs,j2 is multiplied by Col,j2 = 1.00
s/d = 0.3125
Vs,core = Vs,c1 + Vs,c2 = 88467.249
Vs,c1 = 88467.249 is calculated for section web core, with:
d = 440.00
Av = 100530.965

$f_y = 500.00$
 $s = 250.00$
 $V_{s,c1}$ is multiplied by $Col,c1 = 1.00$
 $s/d = 0.56818182$
 $V_{s,c2} = 0.00$ is calculated for section flange core, with:
 $d = 160.00$
 $A_v = 100530.965$
 $f_y = 500.00$
 $s = 250.00$
 $V_{s,c2}$ 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) $\sin + \cos$ 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: $\theta = b_1 + 90^\circ = 90.00$
 $V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, a_1)|)$, with:
 total thickness per orientation, $tf_1 = NL * t / \text{NoDir} = 1.016$
 $df_v = d$ (figure 11.2, ACI 440) = 707.00
 $ff_e ((11-5), ACI 440) = 259.312$
 $E_f = 64828.00$
 $f_e = 0.004$, from (11.6a), ACI 440
 with $f_u = 0.01$
 From (11-11), ACI 440: $V_s + V_f \leq 797164.595$
 $bw = 400.00$

 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 $\theta = 2.0319315E-005$
 $y = (M_y * L_s / 3) / E_{eff} = 0.00345707$ ((4.29), Biskinis Phd)
 $M_y = 6.4998E+008$
 $L_s = M/V$ (with $L_s > 0.1 * L$ and $L_s < 2 * L$) = 2436.529
 From table 10.5, ASCE 41_17: $E_{eff} = \text{factor} * E_c * I_g = 1.5270E+014$
 $\text{factor} = 0.30$
 $A_g = 440000.00$
 Mean concrete strength: $f_c' = (f_c'_{jacket} * \text{Area}_{jacket} + f_c'_{core} * \text{Area}_{core}) / \text{Area}_{section} = 33.00$
 $N = 18154.476$
 $E_c * I_g = E_c * I_{g,jacket} + E_c * I_{g,core} = 5.0901E+014$

 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, $bw = 400.00$
 flange thickness, $t = 400.00$

 $y = \text{Min}(y_{ten}, y_{com})$
 $y_{ten} = 4.8675041E-006$
 with $f_y = 555.56$
 $d = 707.00$
 $y = 0.19281101$
 $A = 0.01015738$
 $B = 0.00446779$
 with $pt = 0.00214476$
 $pc = 0.00416509$

pv = 0.00378591
N = 18154.476
b = 750.00
" = 0.06082037
y_comp = 1.6460425E-005
with fc* (12.3, (ACI 440)) = 33.48734
fc = 33.00
fl = 0.49678681
b = bmax = 750.00
h = hmax = 750.00
Ag = 0.44
g = pt + pc + pv = 0.01009575
rc = 40.00
Ae/Ac = 0.31291181
Effective FRP thickness, tf = NL*t*Cos(b1) = 1.016
effective strain from (12.5) and (12.12), efe = 0.004
fu = 0.01
Ef = 64828.00
Ec = 26999.444
y = 0.19183941
A = 0.01001908
B = 0.00440616
with Es = 200000.00
CONFIRMATION: y = 0.19281101 < t/d

Calculation of ratio lb/d

Adequate Lap Length: lb/d >= 1

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

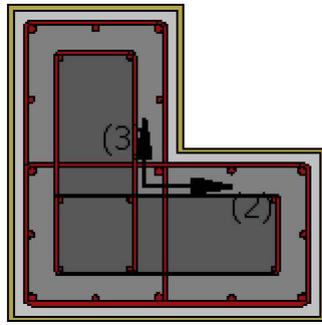
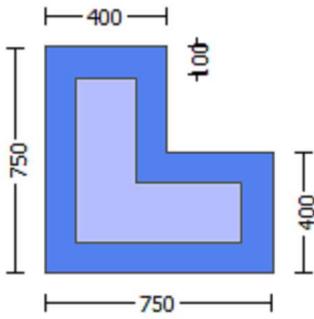
Limit State: Collapse Prevention (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity (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: rcjlcs

Constant Properties

Knowledge Factor, $\gamma = 0.90$

Mean strength values are used for both shear and moment calculations.

Consequently:

Jacket

New material of Secondary Member: Concrete Strength, $f_c = f_{cm} = 33.00$

New material of Secondary Member: Steel Strength, $f_s = f_{sm} = 555.56$

Concrete Elasticity, $E_c = 26999.444$

Steel Elasticity, $E_s = 200000.00$

Existing Column

New material of Secondary Member: Concrete Strength, $f_c = f_{cm} = 33.00$

New material of Secondary Member: Steel Strength, $f_s = f_{sm} = 555.56$

Concrete Elasticity, $E_c = 26999.444$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14

Jacket

New material: Steel Strength, $f_s = 1.25 \cdot f_{sm} = 694.45$

Existing Column

New material: Steel Strength, $f_s = 1.25 \cdot f_{sm} = 694.45$

#####

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

Adequate Lap Length ($l_o/l_{ou, min} \geq 1$)

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $\epsilon_{fu} = 0.01$

Number of directions, $NoDir = 1$

Fiber orientations, $b_i = 0.00^\circ$

Number of layers, $NL = 1$

Radius of rounding corners, $R = 40.00$

Stepwise Properties

At local axis: 3

EDGE -A-

Shear Force, $V_a = -0.00017144$

EDGE -B-

Shear Force, $V_b = 0.00017144$

BOTH EDGES

Axial Force, $F = -16273.607$

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: $As_{mid} = 2007.478$

Calculation of Shear Capacity ratio, $V_e/V_r = 1.05752$

Member Controlled by Shear ($V_e/V_r > 1$)

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 1.1525E+006$

with

$M_{pr1} = \text{Max}(Mu_{1+}, Mu_{1-}) = 1.7288E+009$

$Mu_{1+} = 1.1540E+009$, 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

$Mu_{1-} = 1.7288E+009$, 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

$M_{pr2} = \text{Max}(Mu_{2+}, Mu_{2-}) = 1.7288E+009$

$Mu_{2+} = 1.1540E+009$, 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

$Mu_{2-} = 1.7288E+009$, 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:

$\phi_u = 5.0226943E-005$

$M_u = 1.1540E+009$

with full section properties:

$b = 750.00$

$d = 707.00$

$d' = 43.00$

$v = 0.00093001$

$N = 16273.607$

$f_c = 33.00$

ω (5A.5, TBDY) = 0.002

Final value of ϕ_u : $\phi_u^* = \text{shear_factor} * \text{Max}(\phi_u, \phi_c) = 0.01291652$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $\phi_u = 0.01291652$

ω_e ((5.4c), TBDY) = $a_s e * \text{sh}_{,min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.05541928$

where $f = a_f * \rho_f * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$f_x = 0.04286225$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$a_f = 0.31984848$

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), $pf = 2tf/bw = 0.00508$
 $bw = 400.00$
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, $tf = NL*t*\text{Cos}(b1) = 1.016$
 $fu,f = 1055.00$
 $Ef = 64828.00$
 $u,f = 0.015$

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 $bi^2/6$ 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 $bi^2/6$ as defined at (A.2).

$psh_{min}*Fy_{we} = \text{Min}(psh_x*Fy_{we}, psh_y*Fy_{we}) = 3.0194$

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)

$psh_x*Fy_{we} = psh1*Fy_{we1} + ps2*Fy_{we2} = 3.0194$
 $psh1$ ((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

$psh_y*Fy_{we} = psh1*Fy_{we1} + ps2*Fy_{we2} = 3.0194$
 $psh1$ ((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

$A_{sec} = 440000.00$
 $s1 = 100.00$
 $s2 = 250.00$

fywe1 = 694.45
fywe2 = 694.45
fce = 33.00

From ((5.A.5), TBDY), TBDY: cc = 0.00238888
c = confinement factor = 1.03889

y1 = 0.0025
sh1 = 0.008
ft1 = 833.34
fy1 = 694.45
su1 = 0.032

using (30) in Biskinis/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 = 1.00

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 = 694.45

with Es1 = (Es,jacket*Asl,ten,jacket + Es,core*Asl,ten,core)/Asl,ten = 200000.00

y2 = 0.0025
sh2 = 0.008
ft2 = 833.34
fy2 = 694.45
su2 = 0.032

using (30) in Biskinis/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 = 1.00

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 = 694.45

with Es2 = (Es,jacket*Asl,com,jacket + Es,core*Asl,com,core)/Asl,com = 200000.00

yv = 0.0025
shv = 0.008
ftv = 833.34
fyv = 694.45
suv = 0.032

using (30) in Biskinis/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 = 1.00

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 = 694.45

with Esv = (Es,jacket*Asl,mid,jacket + Es,mid*Asl,mid,core)/Asl,mid = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.0451341

2 = Asl,com/(b*d)*(fs2/fc) = 0.08764993

v = Asl,mid/(b*d)*(fsv/fc) = 0.07967042

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) = 0.05123276

2 = Asl,com/(b*d)*(fs2/fc) = 0.09949345

v = Asl,mid/(b*d)*(fsv/fc) = 0.09043572

Case/Assumption: Unconfined full section - Steel rupture
' satisfies Eq. (4.3)

--->
v < vs,y2 - LHS eq.(4.5) is satisfied

--->
su (4.9) = 0.09885678
Mu = MRc (4.14) = 1.1540E+009
u = su (4.1) = 5.0226943E-005

Calculation of ratio lb/d

Adequate Lap Length: lb/d >= 1

Calculation of Mu1-

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

u = 6.4288704E-005
Mu = 1.7288E+009

with full section properties:

b = 400.00
d = 707.00
d' = 43.00
v = 0.00174378
N = 16273.607
fc = 33.00
co (5A.5, TBDY) = 0.002

Final value of cu: cu* = shear_factor * Max(cu, cc) = 0.01291652

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: cu = 0.01291652

we ((5.4c), TBDY) = ase* sh,min*fywe/fce+Min(fx, fy) = 0.05541928

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 = 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.

$A_{conf,max1} = 353600.00$ 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).
 $psh_{min} * F_{ywe} = \text{Min}(psh_x * F_{ywe}, psh_y * F_{ywe}) = 3.0194$

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)

 $psh_x * F_{ywe} = psh1 * F_{ywe1} + ps2 * F_{ywe2} = 3.0194$

$psh1$ ((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

 $psh_y * F_{ywe} = psh1 * F_{ywe1} + ps2 * F_{ywe2} = 3.0194$

$psh1$ ((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

 $A_{sec} = 440000.00$

$s1 = 100.00$

$s2 = 250.00$

$f_{ywe1} = 694.45$

$f_{ywe2} = 694.45$

$f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY: $cc = 0.00238888$

$c = \text{confinement factor} = 1.03889$

$y1 = 0.0025$

$sh1 = 0.008$

$ft1 = 833.34$

$fy1 = 694.45$

$su1 = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with $shear_factor$ and also multiplied by the $shear_factor$ according to 15.7.1.4, with $Shear_factor = 1.00$

$lo/lo_{u,min} = l_b/l_d = 1.00$

$su1 = 0.4 * esu1_nominal$ ((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 $fs1 = (f_{s,jacket} * A_{s1,ten,jacket} + f_{s,core} * A_{s1,ten,core}) / A_{s1,ten} = 694.45$

with $Es1 = (E_{s,jacket} * A_{s1,ten,jacket} + E_{s,core} * A_{s1,ten,core}) / A_{s1,ten} = 200000.00$

$y2 = 0.0025$

$sh2 = 0.008$

$$ft2 = 833.34$$

$$fy2 = 694.45$$

$$su2 = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$lo/lo_{u,min} = lb/lb_{u,min} = 1.00$$

$$su2 = 0.4 * esu2_{nominal} ((5.5), TBDY) = 0.032$$

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.

$$\text{with } fs2 = (fs_{jacket} * A_{sl,com,jacket} + fs_{core} * A_{sl,com,core}) / A_{sl,com} = 694.45$$

$$\text{with } Es2 = (Es_{jacket} * A_{sl,com,jacket} + Es_{core} * A_{sl,com,core}) / A_{sl,com} = 200000.00$$

$$yv = 0.0025$$

$$shv = 0.008$$

$$ftv = 833.34$$

$$fyv = 694.45$$

$$suv = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$lo/lo_{u,min} = lb/ld = 1.00$$

$$suv = 0.4 * esuv_{nominal} ((5.5), TBDY) = 0.032$$

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.

$$\text{with } fsv = (fs_{jacket} * A_{sl,mid,jacket} + fs_{mid} * A_{sl,mid,core}) / A_{sl,mid} = 694.45$$

$$\text{with } Esv = (Es_{jacket} * A_{sl,mid,jacket} + Es_{mid} * A_{sl,mid,core}) / A_{sl,mid} = 200000.00$$

$$1 = A_{sl,ten} / (b * d) * (fs1 / fc) = 0.16434361$$

$$2 = A_{sl,com} / (b * d) * (fs2 / fc) = 0.08462644$$

$$v = A_{sl,mid} / (b * d) * (fsv / fc) = 0.14938203$$

and confined core properties:

$$b = 340.00$$

$$d = 677.00$$

$$d' = 13.00$$

$$fcc (5A.2, TBDY) = 34.2833$$

$$cc (5A.5, TBDY) = 0.00238888$$

$$c = \text{confinement factor} = 1.03889$$

$$1 = A_{sl,ten} / (b * d) * (fs1 / fc) = 0.20191317$$

$$2 = A_{sl,com} / (b * d) * (fs2 / fc) = 0.10397236$$

$$v = A_{sl,mid} / (b * d) * (fsv / fc) = 0.18353132$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

---->

$v < vs,y2$ - LHS eq.(4.5) is not satisfied

---->

$v < vs,c$ - RHS eq.(4.5) is satisfied

---->

$$su (4.8) = 0.29596233$$

$$Mu = MRc (4.15) = 1.7288E+009$$

$$u = su (4.1) = 6.4288704E-005$$

Calculation of ratio lb/ld

Adequate Lap Length: $lb/ld \geq 1$

Calculation of $Mu2+$

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

u = 5.0226943E-005
Mu = 1.1540E+009

with full section properties:

b = 750.00
d = 707.00
d' = 43.00
v = 0.00093001
N = 16273.607
fc = 33.00
co (5A.5, TBDY) = 0.002

Final value of cu: $cu^* = \text{shear_factor} * \text{Max}(cu, cc) = 0.01291652$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $cu = 0.01291652$

w_e ((5.4c), TBDY) = $ase * sh, \min * fy_{we} / f_{ce} + \text{Min}(f_x, f_y) = 0.05541928$

where $f = af * pf * ff_e / f_{ce}$ 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.

$A_{conf,min1} = 293525.00$ 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).

$$psh_{min} * Fy_{we} = \text{Min}(psh_x * Fy_{we}, psh_y * Fy_{we}) = 3.0194$$

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)

$$psh_x * Fy_{we} = psh1 * Fy_{we1} + ps2 * Fy_{we2} = 3.0194$$

$$psh1 \text{ ((5.4d), TBDY)} = Lstir1 * Astir1 / (Asec * s1) = 0.00367709$$

$$Lstir1 \text{ (Length of stirrups along Y)} = 2060.00$$

$$Astir1 \text{ (stirrups area)} = 78.53982$$

$$psh2 \text{ (5.4d)} = Lstir2 * Astir2 / (Asec * s2) = 0.00067082$$

$$Lstir2 \text{ (Length of stirrups along Y)} = 1468.00$$

$$Astir2 \text{ (stirrups area)} = 50.26548$$

$$psh_y * Fy_{we} = psh1 * Fy_{we1} + ps2 * Fy_{we2} = 3.0194$$

$$psh1 \text{ ((5.4d), TBDY)} = Lstir1 * Astir1 / (Asec * s1) = 0.00367709$$

$$Lstir1 \text{ (Length of stirrups along X)} = 2060.00$$

$$Astir1 \text{ (stirrups area)} = 78.53982$$

$$psh2 \text{ ((5.4d), TBDY)} = Lstir2 * Astir2 / (Asec * s2) = 0.00067082$$

$$Lstir2 \text{ (Length of stirrups along X)} = 1468.00$$

$$Astir2 \text{ (stirrups area)} = 50.26548$$

$$Asec = 440000.00$$

$$s1 = 100.00$$

$$s2 = 250.00$$

$$fy_{we1} = 694.45$$

$$fy_{we2} = 694.45$$

$$f_{ce} = 33.00$$

$$\text{From ((5.A5), TBDY), TBDY: } cc = 0.00238888$$

$$c = \text{confinement factor} = 1.03889$$

$$y1 = 0.0025$$

$$sh1 = 0.008$$

$$ft1 = 833.34$$

$$fy1 = 694.45$$

$$su1 = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$$lo/lou_{min} = lb/ld = 1.00$$

$$su1 = 0.4 * esu1_{nominal} \text{ ((5.5), TBDY)} = 0.032$$

$$\text{From table 5A.1, TBDY: } esu1_{nominal} = 0.08,$$

For calculation of $esu1_{nominal}$ and $y1, sh1, ft1, fy1$, it is considered characteristic value $fsy1 = fs1/1.2$, from table 5.1, TBDY.

$$y1, sh1, ft1, fy1, \text{ are also multiplied by } \text{Min}(1, 1.25 * (lb/ld)^{2/3}), \text{ from 10.3.5, ASCE 41-17.}$$

$$\text{with } fs1 = (fs_{jacket} * Asl_{ten,jacket} + fs_{core} * Asl_{ten,core}) / Asl_{ten} = 694.45$$

$$\text{with } Es1 = (Es_{jacket} * Asl_{ten,jacket} + Es_{core} * Asl_{ten,core}) / Asl_{ten} = 200000.00$$

$$y2 = 0.0025$$

$$sh2 = 0.008$$

$$ft2 = 833.34$$

$$fy2 = 694.45$$

$$su2 = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$$lo/lou_{min} = lb/lb_{min} = 1.00$$

$$su2 = 0.4 * esu2_{nominal} \text{ ((5.5), TBDY)} = 0.032$$

$$\text{From table 5A.1, TBDY: } esu2_{nominal} = 0.08,$$

For calculation of $esu2_{nominal}$ and $y2, sh2, ft2, fy2$, it is considered characteristic value $fsy2 = fs2/1.2$, from table 5.1, TBDY.

$$y1, sh1, ft1, fy1, \text{ are also multiplied by } \text{Min}(1, 1.25 * (lb/ld)^{2/3}), \text{ from 10.3.5, ASCE 41-17.}$$

$$\text{with } fs2 = (fs_{jacket} * Asl_{com,jacket} + fs_{core} * Asl_{com,core}) / Asl_{com} = 694.45$$

$$\text{with } Es2 = (Es_{jacket} * Asl_{com,jacket} + Es_{core} * Asl_{com,core}) / Asl_{com} = 200000.00$$

$$y_v = 0.0025$$

$$sh_v = 0.008$$

$$ft_v = 833.34$$

$$fy_v = 694.45$$

$$su_v = 0.032$$

using (30) in Biskinis/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 = 1.00

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 = (fsjacket*Asl,mid,jacket + fs,mid*Asl,mid,core)/Asl,mid = 694.45

with Esv = (Es,jacket*Asl,mid,jacket + Es,mid*Asl,mid,core)/Asl,mid = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.0451341

2 = Asl,com/(b*d)*(fs2/fc) = 0.08764993

v = Asl,mid/(b*d)*(fsv/fc) = 0.07967042

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) = 0.05123276

2 = Asl,com/(b*d)*(fs2/fc) = 0.09949345

v = Asl,mid/(b*d)*(fsv/fc) = 0.09043572

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

---->

v < vs,y2 - LHS eq.(4.5) is satisfied

---->

su (4.9) = 0.09885678

Mu = MRc (4.14) = 1.1540E+009

u = su (4.1) = 5.0226943E-005

Calculation of ratio lb/d

Adequate Lap Length: lb/d >= 1

Calculation of Mu2-

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

u = 6.4288704E-005

Mu = 1.7288E+009

with full section properties:

b = 400.00

d = 707.00

d' = 43.00

v = 0.00174378

N = 16273.607

fc = 33.00

co (5A.5, TBDY) = 0.002

Final value of cu: cu* = shear_factor * Max(cu, cc) = 0.01291652

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: cu = 0.01291652

we ((5.4c), TBDY) = ase* sh,min*fywe/fce+Min(fx, fy) = 0.05541928

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 $af = 1 - (\text{Unconfined area})/(\text{total area})$
 $af = 0.31984848$
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, $tf = NL*t*\text{Cos}(b1) = 1.016$
 $fu,f = 1055.00$
 $Ef = 64828.00$
 $u,f = 0.015$

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 $bi^2/6$ 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 $bi^2/6$ as defined at (A.2).

$psh_{min}*Fy_{we} = \text{Min}(psh_x*Fy_{we}, psh_y*Fy_{we}) = 3.0194$

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)

$psh_x*Fy_{we} = psh1*Fy_{we1} + ps2*Fy_{we2} = 3.0194$
 $psh1$ ((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

$psh_y*Fy_{we} = psh1*Fy_{we1} + ps2*Fy_{we2} = 3.0194$
 $psh1$ ((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

$A_{sec} = 440000.00$
 $s1 = 100.00$
 $s2 = 250.00$

fywe1 = 694.45
fywe2 = 694.45
fce = 33.00

From ((5.A.5), TBDY), TBDY: cc = 0.00238888
c = confinement factor = 1.03889

y1 = 0.0025
sh1 = 0.008
ft1 = 833.34
fy1 = 694.45
su1 = 0.032

using (30) in Biskinis/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 = 1.00

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 = 694.45

with Es1 = (Es,jacket*Asl,ten,jacket + Es,core*Asl,ten,core)/Asl,ten = 200000.00

y2 = 0.0025
sh2 = 0.008
ft2 = 833.34
fy2 = 694.45
su2 = 0.032

using (30) in Biskinis/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 = 1.00

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 = 694.45

with Es2 = (Es,jacket*Asl,com,jacket + Es,core*Asl,com,core)/Asl,com = 200000.00

yv = 0.0025
shv = 0.008
ftv = 833.34
fyv = 694.45
suv = 0.032

using (30) in Biskinis/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 = 1.00

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 = 694.45

with Esv = (Es,jacket*Asl,mid,jacket + Es,mid*Asl,mid,core)/Asl,mid = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.16434361

2 = Asl,com/(b*d)*(fs2/fc) = 0.08462644

v = Asl,mid/(b*d)*(fsv/fc) = 0.14938203

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) = 0.20191317

2 = Asl,com/(b*d)*(fs2/fc) = 0.10397236

v = Asl,mid/(b*d)*(fsv/fc) = 0.18353132

Case/Assumption: Unconfined full section - Steel rupture
' satisfies Eq. (4.3)

--->
 $v < v_{s,y2}$ - LHS eq.(4.5) is not satisfied
--->
 $v < v_{s,c}$ - RHS eq.(4.5) is satisfied
--->

s_u (4.8) = 0.29596233
 $M_u = MR_c$ (4.15) = 1.7288E+009
 $u = s_u$ (4.1) = 6.4288704E-005

Calculation of ratio l_b/d

Adequate Lap Length: $l_b/d \geq 1$

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 1.0898E+006$

Calculation of Shear Strength at edge 1, $V_{r1} = 1.0898E+006$
 $V_{r1} = V_{Col}$ ((10.3), ASCE 41-17) = $k_n l^* V_{ColO}$
 $V_{ColO} = 1.0898E+006$
 $k_n l = 1$ (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: $f_c' = (f_c'_{jacket} * Area_{jacket} + f_c'_{core} * Area_{core}) / Area_{section} = 33.00$, but $f_c'^{0.5} \leq 8.3$
MPa (22.5.3.1, ACI 318-14)

$M/d = 4.00$
 $M_u = 1518.01$
 $V_u = 0.00017144$
 $d = 0.8 * h = 600.00$
 $N_u = 16273.607$
 $A_g = 300000.00$
From (11.5.4.8), ACI 318-14: $V_s = V_{s,jacket} + V_{s,core} = 901155.609$

where:
 $V_{s,jacket} = V_{s,j1} + V_{s,j2} = 802857.879$
 $V_{s,j1} = 523602.964$ is calculated for section web jacket, with:
 $d = 600.00$
 $A_v = 157079.633$
 $f_y = 555.56$
 $s = 100.00$

$V_{s,j1}$ is multiplied by $Col,j1 = 1.00$
 $s/d = 0.16666667$
 $V_{s,j2} = 279254.914$ is calculated for section flange jacket, with:
 $d = 320.00$
 $A_v = 157079.633$
 $f_y = 555.56$
 $s = 100.00$

$V_{s,j2}$ is multiplied by $Col,j2 = 1.00$
 $s/d = 0.3125$
 $V_{s,core} = V_{s,c1} + V_{s,c2} = 98297.73$
 $V_{s,c1} = 98297.73$ is calculated for section web core, with:
 $d = 440.00$
 $A_v = 100530.965$
 $f_y = 555.56$
 $s = 250.00$

$V_{s,c1}$ is multiplied by $Col,c1 = 1.00$
 $s/d = 0.56818182$
 $V_{s,c2} = 0.00$ is calculated for section flange core, with:
 $d = 160.00$
 $A_v = 100530.965$
 $f_y = 555.56$

$s = 250.00$
 $V_{s,c2}$ 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
 $wf/sf = 1$ (FRP strips adjacent to one another).
 \ln (11.3) $\sin + \cos$ is replaced with $(\cot + \cot a)\sin a$ which is more a generalised expression,
 where θ is the angle of the crack direction (see KANEPE).
 This later relation, considered as a function $V_f(\theta, a)$, is implemented for every different fiber orientation a_i ,
 as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.
 orientation 1: $\theta = b1 + 90^\circ = 90.00$
 $V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, a1)|)$, with:
 total thickness per orientation, $tf1 = NL*t/NoDir = 1.016$
 $dfv = d$ (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: $V_s + V_f \leq 915872.391$
 $bw = 400.00$

 Calculation of Shear Strength at edge 2, $V_{r2} = 1.0898E+006$
 $V_{r2} = V_{Col}$ ((10.3), ASCE 41-17) = $knl * V_{Col0}$
 $V_{Col0} = 1.0898E+006$
 $knl = 1$ (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).

 $\rho = 1$ (normal-weight concrete)
 Mean concrete strength: $f_c' = (f_c'_{jacket} * Area_{jacket} + f_c'_{core} * Area_{core}) / Area_{section} = 33.00$, but $f_c'^{0.5} \leq 8.3$
 MPa (22.5.3.1, ACI 318-14)
 $M/Vd = 4.00$
 $M_u = 1518.01$
 $V_u = 0.00017144$
 $d = 0.8 * h = 600.00$
 $N_u = 16273.607$
 $A_g = 300000.00$
 From (11.5.4.8), ACI 318-14: $V_s = V_{sjacket} + V_{s,core} = 901155.609$
 where:
 $V_{sjacket} = V_{sj1} + V_{sj2} = 802857.879$
 $V_{sj1} = 523602.964$ is calculated for section web jacket, with:
 $d = 600.00$
 $A_v = 157079.633$
 $f_y = 555.56$
 $s = 100.00$
 V_{sj1} is multiplied by $Col,j1 = 1.00$
 $s/d = 0.16666667$
 $V_{sj2} = 279254.914$ is calculated for section flange jacket, with:
 $d = 320.00$
 $A_v = 157079.633$
 $f_y = 555.56$
 $s = 100.00$
 V_{sj2} is multiplied by $Col,j2 = 1.00$
 $s/d = 0.3125$
 $V_{s,core} = V_{s,c1} + V_{s,c2} = 98297.73$
 $V_{s,c1} = 98297.73$ is calculated for section web core, with:
 $d = 440.00$
 $A_v = 100530.965$
 $f_y = 555.56$
 $s = 250.00$
 $V_{s,c1}$ is multiplied by $Col,c1 = 1.00$
 $s/d = 0.56818182$
 $V_{s,c2} = 0.00$ is calculated for section flange core, with:
 $d = 160.00$
 $A_v = 100530.965$

$$f_y = 555.56$$

$$s = 250.00$$

$$V_{s,c2} \text{ is multiplied by } \text{Col},c2 = 0.00$$

$$s/d = 1.5625$$

$$V_f((11-3)-(11.4), \text{ACI } 440) = 372533.843$$

$$f = 0.95, \text{ for fully-wrapped sections}$$

$$w_f/s_f = 1 \text{ (FRP strips adjacent to one another).}$$

In (11.3) $\sin + \cos$ is replaced with $(\cot + \cot a)\sin a$ which is more a generalised expression, where 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.

$$\text{orientation } 1: \theta = \theta_1 + 90^\circ = 90.00$$

$$V_f = \text{Min}(|V_f(45, \theta_1)|, |V_f(-45, a_1)|), \text{ with:}$$

$$\text{total thickness per orientation, } t_{f1} = N_L * t / N_{oDir} = 1.016$$

$$d_{fv} = d \text{ (figure 11.2, ACI } 440) = 707.00$$

$$f_{fe}((11-5), \text{ACI } 440) = 259.312$$

$$E_f = 64828.00$$

$$f_e = 0.004, \text{ from (11.6a), ACI } 440$$

$$\text{with } f_u = 0.01$$

$$\text{From (11-11), ACI } 440: V_s + V_f \leq 915872.391$$

$$b_w = 400.00$$

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: rcjlc3

Constant Properties

$$\text{Knowledge Factor, } \phi = 0.90$$

Mean strength values are used for both shear and moment calculations.

Consequently:

Jacket

$$\text{New material of Secondary Member: Concrete Strength, } f_c = f_{cm} = 33.00$$

$$\text{New material of Secondary Member: Steel Strength, } f_s = f_{sm} = 555.56$$

$$\text{Concrete Elasticity, } E_c = 26999.444$$

$$\text{Steel Elasticity, } E_s = 200000.00$$

Existing Column

$$\text{New material of Secondary Member: Concrete Strength, } f_c = f_{cm} = 33.00$$

$$\text{New material of Secondary Member: Steel Strength, } f_s = f_{sm} = 555.56$$

$$\text{Concrete Elasticity, } E_c = 26999.444$$

$$\text{Steel Elasticity, } E_s = 200000.00$$

#####

Note: Especially for the calculation of moment strengths,

the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14

Jacket

$$\text{New material: Steel Strength, } f_s = 1.25 * f_{sm} = 694.45$$

Existing Column

$$\text{New material: Steel Strength, } f_s = 1.25 * f_{sm} = 694.45$$

#####

$$\text{Max Height, } H_{max} = 750.00$$

$$\text{Min Height, } H_{min} = 400.00$$

$$\text{Max Width, } W_{max} = 750.00$$

$$\text{Min Width, } W_{min} = 400.00$$

$$\text{Jacket Thickness, } t_j = 100.00$$

$$\text{Cover Thickness, } c = 25.00$$

$$\text{Mean Confinement Factor overall section} = 1.03889$$

$$\text{Element Length, } L = 3000.00$$

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
Adequate Lap Length ($l_o/l_{ou}, \min \geq 1$)
FRP Wrapping Data
Type: Carbon
Cured laminate properties (design values)
Thickness, $t = 1.016$
Tensile Strength, $f_{fu} = 1055.00$
Tensile Modulus, $E_f = 64828.00$
Elongation, $e_{fu} = 0.01$
Number of directions, $NoDir = 1$
Fiber orientations, $bi = 0.00^\circ$
Number of layers, $NL = 1$
Radius of rounding corners, $R = 40.00$

Stepwise Properties

At local axis: 2
EDGE -A-
Shear Force, $V_a = -0.0001715$
EDGE -B-
Shear Force, $V_b = 0.0001715$
BOTH EDGES
Axial Force, $F = -16273.607$
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: $As_{c,mid} = 2007.478$

Calculation of Shear Capacity ratio, $V_e/V_r = 1.05752$
Member Controlled by Shear ($V_e/V_r > 1$)
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 1.1525E+006$
with
 $M_{pr1} = \max(\mu_{u1+}, \mu_{u1-}) = 1.7288E+009$
 $\mu_{u1+} = 1.1540E+009$, is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination
 $\mu_{u1-} = 1.7288E+009$, 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
 $M_{pr2} = \max(\mu_{u2+}, \mu_{u2-}) = 1.7288E+009$
 $\mu_{u2+} = 1.1540E+009$, is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the the static loading combination
 $\mu_{u2-} = 1.7288E+009$, 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_{u1+}

Calculation of ultimate curvature μ_u according to 4.1, Biskinis/Fardis 2013:
 $\mu_u = 5.0226943E-005$
 $M_u = 1.1540E+009$

with full section properties:

$b = 750.00$
 $d = 707.00$
 $d' = 43.00$
 $v = 0.00093001$
 $N = 16273.607$

$$f_c = 33.00$$

$$c_o (5A.5, TBDY) = 0.002$$

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.01291652$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } c_u = 0.01291652$$

$$\text{we ((5.4c), TBDY) } = a_{se} * s_{h,\min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.05541928$$

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.

$A_{\text{conf,min2}} = 54741.00$ 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).

$$p_{sh,\min} * F_{ywe} = \text{Min}(p_{sh,x} * F_{ywe}, p_{sh,y} * F_{ywe}) = 3.0194$$

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)

$$p_{sh,x} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{sh2} * F_{ywe2} = 3.0194$$

$$p_{sh1} ((5.4d), TBDY) = L_{stir1} * A_{stir1} / (A_{sec} * s_1) = 0.00367709$$

$$L_{stir1} (\text{Length of stirrups along } Y) = 2060.00$$

$$A_{stir1} (\text{stirrups area}) = 78.53982$$

$$p_{sh2} (5.4d) = L_{stir2} * A_{stir2} / (A_{sec} * s_2) = 0.00067082$$

Lstir2 (Length of stirrups along Y) = 1468.00
Astir2 (stirrups area) = 50.26548

psh_y*Fywe = psh₁*Fywe₁+ps₂*Fywe₂ = 3.0194
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 = 694.45
fywe₂ = 694.45
fce = 33.00

From ((5.A5), TBDY), TBDY: cc = 0.00238888
c = confinement factor = 1.03889

y₁ = 0.0025
sh₁ = 0.008
ft₁ = 833.34
fy₁ = 694.45
su₁ = 0.032

using (30) in Biskinis/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 = 1.00

su₁ = 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 y₁, sh₁,ft₁,fy₁, it is considered
characteristic value fsy₁ = fs₁/1.2, from table 5.1, TBDY.

y₁, sh₁,ft₁,fy₁, are also multiplied by Min(1,1.25*(lb/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} = 694.45

with Es₁ = (Es_{jacket}*Asl_{ten,jacket} + Es_{core}*Asl_{ten,core})/Asl_{ten} = 200000.00

y₂ = 0.0025
sh₂ = 0.008
ft₂ = 833.34
fy₂ = 694.45
su₂ = 0.032

using (30) in Biskinis/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} = 1.00

su₂ = 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 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 Min(1,1.25*(lb/l_d)^{2/3}), from 10.3.5, ASCE 41-17.

with fs₂ = (fs_{jacket}*Asl_{com,jacket} + fs_{core}*Asl_{com,core})/Asl_{com} = 694.45

with Es₂ = (Es_{jacket}*Asl_{com,jacket} + Es_{core}*Asl_{com,core})/Asl_{com} = 200000.00

y_v = 0.0025
sh_v = 0.008
ft_v = 833.34
fy_v = 694.45
su_v = 0.032

using (30) in Biskinis/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 = 1.00

su_v = 0.4*esuv_{nominal} ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esuv_{nominal} = 0.08,

considering characteristic value fsy_v = 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 fsy_v = fs_v/1.2, from table 5.1, TBDY.

y₁, sh₁,ft₁,fy₁, are also multiplied by Min(1,1.25*(lb/l_d)^{2/3}), from 10.3.5, ASCE 41-17.

with fs_v = (fs_{jacket}*Asl_{mid,jacket} + fs_{mid}*Asl_{mid,core})/Asl_{mid} = 694.45

$$\text{with } E_{sv} = (E_{s,jacket} \cdot A_{sl,mid,jacket} + E_{s,mid} \cdot A_{sl,mid,core}) / A_{sl,mid} = 200000.00$$

$$1 = A_{sl,ten} / (b \cdot d) \cdot (f_{s1} / f_c) = 0.0451341$$

$$2 = A_{sl,com} / (b \cdot d) \cdot (f_{s2} / f_c) = 0.08764993$$

$$v = A_{sl,mid} / (b \cdot d) \cdot (f_{sv} / f_c) = 0.07967042$$

and confined core properties:

$$b = 690.00$$

$$d = 677.00$$

$$d' = 13.00$$

$$f_{cc} \text{ (5A.2, TBDY)} = 34.2833$$

$$c_c \text{ (5A.5, TBDY)} = 0.00238888$$

$$c = \text{confinement factor} = 1.03889$$

$$1 = A_{sl,ten} / (b \cdot d) \cdot (f_{s1} / f_c) = 0.05123276$$

$$2 = A_{sl,com} / (b \cdot d) \cdot (f_{s2} / f_c) = 0.09949345$$

$$v = A_{sl,mid} / (b \cdot d) \cdot (f_{sv} / f_c) = 0.09043572$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < v_{s,y2}$ - LHS eq.(4.5) is satisfied

--->

$$s_u \text{ (4.9)} = 0.09885678$$

$$\mu_u = M_{Rc} \text{ (4.14)} = 1.1540E+009$$

$$u = s_u \text{ (4.1)} = 5.0226943E-005$$

Calculation of ratio l_b/d

Adequate Lap Length: $l_b/d \geq 1$

Calculation of μ_{u1} -

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

$$u = 6.4288704E-005$$

$$\mu_u = 1.7288E+009$$

with full section properties:

$$b = 400.00$$

$$d = 707.00$$

$$d' = 43.00$$

$$v = 0.00174378$$

$$N = 16273.607$$

$$f_c = 33.00$$

$$c_c \text{ (5A.5, TBDY)} = 0.002$$

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} \cdot \text{Max}(c_u, c_c) = 0.01291652$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } c_u = 0.01291652$$

$$w_e \text{ ((5.4c), TBDY)} = a_{se} \cdot s_{h,min} \cdot f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.05541928$$

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 $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.31984848$$

$$\text{with Unconfined area} = ((b_{max} - 2R)^2 + (h_{max} - 2R)^2) / 3 = 140733.333$$

$$b_{max} = 750.00$$

$$h_{max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 870.5244$$

$$f_y = 0.04286225$$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.31984848$$

$$\text{with Unconfined area} = ((b_{max} - 2R)^2 + (h_{max} - 2R)^2) / 3 = 140733.333$$

$$b_{max} = 750.00$$

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, $tf = NL*t*Cos(b1) = 1.016$
 $f_{u,f} = 1055.00$
 $E_f = 64828.00$
 $u_{,f} = 0.015$

$ase((5.4d), TBDY) = (ase1*A_{ext} + ase2*A_{int})/A_{sec} = 0.45746528$

$ase1 = Max(((A_{conf,max1} - A_{noConf1})/A_{conf,max1}) * (A_{conf,min1}/A_{conf,max1}), 0) = 0.45746528$

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).

$ase2 (>= ase1) = Max(((A_{conf,max2} - A_{noConf2})/A_{conf,max2}) * (A_{conf,min2}/A_{conf,max2}), 0) = 0.45746528$

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).

$psh_{,min} * F_{ywe} = Min(psh_{,x} * F_{ywe}, psh_{,y} * F_{ywe}) = 3.0194$

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)

$psh_{,x} * F_{ywe} = psh1 * F_{ywe1} + ps2 * F_{ywe2} = 3.0194$

$psh1((5.4d), TBDY) = L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00367709$

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

$psh_{,y} * F_{ywe} = psh1 * F_{ywe1} + ps2 * F_{ywe2} = 3.0194$

$psh1((5.4d), TBDY) = L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00367709$

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

$A_{sec} = 440000.00$

$s1 = 100.00$

$s2 = 250.00$

$f_{ywe1} = 694.45$

$f_{ywe2} = 694.45$

$f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY: $cc = 0.00238888$

$c =$ confinement factor = 1.03889

$y1 = 0.0025$

$sh1 = 0.008$

$ft1 = 833.34$

$fy1 = 694.45$

su1 = 0.032

using (30) in Biskinis/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 = 1.00

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 = 694.45

with Es1 = (Es,jacket*Asl,ten,jacket + Es,core*Asl,ten,core)/Asl,ten = 200000.00

y2 = 0.0025

sh2 = 0.008

ft2 = 833.34

fy2 = 694.45

su2 = 0.032

using (30) in Biskinis/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 = 1.00

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 = 694.45

with Es2 = (Es,jacket*Asl,com,jacket + Es,core*Asl,com,core)/Asl,com = 200000.00

yv = 0.0025

shv = 0.008

ftv = 833.34

fyv = 694.45

suv = 0.032

using (30) in Biskinis/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 = 1.00

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 = 694.45

with Esv = (Es,jacket*Asl,mid,jacket + Es,mid*Asl,mid,core)/Asl,mid = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.16434361

2 = Asl,com/(b*d)*(fs2/fc) = 0.08462644

v = Asl,mid/(b*d)*(fsv/fc) = 0.14938203

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) = 0.20191317

2 = Asl,com/(b*d)*(fs2/fc) = 0.10397236

v = Asl,mid/(b*d)*(fsv/fc) = 0.18353132

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

v < vs,y2 - LHS eq.(4.5) is not satisfied

v < vs,c - RHS eq.(4.5) is satisfied

su (4.8) = 0.29596233

Mu = MRc (4.15) = 1.7288E+009

$$u = s_u(4.1) = 6.4288704E-005$$

Calculation of ratio l_b/d

Adequate Lap Length: $l_b/d \geq 1$

Calculation of μ_{2+}

Calculation of ultimate curvature μ according to 4.1, Biskinis/Fardis 2013:

$$u = 5.0226943E-005$$

$$\mu = 1.1540E+009$$

with full section properties:

$$b = 750.00$$

$$d = 707.00$$

$$d' = 43.00$$

$$v = 0.00093001$$

$$N = 16273.607$$

$$f_c = 33.00$$

$$c_o(5A.5, TBDY) = 0.002$$

$$\text{Final value of } \mu: \mu^* = \text{shear_factor} * \text{Max}(\mu_c, \mu_{cc}) = 0.01291652$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \mu_c = 0.01291652$$

$$\mu_{cc} \text{ ((5.4c), TBDY) } = a_{se} * s_{h,min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.05541928$$

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.

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).

$p_{sh,min} * F_{ywe} = \text{Min}(p_{sh,x} * F_{ywe}, p_{sh,y} * F_{ywe}) = 3.0194$

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)

$p_{sh,x} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{s2} * F_{ywe2} = 3.0194$

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

$p_{sh,y} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{s2} * F_{ywe2} = 3.0194$

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

$A_{sec} = 440000.00$

$s1 = 100.00$

$s2 = 250.00$

$f_{ywe1} = 694.45$

$f_{ywe2} = 694.45$

$f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY: $cc = 0.00238888$

$c =$ confinement factor = 1.03889

$y1 = 0.0025$

$sh1 = 0.008$

$ft1 = 833.34$

$fy1 = 694.45$

$su1 = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor

and also multiplied by the shear_factor according to 15.7.1.4, with

Shear_factor = 1.00

$l_o / l_{ou,min} = l_b / l_d = 1.00$

$su1 = 0.4 * esu1_{nominal}$ ((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 $fs1 = (f_{s,jacket} * A_{s1,ten,jacket} + f_{s,core} * A_{s1,ten,core}) / A_{s1,ten} = 694.45$

with $Es1 = (E_{s,jacket} * A_{s1,ten,jacket} + E_{s,core} * A_{s1,ten,core}) / A_{s1,ten} = 200000.00$

$y2 = 0.0025$

$sh2 = 0.008$

$ft2 = 833.34$

$fy2 = 694.45$

$su2 = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor

and also multiplied by the shear_factor according to 15.7.1.4, with

Shear_factor = 1.00

$l_o / l_{ou,min} = l_b / l_{b,min} = 1.00$

$$su_2 = 0.4 * esu_{2_nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: $esu_{2_nominal} = 0.08$,

For calculation of $esu_{2_nominal}$ and y_2, sh_2, ft_2, fy_2 , it is considered characteristic value $fs_2 = fs_2/1.2$, from table 5.1, TBDY.

y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE 41-17.

$$\text{with } fs_2 = (fs_{jacket} * Asl_{,com,jacket} + fs_{core} * Asl_{,com,core}) / Asl_{,com} = 694.45$$

$$\text{with } Es_2 = (Es_{jacket} * Asl_{,com,jacket} + Es_{core} * Asl_{,com,core}) / Asl_{,com} = 200000.00$$

$$y_v = 0.0025$$

$$sh_v = 0.008$$

$$ft_v = 833.34$$

$$fy_v = 694.45$$

$$suv = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$$lo/lo_{u,min} = lb/ld = 1.00$$

$$suv = 0.4 * esuv_{nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: $esuv_{nominal} = 0.08$,

considering characteristic value $fs_v = fs_v/1.2$, from table 5.1, TBDY
For calculation of $esuv_{nominal}$ and y_v, sh_v, ft_v, fy_v , it is considered characteristic value $fs_v = fs_v/1.2$, from table 5.1, TBDY.

y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE 41-17.

$$\text{with } fs_v = (fs_{jacket} * Asl_{,mid,jacket} + fs_{mid} * Asl_{,mid,core}) / Asl_{,mid} = 694.45$$

$$\text{with } Es_v = (Es_{jacket} * Asl_{,mid,jacket} + Es_{mid} * Asl_{,mid,core}) / Asl_{,mid} = 200000.00$$

$$1 = Asl_{,ten} / (b * d) * (fs_1 / fc) = 0.0451341$$

$$2 = Asl_{,com} / (b * d) * (fs_2 / fc) = 0.08764993$$

$$v = Asl_{,mid} / (b * d) * (fs_v / fc) = 0.07967042$$

and confined core properties:

$$b = 690.00$$

$$d = 677.00$$

$$d' = 13.00$$

$$fcc (5A.2, TBDY) = 34.2833$$

$$cc (5A.5, TBDY) = 0.00238888$$

$$c = \text{confinement factor} = 1.03889$$

$$1 = Asl_{,ten} / (b * d) * (fs_1 / fc) = 0.05123276$$

$$2 = Asl_{,com} / (b * d) * (fs_2 / fc) = 0.09949345$$

$$v = Asl_{,mid} / (b * d) * (fs_v / fc) = 0.09043572$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < v_{s,y_2}$ - LHS eq.(4.5) is satisfied

--->

$$su (4.9) = 0.09885678$$

$$Mu = MRc (4.14) = 1.1540E+009$$

$$u = su (4.1) = 5.0226943E-005$$

Calculation of ratio lb/ld

Adequate Lap Length: $lb/ld \geq 1$

Calculation of Mu_2 -

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

$$u = 6.4288704E-005$$

$$Mu = 1.7288E+009$$

with full section properties:

$$b = 400.00$$

$$d = 707.00$$

$$d' = 43.00$$

$$v = 0.00174378$$

$$N = 16273.607$$

$$f_c = 33.00$$

$$c_o \text{ (5A.5, TBDY)} = 0.002$$

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.01291652$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } c_u = 0.01291652$$

$$\text{we ((5.4c), TBDY)} = a_{se} * s_{h,\min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.05541928$$

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.

$A_{\text{conf,max2}} = 171264.00$ 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).

$$p_{sh,\min} * F_{ywe} = \text{Min}(p_{sh,x} * F_{ywe}, p_{sh,y} * F_{ywe}) = 3.0194$$

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)

$$p_{sh,x} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{sh2} * F_{ywe2} = 3.0194$$

$$p_{sh1} \text{ ((5.4d), TBDY)} = L_{\text{stir1}} * A_{\text{stir1}} / (A_{\text{sec}} * s_1) = 0.00367709$$

$$L_{\text{stir1}} \text{ (Length of stirrups along Y)} = 2060.00$$

$$A_{\text{stir1}} \text{ (stirrups area)} = 78.53982$$

$$p_{sh2} \text{ (5.4d)} = L_{\text{stir2}} * A_{\text{stir2}} / (A_{\text{sec}} * s_2) = 0.00067082$$

Lstir2 (Length of stirrups along Y) = 1468.00
Astir2 (stirrups area) = 50.26548

psh_y*Fywe = psh₁*Fywe₁+ps₂*Fywe₂ = 3.0194
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 = 694.45
fywe₂ = 694.45
fce = 33.00

From ((5.A5), TBDY), TBDY: cc = 0.00238888
c = confinement factor = 1.03889

y₁ = 0.0025
sh₁ = 0.008
ft₁ = 833.34
fy₁ = 694.45
su₁ = 0.032

using (30) in Biskinis/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 = 1.00

su₁ = 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 y₁, sh₁,ft₁,fy₁, it is considered
characteristic value fsy₁ = fs₁/1.2, from table 5.1, TBDY.

y₁, sh₁,ft₁,fy₁, are also multiplied by Min(1,1.25*(lb/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} = 694.45

with Es₁ = (Es_{jacket}*Asl_{ten,jacket} + Es_{core}*Asl_{ten,core})/Asl_{ten} = 200000.00

y₂ = 0.0025
sh₂ = 0.008
ft₂ = 833.34
fy₂ = 694.45
su₂ = 0.032

using (30) in Biskinis/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} = 1.00

su₂ = 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 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 Min(1,1.25*(lb/l_d)^{2/3}), from 10.3.5, ASCE 41-17.

with fs₂ = (fs_{jacket}*Asl_{com,jacket} + fs_{core}*Asl_{com,core})/Asl_{com} = 694.45

with Es₂ = (Es_{jacket}*Asl_{com,jacket} + Es_{core}*Asl_{com,core})/Asl_{com} = 200000.00

y_v = 0.0025
sh_v = 0.008
ft_v = 833.34
fy_v = 694.45
su_v = 0.032

using (30) in Biskinis/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 = 1.00

su_v = 0.4*esuv_{nominal} ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esuv_{nominal} = 0.08,

considering characteristic value fsy_v = fsv/1.2, from table 5.1, TBDY
For calculation of esuv_{nominal} and y_v, sh_v,ft_v,fy_v, it is considered

characteristic value fsy_v = fsv/1.2, from table 5.1, TBDY.

y₁, sh₁,ft₁,fy₁, are also multiplied by Min(1,1.25*(lb/l_d)^{2/3}), from 10.3.5, ASCE 41-17.

with fsv = (fs_{jacket}*Asl_{mid,jacket} + fs_{mid}*Asl_{mid,core})/Asl_{mid} = 694.45

$$\text{with } E_{sv} = (E_{s,jacket} \cdot A_{sl,mid,jacket} + E_{s,mid} \cdot A_{sl,mid,core}) / A_{sl,mid} = 200000.00$$

$$1 = A_{sl,ten} / (b \cdot d) \cdot (f_{s1} / f_c) = 0.16434361$$

$$2 = A_{sl,com} / (b \cdot d) \cdot (f_{s2} / f_c) = 0.08462644$$

$$v = A_{sl,mid} / (b \cdot d) \cdot (f_{sv} / f_c) = 0.14938203$$

and confined core properties:

$$b = 340.00$$

$$d = 677.00$$

$$d' = 13.00$$

$$f_{cc} (5A.2, TBDY) = 34.2833$$

$$c_c (5A.5, TBDY) = 0.00238888$$

$$c = \text{confinement factor} = 1.03889$$

$$1 = A_{sl,ten} / (b \cdot d) \cdot (f_{s1} / f_c) = 0.20191317$$

$$2 = A_{sl,com} / (b \cdot d) \cdot (f_{s2} / f_c) = 0.10397236$$

$$v = A_{sl,mid} / (b \cdot d) \cdot (f_{sv} / f_c) = 0.18353132$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < v_{s,y2}$ - LHS eq.(4.5) is not satisfied

--->

$v < v_{s,c}$ - RHS eq.(4.5) is satisfied

--->

$$s_u (4.8) = 0.29596233$$

$$\mu_u = M_{Rc} (4.15) = 1.7288E+009$$

$$u = s_u (4.1) = 6.4288704E-005$$

Calculation of ratio l_b/d

Adequate Lap Length: $l_b/d \geq 1$

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 1.0898E+006$

Calculation of Shear Strength at edge 1, $V_{r1} = 1.0898E+006$

$$V_{r1} = V_{Co1} ((10.3), ASCE 41-17) = k_{nl} \cdot V_{Co10}$$

$$V_{Co10} = 1.0898E+006$$

$$k_{nl} = 1 \text{ (zero step-static loading)}$$

NOTE: In expression (10-3) ' $V_s = A_v \cdot f_y \cdot d / s$ ' is replaced by ' $V_{s+} = f \cdot V_f$ '
where V_f is the contribution of FRPs (11.3), ACI 440).

= 1 (normal-weight concrete)

Mean concrete strength: $f'_c = (f'_c \cdot A_{jacket} + f'_c \cdot A_{core}) / A_{section} = 33.00$, but $f'_c^{0.5} \leq 8.3$
MPa (22.5.3.1, ACI 318-14)

$$M/d = 4.00$$

$$\mu_u = 1518.777$$

$$V_u = 0.0001715$$

$$d = 0.8 \cdot h = 600.00$$

$$N_u = 16273.607$$

$$A_g = 300000.00$$

$$\text{From (11.5.4.8), ACI 318-14: } V_s = V_{s,jacket} + V_{s,core} = 901155.609$$

where:

$$V_{s,jacket} = V_{s,j1} + V_{s,j2} = 802857.879$$

$V_{s,j1} = 279254.914$ is calculated for section web jacket, with:

$$d = 320.00$$

$$A_v = 157079.633$$

$$f_y = 555.56$$

$$s = 100.00$$

$V_{s,j1}$ is multiplied by $Col_{j1} = 1.00$

$$s/d = 0.3125$$

$V_{s,j2} = 523602.964$ is calculated for section flange jacket, with:

$$d = 600.00$$

$$A_v = 157079.633$$

$$f_y = 555.56$$

$$s = 100.00$$

$V_{s,j2}$ is multiplied by $Col,j2 = 1.00$
 $s/d = 0.16666667$

$V_{s,core} = V_{s,c1} + V_{s,c2} = 98297.73$

$V_{s,c1} = 0.00$ is calculated for section web core, with:

$d = 160.00$

$A_v = 100530.965$

$f_y = 555.56$

$s = 250.00$

$V_{s,c1}$ is multiplied by $Col,c1 = 0.00$

$s/d = 1.5625$

$V_{s,c2} = 98297.73$ is calculated for section flange core, with:

$d = 440.00$

$A_v = 100530.965$

$f_y = 555.56$

$s = 250.00$

$V_{s,c2}$ 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 $(\cot + \csc)\sin\alpha$ 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, $t_{f1} = NL \cdot t / N_{oDir} = 1.016$

$d_{fv} = d$ (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: $V_s + V_f \leq 915872.391$

$b_w = 400.00$

Calculation of Shear Strength at edge 2, $V_{r2} = 1.0898E+006$

$V_{r2} = V_{Col}$ ((10.3), ASCE 41-17) = $k_{nl} \cdot V_{Col0}$

$V_{Col0} = 1.0898E+006$

$k_{nl} = 1$ (zero step-static loading)

NOTE: In expression (10-3) ' $V_s = A_v \cdot f_y \cdot d / s$ ' is replaced by ' $V_s + f \cdot V_f$ ' where V_f is the contribution of FRPs (11.3), ACI 440).

$\lambda = 1$ (normal-weight concrete)

Mean concrete strength: $f'_c = (f'_{c,jacket} \cdot Area_{jacket} + f'_{c,core} \cdot Area_{core}) / Area_{section} = 33.00$, but $f'_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 4.00$

$\mu_u = 1518.777$

$\nu_u = 0.0001715$

$d = 0.8 \cdot h = 600.00$

$N_u = 16273.607$

$A_g = 300000.00$

From (11.5.4.8), ACI 318-14: $V_s = V_{s,jacket} + V_{s,core} = 901155.609$

where:

$V_{s,jacket} = V_{s,j1} + V_{s,j2} = 802857.879$

$V_{s,j1} = 279254.914$ is calculated for section web jacket, with:

$d = 320.00$

$A_v = 157079.633$

$f_y = 555.56$

$s = 100.00$

$V_{s,j1}$ is multiplied by $Col,j1 = 1.00$

$s/d = 0.3125$

$V_{s,j2} = 523602.964$ is calculated for section flange jacket, with:

$d = 600.00$

$A_v = 157079.633$

$f_y = 555.56$

$s = 100.00$
 $V_{s,j2}$ is multiplied by $Col,j2 = 1.00$
 $s/d = 0.16666667$
 $V_{s,core} = V_{s,c1} + V_{s,c2} = 98297.73$
 $V_{s,c1} = 0.00$ is calculated for section web core, with:
 $d = 160.00$
 $A_v = 100530.965$
 $f_y = 555.56$
 $s = 250.00$
 $V_{s,c1}$ is multiplied by $Col,c1 = 0.00$
 $s/d = 1.5625$
 $V_{s,c2} = 98297.73$ is calculated for section flange core, with:
 $d = 440.00$
 $A_v = 100530.965$
 $f_y = 555.56$
 $s = 250.00$
 $V_{s,c2}$ 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).
 $\ln(11.3) \sin + \cos$ is replaced with $(\cot + \cot a) \sin a$ which is more a generalised expression,
 where a is the angle of the crack direction (see KANEPE).
 This later relation, considered as a function $V_f(a)$, is implemented for every different fiber orientation a_i ,
 as well as for 2 crack directions, $a = 45^\circ$ and $a = -45^\circ$ to take into consideration the cyclic seismic loading.
 orientation 1: $a_1 = b_1 + 90^\circ = 90.00$
 $V_f = \text{Min}(|V_f(45, a_1)|, |V_f(-45, a_1)|)$, with:
 total thickness per orientation, $tf_1 = NL * t / NoDir = 1.016$
 $df_v = d$ (figure 11.2, ACI 440) = 707.00
 $ff_e ((11-5), ACI 440) = 259.312$
 $E_f = 64828.00$
 $f_e = 0.004$, from (11.6a), ACI 440
 with $f_u = 0.01$
 From (11-11), ACI 440: $V_s + V_f \leq 915872.391$
 $bw = 400.00$

 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: rcjics

Constant Properties

 Knowledge Factor, $\phi = 0.90$
 Chord Rotation is generally considered as Deformation-Controlled Action according to Table C7-1, ASCE 41-17.
 Mean strengths are used for Deformation-Controlled Actions according to 7.5.1.3, ASCE 41-17
 Consequently:
 Jacket
 New material of Secondary Member: Concrete Strength, $f_c = f_{cm} = 33.00$
 New material of Secondary Member: Steel Strength, $f_s = f_{sm} = 555.56$
 Concrete Elasticity, $E_c = 26999.444$
 Steel Elasticity, $E_s = 200000.00$
 Existing Column
 New material of Secondary Member: Concrete Strength, $f_c = f_{cm} = 33.00$
 New material of Secondary Member: Steel Strength, $f_s = f_{sm} = 555.56$
 Concrete Elasticity, $E_c = 26999.444$
 Steel Elasticity, $E_s = 200000.00$
 Max Height, $H_{max} = 750.00$
 Min Height, $H_{min} = 400.00$
 Max Width, $W_{max} = 750.00$

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
Adequate Lap Length ($l_b/d >= 1$)
FRP Wrapping Data
Type: Carbon
Cured laminate properties (design values)
Thickness, t = 1.016
Tensile Strength, f_{fu} = 1055.00
Tensile Modulus, E_f = 64828.00
Elongation, e_{fu} = 0.01
Number of directions, NoDir = 1
Fiber orientations, b_i : 0.00°
Number of layers, NL = 1
Radius of rounding corners, R = 40.00

Stepwise Properties

Bending Moment, M = -1.5109E+007
Shear Force, V2 = -4866.131
Shear Force, V3 = 131.6809
Axial Force, F = -18154.476
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: Asl,t = 0.00
-Compression: Asl,c = 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

New component: From table 7-7, ASCE 41_17: Final chord rotation Capacity $u_{,R} = 1.0^*$ $u = 0.05473481$
 $u = y + p = 0.05473481$

- Calculation of y -

$y = (M_y * L_s / 3) / E_{eff} = 0.00440532$ ((4.29), Biskinis Phd))
 $M_y = 6.4998E+008$
 $L_s = M/V$ (with $L_s > 0.1 * L$ and $L_s < 2 * L$) = 3104.846
From table 10.5, ASCE 41_17: $E_{eff} = factor * E_c * I_g = 1.5270E+014$
factor = 0.30
 $A_g = 440000.00$
Mean concrete strength: $f_c' = (f_c'_{jacket} * Area_{jacket} + f_c'_{core} * Area_{core}) / Area_{section} = 33.00$
N = 18154.476
 $E_c * I_g = E_c * I_{g,jacket} + E_c * I_{g,core} = 5.0901E+014$

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, $t = 400.00$

$$y = \text{Min}(y_{\text{ten}}, y_{\text{com}})$$

$$y_{\text{ten}} = 4.8675041\text{E-}006$$

with $f_y = 555.56$

$$d = 707.00$$

$$y = 0.19281101$$

$$A = 0.01015738$$

$$B = 0.00446779$$

$$\text{with } p_t = 0.00671904$$

$$p_c = 0.00416509$$

$$p_v = 0.00378591$$

$$N = 18154.476$$

$$b = 750.00$$

$$" = 0.06082037$$

$$y_{\text{comp}} = 1.6460425\text{E-}005$$

with f_c^* (12.3, (ACI 440)) = 33.48734

$$f_c = 33.00$$

$$f_l = 0.49678681$$

$$b = b_{\text{max}} = 750.00$$

$$h = h_{\text{max}} = 750.00$$

$$A_g = 0.44$$

$$g = p_t + p_c + p_v = 0.01009575$$

$$r_c = 40.00$$

$$A_e/A_c = 0.31291181$$

$$\text{Effective FRP thickness, } t_f = N L^* t^* \text{Cos}(b_1) = 1.016$$

effective strain from (12.5) and (12.12), $\epsilon_{fe} = 0.004$

$$f_u = 0.01$$

$$E_f = 64828.00$$

$$E_c = 26999.444$$

$$y = 0.19183941$$

$$A = 0.01001908$$

$$B = 0.00440616$$

$$\text{with } E_s = 200000.00$$

CONFIRMATION: $y = 0.19281101 < t/d$

Calculation of ratio l_b/d

Adequate Lap Length: $l_b/d \geq 1$

- Calculation of p -

From table 10-8: $p = 0.05032949$

with:

- Columns not controlled by inadequate development or splicing along the clear height because $l_b/d \geq 1$

$$\text{shear control ratio } V_y E / V_{Co} I_{OE} = 1.05752$$

$$d = d_{\text{external}} = 707.00$$

$$s = s_{\text{external}} = 0.00$$

$$- t = s_1 + s_2 + 2 \cdot t_f / b_w \cdot (f_{fe} / f_s) = 0.00671904$$

$$\text{jacket: } s_1 = A_{v1} \cdot L_{\text{stir1}} / (s_1 \cdot A_g) = 0.00367709$$

$A_{v1} = 78.53982$, 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.

$$N_{UD} = 18154.476$$

$$A_g = 440000.00$$

$$f_{cE} = (f_{c_jacket} \cdot Area_jacket + f_{c_core} \cdot Area_core) / section_area = 33.00$$

$$f_{yE} = (f_{y_ext_Long_Reinf} \cdot Area_ext_Long_Reinf + f_{y_int_Long_Reinf} \cdot Area_int_Long_Reinf) / Area_Tot_Long_Rein = 555.56$$

$$f_{yE} = (f_{y_ext_Trans_Reinf} \cdot s_1 + f_{y_int_Trans_Reinf} \cdot s_2) / (s_1 + s_2) = 555.56$$

$$p_l = Area_Tot_Long_Rein / (b \cdot d) = 0.01009575$$

$$b = 750.00$$

$$d = 707.00$$

$$f_{cE} = 33.00$$

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

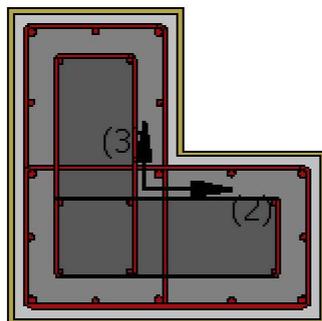
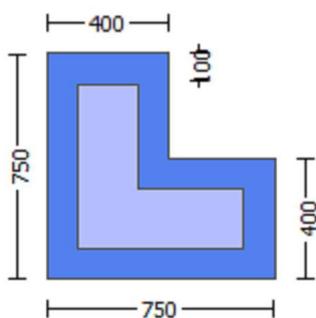
Limit State: Collapse Prevention (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Shear capacity V_{Rd}

Edge: End

Local Axis: (2)



Start Of Calculation of Shear Capacity for element: column JLC1 of floor 1

At local axis: 2

Integration Section: (b)

Section Type: rcjlc

Constant Properties

```

Knowledge Factor,  $\gamma = 0.90$ 
Member Shear Force is generally considered as Force-Controlled Action according to Table C7-1, ASCE 41-17.
Lower-bound strengths are used for Force-Controlled Actions according to 7.5.1.3, ASCE 41-17
Consequently:
Jacket
New material of Secondary Member: Concrete Strength,  $f_c = f_{c\_lower\_bound} = 25.00$ 
New material of Secondary Member: Steel Strength,  $f_s = f_{s\_lower\_bound} = 500.00$ 
Concrete Elasticity,  $E_c = 26999.444$ 
Steel Elasticity,  $E_s = 200000.00$ 
Existing Column
New material of Secondary Member: Concrete Strength,  $f_c = f_{c\_lower\_bound} = 25.00$ 
New material of Secondary Member: Steel Strength,  $f_s = f_{s\_lower\_bound} = 500.00$ 
Concrete Elasticity,  $E_c = 26999.444$ 
Steel Elasticity,  $E_s = 200000.00$ 
#####
Note: Especially for the calculation of  $\gamma$  for displacement ductility demand,
the expected (mean value) strengths are used (7.5.1.3, ASCE 41-17) because bending is considered as
Deformation-Controlled Action (Table C7-1, ASCE 41-17).
Jacket
New material: Concrete Strength,  $f_c = f_{cm} = 33.00$ 
New material: Steel Strength,  $f_s = f_{sm} = 555.56$ 
Existing Column
New material: Concrete Strength,  $f_c = f_{cm} = 33.00$ 
New material: Steel Strength,  $f_s = f_{sm} = 555.56$ 
#####
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
Adequate Lap Length ( $l_o/l_{o,min} = l_b/l_d \geq 1$ )
FRP Wrapping Data
Type: Carbon
Cured laminate properties (design values)
Thickness,  $t = 1.016$ 
Tensile Strength,  $f_{fu} = 1055.00$ 
Tensile Modulus,  $E_f = 64828.00$ 
Elongation,  $e_{fu} = 0.01$ 
Number of directions,  $NoDir = 1$ 
Fiber orientations,  $b_i = 0.00^\circ$ 
Number of layers,  $NL = 1$ 
Radius of rounding corners,  $R = 40.00$ 
-----

Stepwise Properties
-----
EDGE -A-
Bending Moment,  $M_a = -1.5109E+007$ 
Shear Force,  $V_a = -4866.131$ 
EDGE -B-
Bending Moment,  $M_b = 505225.544$ 
Shear Force,  $V_b = 4866.131$ 
BOTH EDGES
Axial Force,  $F = -18154.476$ 
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:  $A_{sl,com} = 2208.54$ 

```

-Middle: Asl,mid = 2007.478

Mean Diameter of Tension Reinforcement, DbL,ten = 16.80

New component: From table 7-7, ASCE 41_17: Final Shear Capacity VR = 1.0*Vn = 1.1008E+006

Vn ((10.3), ASCE 41-17) = knl*VCol0 = 1.1008E+006

VCol = 1.1008E+006

knl = 1.00

displacement_ductility_demand = 0.03726828

NOTE: In expression (10-3) 'Vs = Av*fy*d/s' is replaced by 'Vs+ f*Vf' where Vf is the contribution of FRPs (11.3), ACI 440).

= 1 (normal-weight concrete)

Mean concrete strength: fc' = (fc'_jacket*Area_jacket + fc'_core*Area_core)/Area_section = 25.00, but fc'^0.5 <= 8.3 MPa (22.5.3.1, ACI 318-14)

M/Vd = 2.00

Mu = 505225.544

Vu = 4866.131

d = 0.8*h = 600.00

Nu = 18154.476

Ag = 300000.00

From (11.5.4.8), ACI 318-14: Vs = Vs,jacket + Vs,core = 811033.559

where:

Vs,jacket = Vs,j1 + Vs,j2 = 722566.31

Vs,j1 = 251327.412 is calculated for section web jacket, with:

d = 320.00

Av = 157079.633

fy = 500.00

s = 100.00

Vs,j1 is multiplied by Col,j1 = 1.00

s/d = 0.3125

Vs,j2 = 471238.898 is calculated for section flange jacket, with:

d = 600.00

Av = 157079.633

fy = 500.00

s = 100.00

Vs,j2 is multiplied by Col,j2 = 1.00

s/d = 0.16666667

Vs,core = Vs,c1 + Vs,c2 = 88467.249

Vs,c1 = 0.00 is calculated for section web core, with:

d = 160.00

Av = 100530.965

fy = 500.00

s = 250.00

Vs,c1 is multiplied by Col,c1 = 0.00

s/d = 1.5625

Vs,c2 = 88467.249 is calculated for section flange core, with:

d = 440.00

Av = 100530.965

fy = 500.00

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 + cota)sina which is more a generalised expression, where is the angle of the crack direction (see KANEPE).

This later relation, considered as a function Vf(,), is implemented for every different fiber orientation ai, as well as for 2 crack directions, = 45° and = -45° to take into consideration the cyclic seismic loading.

orientation 1: 1 = b1 + 90° = 90.00

Vf = Min(|Vf(45, 1)|, |Vf(-45,a1)|), with:

total thickness per orientation, tf1 = NL*t/NoDir = 1.016

dfv = d (figure 11.2, ACI 440) = 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: $V_s + V_f \leq 797164.595$
 $bw = 400.00$

displacement ductility demand is calculated as ϕ / y

- Calculation of ϕ / y for END B -
for rotation axis 3 and integ. section (b)

From analysis, chord rotation $\theta = 1.5863445E-005$
 $y = (M_y * L_s / 3) / E_{eff} = 0.00042566$ ((4.29), Biskinis Phd))
 $M_y = 6.4998E+008$
 $L_s = M/V$ (with $L_s > 0.1 * L$ and $L_s < 2 * L$) = 300.00
From table 10.5, ASCE 41_17: $E_{eff} = factor * E_c * I_g = 1.5270E+014$
factor = 0.30
 $A_g = 440000.00$
Mean concrete strength: $f_c' = (f_c'_{jacket} * Area_{jacket} + f_c'_{core} * Area_{core}) / Area_{section} = 33.00$
 $N = 18154.476$
 $E_c * I_g = E_c_{jacket} * I_{g,jacket} + E_c_{core} * I_{g,core} = 5.0901E+014$

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, $bw = 400.00$
flange thickness, $t = 400.00$

$y = \text{Min}(y_{ten}, y_{com})$
 $y_{ten} = 4.8675041E-006$
with $f_y = 555.56$
 $d = 707.00$
 $y = 0.19281101$
 $A = 0.01015738$
 $B = 0.00446779$
with $pt = 0.00214476$
 $pc = 0.00416509$
 $pv = 0.00378591$
 $N = 18154.476$
 $b = 750.00$
 $\alpha = 0.06082037$
 $y_{comp} = 1.6460425E-005$
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), $\epsilon_{fe} = 0.004$
 $f_u = 0.01$
 $E_f = 64828.00$
 $E_c = 26999.444$
 $y = 0.19183941$
 $A = 0.01001908$
 $B = 0.00440616$

with $E_s = 200000.00$

CONFIRMATION: $y = 0.19281101 < t/d$

Calculation of ratio I_b/I_d

Adequate Lap Length: $I_b/I_d \geq 1$

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

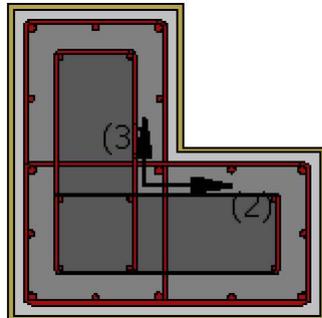
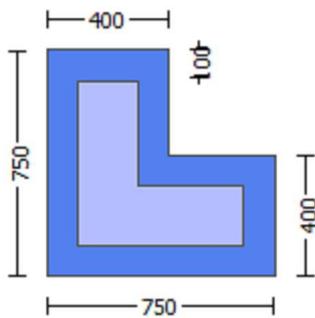
Limit State: Collapse Prevention (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity (θ)

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: rcjlcs

Constant Properties

Knowledge Factor, $\gamma = 0.90$

Mean strength values are used for both shear and moment calculations.

Consequently:

Jacket

New material of Secondary Member: Concrete Strength, $f_c = f_{cm} = 33.00$

New material of Secondary Member: Steel Strength, $f_s = f_{sm} = 555.56$

Concrete Elasticity, $E_c = 26999.444$

Steel Elasticity, $E_s = 200000.00$

Existing Column

```

: New material of Secondary Member: Concrete Strength,  $f_c = f_{cm} = 33.00$ 
: New material of Secondary Member: Steel Strength,  $f_s = f_{sm} = 555.56$ 
: Concrete Elasticity,  $E_c = 26999.444$ 
: Steel Elasticity,  $E_s = 200000.00$ 
: #####
: Note: Especially for the calculation of moment strengths,
: the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14
: Jacket
: New material: Steel Strength,  $f_s = 1.25 \cdot f_{sm} = 694.45$ 
: Existing Column
: New material: Steel Strength,  $f_s = 1.25 \cdot f_{sm} = 694.45$ 
: #####
: 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
: Adequate Lap Length ( $l_o/l_{ou, min} >= 1$ )
: FRP Wrapping Data
: Type: Carbon
: Cured laminate properties (design values)
: Thickness,  $t = 1.016$ 
: Tensile Strength,  $f_{fu} = 1055.00$ 
: Tensile Modulus,  $E_f = 64828.00$ 
: Elongation,  $e_{fu} = 0.01$ 
: Number of directions,  $N_{oDir} = 1$ 
: Fiber orientations,  $b_i = 0.00^\circ$ 
: Number of layers,  $N_L = 1$ 
: Radius of rounding corners,  $R = 40.00$ 
: -----
: Stepwise Properties
: -----
: At local axis: 3
: EDGE -A-
: Shear Force,  $V_a = -0.00017144$ 
: EDGE -B-
: Shear Force,  $V_b = 0.00017144$ 
: BOTH EDGES
: Axial Force,  $F = -16273.607$ 
: Longitudinal Reinforcement Area Distribution (in 2 divisions)
:   -Tension:  $A_{slt} = 0.00$ 
:   -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:  $A_{sl,mid} = 2007.478$ 
: -----
: -----
: Calculation of Shear Capacity ratio,  $V_e/V_r = 1.05752$ 
: Member Controlled by Shear ( $V_e/V_r > 1$ )
: Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 1.1525E+006$ 
: with
:  $M_{pr1} = \text{Max}(M_{u1+}, M_{u1-}) = 1.7288E+009$ 
:  $M_{u1+} = 1.1540E+009$ , 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
:  $M_{u1-} = 1.7288E+009$ , 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

$$M_{pr2} = \text{Max}(M_{u2+}, M_{u2-}) = 1.7288E+009$$

$M_{u2+} = 1.1540E+009$, 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

$M_{u2-} = 1.7288E+009$, 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:

$$\phi_u = 5.0226943E-005$$

$$M_u = 1.1540E+009$$

with full section properties:

$$b = 750.00$$

$$d = 707.00$$

$$d' = 43.00$$

$$v = 0.00093001$$

$$N = 16273.607$$

$$f_c = 33.00$$

$$c_o (5A.5, TBDY) = 0.002$$

$$\text{Final value of } \phi_{cu}^* = \text{shear_factor} * \text{Max}(\phi_{cu}, \phi_{cc}) = 0.01291652$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \phi_{cu} = 0.01291652$$

$$\phi_{we} \text{ ((5.4c), TBDY) } = a_{se} * \phi_{sh, \min} * f_{ywe} / f_{ce} + \text{Min}(\phi_{fx}, \phi_{fy}) = 0.05541928$$

where $\phi_f = a_f * \phi_f' * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$\phi_{fx} = 0.04286225$$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.31984848$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 140733.333$$

$$b_{\max} = 750.00$$

$$h_{\max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } \phi_f = 2t_f / b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 870.5244$$

$$\phi_{fy} = 0.04286225$$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$a_f = 0.31984848$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 140733.333$$

$$b_{\max} = 750.00$$

$$h_{\max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } \phi_f = 2t_f / b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 870.5244$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L * t * \text{Cos}(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{f} = 0.015$$

$$a_{se} \text{ ((5.4d), TBDY) } = (a_{se1} * A_{ext} + a_{se2} * A_{int}) / A_{sec} = 0.45746528$$

$$a_{se1} = \text{Max}(((A_{conf, \max 1} - A_{noConf 1}) / A_{conf, \max 1}) * (A_{conf, \min 1} / A_{conf, \max 1}), 0) = 0.45746528$$

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.

$A_{conf, \max 1} = 353600.00$ 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.

$A_{conf, \min 1} = 293525.00$ is the confined core area at midway between the levels of hoops and

is calculated by reducing all the dimensions of the area $A_{conf, \max 1}$ 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).
 $ase_2 (>= ase_1) = \text{Max}(((A_{conf,max2}-AnoConf_2)/A_{conf,max2}) * (A_{conf,min2}/A_{conf,max2}), 0) = 0.45746528$

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).
 $psh_{,min} * Fy_{we} = \text{Min}(psh_x * Fy_{we}, psh_y * Fy_{we}) = 3.0194$

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)

 $psh_x * Fy_{we} = psh_1 * Fy_{we1} + ps_2 * Fy_{we2} = 3.0194$
 psh_1 ((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 (5.4d) = $L_{stir2} * Astir2 / (A_{sec} * s_2) = 0.00067082$
Lstir2 (Length of stirrups along Y) = 1468.00
Astir2 (stirrups area) = 50.26548

 $psh_y * Fy_{we} = psh_1 * Fy_{we1} + ps_2 * Fy_{we2} = 3.0194$
 psh_1 ((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 ((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 = 694.45

fywe2 = 694.45

fce = 33.00

From ((5.A.5), TBDY), TBDY: cc = 0.00238888

c = confinement factor = 1.03889

y1 = 0.0025

sh1 = 0.008

ft1 = 833.34

fy1 = 694.45

su1 = 0.032

using (30) in Biskinis/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 = 1.00

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 = $(fs_{jacket} * A_{sl,ten,jacket} + fs_{core} * A_{sl,ten,core}) / A_{sl,ten} = 694.45$

with Es1 = $(Es_{jacket} * A_{sl,ten,jacket} + Es_{core} * A_{sl,ten,core}) / A_{sl,ten} = 200000.00$

y2 = 0.0025

sh2 = 0.008

ft2 = 833.34

fy2 = 694.45

su2 = 0.032

using (30) in Biskinis/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 = 1.00

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 $fs2 = (fs_jacket \cdot Asl,com,jacket + fs_core \cdot Asl,com,core) / Asl,com = 694.45$

with $Es2 = (Es_jacket \cdot Asl,com,jacket + Es_core \cdot Asl,com,core) / Asl,com = 200000.00$

$yv = 0.0025$

$shv = 0.008$

$ftv = 833.34$

$fyv = 694.45$

$suv = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with $shear_factor$

and also multiplied by the $shear_factor$ according to 15.7.1.4, with

$Shear_factor = 1.00$

$lo/lou,min = lb/ld = 1.00$

$suv = 0.4 \cdot esuv_nominal$ ((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 $fsv = (fs_jacket \cdot Asl,mid,jacket + fs_mid \cdot Asl,mid,core) / Asl,mid = 694.45$

with $Esv = (Es_jacket \cdot Asl,mid,jacket + Es_mid \cdot Asl,mid,core) / Asl,mid = 200000.00$

$1 = Asl,ten / (b \cdot d) \cdot (fs1 / fc) = 0.0451341$

$2 = Asl,com / (b \cdot d) \cdot (fs2 / fc) = 0.08764993$

$v = Asl,mid / (b \cdot d) \cdot (fsv / fc) = 0.07967042$

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

$1 = Asl,ten / (b \cdot d) \cdot (fs1 / fc) = 0.05123276$

$2 = Asl,com / (b \cdot d) \cdot (fs2 / fc) = 0.09949345$

$v = Asl,mid / (b \cdot d) \cdot (fsv / fc) = 0.09043572$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < vs,y2$ - LHS eq.(4.5) is satisfied

--->

su (4.9) = 0.09885678

$Mu = MRc$ (4.14) = 1.1540E+009

$u = su$ (4.1) = 5.0226943E-005

Calculation of ratio lb/ld

Adequate Lap Length: $lb/ld \geq 1$

Calculation of $Mu1$ -

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

$u = 6.4288704E-005$

$Mu = 1.7288E+009$

with full section properties:

$b = 400.00$

$d = 707.00$

$d' = 43.00$

$v = 0.00174378$

$N = 16273.607$

$fc = 33.00$

$$c_o (5A.5, TBDY) = 0.002$$

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.01291652$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } c_u = 0.01291652$$

$$w_e ((5.4c), TBDY) = a_{se} * s_{h,min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.05541928$$

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 $a_f = 1 - (\text{Unconfined area})/(\text{total area})$

$$a_f = 0.31984848$$

$$\text{with Unconfined area} = ((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 140733.333$$

$$b_{max} = 750.00$$

$$h_{max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 870.5244$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N_L * t * \text{Cos}(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$a_{se} ((5.4d), TBDY) = (a_{se1} * A_{ext} + a_{se2} * A_{int})/A_{sec} = 0.45746528$$

$$a_{se1} = \text{Max}(((A_{conf,max1} - A_{noConf1})/A_{conf,max1}) * (A_{conf,min1}/A_{conf,max1}), 0) = 0.45746528$$

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).

$$p_{sh,min} * F_{ywe} = \text{Min}(p_{sh,x} * F_{ywe}, p_{sh,y} * F_{ywe}) = 3.0194$$

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)

$$p_{sh,x} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{sh2} * F_{ywe2} = 3.0194$$

$$p_{sh1} ((5.4d), TBDY) = L_{stir1} * A_{stir1}/(A_{sec} * s_1) = 0.00367709$$

$$L_{stir1} (\text{Length of stirrups along } Y) = 2060.00$$

$$A_{stir1} (\text{stirrups area}) = 78.53982$$

$$p_{sh2} (5.4d) = L_{stir2} * A_{stir2}/(A_{sec} * s_2) = 0.00067082$$

$$L_{stir2} (\text{Length of stirrups along } Y) = 1468.00$$

$$\text{Astir2 (stirrups area)} = 50.26548$$

$$\text{psh}_y * \text{Fywe} = \text{psh}_1 * \text{Fywe}_1 + \text{ps}_2 * \text{Fywe}_2 = 3.0194$$

$$\text{psh}_1 ((5.4d), \text{TBDY}) = \text{Lstir}_1 * \text{Astir}_1 / (\text{Asec} * \text{s}_1) = 0.00367709$$

$$\text{Lstir}_1 (\text{Length of stirrups along X}) = 2060.00$$

$$\text{Astir}_1 (\text{stirrups area}) = 78.53982$$

$$\text{psh}_2 ((5.4d), \text{TBDY}) = \text{Lstir}_2 * \text{Astir}_2 / (\text{Asec} * \text{s}_2) = 0.00067082$$

$$\text{Lstir}_2 (\text{Length of stirrups along X}) = 1468.00$$

$$\text{Astir}_2 (\text{stirrups area}) = 50.26548$$

$$\text{Asec} = 440000.00$$

$$\text{s}_1 = 100.00$$

$$\text{s}_2 = 250.00$$

$$\text{fywe}_1 = 694.45$$

$$\text{fywe}_2 = 694.45$$

$$\text{fce} = 33.00$$

$$\text{From } ((5.A.5), \text{TBDY}), \text{TBDY: } \text{cc} = 0.00238888$$

$$\text{c} = \text{confinement factor} = 1.03889$$

$$\text{y}_1 = 0.0025$$

$$\text{sh}_1 = 0.008$$

$$\text{ft}_1 = 833.34$$

$$\text{fy}_1 = 694.45$$

$$\text{su}_1 = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$\text{lo/lou, min} = \text{lb/ld} = 1.00$$

$$\text{su}_1 = 0.4 * \text{esu}_1 \text{ nominal } ((5.5), \text{TBDY}) = 0.032$$

$$\text{From table 5A.1, TBDY: } \text{esu}_1 \text{ nominal} = 0.08,$$

For calculation of esu1_nominal and y1, sh1, ft1, fy1, it is considered
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

$$\text{y}_1, \text{sh}_1, \text{ft}_1, \text{fy}_1, \text{ are also multiplied by } \text{Min}(1, 1.25 * (\text{lb/ld})^{2/3}), \text{ from 10.3.5, ASCE 41-17.}$$

$$\text{with } \text{fs}_1 = (\text{fs}_{\text{jacket}} * \text{Asl, ten, jacket} + \text{fs}_{\text{core}} * \text{Asl, ten, core}) / \text{Asl, ten} = 694.45$$

$$\text{with } \text{Es}_1 = (\text{Es}_{\text{jacket}} * \text{Asl, ten, jacket} + \text{Es}_{\text{core}} * \text{Asl, ten, core}) / \text{Asl, ten} = 200000.00$$

$$\text{y}_2 = 0.0025$$

$$\text{sh}_2 = 0.008$$

$$\text{ft}_2 = 833.34$$

$$\text{fy}_2 = 694.45$$

$$\text{su}_2 = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$\text{lo/lou, min} = \text{lb/lb, min} = 1.00$$

$$\text{su}_2 = 0.4 * \text{esu}_2 \text{ nominal } ((5.5), \text{TBDY}) = 0.032$$

$$\text{From table 5A.1, TBDY: } \text{esu}_2 \text{ nominal} = 0.08,$$

For calculation of esu2_nominal and y2, sh2, ft2, fy2, it is considered
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

$$\text{y}_2, \text{sh}_2, \text{ft}_2, \text{fy}_2, \text{ are also multiplied by } \text{Min}(1, 1.25 * (\text{lb/ld})^{2/3}), \text{ from 10.3.5, ASCE 41-17.}$$

$$\text{with } \text{fs}_2 = (\text{fs}_{\text{jacket}} * \text{Asl, com, jacket} + \text{fs}_{\text{core}} * \text{Asl, com, core}) / \text{Asl, com} = 694.45$$

$$\text{with } \text{Es}_2 = (\text{Es}_{\text{jacket}} * \text{Asl, com, jacket} + \text{Es}_{\text{core}} * \text{Asl, com, core}) / \text{Asl, com} = 200000.00$$

$$\text{y}_v = 0.0025$$

$$\text{sh}_v = 0.008$$

$$\text{ft}_v = 833.34$$

$$\text{fy}_v = 694.45$$

$$\text{suv} = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$\text{lo/lou, min} = \text{lb/ld} = 1.00$$

$$\text{suv} = 0.4 * \text{esuv}_v \text{ nominal } ((5.5), \text{TBDY}) = 0.032$$

$$\text{From table 5A.1, TBDY: } \text{esuv}_v \text{ nominal} = 0.08,$$

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.

$$\text{y}_v, \text{sh}_v, \text{ft}_v, \text{fy}_v, \text{ are also multiplied by } \text{Min}(1, 1.25 * (\text{lb/ld})^{2/3}), \text{ from 10.3.5, ASCE 41-17.}$$

$$\text{with } \text{fs}_v = (\text{fs}_{\text{jacket}} * \text{Asl, mid, jacket} + \text{fs}_{\text{mid}} * \text{Asl, mid, core}) / \text{Asl, mid} = 694.45$$

$$\text{with } \text{Esv} = (\text{Es}_{\text{jacket}} * \text{Asl, mid, jacket} + \text{Es}_{\text{mid}} * \text{Asl, mid, core}) / \text{Asl, mid} = 200000.00$$

$$1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.16434361$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.08462644$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.14938203$$

and confined core properties:

$$b = 340.00$$

$$d = 677.00$$

$$d' = 13.00$$

$$f_{cc} (5A.2, TBDY) = 34.2833$$

$$c_c (5A.5, TBDY) = 0.00238888$$

$$c = \text{confinement factor} = 1.03889$$

$$1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.20191317$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.10397236$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.18353132$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < v_{s,y2}$ - LHS eq.(4.5) is not satisfied

--->

$v < v_{s,c}$ - RHS eq.(4.5) is satisfied

--->

$$s_u (4.8) = 0.29596233$$

$$\mu_u = M_{Rc} (4.15) = 1.7288E+009$$

$$u = s_u (4.1) = 6.4288704E-005$$

Calculation of ratio l_b/l_d

Adequate Lap Length: $l_b/l_d \geq 1$

Calculation of μ_{u2+}

Calculation of ultimate curvature μ_u according to 4.1, Biskinis/Fardis 2013:

$$u = 5.0226943E-005$$

$$\mu_u = 1.1540E+009$$

with full section properties:

$$b = 750.00$$

$$d = 707.00$$

$$d' = 43.00$$

$$v = 0.00093001$$

$$N = 16273.607$$

$$f_c = 33.00$$

$$c_c (5A.5, TBDY) = 0.002$$

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.01291652$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } c_u = 0.01291652$$

$$w_e ((5.4c), TBDY) = a_{se} * s_{h,min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.05541928$$

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 = $((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 140733.333$

$$b_{max} = 750.00$$

$$h_{max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{fe} = 870.5244$$

$$f_y = 0.04286225$$

Expression ((15B.6), TBDY) is modified as $a_f = 1 - (\text{Unconfined area})/(\text{total area})$

$$a_f = 0.31984848$$

with Unconfined area = $((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 140733.333$

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, $tf = NL*t*Cos(b1) = 1.016$
 $f_{u,f} = 1055.00$
 $E_f = 64828.00$
 $u_{,f} = 0.015$

$ase((5.4d), TBDY) = (ase1*A_{ext} + ase2*A_{int})/A_{sec} = 0.45746528$

$ase1 = Max(((A_{conf,max1} - A_{noConf1})/A_{conf,max1}) * (A_{conf,min1}/A_{conf,max1}), 0) = 0.45746528$

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).

$ase2 (>= ase1) = Max(((A_{conf,max2} - A_{noConf2})/A_{conf,max2}) * (A_{conf,min2}/A_{conf,max2}), 0) = 0.45746528$

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).

$psh_{,min} * F_{ywe} = Min(psh_{,x} * F_{ywe}, psh_{,y} * F_{ywe}) = 3.0194$

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)

$psh_{,x} * F_{ywe} = psh1 * F_{ywe1} + ps2 * F_{ywe2} = 3.0194$

$psh1((5.4d), TBDY) = L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00367709$

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

$psh_{,y} * F_{ywe} = psh1 * F_{ywe1} + ps2 * F_{ywe2} = 3.0194$

$psh1((5.4d), TBDY) = L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00367709$

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

$A_{sec} = 440000.00$

$s1 = 100.00$

$s2 = 250.00$

$f_{ywe1} = 694.45$

$f_{ywe2} = 694.45$

$f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY: $cc = 0.00238888$

c = confinement factor = 1.03889

$y1 = 0.0025$

$sh1 = 0.008$

$ft1 = 833.34$

$f_{y1} = 694.45$
 $s_{u1} = 0.032$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $l_o/l_{ou,min} = l_b/l_d = 1.00$
 $s_{u1} = 0.4 * e_{s1_nominal} ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $e_{s1_nominal} = 0.08$,
 For calculation of $e_{s1_nominal}$ and y_1, sh_1, ft_1, f_{y1} , it is considered
 characteristic value $f_{s1} = f_{s1}/1.2$, 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 $f_{s1} = (f_{s,jacket} * A_{s1,ten,jacket} + f_{s,core} * A_{s1,ten,core}) / A_{s1,ten} = 694.45$
 with $E_{s1} = (E_{s,jacket} * A_{s1,ten,jacket} + E_{s,core} * A_{s1,ten,core}) / A_{s1,ten} = 200000.00$
 $y_2 = 0.0025$
 $sh_2 = 0.008$
 $ft_2 = 833.34$
 $f_{y2} = 694.45$
 $s_{u2} = 0.032$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $l_o/l_{ou,min} = l_b/l_{b,min} = 1.00$
 $s_{u2} = 0.4 * e_{s2_nominal} ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $e_{s2_nominal} = 0.08$,
 For calculation of $e_{s2_nominal}$ and y_2, sh_2, ft_2, f_{y2} , it is considered
 characteristic value $f_{s2} = f_{s2}/1.2$, from table 5.1, TBDY.
 y_2, sh_2, ft_2, f_{y2} , are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE 41-17.
 with $f_{s2} = (f_{s,jacket} * A_{s2,com,jacket} + f_{s,core} * A_{s2,com,core}) / A_{s2,com} = 694.45$
 with $E_{s2} = (E_{s,jacket} * A_{s2,com,jacket} + E_{s,core} * A_{s2,com,core}) / A_{s2,com} = 200000.00$
 $y_v = 0.0025$
 $sh_v = 0.008$
 $ft_v = 833.34$
 $f_{y_v} = 694.45$
 $s_{u_v} = 0.032$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $l_o/l_{ou,min} = l_b/l_d = 1.00$
 $s_{u_v} = 0.4 * e_{s_{u_v_nominal}} ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $e_{s_{u_v_nominal}} = 0.08$,
 considering characteristic value $f_{s_{u_v}} = f_{s_{u_v}}/1.2$, 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 $f_{s_{u_v}} = f_{s_{u_v}}/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, f_{y1} , are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE 41-17.
 with $f_{s_{u_v}} = (f_{s,jacket} * A_{s_{u_v},mid,jacket} + f_{s,mid} * A_{s_{u_v},mid,core}) / A_{s_{u_v},mid} = 694.45$
 with $E_{s_{u_v}} = (E_{s,jacket} * A_{s_{u_v},mid,jacket} + E_{s,mid} * A_{s_{u_v},mid,core}) / A_{s_{u_v},mid} = 200000.00$
 $1 = A_{s1,ten} / (b * d) * (f_{s1} / f_c) = 0.0451341$
 $2 = A_{s2,com} / (b * d) * (f_{s2} / f_c) = 0.08764993$
 $v = A_{s_{u_v},mid} / (b * d) * (f_{s_{u_v}} / f_c) = 0.07967042$
 and confined core properties:
 $b = 690.00$
 $d = 677.00$
 $d' = 13.00$
 $f_{cc} (5A.2, TBDY) = 34.2833$
 $cc (5A.5, TBDY) = 0.00238888$
 $c = \text{confinement factor} = 1.03889$
 $1 = A_{s1,ten} / (b * d) * (f_{s1} / f_c) = 0.05123276$
 $2 = A_{s2,com} / (b * d) * (f_{s2} / f_c) = 0.09949345$
 $v = A_{s_{u_v},mid} / (b * d) * (f_{s_{u_v}} / f_c) = 0.09043572$
 Case/Assumption: Unconfined full section - Steel rupture
 ' satisfies Eq. (4.3)
 --->
 $v < v_{s,y2}$ - LHS eq.(4.5) is satisfied
 --->
 $s_u (4.9) = 0.09885678$
 $M_u = M_{Rc} (4.14) = 1.1540E+009$
 $u = s_u (4.1) = 5.0226943E-005$

Calculation of ratio l_b/d

Adequate Lap Length: $l_b/d \geq 1$

Calculation of μ_2

Calculation of ultimate curvature μ according to 4.1, Biskinis/Fardis 2013:

$$\mu = 6.4288704E-005$$

$$\mu_2 = 1.7288E+009$$

with full section properties:

$$b = 400.00$$

$$d = 707.00$$

$$d' = 43.00$$

$$v = 0.00174378$$

$$N = 16273.607$$

$$f_c = 33.00$$

$$\alpha (5A.5, \text{TBDY}) = 0.002$$

$$\text{Final value of } \mu_2: \mu_2^* = \text{shear_factor} * \text{Max}(\mu_2, \mu_c) = 0.01291652$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \mu_2 = 0.01291652$$

$$\mu_2 \text{ (5.4c), TBDY} = \alpha * \text{sh}_{\min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.05541928$$

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 $\alpha_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$\alpha_f = 0.31984848$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 140733.333$$

$$b_{\max} = 750.00$$

$$h_{\max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } \rho_f = 2t_f / b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 870.5244$$

$$f_y = 0.04286225$$

Expression ((15B.6), TBDY) is modified as $\alpha_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$\alpha_f = 0.31984848$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 140733.333$$

$$b_{\max} = 750.00$$

$$h_{\max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } \rho_f = 2t_f / b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 870.5244$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L * t * \text{Cos}(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$\mu_{f} = 0.015$$

$$\alpha_{se} \text{ ((5.4d), TBDY)} = (\alpha_{se1} * A_{ext} + \alpha_{se2} * A_{int}) / A_{sec} = 0.45746528$$

$$\alpha_{se1} = \text{Max}(((A_{conf,max1} - A_{noConf1}) / A_{conf,max1}) * (A_{conf,min1} / A_{conf,max1}), 0) = 0.45746528$$

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.

AnoConf1 = 158733.333 is the unconfined external core area which is equal to $b_i^2/6$ as defined at (A.2).
 $ase_2 (>= ase_1) = \text{Max}(((A_{conf,max2}-AnoConf_2)/A_{conf,max2}) * (A_{conf,min2}/A_{conf,max2}), 0) = 0.45746528$

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).

$psh_{,min} * Fy_{we} = \text{Min}(psh_x * Fy_{we}, psh_y * Fy_{we}) = 3.0194$

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)

 $psh_x * Fy_{we} = psh_1 * Fy_{we1} + ps_2 * Fy_{we2} = 3.0194$
 psh_1 ((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 (5.4d) = $L_{stir2} * Astir2 / (A_{sec} * s_2) = 0.00067082$
Lstir2 (Length of stirrups along Y) = 1468.00
Astir2 (stirrups area) = 50.26548

 $psh_y * Fy_{we} = psh_1 * Fy_{we1} + ps_2 * Fy_{we2} = 3.0194$
 psh_1 ((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 ((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 = 694.45

fywe2 = 694.45

fce = 33.00

From ((5.A.5), TBDY), TBDY: cc = 0.00238888

c = confinement factor = 1.03889

y1 = 0.0025

sh1 = 0.008

ft1 = 833.34

fy1 = 694.45

su1 = 0.032

using (30) in Biskinis/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 = 1.00

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 = $(fs_{jacket} * A_{sl,ten,jacket} + fs_{core} * A_{sl,ten,core}) / A_{sl,ten} = 694.45$

with Es1 = $(Es_{jacket} * A_{sl,ten,jacket} + Es_{core} * A_{sl,ten,core}) / A_{sl,ten} = 200000.00$

y2 = 0.0025

sh2 = 0.008

ft2 = 833.34

fy2 = 694.45

su2 = 0.032

using (30) in Biskinis/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 = 1.00

su2 = $0.4 * esu2_{nominal}$ ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: $es_{u2_nominal} = 0.08$,

For calculation of $es_{u2_nominal}$ and y_2, sh_2, ft_2, fy_2 , it is considered characteristic value $fs_{y2} = fs_2/1.2$, from table 5.1, TBDY.

y_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 $fs_2 = (fs_{jacket} \cdot Asl_{com,jacket} + fs_{core} \cdot Asl_{com,core}) / Asl_{com} = 694.45$

with $Es_2 = (Es_{jacket} \cdot Asl_{com,jacket} + Es_{core} \cdot Asl_{com,core}) / Asl_{com} = 200000.00$

$y_v = 0.0025$

$sh_v = 0.008$

$ft_v = 833.34$

$fy_v = 694.45$

$suv = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor

and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$lo/lo_{u,min} = lb/ld = 1.00$

$suv = 0.4 \cdot es_{u2_nominal} ((5.5), TBDY) = 0.032$

From table 5A.1, TBDY: $es_{uv_nominal} = 0.08$,

considering characteristic value $fs_{yv} = fsv/1.2$, 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 $fs_{yv} = fsv/1.2$, 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 $fsv = (fs_{jacket} \cdot Asl_{mid,jacket} + fs_{mid} \cdot Asl_{mid,core}) / Asl_{mid} = 694.45$

with $Es_v = (Es_{jacket} \cdot Asl_{mid,jacket} + Es_{mid} \cdot Asl_{mid,core}) / Asl_{mid} = 200000.00$

$1 = Asl_{ten} / (b \cdot d) \cdot (fs_1 / fc) = 0.16434361$

$2 = Asl_{com} / (b \cdot d) \cdot (fs_2 / fc) = 0.08462644$

$v = Asl_{mid} / (b \cdot d) \cdot (fsv / fc) = 0.14938203$

and confined core properties:

$b = 340.00$

$d = 677.00$

$d' = 13.00$

$f_{cc} (5A.2, TBDY) = 34.2833$

$cc (5A.5, TBDY) = 0.00238888$

$c = \text{confinement factor} = 1.03889$

$1 = Asl_{ten} / (b \cdot d) \cdot (fs_1 / fc) = 0.20191317$

$2 = Asl_{com} / (b \cdot d) \cdot (fs_2 / fc) = 0.10397236$

$v = Asl_{mid} / (b \cdot d) \cdot (fsv / fc) = 0.18353132$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < v_{s,y2}$ - LHS eq.(4.5) is not satisfied

--->

$v < v_{s,c}$ - RHS eq.(4.5) is satisfied

--->

$su (4.8) = 0.29596233$

$Mu = MRc (4.15) = 1.7288E+009$

$u = su (4.1) = 6.4288704E-005$

Calculation of ratio lb/ld

Adequate Lap Length: $lb/ld \geq 1$

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 1.0898E+006$

Calculation of Shear Strength at edge 1, $V_{r1} = 1.0898E+006$

$V_{r1} = V_{Col} ((10.3), ASCE 41-17) = knl \cdot V_{Col0}$

$V_{Col0} = 1.0898E+006$

$knl = 1$ (zero step-static loading)

NOTE: In expression (10-3) ' $V_s = A_v \cdot fy \cdot d / s$ ' 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: $fc' = (fc'_{jacket} \cdot Area_{jacket} + fc'_{core} \cdot Area_{core}) / Area_{section} = 33.00$, but $fc'^{0.5} \leq 8.3$

MPa (22.5.3.1, ACI 318-14)

$$M/Vd = 4.00$$

$$\mu_u = 1518.01$$

$$V_u = 0.00017144$$

$$d = 0.8 \cdot h = 600.00$$

$$N_u = 16273.607$$

$$A_g = 300000.00$$

$$\text{From (11.5.4.8), ACI 318-14: } V_s = V_{s,jacket} + V_{s,core} = 901155.609$$

where:

$$V_{s,jacket} = V_{s,j1} + V_{s,j2} = 802857.879$$

$V_{s,j1} = 523602.964$ is calculated for section web jacket, with:

$$d = 600.00$$

$$A_v = 157079.633$$

$$f_y = 555.56$$

$$s = 100.00$$

$V_{s,j1}$ is multiplied by $Col,j1 = 1.00$

$$s/d = 0.16666667$$

$V_{s,j2} = 279254.914$ is calculated for section flange jacket, with:

$$d = 320.00$$

$$A_v = 157079.633$$

$$f_y = 555.56$$

$$s = 100.00$$

$V_{s,j2}$ is multiplied by $Col,j2 = 1.00$

$$s/d = 0.3125$$

$$V_{s,core} = V_{s,c1} + V_{s,c2} = 98297.73$$

$V_{s,c1} = 98297.73$ is calculated for section web core, with:

$$d = 440.00$$

$$A_v = 100530.965$$

$$f_y = 555.56$$

$$s = 250.00$$

$V_{s,c1}$ is multiplied by $Col,c1 = 1.00$

$$s/d = 0.56818182$$

$V_{s,c2} = 0.00$ is calculated for section flange core, with:

$$d = 160.00$$

$$A_v = 100530.965$$

$$f_y = 555.56$$

$$s = 250.00$$

$V_{s,c2}$ 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.

$$\text{orientation 1: } \theta = b1 + 90^\circ = 90.00$$

$$V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, \theta)|), \text{ with:}$$

$$\text{total thickness per orientation, } t_{f1} = NL \cdot t / \text{NoDir} = 1.016$$

$$d_{fv} = d \text{ (figure 11.2, ACI 440)} = 707.00$$

$$f_{fe} \text{ ((11-5), ACI 440)} = 259.312$$

$$E_f = 64828.00$$

$$f_e = 0.004, \text{ from (11.6a), ACI 440}$$

$$\text{with } f_u = 0.01$$

$$\text{From (11-11), ACI 440: } V_s + V_f \leq 915872.391$$

$$b_w = 400.00$$

Calculation of Shear Strength at edge 2, $V_{r2} = 1.0898E+006$

$$V_{r2} = V_{Col} \text{ ((10.3), ASCE 41-17)} = k_{nl} \cdot V_{Col0}$$

$$V_{Col0} = 1.0898E+006$$

$$k_{nl} = 1 \text{ (zero step-static loading)}$$

NOTE: In expression (10-3) ' $V_s = A_v \cdot f_y \cdot d / s$ ' is replaced by ' $V_s + f \cdot V_f$ ' where V_f is the contribution of FRPs (11.3), ACI 440).

$$= 1 \text{ (normal-weight concrete)}$$

Mean concrete strength: $f_c' = (f_c'_{jacket} \cdot Area_{jacket} + f_c'_{core} \cdot Area_{core}) / Area_{section} = 33.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 4.00$

$\mu_u = 1518.01$

$V_u = 0.00017144$

$d = 0.8 \cdot h = 600.00$

$N_u = 16273.607$

$A_g = 300000.00$

From (11.5.4.8), ACI 318-14: $V_s = V_{sjacket} + V_{s,core} = 901155.609$

where:

$V_{sjacket} = V_{sj1} + V_{sj2} = 802857.879$

$V_{sj1} = 523602.964$ is calculated for section web jacket, with:

$d = 600.00$

$A_v = 157079.633$

$f_y = 555.56$

$s = 100.00$

V_{sj1} is multiplied by $Col,j1 = 1.00$

$s/d = 0.16666667$

$V_{sj2} = 279254.914$ is calculated for section flange jacket, with:

$d = 320.00$

$A_v = 157079.633$

$f_y = 555.56$

$s = 100.00$

V_{sj2} is multiplied by $Col,j2 = 1.00$

$s/d = 0.3125$

$V_{s,core} = V_{s,c1} + V_{s,c2} = 98297.73$

$V_{s,c1} = 98297.73$ is calculated for section web core, with:

$d = 440.00$

$A_v = 100530.965$

$f_y = 555.56$

$s = 250.00$

$V_{s,c1}$ is multiplied by $Col,c1 = 1.00$

$s/d = 0.56818182$

$V_{s,c2} = 0.00$ is calculated for section flange core, with:

$d = 160.00$

$A_v = 100530.965$

$f_y = 555.56$

$s = 250.00$

$V_{s,c2}$ 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: $\theta = 45^\circ + 90^\circ = 135^\circ$

$V_f = \text{Min}(|V_f(45, \alpha)|, |V_f(-45, \alpha)|)$, 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: $V_s + V_f \leq 915872.391$

$b_w = 400.00$

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, $k = 0.90$

Mean strength values are used for both shear and moment calculations.

Consequently:

Jacket

New material of Secondary Member: Concrete Strength, $f_c = f_{cm} = 33.00$

New material of Secondary Member: Steel Strength, $f_s = f_{sm} = 555.56$

Concrete Elasticity, $E_c = 26999.444$

Steel Elasticity, $E_s = 200000.00$

Existing Column

New material of Secondary Member: Concrete Strength, $f_c = f_{cm} = 33.00$

New material of Secondary Member: Steel Strength, $f_s = f_{sm} = 555.56$

Concrete Elasticity, $E_c = 26999.444$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14

Jacket

New material: Steel Strength, $f_s = 1.25 \cdot f_{sm} = 694.45$

Existing Column

New material: Steel Strength, $f_s = 1.25 \cdot f_{sm} = 694.45$

#####

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

Adequate Lap Length ($l_o/l_{ou,min} > 1$)

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $e_{fu} = 0.01$

Number of directions, $N_{oDir} = 1$

Fiber orientations, $b_i = 0.00^\circ$

Number of layers, $N_L = 1$

Radius of rounding corners, $R = 40.00$

Stepwise Properties

At local axis: 2

EDGE -A-

Shear Force, $V_a = -0.0001715$

EDGE -B-

Shear Force, $V_b = 0.0001715$

BOTH EDGES

Axial Force, $F = -16273.607$

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: Asl,com = 2208.54
-Middle: Asl,mid = 2007.478

Calculation of Shear Capacity ratio , $V_e/V_r = 1.05752$

Member Controlled by Shear ($V_e/V_r > 1$)

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 1.1525E+006$

with

$M_{pr1} = \text{Max}(M_{u1+}, M_{u1-}) = 1.7288E+009$

$M_{u1+} = 1.1540E+009$, 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

$M_{u1-} = 1.7288E+009$, 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

$M_{pr2} = \text{Max}(M_{u2+}, M_{u2-}) = 1.7288E+009$

$M_{u2+} = 1.1540E+009$, 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

$M_{u2-} = 1.7288E+009$, 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:

$\phi_u = 5.0226943E-005$

$M_u = 1.1540E+009$

with full section properties:

$b = 750.00$

$d = 707.00$

$d' = 43.00$

$v = 0.00093001$

$N = 16273.607$

$f_c = 33.00$

$\phi_{co} (5A.5, TBDY) = 0.002$

Final value of ϕ_{cu} : $\phi_{cu}^* = \text{shear_factor} * \text{Max}(\phi_{cu}, \phi_{co}) = 0.01291652$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $\phi_{cu} = 0.01291652$

$\phi_{we} ((5.4c), TBDY) = a_{se} * \phi_{sh, \min} * f_{ywe}/f_{ce} + \text{Min}(\phi_{fx}, \phi_{fy}) = 0.05541928$

where $\phi_f = a_f * \phi_{pf} * f_{fe}/f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$\phi_{fx} = 0.04286225$

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), $\phi_{pf} = 2t_f/b_w = 0.00508$

$b_w = 400.00$

effective stress from (A.35), $f_{fe} = 870.5244$

$\phi_{fy} = 0.04286225$

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), $\phi_{pf} = 2t_f/b_w = 0.00508$

$b_w = 400.00$

effective stress from (A.35), $f_{fe} = 870.5244$

$R = 40.00$

Effective FRP thickness, $t_f = N L * t * \text{Cos}(b_1) = 1.016$

$f_{u,f} = 1055.00$

$$E_f = 64828.00$$

$$u, f = 0.015$$

$$ase \text{ ((5.4d), TBDY)} = (ase1 * A_{ext} + ase2 * A_{int}) / A_{sec} = 0.45746528$$

$$ase1 = \text{Max}(((A_{conf,max1} - A_{noConf1}) / A_{conf,max1}) * (A_{conf,min1} / A_{conf,max1}), 0) = 0.45746528$$

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).

$$p_{sh,min} * F_{ywe} = \text{Min}(p_{sh,x} * F_{ywe}, p_{sh,y} * F_{ywe}) = 3.0194$$

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)

$$p_{sh,x} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{sh2} * F_{ywe2} = 3.0194$$

$$p_{sh1} \text{ ((5.4d), TBDY)} = L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00367709$$

$$L_{stir1} \text{ (Length of stirrups along Y)} = 2060.00$$

$$A_{stir1} \text{ (stirrups area)} = 78.53982$$

$$p_{sh2} \text{ (5.4d)} = L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00067082$$

$$L_{stir2} \text{ (Length of stirrups along Y)} = 1468.00$$

$$A_{stir2} \text{ (stirrups area)} = 50.26548$$

$$p_{sh,y} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{sh2} * F_{ywe2} = 3.0194$$

$$p_{sh1} \text{ ((5.4d), TBDY)} = L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00367709$$

$$L_{stir1} \text{ (Length of stirrups along X)} = 2060.00$$

$$A_{stir1} \text{ (stirrups area)} = 78.53982$$

$$p_{sh2} \text{ ((5.4d), TBDY)} = L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00067082$$

$$L_{stir2} \text{ (Length of stirrups along X)} = 1468.00$$

$$A_{stir2} \text{ (stirrups area)} = 50.26548$$

$$A_{sec} = 440000.00$$

$$s1 = 100.00$$

$$s2 = 250.00$$

$$f_{ywe1} = 694.45$$

$$f_{ywe2} = 694.45$$

$$f_{ce} = 33.00$$

$$\text{From ((5.A5), TBDY), TBDY: } cc = 0.00238888$$

$$c = \text{confinement factor} = 1.03889$$

$$y1 = 0.0025$$

$$sh1 = 0.008$$

$$ft1 = 833.34$$

$$fy1 = 694.45$$

$$su1 = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor

and also multiplied by the shear_factor according to 15.7.1.4, with

Shear_factor = 1.00

$$l_o / l_{ou,min} = l_b / l_d = 1.00$$

$$su1 = 0.4 * esu1_{nominal} \text{ ((5.5), TBDY)} = 0.032$$

From table 5A.1, TBDY: $esu1_{nominal} = 0.08$,

For calculation of $esu1_{nominal}$ and $y1$, $sh1$, $ft1$, $fy1$, it is considered

characteristic value $f_{s1} = f_s/1.2$, 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 $f_{s1} = (f_{s,jacket} \cdot A_{s,ten,jacket} + f_{s,core} \cdot A_{s,ten,core}) / A_{s,ten} = 694.45$

with $E_{s1} = (E_{s,jacket} \cdot A_{s,ten,jacket} + E_{s,core} \cdot A_{s,ten,core}) / A_{s,ten} = 200000.00$

$y_2 = 0.0025$

$sh_2 = 0.008$

$ft_2 = 833.34$

$fy_2 = 694.45$

$su_2 = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor

and also multiplied by the shear_factor according to 15.7.1.4, with

Shear_factor = 1.00

$l_o/l_{o,min} = l_b/l_{b,min} = 1.00$

$su_2 = 0.4 \cdot esu_{2,nominal} ((5.5), TBDY) = 0.032$

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 $f_{s2} = f_s/1.2$, 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 $f_{s2} = (f_{s,jacket} \cdot A_{s,com,jacket} + f_{s,core} \cdot A_{s,com,core}) / A_{s,com} = 694.45$

with $E_{s2} = (E_{s,jacket} \cdot A_{s,com,jacket} + E_{s,core} \cdot A_{s,com,core}) / A_{s,com} = 200000.00$

$y_v = 0.0025$

$sh_v = 0.008$

$ft_v = 833.34$

$fy_v = 694.45$

$su_v = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor

and also multiplied by the shear_factor according to 15.7.1.4, with

Shear_factor = 1.00

$l_o/l_{o,min} = l_b/l_d = 1.00$

$su_v = 0.4 \cdot esu_{v,nominal} ((5.5), TBDY) = 0.032$

From table 5A.1, TBDY: $esu_{v,nominal} = 0.08$,

considering characteristic value $f_{sv} = f_{sv}/1.2$, 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 $f_{sv} = f_{sv}/1.2$, from table 5.1, TBDY.

y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$, from 10.3.5, ASCE 41-17.

with $f_{sv} = (f_{s,jacket} \cdot A_{s,mid,jacket} + f_{s,mid} \cdot A_{s,mid,core}) / A_{s,mid} = 694.45$

with $E_{sv} = (E_{s,jacket} \cdot A_{s,mid,jacket} + E_{s,mid} \cdot A_{s,mid,core}) / A_{s,mid} = 200000.00$

$1 = A_{s,ten} / (b \cdot d) \cdot (f_{s1} / f_c) = 0.0451341$

$2 = A_{s,com} / (b \cdot d) \cdot (f_{s2} / f_c) = 0.08764993$

$v = A_{s,mid} / (b \cdot d) \cdot (f_{sv} / f_c) = 0.07967042$

and confined core properties:

$b = 690.00$

$d = 677.00$

$d' = 13.00$

$f_{cc} (5A.2, TBDY) = 34.2833$

$cc (5A.5, TBDY) = 0.00238888$

$c = \text{confinement factor} = 1.03889$

$1 = A_{s,ten} / (b \cdot d) \cdot (f_{s1} / f_c) = 0.05123276$

$2 = A_{s,com} / (b \cdot d) \cdot (f_{s2} / f_c) = 0.09949345$

$v = A_{s,mid} / (b \cdot d) \cdot (f_{sv} / f_c) = 0.09043572$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

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$v < v_{s,y2}$ - LHS eq.(4.5) is satisfied

---->

$su (4.9) = 0.09885678$

$Mu = MRc (4.14) = 1.1540E+009$

$u = su (4.1) = 5.0226943E-005$

Calculation of ratio l_b/l_d

Adequate Lap Length: $l_b/l_d \geq 1$

Calculation of Mu_1 -

Calculation of ultimate curvature ϕ_u according to 4.1, Biskinis/Fardis 2013:

$$u = 6.4288704E-005$$

$$\mu = 1.7288E+009$$

with full section properties:

$$b = 400.00$$

$$d = 707.00$$

$$d' = 43.00$$

$$v = 0.00174378$$

$$N = 16273.607$$

$$f_c = 33.00$$

$$\alpha_{co} (5A.5, TBDY) = 0.002$$

$$\text{Final value of } \phi_u: \phi_u = \text{shear_factor} * \text{Max}(\phi_{cu}, \phi_{cc}) = 0.01291652$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \phi_{cu} = 0.01291652$$

$$\phi_{we} ((5.4c), TBDY) = \alpha_{se} * \text{sh}_{, \text{min}} * f_{ywe} / f_{ce} + \text{Min}(\phi_{fx}, \phi_{fy}) = 0.05541928$$

where $\phi_f = \alpha_f * \rho_f * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$\phi_{fx} = 0.04286225$$

Expression ((15B.6), TBDY) is modified as $\alpha_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$\alpha_f = 0.31984848$$

$$\text{with Unconfined area} = ((b_{\text{max}} - 2R)^2 + (h_{\text{max}} - 2R)^2) / 3 = 140733.333$$

$$b_{\text{max}} = 750.00$$

$$h_{\text{max}} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } \rho_f = 2t_f / b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{fe} = 870.5244$$

$$\phi_{fy} = 0.04286225$$

Expression ((15B.6), TBDY) is modified as $\alpha_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$\alpha_f = 0.31984848$$

$$\text{with Unconfined area} = ((b_{\text{max}} - 2R)^2 + (h_{\text{max}} - 2R)^2) / 3 = 140733.333$$

$$b_{\text{max}} = 750.00$$

$$h_{\text{max}} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } \rho_f = 2t_f / b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{fe} = 870.5244$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L * t * \text{Cos}(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$\alpha_{se} ((5.4d), TBDY) = (\alpha_{se1} * A_{\text{ext}} + \alpha_{se2} * A_{\text{int}}) / A_{\text{sec}} = 0.45746528$$

$$\alpha_{se1} = \text{Max}(((A_{\text{conf,max1}} - A_{\text{noConf1}}) / A_{\text{conf,max1}}) * (A_{\text{conf,min1}} / A_{\text{conf,max1}}), 0) = 0.45746528$$

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.

$A_{\text{conf,min1}} = 293525.00$ 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).

$$\alpha_{se2} (>= \alpha_{se1}) = \text{Max}(((A_{\text{conf,max2}} - A_{\text{noConf2}}) / A_{\text{conf,max2}}) * (A_{\text{conf,min2}} / A_{\text{conf,max2}}), 0) = 0.45746528$$

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.

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).
 $psh,min*Fywe = \text{Min}(psh,x*Fywe, psh,y*Fywe) = 3.0194$

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)

 $psh_x*Fywe = psh1*Fywe1 + ps2*Fywe2 = 3.0194$
 $psh1$ ((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

 $psh_y*Fywe = psh1*Fywe1 + ps2*Fywe2 = 3.0194$
 $psh1$ ((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 = 694.45
fywe2 = 694.45
fce = 33.00

From ((5.A5), TBDY), TBDY: cc = 0.00238888
c = confinement factor = 1.03889

y1 = 0.0025
sh1 = 0.008
ft1 = 833.34
fy1 = 694.45
su1 = 0.032

using (30) in Biskinis/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 = 1.00

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 $fs1 = (fs,jacket*Asl,ten,jacket + fs,core*Asl,ten,core)/Asl,ten = 694.45$

with $Es1 = (Es,jacket*Asl,ten,jacket + Es,core*Asl,ten,core)/Asl,ten = 200000.00$

y2 = 0.0025
sh2 = 0.008
ft2 = 833.34
fy2 = 694.45
su2 = 0.032

using (30) in Biskinis/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 = 1.00

su2 = $0.4*esu2_nominal$ ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu2_nominal = 0.08,

For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered characteristic value $fsy2 = fs2/1.2$, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25*(lb/ld)^{2/3})$, from 10.3.5, ASCE 41-17.

with $fs2 = (fs,jacket*Asl,com,jacket + fs,core*Asl,com,core)/Asl,com = 694.45$

with $Es2 = (Es,jacket*Asl,com,jacket + Es,core*Asl,com,core)/Asl,com = 200000.00$

yv = 0.0025
shv = 0.008
ftv = 833.34

$f_{yv} = 694.45$
 $s_{uv} = 0.032$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $l_o/l_{ou,min} = l_b/l_d = 1.00$
 $s_{uv} = 0.4 * e_{suv_nominal} ((5.5), TBDY) = 0.032$
 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.
 $\gamma_1, sh_1, ft_1, fy_1$, are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE 41-17.
 with $f_{sv} = (f_{s,jacket} * A_{s,mid,jacket} + f_{s,mid} * A_{s,mid,core}) / A_{s,mid} = 694.45$
 with $E_{sv} = (E_{s,jacket} * A_{s,mid,jacket} + E_{s,mid} * A_{s,mid,core}) / A_{s,mid} = 200000.00$
 $1 = A_{s,ten} / (b * d) * (f_{s1} / f_c) = 0.16434361$
 $2 = A_{s,com} / (b * d) * (f_{s2} / f_c) = 0.08462644$
 $v = A_{s,mid} / (b * d) * (f_{sv} / f_c) = 0.14938203$

and confined core properties:

$b = 340.00$
 $d = 677.00$
 $d' = 13.00$
 $f_{cc} (5A.2, TBDY) = 34.2833$
 $cc (5A.5, TBDY) = 0.00238888$
 $c = \text{confinement factor} = 1.03889$
 $1 = A_{s,ten} / (b * d) * (f_{s1} / f_c) = 0.20191317$
 $2 = A_{s,com} / (b * d) * (f_{s2} / f_c) = 0.10397236$
 $v = A_{s,mid} / (b * d) * (f_{sv} / f_c) = 0.18353132$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

---->

$v < v_{s,y2}$ - LHS eq.(4.5) is not satisfied

---->

$v < v_{s,c}$ - RHS eq.(4.5) is satisfied

---->

$su (4.8) = 0.29596233$

$Mu = MRc (4.15) = 1.7288E+009$

$u = su (4.1) = 6.4288704E-005$

 Calculation of ratio l_b/l_d

Adequate Lap Length: $l_b/l_d \geq 1$

 Calculation of Mu_{2+}

 Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

$u = 5.0226943E-005$

$Mu = 1.1540E+009$

 with full section properties:

$b = 750.00$

$d = 707.00$

$d' = 43.00$

$v = 0.00093001$

$N = 16273.607$

$f_c = 33.00$

$co (5A.5, TBDY) = 0.002$

Final value of cu : $cu^* = \text{shear_factor} * \text{Max}(cu, cc) = 0.01291652$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $cu = 0.01291652$

where $we ((5.4c), TBDY) = ase * sh_{,min} * fy_{we} / f_{ce} + \text{Min}(fx, fy) = 0.05541928$

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 $a_f = 1 - (\text{Unconfined area})/(\text{total area})$

$$a_f = 0.31984848$$

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 = $((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2)/3 = 140733.333$

$$b_{\max} = 750.00$$

$$h_{\max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 870.5244$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N_L * t * \cos(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$a_{se} \text{ ((5.4d), TBDY) } = (a_{se1} * A_{ext} + a_{se2} * A_{int}) / A_{sec} = 0.45746528$$

$$a_{se1} = \text{Max}(((A_{conf,max1} - A_{noConf1}) / A_{conf,max1}) * (A_{conf,min1} / A_{conf,max1}), 0) = 0.45746528$$

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).

$$p_{sh,min} * F_{ywe} = \text{Min}(p_{sh,x} * F_{ywe}, p_{sh,y} * F_{ywe}) = 3.0194$$

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)

$$p_{sh,x} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{sh2} * F_{ywe2} = 3.0194$$

$$p_{sh1} \text{ ((5.4d), TBDY) } = L_{stir1} * A_{stir1} / (A_{sec} * s_1) = 0.00367709$$

$$L_{stir1} \text{ (Length of stirrups along Y) } = 2060.00$$

$$A_{stir1} \text{ (stirrups area) } = 78.53982$$

$$p_{sh2} \text{ (5.4d) } = L_{stir2} * A_{stir2} / (A_{sec} * s_2) = 0.00067082$$

$$L_{stir2} \text{ (Length of stirrups along Y) } = 1468.00$$

$$A_{stir2} \text{ (stirrups area) } = 50.26548$$

$$p_{sh,y} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{sh2} * F_{ywe2} = 3.0194$$

$$p_{sh1} \text{ ((5.4d), TBDY) } = L_{stir1} * A_{stir1} / (A_{sec} * s_1) = 0.00367709$$

$$L_{stir1} \text{ (Length of stirrups along X) } = 2060.00$$

$$A_{stir1} \text{ (stirrups area) } = 78.53982$$

$$p_{sh2} \text{ ((5.4d), TBDY) } = L_{stir2} * A_{stir2} / (A_{sec} * s_2) = 0.00067082$$

Lstir2 (Length of stirrups along X) = 1468.00
Astir2 (stirrups area) = 50.26548

Asec = 440000.00
s1 = 100.00
s2 = 250.00
fywe1 = 694.45
fywe2 = 694.45
fce = 33.00

From ((5.A.5), TBDY), TBDY: cc = 0.00238888
c = confinement factor = 1.03889

y1 = 0.0025
sh1 = 0.008
ft1 = 833.34
fy1 = 694.45
su1 = 0.032

using (30) in Biskinis/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 = 1.00

su1 = 0.4*esu1_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu1_nominal = 0.08,

For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$, from 10.3.5, ASCE 41-17.

with fs1 = (fs,jacket*Asl,ten,jacket + fs,core*Asl,ten,core)/Asl,ten = 694.45

with Es1 = (Es,jacket*Asl,ten,jacket + Es,core*Asl,ten,core)/Asl,ten = 200000.00

y2 = 0.0025
sh2 = 0.008
ft2 = 833.34
fy2 = 694.45
su2 = 0.032

using (30) in Biskinis/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 = 1.00

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 = 694.45

with Es2 = (Es,jacket*Asl,com,jacket + Es,core*Asl,com,core)/Asl,com = 200000.00

yv = 0.0025
shv = 0.008
ftv = 833.34
fyv = 694.45
suv = 0.032

using (30) in Biskinis/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 = 1.00

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 = 694.45

with Esv = (Es,jacket*Asl,mid,jacket + Es,mid*Asl,mid,core)/Asl,mid = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.0451341

2 = Asl,com/(b*d)*(fs2/fc) = 0.08764993

v = Asl,mid/(b*d)*(fsv/fc) = 0.07967042

and confined core properties:

b = 690.00
d = 677.00
d' = 13.00

$$f_{cc} (5A.2, TBDY) = 34.2833$$

$$c_c (5A.5, TBDY) = 0.00238888$$

$$c = \text{confinement factor} = 1.03889$$

$$1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.05123276$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.09949345$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.09043572$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < v_{s,y2}$ - LHS eq.(4.5) is satisfied

--->

$$s_u (4.9) = 0.09885678$$

$$\mu_u = M_{Rc} (4.14) = 1.1540E+009$$

$$u = s_u (4.1) = 5.0226943E-005$$

Calculation of ratio l_b/l_d

Adequate Lap Length: $l_b/l_d \geq 1$

Calculation of μ_{u2} -

Calculation of ultimate curvature μ_u according to 4.1, Biskinis/Fardis 2013:

$$u = 6.4288704E-005$$

$$\mu_u = 1.7288E+009$$

with full section properties:

$$b = 400.00$$

$$d = 707.00$$

$$d' = 43.00$$

$$v = 0.00174378$$

$$N = 16273.607$$

$$f_c = 33.00$$

$$c_o (5A.5, TBDY) = 0.002$$

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.01291652$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } c_u = 0.01291652$$

$$w_e ((5.4c), TBDY) = a_{se} * s_{h,min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.05541928$$

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 $a_f = 1 - (\text{Unconfined area})/(\text{total area})$

$$a_f = 0.31984848$$

$$\text{with Unconfined area} = ((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 140733.333$$

$$b_{max} = 750.00$$

$$h_{max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{fe} = 870.5244$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L * t * \text{Cos}(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u, f = 0.015$$

$$ase \text{ ((5.4d), TBDY)} = (ase1 * A_{ext} + ase2 * A_{int}) / A_{sec} = 0.45746528$$

$$ase1 = \text{Max}(((A_{conf,max1} - A_{noConf1}) / A_{conf,max1}) * (A_{conf,min1} / A_{conf,max1}), 0) = 0.45746528$$

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).

$$p_{sh,min} * F_{ywe} = \text{Min}(p_{sh,x} * F_{ywe}, p_{sh,y} * F_{ywe}) = 3.0194$$

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)

$$p_{sh,x} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{sh2} * F_{ywe2} = 3.0194$$

$$p_{sh1} \text{ ((5.4d), TBDY)} = L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00367709$$

$$L_{stir1} \text{ (Length of stirrups along Y)} = 2060.00$$

$$A_{stir1} \text{ (stirrups area)} = 78.53982$$

$$p_{sh2} \text{ (5.4d)} = L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00067082$$

$$L_{stir2} \text{ (Length of stirrups along Y)} = 1468.00$$

$$A_{stir2} \text{ (stirrups area)} = 50.26548$$

$$p_{sh,y} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{sh2} * F_{ywe2} = 3.0194$$

$$p_{sh1} \text{ ((5.4d), TBDY)} = L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00367709$$

$$L_{stir1} \text{ (Length of stirrups along X)} = 2060.00$$

$$A_{stir1} \text{ (stirrups area)} = 78.53982$$

$$p_{sh2} \text{ ((5.4d), TBDY)} = L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00067082$$

$$L_{stir2} \text{ (Length of stirrups along X)} = 1468.00$$

$$A_{stir2} \text{ (stirrups area)} = 50.26548$$

$$A_{sec} = 440000.00$$

$$s1 = 100.00$$

$$s2 = 250.00$$

$$f_{ywe1} = 694.45$$

$$f_{ywe2} = 694.45$$

$$f_{ce} = 33.00$$

$$\text{From ((5.A5), TBDY), TBDY: } c_c = 0.00238888$$

$$c = \text{confinement factor} = 1.03889$$

$$y1 = 0.0025$$

$$sh1 = 0.008$$

$$ft1 = 833.34$$

$$fy1 = 694.45$$

$$su1 = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor

and also multiplied by the shear_factor according to 15.7.1.4, with

Shear_factor = 1.00

$$l_o / l_{ou,min} = l_b / l_d = 1.00$$

$$su1 = 0.4 * esu1_{nominal} \text{ ((5.5), TBDY)} = 0.032$$

From table 5A.1, TBDY: $esu1_{nominal} = 0.08$,

For calculation of $esu1_{nominal}$ and $y1$, $sh1$, $ft1$, $fy1$, it is considered

characteristic value $f_{sy1} = f_{s1}/1.2$, 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 $f_{s1} = (f_{s,jacket} \cdot A_{s,ten,jacket} + f_{s,core} \cdot A_{s,ten,core})/A_{s,ten} = 694.45$

with $E_{s1} = (E_{s,jacket} \cdot A_{s,ten,jacket} + E_{s,core} \cdot A_{s,ten,core})/A_{s,ten} = 200000.00$

$y_2 = 0.0025$

$sh_2 = 0.008$

$ft_2 = 833.34$

$fy_2 = 694.45$

$su_2 = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor

and also multiplied by the shear_factor according to 15.7.1.4, with

Shear_factor = 1.00

$l_o/l_{o,min} = l_b/l_{d,min} = 1.00$

$su_2 = 0.4 \cdot esu_{2,nominal} ((5.5), TBDY) = 0.032$

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 $f_{s2} = (f_{s,jacket} \cdot A_{s,com,jacket} + f_{s,core} \cdot A_{s,com,core})/A_{s,com} = 694.45$

with $E_{s2} = (E_{s,jacket} \cdot A_{s,com,jacket} + E_{s,core} \cdot A_{s,com,core})/A_{s,com} = 200000.00$

$y_v = 0.0025$

$sh_v = 0.008$

$ft_v = 833.34$

$fy_v = 694.45$

$su_v = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor

and also multiplied by the shear_factor according to 15.7.1.4, with

Shear_factor = 1.00

$l_o/l_{o,min} = l_b/l_d = 1.00$

$su_v = 0.4 \cdot esuv_{nominal} ((5.5), TBDY) = 0.032$

From table 5A.1, TBDY: $esuv_{nominal} = 0.08$,

considering characteristic value $f_{syv} = f_{sv}/1.2$, from table 5.1, TBDY

For calculation of $esuv_{nominal}$ and y_v, sh_v, ft_v, fy_v , it is considered

characteristic value $f_{syv} = f_{sv}/1.2$, 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 $f_{sv} = (f_{s,jacket} \cdot A_{s,mid,jacket} + f_{s,mid} \cdot A_{s,mid,core})/A_{s,mid} = 694.45$

with $E_{sv} = (E_{s,jacket} \cdot A_{s,mid,jacket} + E_{s,mid} \cdot A_{s,mid,core})/A_{s,mid} = 200000.00$

$1 = A_{s,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.16434361$

$2 = A_{s,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.08462644$

$v = A_{s,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.14938203$

and confined core properties:

$b = 340.00$

$d = 677.00$

$d' = 13.00$

$f_{cc} (5A.2, TBDY) = 34.2833$

$cc (5A.5, TBDY) = 0.00238888$

$c = \text{confinement factor} = 1.03889$

$1 = A_{s,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.20191317$

$2 = A_{s,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.10397236$

$v = A_{s,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.18353132$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

---->

$v < v_{s,y2}$ - LHS eq.(4.5) is not satisfied

---->

$v < v_{s,c}$ - RHS eq.(4.5) is satisfied

---->

$su (4.8) = 0.29596233$

$Mu = MRc (4.15) = 1.7288E+009$

$u = su (4.1) = 6.4288704E-005$

Calculation of ratio l_b/l_d

Adequate Lap Length: $l_b/l_d \geq 1$

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 1.0898\text{E}+006$

Calculation of Shear Strength at edge 1, $V_{r1} = 1.0898\text{E}+006$

$V_{r1} = V_{\text{Col}} ((10.3), \text{ASCE } 41-17) = k_{nl} * V_{\text{Col}0}$

$V_{\text{Col}0} = 1.0898\text{E}+006$

$k_{nl} = 1$ (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: $f_c' = (f_c'_{\text{jacket}} * \text{Area}_{\text{jacket}} + f_c'_{\text{core}} * \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 33.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 4.00$

$\mu_u = 1518.777$

$V_u = 0.0001715$

$d = 0.8 * h = 600.00$

$N_u = 16273.607$

$A_g = 300000.00$

From (11.5.4.8), ACI 318-14: $V_s = V_{s,\text{jacket}} + V_{s,\text{core}} = 901155.609$

where:

$V_{s,\text{jacket}} = V_{s,j1} + V_{s,j2} = 802857.879$

$V_{s,j1} = 279254.914$ is calculated for section web jacket, with:

$d = 320.00$

$A_v = 157079.633$

$f_y = 555.56$

$s = 100.00$

$V_{s,j1}$ is multiplied by $\text{Col},j1 = 1.00$

$s/d = 0.3125$

$V_{s,j2} = 523602.964$ is calculated for section flange jacket, with:

$d = 600.00$

$A_v = 157079.633$

$f_y = 555.56$

$s = 100.00$

$V_{s,j2}$ is multiplied by $\text{Col},j2 = 1.00$

$s/d = 0.16666667$

$V_{s,\text{core}} = V_{s,c1} + V_{s,c2} = 98297.73$

$V_{s,c1} = 0.00$ is calculated for section web core, with:

$d = 160.00$

$A_v = 100530.965$

$f_y = 555.56$

$s = 250.00$

$V_{s,c1}$ is multiplied by $\text{Col},c1 = 0.00$

$s/d = 1.5625$

$V_{s,c2} = 98297.73$ is calculated for section flange core, with:

$d = 440.00$

$A_v = 100530.965$

$f_y = 555.56$

$s = 250.00$

$V_{s,c2}$ 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 $V_f(\theta, a)$, 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, $t_{f1} = N_L * t / \text{NoDir} = 1.016$

$d_{fv} = d$ (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: $V_s + V_f \leq 915872.391$
 $bw = 400.00$

Calculation of Shear Strength at edge 2, $V_{r2} = 1.0898E+006$
 $V_{r2} = V_{Col} ((10.3), ASCE 41-17) = knl * V_{Col0}$
 $V_{Col0} = 1.0898E+006$
 $knl = 1$ (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: $f_c' = (f_c'_{jacket} * Area_{jacket} + f_c'_{core} * Area_{core}) / Area_{section} = 33.00$, but $f_c'^{0.5} \leq 8.3$
MPa (22.5.3.1, ACI 318-14)

$M / Vd = 4.00$

$\mu_u = 1518.777$

$V_u = 0.0001715$

$d = 0.8 * h = 600.00$

$N_u = 16273.607$

$A_g = 300000.00$

From (11.5.4.8), ACI 318-14: $V_s = V_{sjacket} + V_{s,core} = 901155.609$

where:

$V_{sjacket} = V_{sj1} + V_{sj2} = 802857.879$

$V_{sj1} = 279254.914$ is calculated for section web jacket, with:

$d = 320.00$

$A_v = 157079.633$

$f_y = 555.56$

$s = 100.00$

V_{sj1} is multiplied by $Col_{j1} = 1.00$

$s/d = 0.3125$

$V_{sj2} = 523602.964$ is calculated for section flange jacket, with:

$d = 600.00$

$A_v = 157079.633$

$f_y = 555.56$

$s = 100.00$

V_{sj2} is multiplied by $Col_{j2} = 1.00$

$s/d = 0.16666667$

$V_{s,core} = V_{s,c1} + V_{s,c2} = 98297.73$

$V_{s,c1} = 0.00$ is calculated for section web core, with:

$d = 160.00$

$A_v = 100530.965$

$f_y = 555.56$

$s = 250.00$

$V_{s,c1}$ is multiplied by $Col_{c1} = 0.00$

$s/d = 1.5625$

$V_{s,c2} = 98297.73$ is calculated for section flange core, with:

$d = 440.00$

$A_v = 100530.965$

$f_y = 555.56$

$s = 250.00$

$V_{s,c2}$ 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) $\sin \theta + \cos \theta$ 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, $t_{f1} = NL * t / \text{NoDir} = 1.016$

$d_{fv} = d$ (figure 11.2, ACI 440) = 707.00

$f_{fe} ((11-5), ACI 440) = 259.312$

$E_f = 64828.00$

fe = 0.004, from (11.6a), ACI 440
with fu = 0.01
From (11-11), ACI 440: Vs + Vf <= 915872.391
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: rcjls

Constant Properties

Knowledge Factor, = 0.90
Chord Rotation is generally considered as Deformation-Controlled Action according to Table C7-1, ASCE 41-17.
Mean strengths are used for Deformation-Controlled Actions according to 7.5.1.3, ASCE 41-17
Consequently:
Jacket
New material of Secondary Member: Concrete Strength, fc = fcm = 33.00
New material of Secondary Member: Steel Strength, fs = fsm = 555.56
Concrete Elasticity, Ec = 26999.444
Steel Elasticity, Es = 200000.00
Existing Column
New material of Secondary Member: Concrete Strength, fc = fcm = 33.00
New material of Secondary Member: Steel Strength, fs = fsm = 555.56
Concrete Elasticity, Ec = 26999.444
Steel Elasticity, Es = 200000.00
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
Adequate Lap Length (lb/ld >= 1)
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

Bending Moment, M = -72349.636
Shear Force, V2 = 4866.131
Shear Force, V3 = -131.6809
Axial Force, F = -18154.476
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: Aslt = 0.00

-Compression: Asl,c = 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

New component: From table 7-7, ASCE 41_17: Final chord rotation Capacity $u,R = 1.0^*$ $u = 0.05110905$
 $u = y + p = 0.05110905$

- Calculation of y -

$y = (My * Ls / 3) / Eleff = 0.00077956$ ((4.29), Biskinis Phd))
 $My = 6.4998E+008$
 $Ls = M/V$ (with $Ls > 0.1 * L$ and $Ls < 2 * L$) = 549.4315
 From table 10.5, ASCE 41_17: $Eleff = factor * Ec * Ig = 1.5270E+014$
 $factor = 0.30$
 $Ag = 440000.00$
 Mean concrete strength: $fc' = (fc'_jacket * Area_jacket + fc'_core * Area_core) / Area_section = 33.00$
 $N = 18154.476$
 $Ec * Ig = Ec_jacket * Ig_jacket + Ec_core * Ig_core = 5.0901E+014$

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, $t = 400.00$

$y = \text{Min}(y_{ten}, y_{com})$
 $y_{ten} = 4.8675041E-006$
 with $fy = 555.56$
 $d = 707.00$
 $y = 0.19281101$
 $A = 0.01015738$
 $B = 0.00446779$
 with $pt = 0.00671904$
 $pc = 0.00416509$
 $pv = 0.00378591$
 $N = 18154.476$
 $b = 750.00$
 $" = 0.06082037$
 $y_{comp} = 1.6460425E-005$
 with $fc' (12.3, (ACI 440)) = 33.48734$
 $fc = 33.00$
 $fl = 0.49678681$
 $b = b_{max} = 750.00$
 $h = h_{max} = 750.00$
 $Ag = 0.44$
 $g = pt + pc + pv = 0.01009575$
 $rc = 40.00$

$$A_e/A_c = 0.31291181$$

$$\text{Effective FRP thickness, } t_f = NL * t * \cos(b1) = 1.016$$

$$\text{effective strain from (12.5) and (12.12), } \epsilon_{fe} = 0.004$$

$$f_u = 0.01$$

$$E_f = 64828.00$$

$$E_c = 26999.444$$

$$y = 0.19183941$$

$$A = 0.01001908$$

$$B = 0.00440616$$

$$\text{with } E_s = 200000.00$$

$$\text{CONFIRMATION: } y = 0.19281101 < t/d$$

Calculation of ratio l_b/d

Adequate Lap Length: $l_b/d \geq 1$

- Calculation of ρ -

From table 10-8: $\rho = 0.05032949$

with:

- Columns not controlled by inadequate development or splicing along the clear height because $l_b/d \geq 1$

$$\text{shear control ratio } V_y E / V_{Co} I_{OE} = 1.05752$$

$$d = d_{\text{external}} = 707.00$$

$$s = s_{\text{external}} = 0.00$$

$$- t = s_1 + s_2 + 2 * t_f / b_w * (f_{fe} / f_s) = 0.00671904$$

$$\text{jacket: } s_1 = A_{v1} * L_{\text{stir1}} / (s_1 * A_g) = 0.00367709$$

$A_{v1} = 78.53982$, 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.

$$N_{UD} = 18154.476$$

$$A_g = 440000.00$$

$$f_{cE} = (f_{c_jacket} * \text{Area}_{\text{jacket}} + f_{c_core} * \text{Area}_{\text{core}}) / \text{section_area} = 33.00$$

$$f_{yIE} = (f_{y_ext_Long_Reinf} * \text{Area}_{\text{ext_Long_Reinf}} + f_{y_int_Long_Reinf} * \text{Area}_{\text{int_Long_Reinf}}) / \text{Area}_{\text{Tot_Long_Rein}} =$$

$$555.56$$

$$f_{ytE} = (f_{y_ext_Trans_Reinf} * s_1 + f_{y_int_Trans_Reinf} * s_2) / (s_1 + s_2) = 555.56$$

$$\rho_l = \text{Area}_{\text{Tot_Long_Rein}} / (b * d) = 0.01009575$$

$$b = 750.00$$

$$d = 707.00$$

$$f_{cE} = 33.00$$

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

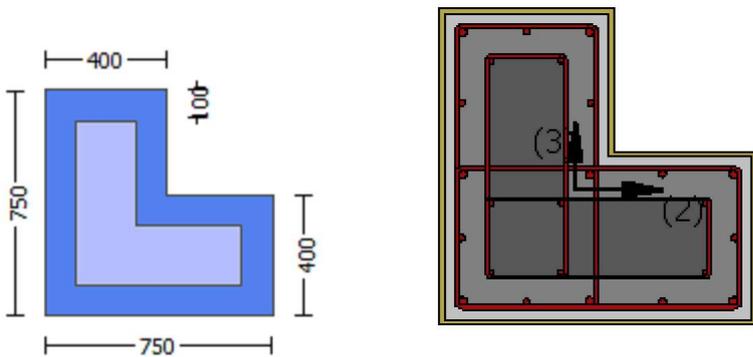
Limit State: Collapse Prevention (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Shear capacity VRd

Edge: End

Local Axis: (3)



Start Of Calculation of Shear Capacity for element: column JLC1 of floor 1

At local axis: 3

Integration Section: (b)

Section Type: rcjlcs

Constant Properties

Knowledge Factor, $\gamma = 0.90$

Member Shear Force is generally considered as Force-Controlled Action according to Table C7-1, ASCE 41-17.

Lower-bound strengths are used for Force-Controlled Actions according to 7.5.1.3, ASCE 41-17

Consequently:

Jacket

New material of Secondary Member: Concrete Strength, $f_c = f_{c_lower_bound} = 25.00$

New material of Secondary Member: Steel Strength, $f_s = f_{s_lower_bound} = 500.00$

Concrete Elasticity, $E_c = 26999.444$

Steel Elasticity, $E_s = 200000.00$

Existing Column

New material of Secondary Member: Concrete Strength, $f_c = f_{c_lower_bound} = 25.00$

New material of Secondary Member: Steel Strength, $f_s = f_{s_lower_bound} = 500.00$

Concrete Elasticity, $E_c = 26999.444$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of γ for displacement ductility demand, the expected (mean value) strengths are used (7.5.1.3, ASCE 41-17) because bending is considered as Deformation-Controlled Action (Table C7-1, ASCE 41-17).

Jacket

New material: Concrete Strength, $f_c = f_{cm} = 33.00$

New material: Steel Strength, $f_s = f_{sm} = 555.56$

Existing Column

New material: Concrete Strength, $f_c = f_{cm} = 33.00$

New material: Steel Strength, $f_s = f_{sm} = 555.56$

#####

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
Adequate Lap Length ($l_o/l_{o,u,min} = l_b/l_d >= 1$)
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 = -320844.41
Shear Force, Va = 131.6809
EDGE -B-
Bending Moment, Mb = -72349.636
Shear Force, Vb = -131.6809
BOTH EDGES
Axial Force, F = -18154.476
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

New component: From table 7-7, ASCE 41_17: Final Shear Capacity VR = 1.0*Vn = 1.1008E+006
Vn ((10.3), ASCE 41-17) = knl*VCol0 = 1.1008E+006
VCol = 1.1008E+006
knl = 1.00
displacement_ductility_demand = 1.0996272E-005

NOTE: In expression (10-3) 'Vs = Av*fy*d/s' is replaced by 'Vs+ f*Vf'
where Vf is the contribution of FRPs (11.3), ACI 440).

= 1 (normal-weight concrete)
Mean concrete strength: fc' = (fc'_jacket*Area_jacket + fc'_core*Area_core)/Area_section = 25.00, but fc'^0.5 <= 8.3
MPa (22.5.3.1, ACI 318-14)
M/Vd = 2.00
Mu = 72349.636
Vu = 131.6809
d = 0.8*h = 600.00
Nu = 18154.476
Ag = 300000.00
From (11.5.4.8), ACI 318-14: Vs = Vs,jacket + Vs,core = 811033.559

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 $Col,j2 = 1.00$

$$s/d = 0.3125$$

$$V_{s,core} = V_{s,c1} + V_{s,c2} = 88467.249$$

$V_{s,c1} = 88467.249$ is calculated for section web core, with:

$$d = 440.00$$

$$A_v = 100530.965$$

$$f_y = 500.00$$

$$s = 250.00$$

$V_{s,c1}$ is multiplied by $Col,c1 = 1.00$

$$s/d = 0.56818182$$

$V_{s,c2} = 0.00$ is calculated for section flange core, with:

$$d = 160.00$$

$$A_v = 100530.965$$

$$f_y = 500.00$$

$$s = 250.00$$

$V_{s,c2}$ is multiplied by $Col,c2 = 0.00$

$$s/d = 1.5625$$

$$V_f((11-3)-(11.4), ACI 440) = 372533.843$$

$$f = 0.95, \text{ for fully-wrapped sections}$$

$w_f/s_f = 1$ (FRP strips adjacent to one another).

In (11.3) $\sin + \cos$ is replaced with $(\cot + \cot a)\sin a$ which is more a generalised expression,

where α is the angle of the crack direction (see KANEPE).

This later relation, considered as a function $V_f(\alpha, a_1)$, 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: $\alpha = b_1 + 90^\circ = 90.00$

$$V_f = \text{Min}(|V_f(45, \alpha_1)|, |V_f(-45, \alpha_1)|), \text{ with:}$$

total thickness per orientation, $tf_1 = NL * t / \text{NoDir} = 1.016$

$$df_v = d \text{ (figure 11.2, ACI 440)} = 707.00$$

$$ffe((11-5), ACI 440) = 259.312$$

$$E_f = 64828.00$$

$$f_e = 0.004, \text{ from (11.6a), ACI 440}$$

$$\text{with } f_u = 0.01$$

$$\text{From (11-11), ACI 440: } V_s + V_f \leq 797164.595$$

$$bw = 400.00$$

displacement_ductility_demand is calculated as δ / y

- Calculation of δ / y for END B -

for rotation axis 2 and integ. section (b)

From analysis, chord rotation $\theta = 8.5722711E-009$

$$y = (M_y * L_s / 3) / E_{eff} = 0.00077956 \text{ ((4.29), Biskinis Phd)}$$

$$M_y = 6.4998E+008$$

$$L_s = M/V \text{ (with } L_s > 0.1 * L \text{ and } L_s < 2 * L) = 549.4315$$

$$\text{From table 10.5, ASCE 41_17: } E_{eff} = \text{factor} * E_c * I_g = 1.5270E+014$$

$$\text{factor} = 0.30$$

$$A_g = 440000.00$$

$$\text{Mean concrete strength: } f_c' = (f_c'_{jacket} * \text{Area}_{jacket} + f_c'_{core} * \text{Area}_{core}) / \text{Area}_{section} = 33.00$$

$$N = 18154.476$$

$$E_c * I_g = E_c * I_{g,jacket} + E_c * I_{g,core} = 5.0901E+014$$

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, $t = 400.00$

$y = \text{Min}(y_{\text{ten}}, y_{\text{com}})$

$y_{\text{ten}} = 4.8675041\text{E-}006$

with $f_y = 555.56$

$d = 707.00$

$y = 0.19281101$

$A = 0.01015738$

$B = 0.00446779$

with $p_t = 0.00214476$

$p_c = 0.00416509$

$p_v = 0.00378591$

$N = 18154.476$

$b = 750.00$

" = 0.06082037

$y_{\text{comp}} = 1.6460425\text{E-}005$

with f_c^* (12.3, (ACI 440)) = 33.48734

$f_c = 33.00$

$f_l = 0.49678681$

$b = b_{\text{max}} = 750.00$

$h = h_{\text{max}} = 750.00$

$A_g = 0.44$

$g = p_t + p_c + p_v = 0.01009575$

$r_c = 40.00$

$A_e/A_c = 0.31291181$

Effective FRP thickness, $t_f = NL*t*\text{Cos}(b1) = 1.016$

effective strain from (12.5) and (12.12), $e_{fe} = 0.004$

$f_u = 0.01$

$E_f = 64828.00$

$E_c = 26999.444$

$y = 0.19183941$

$A = 0.01001908$

$B = 0.00440616$

with $E_s = 200000.00$

CONFIRMATION: $y = 0.19281101 < t/d$

Calculation of ratio l_b/d

Adequate Lap Length: $l_b/d \geq 1$

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

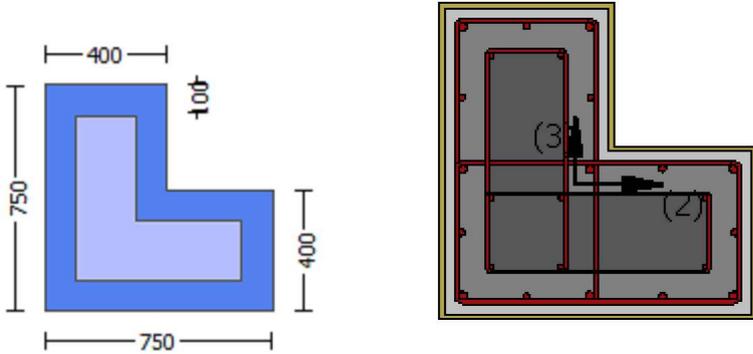
Limit State: Collapse Prevention (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity (θ_r)

Edge: End

Local Axis: (3)



Start Of Calculation of Shear Capacity ratio for element: column JLC1 of floor 1

At Shear local axis: 3

(Bending local axis: 2)

Section Type: rcjlcs

Constant Properties

Knowledge Factor, $\gamma = 0.90$

Mean strength values are used for both shear and moment calculations.

Consequently:

Jacket

New material of Secondary Member: Concrete Strength, $f_c = f_{cm} = 33.00$

New material of Secondary Member: Steel Strength, $f_s = f_{sm} = 555.56$

Concrete Elasticity, $E_c = 26999.444$

Steel Elasticity, $E_s = 200000.00$

Existing Column

New material of Secondary Member: Concrete Strength, $f_c = f_{cm} = 33.00$

New material of Secondary Member: Steel Strength, $f_s = f_{sm} = 555.56$

Concrete Elasticity, $E_c = 26999.444$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14

Jacket

New material: Steel Strength, $f_s = 1.25 \cdot f_{sm} = 694.45$

Existing Column

New material: Steel Strength, $f_s = 1.25 \cdot f_{sm} = 694.45$

#####

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
Adequate Lap Length ($l_o/l_{ou, \min} \geq 1$)
FRP Wrapping Data
Type: Carbon
Cured laminate properties (design values)
Thickness, $t = 1.016$
Tensile Strength, $f_{fu} = 1055.00$
Tensile Modulus, $E_f = 64828.00$
Elongation, $\epsilon_{fu} = 0.01$
Number of directions, $N_{oDir} = 1$
Fiber orientations, $b_i: 0.00^\circ$
Number of layers, $N_L = 1$
Radius of rounding corners, $R = 40.00$

Stepwise Properties

At local axis: 3
EDGE -A-
Shear Force, $V_a = -0.00017144$
EDGE -B-
Shear Force, $V_b = 0.00017144$
BOTH EDGES
Axial Force, $F = -16273.607$
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, $V_e/V_r = 1.05752$
Member Controlled by Shear ($V_e/V_r > 1$)
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 1.1525E+006$
with
 $M_{pr1} = \text{Max}(Mu_{1+}, Mu_{1-}) = 1.7288E+009$
 $Mu_{1+} = 1.1540E+009$, 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
 $Mu_{1-} = 1.7288E+009$, 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
 $M_{pr2} = \text{Max}(Mu_{2+}, Mu_{2-}) = 1.7288E+009$
 $Mu_{2+} = 1.1540E+009$, 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
 $Mu_{2-} = 1.7288E+009$, 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:
 $\phi_u = 5.0226943E-005$
 $M_u = 1.1540E+009$

with full section properties:

$b = 750.00$
 $d = 707.00$
 $d' = 43.00$
 $v = 0.00093001$
 $N = 16273.607$
 $f_c = 33.00$

$$c_o (5A.5, TBDY) = 0.002$$

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.01291652$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } c_u = 0.01291652$$

$$w_e ((5.4c), TBDY) = a_{se} * s_{h,min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.05541928$$

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 $a_f = 1 - (\text{Unconfined area})/(\text{total area})$

$$a_f = 0.31984848$$

$$\text{with Unconfined area} = ((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 140733.333$$

$$b_{max} = 750.00$$

$$h_{max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 870.5244$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N_L * t * \text{Cos}(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$a_{se} ((5.4d), TBDY) = (a_{se1} * A_{ext} + a_{se2} * A_{int})/A_{sec} = 0.45746528$$

$$a_{se1} = \text{Max}(((A_{conf,max1} - A_{noConf1})/A_{conf,max1}) * (A_{conf,min1}/A_{conf,max1}), 0) = 0.45746528$$

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).

$$p_{sh,min} * F_{ywe} = \text{Min}(p_{sh,x} * F_{ywe}, p_{sh,y} * F_{ywe}) = 3.0194$$

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)

$$p_{sh,x} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{sh2} * F_{ywe2} = 3.0194$$

$$p_{sh1} ((5.4d), TBDY) = L_{stir1} * A_{stir1}/(A_{sec} * s_1) = 0.00367709$$

$$L_{stir1} (\text{Length of stirrups along } Y) = 2060.00$$

$$A_{stir1} (\text{stirrups area}) = 78.53982$$

$$p_{sh2} (5.4d) = L_{stir2} * A_{stir2}/(A_{sec} * s_2) = 0.00067082$$

$$L_{stir2} (\text{Length of stirrups along } Y) = 1468.00$$

$$\text{Astir2 (stirrups area)} = 50.26548$$

$$\text{psh}_y * \text{Fywe} = \text{psh}_1 * \text{Fywe}_1 + \text{ps}_2 * \text{Fywe}_2 = 3.0194$$

$$\text{psh}_1 ((5.4d), \text{TBDY}) = \text{Lstir}_1 * \text{Astir}_1 / (\text{Asec} * \text{s}_1) = 0.00367709$$

$$\text{Lstir}_1 (\text{Length of stirrups along X}) = 2060.00$$

$$\text{Astir}_1 (\text{stirrups area}) = 78.53982$$

$$\text{psh}_2 ((5.4d), \text{TBDY}) = \text{Lstir}_2 * \text{Astir}_2 / (\text{Asec} * \text{s}_2) = 0.00067082$$

$$\text{Lstir}_2 (\text{Length of stirrups along X}) = 1468.00$$

$$\text{Astir}_2 (\text{stirrups area}) = 50.26548$$

$$\text{Asec} = 440000.00$$

$$\text{s}_1 = 100.00$$

$$\text{s}_2 = 250.00$$

$$\text{fywe}_1 = 694.45$$

$$\text{fywe}_2 = 694.45$$

$$\text{fce} = 33.00$$

$$\text{From } ((5.A.5), \text{TBDY}), \text{TBDY: } \text{cc} = 0.00238888$$

$$\text{c} = \text{confinement factor} = 1.03889$$

$$\text{y}_1 = 0.0025$$

$$\text{sh}_1 = 0.008$$

$$\text{ft}_1 = 833.34$$

$$\text{fy}_1 = 694.45$$

$$\text{su}_1 = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$\text{lo/lou,min} = \text{lb/ld} = 1.00$$

$$\text{su}_1 = 0.4 * \text{esu}_1 \text{nominal } ((5.5), \text{TBDY}) = 0.032$$

$$\text{From table 5A.1, TBDY: } \text{esu}_1 \text{nominal} = 0.08,$$

For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

$$\text{y}_1, \text{sh}_1, \text{ft}_1, \text{fy}_1, \text{ are also multiplied by } \text{Min}(1, 1.25 * (\text{lb/ld})^{2/3}), \text{ from 10.3.5, ASCE 41-17.}$$

$$\text{with } \text{fs}_1 = (\text{fs,jacket} * \text{Asl,ten,jacket} + \text{fs,core} * \text{Asl,ten,core}) / \text{Asl,ten} = 694.45$$

$$\text{with } \text{Es}_1 = (\text{Es,jacket} * \text{Asl,ten,jacket} + \text{Es,core} * \text{Asl,ten,core}) / \text{Asl,ten} = 200000.00$$

$$\text{y}_2 = 0.0025$$

$$\text{sh}_2 = 0.008$$

$$\text{ft}_2 = 833.34$$

$$\text{fy}_2 = 694.45$$

$$\text{su}_2 = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$\text{lo/lou,min} = \text{lb/lb,min} = 1.00$$

$$\text{su}_2 = 0.4 * \text{esu}_2 \text{nominal } ((5.5), \text{TBDY}) = 0.032$$

$$\text{From table 5A.1, TBDY: } \text{esu}_2 \text{nominal} = 0.08,$$

For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

$$\text{y}_2, \text{sh}_2, \text{ft}_2, \text{fy}_2, \text{ are also multiplied by } \text{Min}(1, 1.25 * (\text{lb/ld})^{2/3}), \text{ from 10.3.5, ASCE 41-17.}$$

$$\text{with } \text{fs}_2 = (\text{fs,jacket} * \text{Asl,com,jacket} + \text{fs,core} * \text{Asl,com,core}) / \text{Asl,com} = 694.45$$

$$\text{with } \text{Es}_2 = (\text{Es,jacket} * \text{Asl,com,jacket} + \text{Es,core} * \text{Asl,com,core}) / \text{Asl,com} = 200000.00$$

$$\text{y}_v = 0.0025$$

$$\text{sh}_v = 0.008$$

$$\text{ft}_v = 833.34$$

$$\text{fy}_v = 694.45$$

$$\text{suv} = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$\text{lo/lou,min} = \text{lb/ld} = 1.00$$

$$\text{suv} = 0.4 * \text{esuv}_v \text{nominal } ((5.5), \text{TBDY}) = 0.032$$

$$\text{From table 5A.1, TBDY: } \text{esuv}_v \text{nominal} = 0.08,$$

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.

$$\text{y}_v, \text{sh}_v, \text{ft}_v, \text{fy}_v, \text{ are also multiplied by } \text{Min}(1, 1.25 * (\text{lb/ld})^{2/3}), \text{ from 10.3.5, ASCE 41-17.}$$

$$\text{with } \text{fs}_v = (\text{fs,jacket} * \text{Asl,mid,jacket} + \text{fs,mid} * \text{Asl,mid,core}) / \text{Asl,mid} = 694.45$$

$$\text{with } \text{Esv} = (\text{Es,jacket} * \text{Asl,mid,jacket} + \text{Es,mid} * \text{Asl,mid,core}) / \text{Asl,mid} = 200000.00$$

$$1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.0451341$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.08764993$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.07967042$$

and confined core properties:

$$b = 690.00$$

$$d = 677.00$$

$$d' = 13.00$$

$$f_{cc} (5A.2, TBDY) = 34.2833$$

$$c_c (5A.5, TBDY) = 0.00238888$$

$$c = \text{confinement factor} = 1.03889$$

$$1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.05123276$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.09949345$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.09043572$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < v_{s,y2}$ - LHS eq.(4.5) is satisfied

--->

$$s_u (4.9) = 0.09885678$$

$$\mu_u = M_{Rc} (4.14) = 1.1540E+009$$

$$u = s_u (4.1) = 5.0226943E-005$$

Calculation of ratio l_b/d

Adequate Lap Length: $l_b/d \geq 1$

Calculation of μ_{u1} -

Calculation of ultimate curvature μ_u according to 4.1, Biskinis/Fardis 2013:

$$u = 6.4288704E-005$$

$$\mu_u = 1.7288E+009$$

with full section properties:

$$b = 400.00$$

$$d = 707.00$$

$$d' = 43.00$$

$$v = 0.00174378$$

$$N = 16273.607$$

$$f_c = 33.00$$

$$c_o (5A.5, TBDY) = 0.002$$

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.01291652$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } c_u = 0.01291652$$

$$w_e ((5.4c), TBDY) = a_{se} * s_{h,min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.05541928$$

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 $a_f = 1 - (\text{Unconfined area})/(\text{total area})$

$$a_f = 0.31984848$$

$$\text{with Unconfined area} = ((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 140733.333$$

$$b_{max} = 750.00$$

$$h_{max} = 750.00$$

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).

$p_{sh,min} * F_{ywe} = \text{Min}(p_{sh,x} * F_{ywe}, p_{sh,y} * F_{ywe}) = 3.0194$

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)

$p_{sh,x} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{sh2} * F_{ywe2} = 3.0194$

$p_{sh1}((5.4d), \text{TBDY}) = L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00367709$

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

$p_{sh,y} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{sh2} * F_{ywe2} = 3.0194$

$p_{sh1}((5.4d), \text{TBDY}) = L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00367709$

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

$A_{sec} = 440000.00$

$s1 = 100.00$

$s2 = 250.00$

$f_{ywe1} = 694.45$

$f_{ywe2} = 694.45$

$f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY: $cc = 0.00238888$

$c =$ confinement factor = 1.03889

$y1 = 0.0025$

$sh1 = 0.008$

$ft1 = 833.34$

$fy1 = 694.45$

$su1 = 0.032$

using (30) in Biskinis/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 = 1.00

su1 = 0.4*esu1_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu1_nominal = 0.08,

For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/d)^ 2/3), from 10.3.5, ASCE 41-17.

with fs1 = (fs,jacket*Asl,ten,jacket + fs,core*Asl,ten,core)/Asl,ten = 694.45

with Es1 = (Es,jacket*Asl,ten,jacket + Es,core*Asl,ten,core)/Asl,ten = 200000.00

y2 = 0.0025

sh2 = 0.008

ft2 = 833.34

fy2 = 694.45

su2 = 0.032

using (30) in Biskinis/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 = 1.00

su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu2_nominal = 0.08,

For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/d)^ 2/3), from 10.3.5, ASCE 41-17.

with fs2 = (fs,jacket*Asl,com,jacket + fs,core*Asl,com,core)/Asl,com = 694.45

with Es2 = (Es,jacket*Asl,com,jacket + Es,core*Asl,com,core)/Asl,com = 200000.00

yv = 0.0025

shv = 0.008

ftv = 833.34

fyv = 694.45

suv = 0.032

using (30) in Biskinis/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 = 1.00

suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esuv_nominal = 0.08,

considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY
For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered
characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/d)^ 2/3), from 10.3.5, ASCE 41-17.

with fsv = (fs,jacket*Asl,mid,jacket + fs,mid*Asl,mid,core)/Asl,mid = 694.45

with Esv = (Es,jacket*Asl,mid,jacket + Es,mid*Asl,mid,core)/Asl,mid = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.16434361

2 = Asl,com/(b*d)*(fs2/fc) = 0.08462644

v = Asl,mid/(b*d)*(fsv/fc) = 0.14938203

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) = 0.20191317

2 = Asl,com/(b*d)*(fs2/fc) = 0.10397236

v = Asl,mid/(b*d)*(fsv/fc) = 0.18353132

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

v < vs,y2 - LHS eq.(4.5) is not satisfied

--->

v < vs,c - RHS eq.(4.5) is satisfied

--->

su (4.8) = 0.29596233

Mu = MRc (4.15) = 1.7288E+009

u = su (4.1) = 6.4288704E-005

Calculation of ratio l_b/d

Adequate Lap Length: $l_b/d \geq 1$

Calculation of μ_{2+}

Calculation of ultimate curvature μ according to 4.1, Biskinis/Fardis 2013:

$\mu = 5.0226943E-005$

$\mu_{2+} = 1.1540E+009$

with full section properties:

$b = 750.00$

$d = 707.00$

$d' = 43.00$

$v = 0.00093001$

$N = 16273.607$

$f_c = 33.00$

ω (5A.5, TBDY) = 0.002

Final value of μ_{cu} : $\mu_{cu}^* = \text{shear_factor} * \text{Max}(\mu_{cu}, \mu_{cc}) = 0.01291652$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $\mu_{cu} = 0.01291652$

μ_{ve} ((5.4c), TBDY) = $\omega_{se} * \text{sh}_{,\min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.05541928$

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 = $((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2)/3 = 140733.333$

$b_{\max} = 750.00$

$h_{\max} = 750.00$

From EC8 A.4.4.3(6), $\omega_{se} = 2t_f/b_w = 0.00508$

$b_w = 400.00$

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 = $((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2)/3 = 140733.333$

$b_{\max} = 750.00$

$h_{\max} = 750.00$

From EC8 A.4.4.3(6), $\omega_{se} = 2t_f/b_w = 0.00508$

$b_w = 400.00$

effective stress from (A.35), $f_{fe} = 870.5244$

$R = 40.00$

Effective FRP thickness, $t_f = NL * t * \text{Cos}(b_1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$\omega_{u,f} = 0.015$

ω_{se} ((5.4d), TBDY) = $(\omega_{se1} * A_{ext} + \omega_{se2} * A_{int})/A_{sec} = 0.45746528$

$\omega_{se1} = \text{Max}(((A_{conf,max1} - A_{noConf1})/A_{conf,max1}) * (A_{conf,min1}/A_{conf,max1}), 0) = 0.45746528$

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.

AnoConf1 = 158733.333 is the unconfined external core area which is equal to $b_i^2/6$ as defined at (A.2).
 $ase_2 (>= ase_1) = \text{Max}(((A_{conf,max2}-AnoConf_2)/A_{conf,max2}) * (A_{conf,min2}/A_{conf,max2}), 0) = 0.45746528$

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).
 $psh_{,min} * Fy_{we} = \text{Min}(psh_{,x} * Fy_{we}, psh_{,y} * Fy_{we}) = 3.0194$

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)

 $psh_{,x} * Fy_{we} = psh_1 * Fy_{we1} + ps_2 * Fy_{we2} = 3.0194$
 $psh_1 ((5.4d), TBDY) = L_{stir1} * Astir1 / (A_{sec} * s_1) = 0.00367709$
Lstir1 (Length of stirrups along Y) = 2060.00
Astir1 (stirrups area) = 78.53982
 $psh_2 ((5.4d)) = L_{stir2} * Astir2 / (A_{sec} * s_2) = 0.00067082$
Lstir2 (Length of stirrups along Y) = 1468.00
Astir2 (stirrups area) = 50.26548

 $psh_{,y} * Fy_{we} = psh_1 * Fy_{we1} + ps_2 * Fy_{we2} = 3.0194$
 $psh_1 ((5.4d), TBDY) = L_{stir1} * Astir1 / (A_{sec} * s_1) = 0.00367709$
Lstir1 (Length of stirrups along X) = 2060.00
Astir1 (stirrups area) = 78.53982
 $psh_2 ((5.4d), TBDY) = L_{stir2} * Astir2 / (A_{sec} * s_2) = 0.00067082$
Lstir2 (Length of stirrups along X) = 1468.00
Astir2 (stirrups area) = 50.26548

Asec = 440000.00

s1 = 100.00

s2 = 250.00

fywe1 = 694.45

fywe2 = 694.45

fce = 33.00

From ((5.A.5), TBDY), TBDY: cc = 0.00238888

c = confinement factor = 1.03889

y1 = 0.0025

sh1 = 0.008

ft1 = 833.34

fy1 = 694.45

su1 = 0.032

using (30) in Biskinis/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 = 1.00

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,t_en,jacket + fs,core * Asl,t_en,core) / Asl,t_en = 694.45

with Es1 = (Es,jacket * Asl,t_en,jacket + Es,core * Asl,t_en,core) / Asl,t_en = 200000.00

y2 = 0.0025

sh2 = 0.008

ft2 = 833.34

fy2 = 694.45

su2 = 0.032

using (30) in Biskinis/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 = 1.00

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 $fs2 = (fs_jacket \cdot Asl,com,jacket + fs_core \cdot Asl,com,core) / Asl,com = 694.45$

with $Es2 = (Es_jacket \cdot Asl,com,jacket + Es_core \cdot Asl,com,core) / Asl,com = 200000.00$

$yv = 0.0025$

$shv = 0.008$

$ftv = 833.34$

$fyv = 694.45$

$suv = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with $shear_factor$

and also multiplied by the $shear_factor$ according to 15.7.1.4, with $Shear_factor = 1.00$

$lo/lo, min = lb/ld = 1.00$

$suv = 0.4 \cdot esuv_nominal$ ((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 $fsv = (fs_jacket \cdot Asl,mid,jacket + fs_mid \cdot Asl,mid,core) / Asl,mid = 694.45$

with $Esv = (Es_jacket \cdot Asl,mid,jacket + Es_mid \cdot Asl,mid,core) / Asl,mid = 200000.00$

$1 = Asl,ten / (b \cdot d) \cdot (fs1 / fc) = 0.0451341$

$2 = Asl,com / (b \cdot d) \cdot (fs2 / fc) = 0.08764993$

$v = Asl,mid / (b \cdot d) \cdot (fsv / fc) = 0.07967042$

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

$1 = Asl,ten / (b \cdot d) \cdot (fs1 / fc) = 0.05123276$

$2 = Asl,com / (b \cdot d) \cdot (fs2 / fc) = 0.09949345$

$v = Asl,mid / (b \cdot d) \cdot (fsv / fc) = 0.09043572$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < vs,y2$ - LHS eq.(4.5) is satisfied

--->

su (4.9) = 0.09885678

$Mu = MRc$ (4.14) = 1.1540E+009

$u = su$ (4.1) = 5.0226943E-005

Calculation of ratio lb/ld

Adequate Lap Length: $lb/ld \geq 1$

Calculation of $Mu2$ -

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

$u = 6.4288704E-005$

$Mu = 1.7288E+009$

with full section properties:

$b = 400.00$

$d = 707.00$

$d' = 43.00$

$v = 0.00174378$

$N = 16273.607$

$fc = 33.00$

co (5A.5, TBDY) = 0.002

Final value of cu: $cu^* = \text{shear_factor} * \text{Max}(cu, cc) = 0.01291652$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $cu = 0.01291652$

we ((5.4c), TBDY) = $ase * sh_{,min} * fy_{we} / f_{ce} + \text{Min}(fx, fy) = 0.05541928$

where $f = af * pf * ff_e / f_{ce}$ 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).

$psh_{,min} * F_{ywe} = \text{Min}(psh_x * F_{ywe}, psh_y * F_{ywe}) = 3.0194$

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)

 $psh_x * F_{ywe} = psh1 * F_{ywe1} + ps2 * F_{ywe2} = 3.0194$

$psh1$ ((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

Astir2 (stirrups area) = 50.26548

psh_y*Fywe = psh₁*Fywe₁+ps₂*Fywe₂ = 3.0194
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 = 694.45

fywe₂ = 694.45

fce = 33.00

From ((5.A5), TBDY), TBDY: cc = 0.00238888

c = confinement factor = 1.03889

y₁ = 0.0025

sh₁ = 0.008

ft₁ = 833.34

fy₁ = 694.45

su₁ = 0.032

using (30) in Biskinis/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 = 1.00

su₁ = 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 y₁, sh₁,ft₁,fy₁, it is considered
characteristic value fsy₁ = fs₁/1.2, from table 5.1, TBDY.

y₁, sh₁,ft₁,fy₁, are also multiplied by Min(1,1.25*(lb/ld)^{2/3}), from 10.3.5, ASCE 41-17.

with fs₁ = (fs,jacket*Asl,ten,jacket + fs,core*Asl,ten,core)/Asl,ten = 694.45

with Es₁ = (Es,jacket*Asl,ten,jacket + Es,core*Asl,ten,core)/Asl,ten = 200000.00

y₂ = 0.0025

sh₂ = 0.008

ft₂ = 833.34

fy₂ = 694.45

su₂ = 0.032

using (30) in Biskinis/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 = 1.00

su₂ = 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 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 Min(1,1.25*(lb/ld)^{2/3}), from 10.3.5, ASCE 41-17.

with fs₂ = (fs,jacket*Asl,com,jacket + fs,core*Asl,com,core)/Asl,com = 694.45

with Es₂ = (Es,jacket*Asl,com,jacket + Es,core*Asl,com,core)/Asl,com = 200000.00

y_v = 0.0025

sh_v = 0.008

ft_v = 833.34

fy_v = 694.45

suv = 0.032

using (30) in Biskinis/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 = 1.00

suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esuv_nominal = 0.08,

considering characteristic value fsy_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 fsy_v = fs_v/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 fs_v = (fs,jacket*Asl,mid,jacket + fs,mid*Asl,mid,core)/Asl,mid = 694.45

with Es_v = (Es,jacket*Asl,mid,jacket + Es,mid*Asl,mid,core)/Asl,mid = 200000.00

$$1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.16434361$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.08462644$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.14938203$$

and confined core properties:

$$b = 340.00$$

$$d = 677.00$$

$$d' = 13.00$$

$$f_{cc} (5A.2, TBDY) = 34.2833$$

$$c_c (5A.5, TBDY) = 0.00238888$$

$$c = \text{confinement factor} = 1.03889$$

$$1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.20191317$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.10397236$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.18353132$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < v_{s,y2}$ - LHS eq.(4.5) is not satisfied

--->

$v < v_{s,c}$ - RHS eq.(4.5) is satisfied

--->

$$s_u (4.8) = 0.29596233$$

$$M_u = M_{Rc} (4.15) = 1.7288E+009$$

$$u = s_u (4.1) = 6.4288704E-005$$

Calculation of ratio l_b/l_d

Adequate Lap Length: $l_b/l_d \geq 1$

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 1.0898E+006$

Calculation of Shear Strength at edge 1, $V_{r1} = 1.0898E+006$

$$V_{r1} = V_{Col} ((10.3), ASCE 41-17) = k_{nl} * V_{Col0}$$

$$V_{Col0} = 1.0898E+006$$

$$k_{nl} = 1 \text{ (zero step-static loading)}$$

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)

$$\text{Mean concrete strength: } f_c' = (f_c'_{jacket} * \text{Area}_{jacket} + f_c'_{core} * \text{Area}_{core}) / \text{Area}_{section} = 33.00, \text{ but } f_c'^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

$$M/Vd = 4.00$$

$$M_u = 1518.01$$

$$V_u = 0.00017144$$

$$d = 0.8 * h = 600.00$$

$$N_u = 16273.607$$

$$A_g = 300000.00$$

$$\text{From (11.5.4.8), ACI 318-14: } V_s = V_{sjacket} + V_{s,core} = 901155.609$$

where:

$$V_{sjacket} = V_{sj1} + V_{sj2} = 802857.879$$

$V_{sj1} = 523602.964$ is calculated for section web jacket, with:

$$d = 600.00$$

$$A_v = 157079.633$$

$$f_y = 555.56$$

$$s = 100.00$$

V_{sj1} is multiplied by $Col_{j1} = 1.00$

$$s/d = 0.16666667$$

$V_{sj2} = 279254.914$ is calculated for section flange jacket, with:

$$d = 320.00$$

$$A_v = 157079.633$$

$$f_y = 555.56$$

$$s = 100.00$$

V_{sj2} is multiplied by $Col_{j2} = 1.00$

$s/d = 0.3125$
 $V_{s,core} = V_{s,c1} + V_{s,c2} = 98297.73$
 $V_{s,c1} = 98297.73$ is calculated for section web core, with:
 $d = 440.00$
 $A_v = 100530.965$
 $f_y = 555.56$
 $s = 250.00$
 $V_{s,c1}$ is multiplied by $Col,c1 = 1.00$
 $s/d = 0.56818182$
 $V_{s,c2} = 0.00$ is calculated for section flange core, with:
 $d = 160.00$
 $A_v = 100530.965$
 $f_y = 555.56$
 $s = 250.00$
 $V_{s,c2}$ 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
 $wf/sf = 1$ (FRP strips adjacent to one another).
 \ln (11.3) $\sin + \cos$ is replaced with $(\cot + \cot a)\sin a$ which is more a generalised expression,
 where 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: $\theta = 45^\circ$
 $V_f = \text{Min}(|V_f(45^\circ)|, |V_f(-45^\circ)|)$, 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: $V_s + V_f \leq 915872.391$
 $b_w = 400.00$

Calculation of Shear Strength at edge 2, $V_{r2} = 1.0898E+006$
 $V_{r2} = V_{Col}$ ((10.3), ASCE 41-17) = $k_n l \cdot V_{Col0}$
 $V_{Col0} = 1.0898E+006$
 $k_n l = 1$ (zero step-static loading)

NOTE: In expression (10-3) ' $V_s = A_v \cdot f_y \cdot d / s$ ' is replaced by ' $V_s + f \cdot V_f$ '
 where V_f is the contribution of FRPs (11.3), ACI 440).

$\lambda = 1$ (normal-weight concrete)
 Mean concrete strength: $f_c' = (f_c'_{jacket} \cdot Area_{jacket} + f_c'_{core} \cdot Area_{core}) / Area_{section} = 33.00$, but $f_c'^{0.5} \leq 8.3$
 MPa (22.5.3.1, ACI 318-14)
 $M/Vd = 4.00$
 $\mu_u = 1518.01$
 $\nu_u = 0.00017144$
 $d = 0.8 \cdot h = 600.00$
 $N_u = 16273.607$
 $A_g = 300000.00$
 From (11.5.4.8), ACI 318-14: $V_s = V_{s,jacket} + V_{s,core} = 901155.609$
 where:
 $V_{s,jacket} = V_{s,j1} + V_{s,j2} = 802857.879$
 $V_{s,j1} = 523602.964$ is calculated for section web jacket, with:
 $d = 600.00$
 $A_v = 157079.633$
 $f_y = 555.56$
 $s = 100.00$
 $V_{s,j1}$ is multiplied by $Col,j1 = 1.00$
 $s/d = 0.16666667$
 $V_{s,j2} = 279254.914$ is calculated for section flange jacket, with:
 $d = 320.00$
 $A_v = 157079.633$
 $f_y = 555.56$
 $s = 100.00$

V_{s,j2} is multiplied by Col,j2 = 1.00
s/d = 0.3125

V_{s,core} = V_{s,c1} + V_{s,c2} = 98297.73

V_{s,c1} = 98297.73 is calculated for section web core, with:
d = 440.00

A_v = 100530.965
f_y = 555.56
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 = 555.56
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 + cota)sinα 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(α, a_i), is implemented for every different fiber orientation a_i,
as well as for 2 crack directions, α = 45° and α = -45° to take into consideration the cyclic seismic loading.

orientation 1: α = b1 + 90° = 90.00

V_f = Min(|V_f(45, a₁)|, |V_f(-45, a₁)|), with:

total thickness per orientation, t_{f1} = NL*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 ≤ 915872.391

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, k = 0.90

Mean strength values are used for both shear and moment calculations.

Consequently:

Jacket

New material of Secondary Member: Concrete Strength, f_c = f_{cm} = 33.00

New material of Secondary Member: Steel Strength, f_s = f_{sm} = 555.56

Concrete Elasticity, E_c = 26999.444

Steel Elasticity, E_s = 200000.00

Existing Column

New material of Secondary Member: Concrete Strength, f_c = f_{cm} = 33.00

New material of Secondary Member: Steel Strength, f_s = f_{sm} = 555.56

Concrete Elasticity, E_c = 26999.444

Steel Elasticity, E_s = 200000.00

#####

Note: Especially for the calculation of moment strengths,

the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14

Jacket

New material: Steel Strength, f_s = 1.25*f_{sm} = 694.45

Existing Column

New material: Steel Strength, $f_s = 1.25 \cdot f_{sm} = 694.45$

#####

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

Adequate Lap Length ($l_o/l_{ou,min} > 1$)

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $e_{fu} = 0.01$

Number of directions, $NoDir = 1$

Fiber orientations, $b_i = 0.00^\circ$

Number of layers, $NL = 1$

Radius of rounding corners, $R = 40.00$

Stepwise Properties

At local axis: 2

EDGE -A-

Shear Force, $V_a = -0.0001715$

EDGE -B-

Shear Force, $V_b = 0.0001715$

BOTH EDGES

Axial Force, $F = -16273.607$

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, $V_e/V_r = 1.05752$

Member Controlled by Shear ($V_e/V_r > 1$)

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 1.1525E+006$

with

$M_{pr1} = \text{Max}(Mu_{1+}, Mu_{1-}) = 1.7288E+009$

$Mu_{1+} = 1.1540E+009$, 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

$Mu_{1-} = 1.7288E+009$, 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

$M_{pr2} = \text{Max}(Mu_{2+}, Mu_{2-}) = 1.7288E+009$

$Mu_{2+} = 1.1540E+009$, 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

$Mu_{2-} = 1.7288E+009$, 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 μ according to 4.1, Biskinis/Fardis 2013:

$$\mu = 5.0226943E-005$$

$$\mu_u = 1.1540E+009$$

with full section properties:

$$b = 750.00$$

$$d = 707.00$$

$$d' = 43.00$$

$$v = 0.00093001$$

$$N = 16273.607$$

$$f_c = 33.00$$

$$\alpha (5A.5, \text{TBDY}) = 0.002$$

$$\text{Final value of } \mu_u: \mu_u = \text{shear_factor} * \text{Max}(\mu_c, \mu_c) = 0.01291652$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \mu_u = 0.01291652$$

$$\mu_c \text{ ((5.4c), TBDY) } = \alpha * \text{sh}_{\min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.05541928$$

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 $\alpha_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$\alpha_f = 0.31984848$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 140733.333$$

$$b_{\max} = 750.00$$

$$h_{\max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } \rho_f = 2t_f / b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 870.5244$$

$$f_y = 0.04286225$$

Expression ((15B.6), TBDY) is modified as $\alpha_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$\alpha_f = 0.31984848$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 140733.333$$

$$b_{\max} = 750.00$$

$$h_{\max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } \rho_f = 2t_f / b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 870.5244$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L * t * \text{Cos}(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$\alpha_{se} \text{ ((5.4d), TBDY) } = (\alpha_{se1} * A_{ext} + \alpha_{se2} * A_{int}) / A_{sec} = 0.45746528$$

$$\alpha_{se1} = \text{Max}(((A_{conf,max1} - A_{noConf1}) / A_{conf,max1}) * (A_{conf,min1} / A_{conf,max1}), 0) = 0.45746528$$

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).

$$\alpha_{se2} (\geq \alpha_{se1}) = \text{Max}(((A_{conf,max2} - A_{noConf2}) / A_{conf,max2}) * (A_{conf,min2} / A_{conf,max2}), 0) = 0.45746528$$

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.

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).
 $psh,min*Fywe = \text{Min}(psh,x*Fywe, psh,y*Fywe) = 3.0194$

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)

 $psh_x*Fywe = psh1*Fywe1 + ps2*Fywe2 = 3.0194$
 $psh1$ ((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

 $psh_y*Fywe = psh1*Fywe1 + ps2*Fywe2 = 3.0194$
 $psh1$ ((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 = 694.45
fywe2 = 694.45
fce = 33.00

From ((5.A5), TBDY), TBDY: cc = 0.00238888
c = confinement factor = 1.03889

y1 = 0.0025
sh1 = 0.008
ft1 = 833.34
fy1 = 694.45
su1 = 0.032

using (30) in Biskinis/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 = 1.00

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 $fs1 = (fs,jacket*Asl,ten,jacket + fs,core*Asl,ten,core)/Asl,ten = 694.45$

with $Es1 = (Es,jacket*Asl,ten,jacket + Es,core*Asl,ten,core)/Asl,ten = 200000.00$

y2 = 0.0025
sh2 = 0.008
ft2 = 833.34
fy2 = 694.45
su2 = 0.032

using (30) in Biskinis/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 = 1.00

su2 = $0.4*esu2_nominal$ ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu2_nominal = 0.08,

For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered characteristic value $fsy2 = fs2/1.2$, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25*(lb/ld)^{2/3})$, from 10.3.5, ASCE 41-17.

with $fs2 = (fs,jacket*Asl,com,jacket + fs,core*Asl,com,core)/Asl,com = 694.45$

with $Es2 = (Es,jacket*Asl,com,jacket + Es,core*Asl,com,core)/Asl,com = 200000.00$

yv = 0.0025
shv = 0.008
ftv = 833.34

$f_{yv} = 694.45$
 $s_{uv} = 0.032$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $l_o/l_{ou,min} = l_b/l_d = 1.00$
 $s_{uv} = 0.4 * e_{suv_nominal} ((5.5), TBDY) = 0.032$
 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 $f_{sv} = (f_{s,jacket} * A_{s,mid,jacket} + f_{s,mid} * A_{s,mid,core}) / A_{s,mid} = 694.45$
 with $E_{sv} = (E_{s,jacket} * A_{s,mid,jacket} + E_{s,mid} * A_{s,mid,core}) / A_{s,mid} = 200000.00$
 $1 = A_{s,ten} / (b * d) * (f_{s1} / f_c) = 0.0451341$
 $2 = A_{s,com} / (b * d) * (f_{s2} / f_c) = 0.08764993$
 $v = A_{s,mid} / (b * d) * (f_{sv} / f_c) = 0.07967042$
 and confined core properties:
 $b = 690.00$
 $d = 677.00$
 $d' = 13.00$
 $f_{cc} (5A.2, TBDY) = 34.2833$
 $cc (5A.5, TBDY) = 0.00238888$
 $c = \text{confinement factor} = 1.03889$
 $1 = A_{s,ten} / (b * d) * (f_{s1} / f_c) = 0.05123276$
 $2 = A_{s,com} / (b * d) * (f_{s2} / f_c) = 0.09949345$
 $v = A_{s,mid} / (b * d) * (f_{sv} / f_c) = 0.09043572$
 Case/Assumption: Unconfined full section - Steel rupture
 ' satisfies Eq. (4.3)

--->
 $v < v_{s,y2}$ - LHS eq.(4.5) is satisfied
 --->
 $su (4.9) = 0.09885678$
 $Mu = MRc (4.14) = 1.1540E+009$
 $u = su (4.1) = 5.0226943E-005$

 Calculation of ratio l_b/l_d

Adequate Lap Length: $l_b/l_d \geq 1$

 Calculation of Mu_1 -

 Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

$u = 6.4288704E-005$
 $Mu = 1.7288E+009$

 with full section properties:

$b = 400.00$
 $d = 707.00$
 $d' = 43.00$
 $v = 0.00174378$
 $N = 16273.607$
 $f_c = 33.00$
 $co (5A.5, TBDY) = 0.002$
 Final value of cu : $cu^* = \text{shear_factor} * \text{Max}(cu, cc) = 0.01291652$
 The Shear_factor is considered equal to 1 (pure moment strength)
 From (5.4b), TBDY: $cu = 0.01291652$
 $we ((5.4c), TBDY) = a_s * sh_{,min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.05541928$
 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 $a_f = 1 - (\text{Unconfined area}) / (\text{total area})$

af = 0.31984848
with Unconfined area = $((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 140733.333$
bmax = 750.00
hmax = 750.00
From EC8 A.4.4.3(6), pf = $2t_f/b_w = 0.00508$
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 = $((b_{max}-2R)^2 + (h_{max}-2R)^2)/3 = 140733.333$
bmax = 750.00
hmax = 750.00
From EC8 A.4.4.3(6), pf = $2t_f/b_w = 0.00508$
bw = 400.00
effective stress from (A.35), ff,e = 870.5244

R = 40.00
Effective FRP thickness, tf = $NL*t*\text{Cos}(b_1) = 1.016$
fu,f = 1055.00
Ef = 64828.00
u,f = 0.015

ase ((5.4d), TBDY) = $(ase_1*A_{ext} + ase_2*A_{int})/A_{sec} = 0.45746528$

ase1 = $\text{Max}(((A_{conf,max1} - A_{noConf1})/A_{conf,max1}) * (A_{conf,min1}/A_{conf,max1}), 0) = 0.45746528$

The definitions of 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 ($\geq ase_1$) = $\text{Max}(((A_{conf,max2} - A_{noConf2})/A_{conf,max2}) * (A_{conf,min2}/A_{conf,max2}), 0) = 0.45746528$

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*Fywe = $\text{Min}(psh_x*Fywe, psh_y*Fywe) = 3.0194$

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 = $psh_1*Fywe_1 + ps_2*Fywe_2 = 3.0194$
psh1 ((5.4d), TBDY) = $L_{stir1}*A_{stir1}/(A_{sec}*s_1) = 0.00367709$
Lstir1 (Length of stirrups along Y) = 2060.00
Astir1 (stirrups area) = 78.53982
psh2 ((5.4d), TBDY) = $L_{stir2}*A_{stir2}/(A_{sec}*s_2) = 0.00067082$
Lstir2 (Length of stirrups along Y) = 1468.00
Astir2 (stirrups area) = 50.26548

psh_y*Fywe = $psh_1*Fywe_1 + ps_2*Fywe_2 = 3.0194$
psh1 ((5.4d), TBDY) = $L_{stir1}*A_{stir1}/(A_{sec}*s_1) = 0.00367709$
Lstir1 (Length of stirrups along X) = 2060.00
Astir1 (stirrups area) = 78.53982
psh2 ((5.4d), TBDY) = $L_{stir2}*A_{stir2}/(A_{sec}*s_2) = 0.00067082$
Lstir2 (Length of stirrups along X) = 1468.00
Astir2 (stirrups area) = 50.26548

Asec = 440000.00

s1 = 100.00

s2 = 250.00

fywe1 = 694.45

fywe2 = 694.45

fce = 33.00

From ((5.A.5), TBDY), TBDY: cc = 0.00238888

c = confinement factor = 1.03889

y1 = 0.0025

sh1 = 0.008

ft1 = 833.34

fy1 = 694.45

su1 = 0.032

using (30) in Biskinis/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 = 1.00

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 = (fsjacket*Asl,ten,jacket + fs,core*Asl,ten,core)/Asl,ten = 694.45

with Es1 = (Es,jacket*Asl,ten,jacket + Es,core*Asl,ten,core)/Asl,ten = 200000.00

y2 = 0.0025

sh2 = 0.008

ft2 = 833.34

fy2 = 694.45

su2 = 0.032

using (30) in Biskinis/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 = 1.00

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 = 694.45

with Es2 = (Es,jacket*Asl,com,jacket + Es,core*Asl,com,core)/Asl,com = 200000.00

yv = 0.0025

shv = 0.008

ftv = 833.34

fyv = 694.45

suv = 0.032

using (30) in Biskinis/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 = 1.00

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 fsy = 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 = 694.45

with Esv = (Es,jacket*Asl,mid,jacket + Es,mid*Asl,mid,core)/Asl,mid = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.16434361

2 = Asl,com/(b*d)*(fs2/fc) = 0.08462644

v = Asl,mid/(b*d)*(fsv/fc) = 0.14938203

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 = $Asl_{ten}/(b*d)*(fs1/fc) = 0.20191317$

2 = $Asl_{com}/(b*d)*(fs2/fc) = 0.10397236$

v = $Asl_{mid}/(b*d)*(fsv/fc) = 0.18353132$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

v < $v_{s,y2}$ - LHS eq.(4.5) is not satisfied

v < $v_{s,c}$ - RHS eq.(4.5) is satisfied

su (4.8) = 0.29596233

Mu = MRc (4.15) = 1.7288E+009

u = su (4.1) = 6.4288704E-005

Calculation of ratio lb/l_d

Adequate Lap Length: lb/l_d >= 1

Calculation of Mu₂₊

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

u = 5.0226943E-005

Mu = 1.1540E+009

with full section properties:

b = 750.00

d = 707.00

d' = 43.00

v = 0.00093001

N = 16273.607

fc = 33.00

co (5A.5, TBDY) = 0.002

Final value of cu: cu* = shear_factor * Max(cu, cc) = 0.01291652

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: cu = 0.01291652

we ((5.4c), TBDY) = ase* sh,min*fywe/fce+ Min(fx, fy) = 0.05541928

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), ffe = 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), ffe = 870.5244

R = 40.00

Effective FRP thickness, tf = NL*t*Cos(b1) = 1.016

fu,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).

$$p_{sh,min} * F_{ywe} = \text{Min}(p_{sh,x} * F_{ywe}, p_{sh,y} * F_{ywe}) = 3.0194$$

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)

$$p_{sh,x} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{sh2} * F_{ywe2} = 3.0194$$

$$p_{sh1} \text{ ((5.4d), TBDY)} = L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00367709$$

$$L_{stir1} \text{ (Length of stirrups along Y)} = 2060.00$$

$$A_{stir1} \text{ (stirrups area)} = 78.53982$$

$$p_{sh2} \text{ (5.4d)} = L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00067082$$

$$L_{stir2} \text{ (Length of stirrups along Y)} = 1468.00$$

$$A_{stir2} \text{ (stirrups area)} = 50.26548$$

$$p_{sh,y} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{sh2} * F_{ywe2} = 3.0194$$

$$p_{sh1} \text{ ((5.4d), TBDY)} = L_{stir1} * A_{stir1} / (A_{sec} * s1) = 0.00367709$$

$$L_{stir1} \text{ (Length of stirrups along X)} = 2060.00$$

$$A_{stir1} \text{ (stirrups area)} = 78.53982$$

$$p_{sh2} \text{ ((5.4d), TBDY)} = L_{stir2} * A_{stir2} / (A_{sec} * s2) = 0.00067082$$

$$L_{stir2} \text{ (Length of stirrups along X)} = 1468.00$$

$$A_{stir2} \text{ (stirrups area)} = 50.26548$$

$$A_{sec} = 440000.00$$

$$s1 = 100.00$$

$$s2 = 250.00$$

$$f_{ywe1} = 694.45$$

$$f_{ywe2} = 694.45$$

$$f_{ce} = 33.00$$

$$\text{From ((5.A5), TBDY), TBDY: } cc = 0.00238888$$

$$c = \text{confinement factor} = 1.03889$$

$$y1 = 0.0025$$

$$sh1 = 0.008$$

$$ft1 = 833.34$$

$$fy1 = 694.45$$

$$su1 = 0.032$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor

and also multiplied by the shear_factor according to 15.7.1.4, with

Shear_factor = 1.00

$$l_o / l_{ou,min} = l_b / l_d = 1.00$$

$$su1 = 0.4 * esu1_{nominal} \text{ ((5.5), TBDY)} = 0.032$$

From table 5A.1, TBDY: $esu1_{nominal} = 0.08$,

For calculation of $esu1_{nominal}$ and $y1$, $sh1$, $ft1$, $fy1$, it is considered

characteristic value $f_{sy1} = f_{s1}/1.2$, 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 $f_{s1} = (f_{s,jacket} \cdot A_{s,ten,jacket} + f_{s,core} \cdot A_{s,ten,core})/A_{s,ten} = 694.45$

with $E_{s1} = (E_{s,jacket} \cdot A_{s,ten,jacket} + E_{s,core} \cdot A_{s,ten,core})/A_{s,ten} = 200000.00$

$y_2 = 0.0025$

$sh_2 = 0.008$

$ft_2 = 833.34$

$fy_2 = 694.45$

$su_2 = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor

and also multiplied by the shear_factor according to 15.7.1.4, with

Shear_factor = 1.00

$l_o/l_{o,min} = l_b/l_{b,min} = 1.00$

$su_2 = 0.4 \cdot esu_{2,nominal} ((5.5), TBDY) = 0.032$

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 $f_{s2} = (f_{s,jacket} \cdot A_{s,com,jacket} + f_{s,core} \cdot A_{s,com,core})/A_{s,com} = 694.45$

with $E_{s2} = (E_{s,jacket} \cdot A_{s,com,jacket} + E_{s,core} \cdot A_{s,com,core})/A_{s,com} = 200000.00$

$y_v = 0.0025$

$sh_v = 0.008$

$ft_v = 833.34$

$fy_v = 694.45$

$su_v = 0.032$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor

and also multiplied by the shear_factor according to 15.7.1.4, with

Shear_factor = 1.00

$l_o/l_{o,min} = l_b/l_d = 1.00$

$su_v = 0.4 \cdot esu_{v,nominal} ((5.5), TBDY) = 0.032$

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 $f_{sv} = (f_{s,jacket} \cdot A_{s,mid,jacket} + f_{s,mid} \cdot A_{s,mid,core})/A_{s,mid} = 694.45$

with $E_{sv} = (E_{s,jacket} \cdot A_{s,mid,jacket} + E_{s,mid} \cdot A_{s,mid,core})/A_{s,mid} = 200000.00$

$1 = A_{s,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.0451341$

$2 = A_{s,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.08764993$

$v = A_{s,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.07967042$

and confined core properties:

$b = 690.00$

$d = 677.00$

$d' = 13.00$

$f_{cc} (5A.2, TBDY) = 34.2833$

$cc (5A.5, TBDY) = 0.00238888$

$c = \text{confinement factor} = 1.03889$

$1 = A_{s,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.05123276$

$2 = A_{s,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.09949345$

$v = A_{s,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.09043572$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

---->

$v < v_{s,y2}$ - LHS eq.(4.5) is satisfied

---->

$su (4.9) = 0.09885678$

$Mu = MRc (4.14) = 1.1540E+009$

$u = su (4.1) = 5.0226943E-005$

Calculation of ratio l_b/l_d

Adequate Lap Length: $l_b/l_d \geq 1$

Calculation of Mu_2 -

Calculation of ultimate curvature ϕ_u according to 4.1, Biskinis/Fardis 2013:

$$u = 6.4288704E-005$$

$$\mu = 1.7288E+009$$

with full section properties:

$$b = 400.00$$

$$d = 707.00$$

$$d' = 43.00$$

$$v = 0.00174378$$

$$N = 16273.607$$

$$f_c = 33.00$$

$$\alpha_{co} (5A.5, TBDY) = 0.002$$

$$\text{Final value of } \phi_u: \phi_u = \text{shear_factor} * \text{Max}(\phi_{cu}, \phi_{cc}) = 0.01291652$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \phi_{cu} = 0.01291652$$

$$\phi_{we} ((5.4c), TBDY) = \alpha_{se} * \text{sh}_{,\min} * f_{ywe} / f_{ce} + \text{Min}(\phi_{fx}, \phi_{fy}) = 0.05541928$$

where $\phi_f = \alpha_f * \rho_f * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$\phi_{fx} = 0.04286225$$

Expression ((15B.6), TBDY) is modified as $\alpha_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$\alpha_f = 0.31984848$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 140733.333$$

$$b_{\max} = 750.00$$

$$h_{\max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } \rho_f = 2t_f / b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{fe} = 870.5244$$

$$\phi_{fy} = 0.04286225$$

Expression ((15B.6), TBDY) is modified as $\alpha_f = 1 - (\text{Unconfined area}) / (\text{total area})$

$$\alpha_f = 0.31984848$$

$$\text{with Unconfined area} = ((b_{\max} - 2R)^2 + (h_{\max} - 2R)^2) / 3 = 140733.333$$

$$b_{\max} = 750.00$$

$$h_{\max} = 750.00$$

$$\text{From EC8 A.4.4.3(6), } \rho_f = 2t_f / b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{fe} = 870.5244$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L * t * \text{Cos}(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$\alpha_{se} ((5.4d), TBDY) = (\alpha_{se1} * A_{ext} + \alpha_{se2} * A_{int}) / A_{sec} = 0.45746528$$

$$\alpha_{se1} = \text{Max}(((A_{\text{conf,max1}} - A_{\text{noConf1}}) / A_{\text{conf,max1}}) * (A_{\text{conf,min1}} / A_{\text{conf,max1}}), 0) = 0.45746528$$

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., 10.1061/(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).

$$\alpha_{se2} (>= \alpha_{se1}) = \text{Max}(((A_{\text{conf,max2}} - A_{\text{noConf2}}) / A_{\text{conf,max2}}) * (A_{\text{conf,min2}} / A_{\text{conf,max2}}), 0) = 0.45746528$$

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.

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).
 $psh,min*Fywe = \text{Min}(psh,x*Fywe, psh,y*Fywe) = 3.0194$

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)

 $psh_x*Fywe = psh1*Fywe1 + ps2*Fywe2 = 3.0194$
 $psh1$ ((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

 $psh_y*Fywe = psh1*Fywe1 + ps2*Fywe2 = 3.0194$
 $psh1$ ((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 = 694.45
fywe2 = 694.45
fce = 33.00

From ((5.A5), TBDY), TBDY: cc = 0.00238888
c = confinement factor = 1.03889

y1 = 0.0025
sh1 = 0.008
ft1 = 833.34
fy1 = 694.45
su1 = 0.032

using (30) in Biskinis/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 = 1.00

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 $fs1 = (fs,jacket*Asl,ten,jacket + fs,core*Asl,ten,core)/Asl,ten = 694.45$

with $Es1 = (Es,jacket*Asl,ten,jacket + Es,core*Asl,ten,core)/Asl,ten = 200000.00$

y2 = 0.0025
sh2 = 0.008
ft2 = 833.34
fy2 = 694.45
su2 = 0.032

using (30) in Biskinis/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 = 1.00

su2 = $0.4*esu2_nominal$ ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu2_nominal = 0.08,

For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered characteristic value $fsy2 = fs2/1.2$, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25*(lb/ld)^{2/3})$, from 10.3.5, ASCE 41-17.

with $fs2 = (fs,jacket*Asl,com,jacket + fs,core*Asl,com,core)/Asl,com = 694.45$

with $Es2 = (Es,jacket*Asl,com,jacket + Es,core*Asl,com,core)/Asl,com = 200000.00$

yv = 0.0025
shv = 0.008
ftv = 833.34

$f_{yv} = 694.45$
 $s_{uv} = 0.032$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $l_o/l_{ou,min} = l_b/l_d = 1.00$
 $s_{uv} = 0.4 * e_{suv_nominal} ((5.5), TBDY) = 0.032$
 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 $f_{sv} = (f_{s,jacket} * A_{sl,mid,jacket} + f_{s,mid} * A_{sl,mid,core}) / A_{sl,mid} = 694.45$
 with $E_{sv} = (E_{s,jacket} * A_{sl,mid,jacket} + E_{s,mid} * A_{sl,mid,core}) / A_{sl,mid} = 200000.00$
 $1 = A_{sl,ten} / (b * d) * (f_{s1} / f_c) = 0.16434361$
 $2 = A_{sl,com} / (b * d) * (f_{s2} / f_c) = 0.08462644$
 $v = A_{sl,mid} / (b * d) * (f_{sv} / f_c) = 0.14938203$

and confined core properties:

$b = 340.00$
 $d = 677.00$
 $d' = 13.00$
 $f_{cc} (5A.2, TBDY) = 34.2833$
 $cc (5A.5, TBDY) = 0.00238888$
 $c = \text{confinement factor} = 1.03889$
 $1 = A_{sl,ten} / (b * d) * (f_{s1} / f_c) = 0.20191317$
 $2 = A_{sl,com} / (b * d) * (f_{s2} / f_c) = 0.10397236$
 $v = A_{sl,mid} / (b * d) * (f_{sv} / f_c) = 0.18353132$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

$v < v_{s,y2}$ - LHS eq.(4.5) is not satisfied

$v < v_{s,c}$ - RHS eq.(4.5) is satisfied

$su (4.8) = 0.29596233$

$Mu = MRc (4.15) = 1.7288E+009$

$u = su (4.1) = 6.4288704E-005$

 Calculation of ratio l_b/l_d

Adequate Lap Length: $l_b/l_d \geq 1$

 Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 1.0898E+006$

 Calculation of Shear Strength at edge 1, $V_{r1} = 1.0898E+006$

$V_{r1} = V_{Col} ((10.3), ASCE 41-17) = k_{nl} * V_{Col0}$

$V_{Col0} = 1.0898E+006$

$k_{nl} = 1$ (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: $f'_c = (f'_{c,jacket} * Area_{jacket} + f'_{c,core} * Area_{core}) / Area_{section} = 33.00$, but $f_c^{0.5} \leq 8.3$
 MPa (22.5.3.1, ACI 318-14)

$M/Vd = 4.00$

$Mu = 1518.777$

$Vu = 0.0001715$

$d = 0.8 * h = 600.00$

$Nu = 16273.607$

$Ag = 300000.00$

From (11.5.4.8), ACI 318-14: $V_s = V_{s,jacket} + V_{s,core} = 901155.609$

where:

$$V_{s,jacket} = V_{s,j1} + V_{s,j2} = 802857.879$$

$V_{s,j1} = 279254.914$ is calculated for section web jacket, with:

$$d = 320.00$$

$$A_v = 157079.633$$

$$f_y = 555.56$$

$$s = 100.00$$

$V_{s,j1}$ is multiplied by $Col,j1 = 1.00$

$$s/d = 0.3125$$

$V_{s,j2} = 523602.964$ is calculated for section flange jacket, with:

$$d = 600.00$$

$$A_v = 157079.633$$

$$f_y = 555.56$$

$$s = 100.00$$

$V_{s,j2}$ is multiplied by $Col,j2 = 1.00$

$$s/d = 0.16666667$$

$$V_{s,core} = V_{s,c1} + V_{s,c2} = 98297.73$$

$V_{s,c1} = 0.00$ is calculated for section web core, with:

$$d = 160.00$$

$$A_v = 100530.965$$

$$f_y = 555.56$$

$$s = 250.00$$

$V_{s,c1}$ is multiplied by $Col,c1 = 0.00$

$$s/d = 1.5625$$

$V_{s,c2} = 98297.73$ is calculated for section flange core, with:

$$d = 440.00$$

$$A_v = 100530.965$$

$$f_y = 555.56$$

$$s = 250.00$$

$V_{s,c2}$ is multiplied by $Col,c2 = 1.00$

$$s/d = 0.56818182$$

$V_f((11-3)-(11.4), ACI 440) = 372533.843$

$$f = 0.95, \text{ for fully-wrapped sections}$$

$w_f/s_f = 1$ (FRP strips adjacent to one another).

In (11.3) $\sin + \cos$ is replaced with $(\cot + \cot a)\sin a$ which is more a generalised expression, where 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, $tf1 = NL*t/NoDir = 1.016$

$dfv = d$ (figure 11.2, ACI 440) = 707.00

$ffe((11-5), ACI 440) = 259.312$

$$E_f = 64828.00$$

$$f_e = 0.004, \text{ from (11.6a), ACI 440}$$

$$\text{with } f_u = 0.01$$

From (11-11), ACI 440: $V_s + V_f \leq 915872.391$

$$bw = 400.00$$

Calculation of Shear Strength at edge 2, $V_{r2} = 1.0898E+006$

$V_{r2} = V_{Col}((10.3), ASCE 41-17) = knl * V_{Col0}$

$$V_{Col0} = 1.0898E+006$$

$knl = 1$ (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: $f_c' = (f_c'_{jacket} * Area_{jacket} + f_c'_{core} * Area_{core}) / Area_{section} = 33.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$$M/Vd = 4.00$$

$$\mu_u = 1518.777$$

$$V_u = 0.0001715$$

$$d = 0.8 * h = 600.00$$

$$N_u = 16273.607$$

$$A_g = 300000.00$$

From (11.5.4.8), ACI 318-14: $V_s = V_{s,jacket} + V_{s,core} = 901155.609$

where:

$$V_{s,jacket} = V_{s,j1} + V_{s,j2} = 802857.879$$

$V_{s,j1} = 279254.914$ is calculated for section web jacket, with:

$$d = 320.00$$

$$A_v = 157079.633$$

$$f_y = 555.56$$

$$s = 100.00$$

$V_{s,j1}$ is multiplied by $Col,j1 = 1.00$

$$s/d = 0.3125$$

$V_{s,j2} = 523602.964$ is calculated for section flange jacket, with:

$$d = 600.00$$

$$A_v = 157079.633$$

$$f_y = 555.56$$

$$s = 100.00$$

$V_{s,j2}$ is multiplied by $Col,j2 = 1.00$

$$s/d = 0.16666667$$

$$V_{s,core} = V_{s,c1} + V_{s,c2} = 98297.73$$

$V_{s,c1} = 0.00$ is calculated for section web core, with:

$$d = 160.00$$

$$A_v = 100530.965$$

$$f_y = 555.56$$

$$s = 250.00$$

$V_{s,c1}$ is multiplied by $Col,c1 = 0.00$

$$s/d = 1.5625$$

$V_{s,c2} = 98297.73$ is calculated for section flange core, with:

$$d = 440.00$$

$$A_v = 100530.965$$

$$f_y = 555.56$$

$$s = 250.00$$

$V_{s,c2}$ is multiplied by $Col,c2 = 1.00$

$$s/d = 0.56818182$$

$$V_f((11-3)-(11.4), ACI 440) = 372533.843$$

$$f = 0.95, \text{ for fully-wrapped sections}$$

$w_f/s_f = 1$ (FRP strips adjacent to one another).

In (11.3) $\sin + \cos$ is replaced with $(\cot + \cot a)\sin a$ which is more a generalised expression,

where a is the angle of the crack direction (see KANEPE).

This later relation, considered as a function $V_f(\alpha, a)$, 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.

$$\text{orientation 1: } \alpha = b1 + 90^\circ = 90.00$$

$$V_f = \text{Min}(|V_f(45, a1)|, |V_f(-45, a1)|), \text{ with:}$$

$$\text{total thickness per orientation, } t_{f1} = NL * t / \text{NoDir} = 1.016$$

$$d_{fv} = d \text{ (figure 11.2, ACI 440)} = 707.00$$

$$f_{fe}((11-5), ACI 440) = 259.312$$

$$E_f = 64828.00$$

$$f_e = 0.004, \text{ from (11.6a), ACI 440}$$

$$\text{with } f_u = 0.01$$

$$\text{From (11-11), ACI 440: } V_s + V_f \leq 915872.391$$

$$b_w = 400.00$$

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: (b)

Section Type: rcjlc

Constant Properties

Knowledge Factor, $\gamma = 0.90$

Chord Rotation is generally considered as Deformation-Controlled Action according to Table C7-1, ASCE 41-17.

Mean strengths are used for Deformation-Controlled Actions according to 7.5.1.3, ASCE 41-17

Consequently:

Jacket

New material of Secondary Member: Concrete Strength, $f_c = f_{cm} = 33.00$

New material of Secondary Member: Steel Strength, $f_s = f_{sm} = 555.56$

Concrete Elasticity, $E_c = 26999.444$

Steel Elasticity, $E_s = 200000.00$

Existing Column

New material of Secondary Member: Concrete Strength, $f_c = f_{cm} = 33.00$

New material of Secondary Member: Steel Strength, $f_s = f_{sm} = 555.56$

Concrete Elasticity, $E_c = 26999.444$

Steel Elasticity, $E_s = 200000.00$

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

Adequate Lap Length ($l_b/d > 1$)

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $e_{fu} = 0.01$

Number of directions, $N_{oDir} = 1$

Fiber orientations, $b_i = 0.00^\circ$

Number of layers, $N_L = 1$

Radius of rounding corners, $R = 40.00$

Stepwise Properties

Bending Moment, $M = 505225.544$

Shear Force, $V_2 = 4866.131$

Shear Force, $V_3 = -131.6809$

Axial Force, $F = -18154.476$

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: $A_{sl,mid} = 2007.478$

Longitudinal External Reinforcement Area Distribution (in 3 divisions)

-Tension: $A_{sl,ten,jacket} = 829.3805$

-Compression: $A_{sl,com,jacket} = 1746.726$

-Middle: $A_{sl,mid,jacket} = 1545.664$

Longitudinal Internal Reinforcement Area Distribution (in 3 divisions)

-Tension: $A_{sl,ten,core} = 307.8761$

-Compression: $A_{sl,com,core} = 461.8141$

-Middle: $A_{sl,mid,core} = 461.8141$

Mean Diameter of Tension Reinforcement, $DbL = 16.80$

New component: From table 7-7, ASCE 41_17: Final chord rotation Capacity $u_{,R} = 1.0^*$ $u = 0.05075515$

$u = y + p = 0.05075515$

- Calculation of y -

$y = (M_y * L_s / 3) / E_{eff} = 0.00042566$ ((4.29), Biskinis Phd)
 $M_y = 6.4998E+008$
 $L_s = M/V$ (with $L_s > 0.1 * L$ and $L_s < 2 * L$) = 300.00
 From table 10.5, ASCE 41_17: $E_{eff} = factor * E_c * I_g = 1.5270E+014$
 $factor = 0.30$
 $A_g = 440000.00$
 Mean concrete strength: $f_c' = (f_c'_{jacket} * Area_{jacket} + f_c'_{core} * Area_{core}) / Area_{section} = 33.00$
 $N = 18154.476$
 $E_c * I_g = E_c_{jacket} * I_{g,jacket} + E_c_{core} * I_{g,core} = 5.0901E+014$

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, $t = 400.00$

$y = \text{Min}(y_{ten}, y_{com})$
 $y_{ten} = 4.8675041E-006$
 with $f_y = 555.56$
 $d = 707.00$
 $y = 0.19281101$
 $A = 0.01015738$
 $B = 0.00446779$
 with $p_t = 0.00671904$
 $p_c = 0.00416509$
 $p_v = 0.00378591$
 $N = 18154.476$
 $b = 750.00$
 $" = 0.06082037$
 $y_{comp} = 1.6460425E-005$
 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), $\epsilon_{fe} = 0.004$
 $f_u = 0.01$
 $E_f = 64828.00$
 $E_c = 26999.444$
 $y = 0.19183941$
 $A = 0.01001908$
 $B = 0.00440616$
 with $E_s = 200000.00$
 CONFIRMATION: $y = 0.19281101 < t/d$

Calculation of ratio l_b/d

Adequate Lap Length: $l_b/d \geq 1$

- Calculation of p -

From table 10-8: $p = 0.05032949$

with:

- Columns not controlled by inadequate development or splicing along the clear height because $l_b/d \geq 1$

shear control ratio $V_y E / V_{CoI} E = 1.05752$

$d = d_{external} = 707.00$

$s = s_{external} = 0.00$

$t = s_1 + s_2 + 2 * t_f / b_w * (f_{fe} / f_s) = 0.00671904$

jacket: $s_1 = A_{v1} * L_{stir1} / (s_1 * A_g) = 0.00367709$

$A_{v1} = 78.53982$, 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: $s_2 = A_{v2} * L_{stir2} / (s_2 * A_g) = 0.00067082$

$A_{v2} = 50.26548$, 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 $2 * t_f / b_w * (f_{fe} / f_s)$ is implemented to account for FRP contribution

where $f = 2 * t_f / b_w$ is FRP ratio (EC8 - 3, A.4.4.3(6)) and f_{fe} / f_s normalises f to steel strength

All these variables have already been given in Shear control ratio calculation.

For the normalisation f_s of jacket is used.

$NUD = 18154.476$

$A_g = 440000.00$

$f_{cE} = (f_{c_jacket} * Area_jacket + f_{c_core} * Area_core) / section_area = 33.00$

$f_{yE} = (f_{y_ext_Long_Reinf} * Area_ext_Long_Reinf + f_{y_int_Long_Reinf} * Area_int_Long_Reinf) / Area_Tot_Long_Rein =$

555.56

$f_{yE} = (f_{y_ext_Trans_Reinf} * s_1 + f_{y_int_Trans_Reinf} * s_2) / (s_1 + s_2) = 555.56$

$\rho_l = Area_Tot_Long_Rein / (b * d) = 0.01009575$

$b = 750.00$

$d = 707.00$

$f_{cE} = 33.00$

End Of Calculation of Chord Rotation Capacity for element: column JLC1 of floor 1

At local axis: 3

Integration Section: (b)
