

Detailed Member Calculations

Units: N&mm

Regulation: ASCE 41-17

Calculation No. 1

column C1, Floor 1

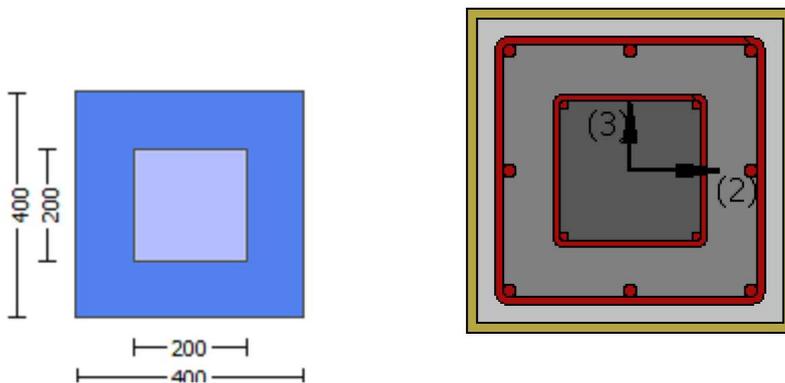
Limit State: Immediate Occupancy (data interpolation between analysis steps 2 and 3)

Analysis: Uniform +X

Check: Shear capacity V_{Rd}

Edge: Start

Local Axis: (2)



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

At local axis: 2

Integration Section: (a)

Section Type: rcjrs

Constant Properties

Knowledge Factor, $\gamma = 0.80$

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

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

Consequently:

Jacket

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

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

Concrete Elasticity, $E_c = 26999.444$
Steel Elasticity, $E_s = 200000.00$
Existing Column
Existing material of Secondary Member: Concrete Strength, $f_c = f_{c_lower_bound} = 16.00$
Existing material of Secondary Member: Steel Strength, $f_s = f_{s_lower_bound} = 400.00$
Concrete Elasticity, $E_c = 21019.039$
Steel Elasticity, $E_s = 200000.00$

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

External Height, $H = 400.00$
External Width, $W = 400.00$
Internal Height, $H = 200.00$
Internal Width, $W = 200.00$
Cover Thickness, $c = 25.00$
Element Length, $L = 3000.00$
Secondary Member
Ribbed Bars
Ductile Steel
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
Lap Length $l_o = l_b = 300.00$
FRP Wrapping Data
Type: Carbon
Cured laminate properties (design values)
Thickness, $t = 1.016$
Tensile Strength, $f_{fu} = 1055.00$
Tensile Modulus, $E_f = 64828.00$
Elongation, $e_{fu} = 0.01$
Number of directions, $NoDir = 1$
Fiber orientations, $bi: 0.00^\circ$
Number of layers, $NL = 1$
Radius of rounding corners, $R = 40.00$

Stepwise Properties

EDGE -A-
Bending Moment, $M_a = -2.2502E+007$
Shear Force, $V_a = -7481.276$
EDGE -B-
Bending Moment, $M_b = 46945.948$
Shear Force, $V_b = 7481.276$
BOTH EDGES
Axial Force, $F = -6438.97$
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: $As_t = 829.3805$
-Compression: $As_c = 1231.504$
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension: $As_{l,ten} = 829.3805$
-Compression: $As_{l,com} = 829.3805$
-Middle: $As_{l,mid} = 402.1239$
Mean Diameter of Tension Reinforcement, $Db_{L,ten} = 14.40$

Existing component: From table 7-7, ASCE 41_17: Final Shear Capacity $VR = *V_n = 385805.877$
 $V_n ((10.3), ASCE 41-17) = knl*V_{CoIo} = 482257.347$

VCol = 482257.347

knl = 1.00

displacement_ductility_demand = 0.06432978

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: $fc' = (fc'_{jacket} \cdot Area_{jacket} + fc'_{core} \cdot Area_{core}) / Area_{section} = 22.75$, but $fc'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

M/Vd = 4.00

Mu = 2.2502E+007

Vu = 7481.276

d = 0.8*h = 320.00

Nu = 6438.97

Ag = 160000.00

From (11.5.4.8), ACI 318-14: Vs = Vs1 + Vs2 = 251327.412

where:

Vs1 = 251327.412 is calculated for jacket, with:

d = 320.00

Av = 157079.633

fy = 500.00

s = 100.00

Vs1 is multiplied by Col1 = 1.00

s/d = 0.3125

Vs2 = 0.00 is calculated for core, with:

d = 160.00

Av = 100530.965

fy = 400.00

s = 250.00

Vs2 is multiplied by Col2 = 0.00

s/d = 1.5625

Vf ((11-3)-(11.4), ACI 440) = 188111.148

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

This later relation, considered as a function Vf(α), is implemented for every different cyclic 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: $\alpha = b1 + 90^\circ = 90.00$

Vf = Min(|Vf(45, α)|, |Vf(-45, α)|), with:

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

dfv = d (figure 11.2, ACI 440) = 357.00

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 <= 405571.497

bw = 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 $\theta = 0.00053579$

y = (My*Ls/3)/Eleff = 0.00832882 ((4.29), Biskinis Phd)

My = 1.4156E+008

Ls = M/V (with Ls > 0.1*L and Ls < 2*L) = 3007.725

From table 10.5, ASCE 41_17: Eleff = factor*Ec*Ig = 1.7040E+013

factor = 0.30

Ag = 160000.00

Mean concrete strength: $fc' = (fc'_{jacket} \cdot Area_{jacket} + fc'_{core} \cdot Area_{core}) / Area_{section} = 29.75$

N = 6438.97

$Ec \cdot Ig = Ec_{jacket} \cdot Ig_{jacket} + Ec_{core} \cdot Ig_{core} = 5.6801E+013$

Calculation of Yielding Moment M_y

Calculation of γ and M_y according to Annex 7

$y = \text{Min}(y_{\text{ten}}, y_{\text{com}})$
 $y_{\text{ten}} = 8.5640402\text{E-}006$
with ((10.1), ASCE 41-17) $f_y = \text{Min}(f_y, 1.25 \cdot f_y \cdot (l_b/d)^{2/3}) = 454.4281$
 $d = 357.00$
 $y = 0.2568299$
 $A = 0.01453119$
 $B = 0.00818436$
with $pt = 0.00580799$
 $pc = 0.00580799$
 $pv = 0.00281599$
 $N = 6438.97$
 $b = 400.00$
 $" = 0.12044818$
 $y_{\text{comp}} = 2.5296911\text{E-}005$
with f_c^* (12.3, (ACI 440)) = 34.65599
 $f_c = 33.00$
 $fl = 0.93147527$
 $b = 400.00$
 $h = 400.00$
 $A_g = 160000.00$
From (12.9), ACI 440: $k_a = 0.56708553$
 $g = pt + pc + pv = 0.01443197$
 $rc = 40.00$
 $A_e/A_c = 0.56708553$
Effective FRP thickness, $t_f = NL \cdot t \cdot \text{Cos}(b_1) = 1.016$
effective strain from (12.5) and (12.12), $\epsilon_{fe} = 0.004$
 $f_u = 0.01$
 $E_f = 64828.00$
 $E_c = 26999.444$
 $y = 0.25583518$
 $A = 0.01433439$
 $B = 0.00808514$
with $E_s = 200000.00$

Calculation of ratio l_b/d

Lap Length: $l_d/l_d, \text{min} = 0.56621983$

$l_b = 300.00$

$l_d = 529.8296$

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

$= 1$

$db = 14.66667$

Mean strength value of all re-bars: $f_y = 525.2545$

Mean concrete strength: $f_c' = (f_c'_{\text{jacket}} \cdot \text{Area}_{\text{jacket}} + f_c'_{\text{core}} \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 29.75$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 3.43481$

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

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

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

$n = 12.00$

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

At local axis: 2

Integration Section: (a)

Calculation No. 2

column C1, Floor 1

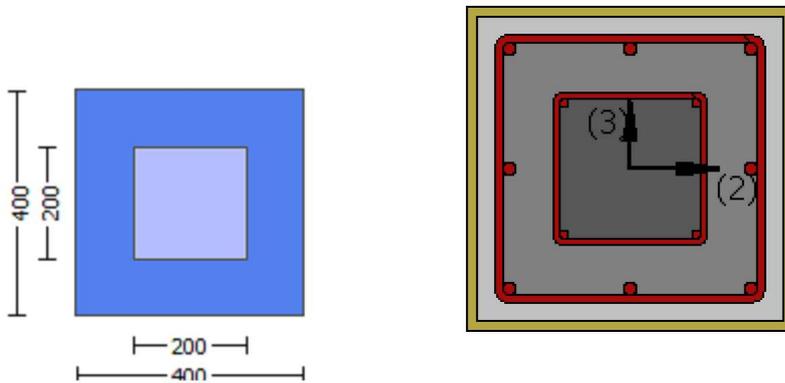
Limit State: Immediate Occupancy (data interpolation between analysis steps 2 and 3)

Analysis: Uniform +X

Check: Chord rotation capacity (θ)

Edge: Start

Local Axis: (2)



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

At Shear local axis: 3

(Bending local axis: 2)

Section Type: rcjrs

Constant Properties

Knowledge Factor, $\phi = 0.80$

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

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

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

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

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Note: Especially for the calculation of moment strengths,

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

Jacket

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

Existing Column

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

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External Height, H = 400.00
External Width, W = 400.00
Internal Height, H = 200.00
Internal Width, W = 200.00
Cover Thickness, c = 25.00
Mean Confinement Factor overall section = 1.13212
Element Length, L = 3000.00
Secondary Member
Ribbed Bars
Ductile Steel
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
Lap Length l_o = 300.00
FRP Wrapping Data
Type: Carbon
Cured laminate properties (design values)
Thickness, t = 1.016
Tensile Strength, f_{fu} = 1055.00
Tensile Modulus, E_f = 64828.00
Elongation, e_{fu} = 0.01
Number of directions, NoDir = 1
Fiber orientations, b_i : 0.00°
Number of layers, NL = 1
Radius of rounding corners, R = 40.00

Stepwise Properties

At local axis: 3
EDGE -A-
Shear Force, V_a = 2.8976040E-031
EDGE -B-
Shear Force, V_b = -2.8976040E-031
BOTH EDGES
Axial Force, F = -5926.932
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: A_{sl} = 0.00
-Compression: A_{slc} = 2060.885
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension: $A_{sl,ten}$ = 829.3805
-Compression: $A_{sl,com}$ = 829.3805
-Middle: $A_{sl,mid}$ = 402.1239

Calculation of Shear Capacity ratio , V_e/V_r = 0.19159777
Member Controlled by Flexure ($V_e/V_r < 1$)
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 121293.391$
with
 $M_{pr1} = \text{Max}(\mu_{u1+} , \mu_{u1-}) = 1.8194E+008$
 $\mu_{u1+} = 1.8194E+008$, is the ultimate moment strength at the edge 1 of the member in the actual moment direction
which is defined for the static loading combination
 $\mu_{u1-} = 1.8194E+008$, is the ultimate moment strength at the edge 1 of the member in the opposite moment
direction which is defined for the static loading combination
 $M_{pr2} = \text{Max}(\mu_{u2+} , \mu_{u2-}) = 1.8194E+008$
 $\mu_{u2+} = 1.8194E+008$, is the ultimate moment strength at the edge 2 of the member in the actual moment direction
which is defined for the the static loading combination
 $\mu_{u2-} = 1.8194E+008$, is the ultimate moment strength at the edge 2 of the member in the opposite moment
direction which is defined for the the static loading combination

Calculation of μ_{u1+}

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

$$u = 3.6747033E-005$$

$$\mu = 1.8194E+008$$

with full section properties:

$$b = 400.00$$

$$d = 357.00$$

$$d' = 43.00$$

$$v = 0.00125773$$

$$N = 5926.932$$

$$f_c = 33.00$$

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

$$\text{Final value of } \phi_u: \phi_u^* = \text{shear_factor} * \text{Max}(\phi_u, \phi_c) = 0.01505571$$

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

$$\text{From (5.4b), TBDY: } \phi_u = 0.01505571$$

$$\omega_e ((5.4c), TBDY) = a_{se} * \text{sh}_{, \min} * f_{ywe} / f_{ce} + \text{Min}(\phi_x, \phi_y) = 0.08345896$$

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

$$\phi_x = 0.07683125$$

$$a_f = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

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

$$b_w = 400.00$$

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

$$f_y = 0.07683125$$

$$a_f = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

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

$$b_w = 400.00$$

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

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$a_{se} ((5.4d), TBDY) = (a_{se1} * A_{ext} + a_{se2} * A_{int}) / A_{sec} = 0.24250288$$

$$a_{se1} = 0.24250288$$

$$b_{o,1} = 340.00$$

$$h_{o,1} = 340.00$$

$$b_{i2,1} = 462400.00$$

$$a_{se2} = \text{Max}(a_{se1}, a_{se2}) = 0.24250288$$

$$b_{o,2} = 192.00$$

$$h_{o,2} = 192.00$$

$$b_{i2,2} = 147456.00$$

$$p_{sh, \min} * F_{ywe} = \text{Min}(p_{sh,x} * F_{ywe}, p_{sh,y} * F_{ywe}) = 3.00635$$

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

$$p_{sh,x} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{sh2} * F_{ywe2} = 3.00635$$

$$p_{s1} (\text{external}) = (A_{sh1} * h_1 / s_1) / A_{sec} = 0.00392699$$

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

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

$$h_1 = 400.00$$

$$p_{s2} (\text{internal}) = (A_{sh2} * h_2 / s_2) / A_{sec} = 0.00050265$$

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

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

$$h_2 = 200.00$$

$$p_{sh,y} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{sh2} * F_{ywe2} = 3.00635$$

$$p_{s1} (\text{external}) = (A_{sh1} * h_1 / s_1) / A_{sec} = 0.00392699$$

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

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

$$h_1 = 400.00$$

$$ps_2 \text{ (internal)} = (Ash_2 * h_2 / s_2) / A_{sec} = 0.00050265$$

$$Ash_2 = Astir_2 * ns_2 = 100.531$$

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

$$h_2 = 200.00$$

$$A_{sec} = 160000.00$$

$$s_1 = 100.00$$

$$s_2 = 250.00$$

$$fy_{we1} = 694.45$$

$$fy_{we2} = 555.55$$

$$f_{ce} = 33.00$$

$$\text{From ((5.A.5), TBDY), TBDY: } cc = 0.00332119$$

$$c = \text{confinement factor} = 1.13212$$

$$y_1 = 0.00184318$$

$$sh_1 = 0.00589816$$

$$ft_1 = 580.8818$$

$$fy_1 = 484.0682$$

$$su_1 = 0.01099427$$

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

$$lo/lou, \min = lb/ld = 0.45297586$$

$$su_1 = 0.4 * esu_1 \text{ nominal ((5.5), TBDY)} = 0.032$$

$$\text{From table 5A.1, TBDY: } esu_1 \text{ nominal} = 0.08,$$

For calculation of esu_1 nominal and y_1, sh_1, ft_1, fy_1, it is considered
characteristic value fsy_1 = fs_1/1.2, from table 5.1, TBDY.

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

$$\text{with } fs_1 = (fs_{jacket} * A_{sl,ten,jacket} + fs_{core} * A_{sl,ten,core}) / A_{sl,ten} = 484.0682$$

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

$$y_2 = 0.00184318$$

$$sh_2 = 0.00589816$$

$$ft_2 = 580.8818$$

$$fy_2 = 484.0682$$

$$su_2 = 0.01099427$$

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

$$lo/lou, \min = lb/lb, \min = 0.45297586$$

$$su_2 = 0.4 * esu_2 \text{ nominal ((5.5), TBDY)} = 0.032$$

$$\text{From table 5A.1, TBDY: } esu_2 \text{ nominal} = 0.08,$$

For calculation of esu_2 nominal and y_2, sh_2, ft_2, fy_2, it is considered
characteristic value fsy_2 = fs_2/1.2, from table 5.1, TBDY.

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

$$\text{with } fs_2 = (fs_{jacket} * A_{sl,com,jacket} + fs_{core} * A_{sl,com,core}) / A_{sl,com} = 484.0682$$

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

$$y_v = 0.00184318$$

$$sh_v = 0.00589816$$

$$ft_v = 614.3968$$

$$fy_v = 511.9973$$

$$su_v = 0.01099427$$

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

$$lo/lou, \min = lb/ld = 0.45297586$$

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

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

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

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

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

$$\text{with } fsv = (fs_{jacket} * A_{sl,mid,jacket} + fs_{mid} * A_{sl,mid,core}) / A_{sl,mid} = 511.9973$$

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

$$1 = A_{sl,ten} / (b * d) * (fs_1 / f_c) = 0.0851958$$

$$2 = A_{sl,com} / (b * d) * (fs_2 / f_c) = 0.0851958$$

$$v = A_{sl,mid} / (b * d) * (fsv / f_c) = 0.04369034$$

and confined core properties:

$$b = 340.00$$

$d = 327.00$
 $d' = 13.00$
 $f_{cc} (5A.2, TBDY) = 37.35991$
 $cc (5A.5, TBDY) = 0.00332119$
 $c = \text{confinement factor} = 1.13212$
 $1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.1094258$
 $2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.1094258$
 $v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.05611603$
 Case/Assumption: Unconfined full section - Steel rupture
 ' satisfies Eq. (4.3)

--->
 $v < v_{s,y2}$ - LHS eq.(4.5) is satisfied
 --->
 $su (4.9) = 0.16193824$
 $Mu = MRc (4.14) = 1.8194E+008$
 $u = su (4.1) = 3.6747033E-005$

 Calculation of ratio l_b/l_d

 Lap Length: $l_b/l_d = 0.45297586$
 $l_b = 300.00$
 $l_d = 662.2869$

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

$db = 14.66667$
 Mean strength value of all re-bars: $f_y = 656.5682$
 Mean concrete strength: $f_c' = (f_c'_{jacket} * Area_{jacket} + f_c'_{core} * Area_{core}) / Area_{section} = 29.75$, but $f_c'^{0.5} \leq 8.3$
 MPa (22.5.3.1, ACI 318-14)
 $t = 1.00$
 $s = 0.80$
 $e = 1.00$
 $cb = 25.00$
 $K_{tr} = 3.43481$
 $A_{tr} = \text{Min}(A_{tr,x}, A_{tr,y}) = 257.6106$
 where $A_{tr,x}, A_{tr,y}$ are the sum of the area of all stirrup legs along X and Y local axis
 $s = \text{Max}(s_{external}, s_{internal}) = 250.00$
 $n = 12.00$

 Calculation of Mu_1 -

 Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:
 $u = 3.6747033E-005$
 $Mu = 1.8194E+008$

 with full section properties:

$b = 400.00$
 $d = 357.00$
 $d' = 43.00$
 $v = 0.00125773$
 $N = 5926.932$
 $f_c = 33.00$
 $co (5A.5, TBDY) = 0.002$
 Final value of cu : $cu^* = \text{shear_factor} * \text{Max}(cu, cc) = 0.01505571$
 The Shear_factor is considered equal to 1 (pure moment strength)
 From (5.4b), TBDY: $cu = 0.01505571$
 $w_e ((5.4c), TBDY) = a_{se} * sh_{,min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.08345896$
 where $f = a_f * p_f * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

 $f_x = 0.07683125$
 $a_f = 0.57333333$
 $b = 400.00$
 $h = 400.00$

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

$fy = 0.07683125$
 $af = 0.57333333$
 $b = 400.00$
 $h = 400.00$
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, $tf = NL*t*Cos(b1) = 1.016$
 $fu,f = 1055.00$
 $Ef = 64828.00$
 $u,f = 0.015$
 $ase ((5.4d), TBDY) = (ase1*Aext+ase2*Aint)/Asec = 0.24250288$
 $ase1 = 0.24250288$
 $bo_1 = 340.00$
 $ho_1 = 340.00$
 $bi2_1 = 462400.00$
 $ase2 = Max(ase1,ase2) = 0.24250288$
 $bo_2 = 192.00$
 $ho_2 = 192.00$
 $bi2_2 = 147456.00$

$psh,min*Fywe = Min(psh,x*Fywe, psh,y*Fywe) = 3.00635$
Expression ((5.4d), TBDY) for $psh,min*Fywe$ has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$psh_x*Fywe = psh1*Fywe1+ps2*Fywe2 = 3.00635$
 $ps1 (external) = (Ash1*h1/s1)/Asec = 0.00392699$
 $Ash1 = Astir_1*ns_1 = 157.0796$
No stirrups, $ns_1 = 2.00$
 $h1 = 400.00$
 $ps2 (internal) = (Ash2*h2/s2)/Asec = 0.00050265$
 $Ash2 = Astir_2*ns_2 = 100.531$
No stirrups, $ns_2 = 2.00$
 $h2 = 200.00$

$psh_y*Fywe = psh1*Fywe1+ps2*Fywe2 = 3.00635$
 $ps1 (external) = (Ash1*h1/s1)/Asec = 0.00392699$
 $Ash1 = Astir_1*ns_1 = 157.0796$
No stirrups, $ns_1 = 2.00$
 $h1 = 400.00$
 $ps2 (internal) = (Ash2*h2/s2)/Asec = 0.00050265$
 $Ash2 = Astir_2*ns_2 = 100.531$
No stirrups, $ns_2 = 2.00$
 $h2 = 200.00$

$Asec = 160000.00$
 $s1 = 100.00$
 $s2 = 250.00$
 $fywe1 = 694.45$
 $fywe2 = 555.55$
 $fce = 33.00$

From ((5.A5), TBDY), TBDY: $cc = 0.00332119$
 $c = \text{confinement factor} = 1.13212$

$y1 = 0.00184318$
 $sh1 = 0.00589816$
 $ft1 = 580.8818$
 $fy1 = 484.0682$
 $su1 = 0.01099427$

using (30) in Biskinis/Fardis (2013) multiplied with $shear_factor$
and also multiplied by the $shear_factor$ according to 15.7.1.4, with
 $Shear_factor = 1.00$
 $lo/lou,min = lb/ld = 0.45297586$

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

From table 5A.1, TBDY: $esu1_nominal = 0.08$,

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

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

$$\text{with } fs1 = (fs_jacket * Asl,ten,jacket + fs_core * Asl,ten,core) / Asl,ten = 484.0682$$

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

$$y2 = 0.00184318$$

$$sh2 = 0.00589816$$

$$ft2 = 580.8818$$

$$fy2 = 484.0682$$

$$su2 = 0.01099427$$

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

$$lo/lou,min = lb/lb,min = 0.45297586$$

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

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.

$y2, sh2, ft2, fy2$, are also multiplied by $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE 41-17.

$$\text{with } fs2 = (fs_jacket * Asl,com,jacket + fs_core * Asl,com,core) / Asl,com = 484.0682$$

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

$$yv = 0.00184318$$

$$shv = 0.00589816$$

$$ftv = 614.3968$$

$$fyv = 511.9973$$

$$suv = 0.01099427$$

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

$$lo/lou,min = lb/ld = 0.45297586$$

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

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.

yv, shv, ftv, fyv , are also multiplied by $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE 41-17.

$$\text{with } fsv = (fs_jacket * Asl,mid,jacket + fs_mid * Asl,mid,core) / Asl,mid = 511.9973$$

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

$$1 = Asl,ten / (b * d) * (fs1 / fc) = 0.0851958$$

$$2 = Asl,com / (b * d) * (fs2 / fc) = 0.0851958$$

$$v = Asl,mid / (b * d) * (fsv / fc) = 0.04369034$$

and confined core properties:

$$b = 340.00$$

$$d = 327.00$$

$$d' = 13.00$$

$$fcc (5A.2, TBDY) = 37.35991$$

$$cc (5A.5, TBDY) = 0.00332119$$

$$c = \text{confinement factor} = 1.13212$$

$$1 = Asl,ten / (b * d) * (fs1 / fc) = 0.1094258$$

$$2 = Asl,com / (b * d) * (fs2 / fc) = 0.1094258$$

$$v = Asl,mid / (b * d) * (fsv / fc) = 0.05611603$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

$$su (4.9) = 0.16193824$$

$$Mu = MRc (4.14) = 1.8194E+008$$

$$u = su (4.1) = 3.6747033E-005$$

Calculation of ratio lb/ld

$$\text{Lap Length: } lb/ld = 0.45297586$$

$$lb = 300.00$$

ld = 662.2869

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

= 1

db = 14.66667

Mean strength value of all re-bars: fy = 656.5682

Mean concrete strength: fc' = (fc'_jacket*Area_jacket + fc'_core*Area_core)/Area_section = 29.75, but fc'^0.5 <= 8.3 MPa (22.5.3.1, ACI 318-14)

t = 1.00

s = 0.80

e = 1.00

cb = 25.00

Ktr = 3.43481

Atr = Min(Atr_x,Atr_y) = 257.6106

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

s = Max(s_external,s_internal) = 250.00

n = 12.00

Calculation of Mu2+

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

u = 3.6747033E-005

Mu = 1.8194E+008

with full section properties:

b = 400.00

d = 357.00

d' = 43.00

v = 0.00125773

N = 5926.932

fc = 33.00

co (5A.5, TBDY) = 0.002

Final value of cu: cu* = shear_factor * Max(cu, cc) = 0.01505571

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

From (5.4b), TBDY: cu = 0.01505571

we ((5.4c), TBDY) = ase* sh,min*fywe/fce+Min(fx, fy) = 0.08345896

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

fx = 0.07683125

af = 0.573333333

b = 400.00

h = 400.00

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 = 0.07683125

af = 0.573333333

b = 400.00

h = 400.00

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 = 0.24250288

ase1 = 0.24250288

bo_1 = 340.00

ho_1 = 340.00

bi2_1 = 462400.00

$$ase2 = \text{Max}(ase1, ase2) = 0.24250288$$

$$bo_2 = 192.00$$

$$ho_2 = 192.00$$

$$bi2_2 = 147456.00$$

$$psh, \text{min} * Fywe = \text{Min}(psh, x * Fywe, psh, y * Fywe) = 3.00635$$

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

$$psh_x * Fywe = psh1 * Fywe1 + ps2 * Fywe2 = 3.00635$$

$$ps1 \text{ (external)} = (Ash1 * h1 / s1) / Asec = 0.00392699$$

$$Ash1 = Astir_1 * ns_1 = 157.0796$$

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

$$h1 = 400.00$$

$$ps2 \text{ (internal)} = (Ash2 * h2 / s2) / Asec = 0.00050265$$

$$Ash2 = Astir_2 * ns_2 = 100.531$$

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

$$h2 = 200.00$$

$$psh_y * Fywe = psh1 * Fywe1 + ps2 * Fywe2 = 3.00635$$

$$ps1 \text{ (external)} = (Ash1 * h1 / s1) / Asec = 0.00392699$$

$$Ash1 = Astir_1 * ns_1 = 157.0796$$

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

$$h1 = 400.00$$

$$ps2 \text{ (internal)} = (Ash2 * h2 / s2) / Asec = 0.00050265$$

$$Ash2 = Astir_2 * ns_2 = 100.531$$

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

$$h2 = 200.00$$

$$Asec = 160000.00$$

$$s1 = 100.00$$

$$s2 = 250.00$$

$$fywe1 = 694.45$$

$$fywe2 = 555.55$$

$$fce = 33.00$$

From ((5.A5), TBDY), TBDY: $cc = 0.00332119$

$$c = \text{confinement factor} = 1.13212$$

$$y1 = 0.00184318$$

$$sh1 = 0.00589816$$

$$ft1 = 580.8818$$

$$fy1 = 484.0682$$

$$su1 = 0.01099427$$

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

$$lo/lou, \text{min} = lb/ld = 0.45297586$$

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

From table 5A.1, TBDY: $esu1_nominal = 0.08$,

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

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

$$\text{with } fs1 = (fs, \text{jacket} * Asl, \text{ten, jacket} + fs, \text{core} * Asl, \text{ten, core}) / Asl, \text{ten} = 484.0682$$

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

$$y2 = 0.00184318$$

$$sh2 = 0.00589816$$

$$ft2 = 580.8818$$

$$fy2 = 484.0682$$

$$su2 = 0.01099427$$

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

$$lo/lou, \text{min} = lb/lb, \text{min} = 0.45297586$$

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

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

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

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

$$\text{with } fs2 = (fs, \text{jacket} * Asl, \text{com, jacket} + fs, \text{core} * Asl, \text{com, core}) / Asl, \text{com} = 484.0682$$

with $E_s2 = (E_{s,jacket} \cdot A_{s,com,jacket} + E_{s,core} \cdot A_{s,com,core}) / A_{s,com} = 200000.00$
 $y_v = 0.00184318$
 $sh_v = 0.00589816$
 $ft_v = 614.3968$
 $fy_v = 511.9973$
 $suv = 0.01099427$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $lo/lou,min = lb/ld = 0.45297586$
 $suv = 0.4 \cdot esuv_nominal ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $esuv_nominal = 0.08$,
 considering characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY
 For calculation of $esuv_nominal$ and y_v, sh_v, ft_v, fy_v , it is considered
 characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$, from 10.3.5, ASCE 41-17.
 with $fsv = (f_{s,jacket} \cdot A_{s,mid,jacket} + f_{s,mid} \cdot A_{s,mid,core}) / A_{s,mid} = 511.9973$
 with $E_{sv} = (E_{s,jacket} \cdot A_{s,mid,jacket} + E_{s,mid} \cdot A_{s,mid,core}) / A_{s,mid} = 200000.00$
 $1 = A_{s,ten} / (b \cdot d) \cdot (f_{s1} / f_c) = 0.0851958$
 $2 = A_{s,com} / (b \cdot d) \cdot (f_{s2} / f_c) = 0.0851958$
 $v = A_{s,mid} / (b \cdot d) \cdot (f_{sv} / f_c) = 0.04369034$
 and confined core properties:
 $b = 340.00$
 $d = 327.00$
 $d' = 13.00$
 $f_{cc} (5A.2, TBDY) = 37.35991$
 $cc (5A.5, TBDY) = 0.00332119$
 $c = \text{confinement factor} = 1.13212$
 $1 = A_{s,ten} / (b \cdot d) \cdot (f_{s1} / f_c) = 0.1094258$
 $2 = A_{s,com} / (b \cdot d) \cdot (f_{s2} / f_c) = 0.1094258$
 $v = A_{s,mid} / (b \cdot d) \cdot (f_{sv} / f_c) = 0.05611603$
 Case/Assumption: Unconfined full section - Steel rupture
 ' satisfies Eq. (4.3)

Calculation of ratio lb/ld

Lap Length: $lb/ld = 0.45297586$
 $lb = 300.00$
 $ld = 662.2869$
 Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
 $= 1$
 $db = 14.66667$
 Mean strength value of all re-bars: $fy = 656.5682$
 Mean concrete strength: $fc' = (fc'_{jacket} \cdot Area_{jacket} + fc'_{core} \cdot Area_{core}) / Area_{section} = 29.75$, but $fc'^{0.5} \leq 8.3$
 MPa (22.5.3.1, ACI 318-14)
 $t = 1.00$
 $s = 0.80$
 $e = 1.00$
 $cb = 25.00$
 $K_{tr} = 3.43481$
 $A_{tr} = \text{Min}(A_{tr,x}, A_{tr,y}) = 257.6106$
 where $A_{tr,x}, A_{tr,y}$ are the sum of the area of all stirrup legs along X and Y loxal axis
 $s = \text{Max}(s_{external}, s_{internal}) = 250.00$
 $n = 12.00$

Calculation of Mu2-

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

$$u = 3.6747033E-005$$

$$Mu = 1.8194E+008$$

with full section properties:

$$b = 400.00$$

$$d = 357.00$$

$$d' = 43.00$$

$$v = 0.00125773$$

$$N = 5926.932$$

$$f_c = 33.00$$

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

$$\text{Final value of } \phi_u: \phi_u^* = \text{shear_factor} * \text{Max}(\phi_{cu}, \phi_{cc}) = 0.01505571$$

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

$$\text{From (5.4b), TBDY: } \phi_{cu} = 0.01505571$$

$$\phi_{cc} ((5.4c), TBDY) = \alpha_{se} * \text{sh}_{,min} * f_{ywe} / f_{ce} + \text{Min}(\phi_{fx}, \phi_{fy}) = 0.08345896$$

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

$$\phi_{fx} = 0.07683125$$

$$\alpha_f = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

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

$$b_w = 400.00$$

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

$$\phi_{fy} = 0.07683125$$

$$\alpha_f = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

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

$$b_w = 400.00$$

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

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$\alpha_{se} ((5.4d), TBDY) = (\alpha_{se1} * A_{ext} + \alpha_{se2} * A_{int}) / A_{sec} = 0.24250288$$

$$\alpha_{se1} = 0.24250288$$

$$b_{o,1} = 340.00$$

$$h_{o,1} = 340.00$$

$$b_{i2,1} = 462400.00$$

$$\alpha_{se2} = \text{Max}(\alpha_{se1}, \alpha_{se2}) = 0.24250288$$

$$b_{o,2} = 192.00$$

$$h_{o,2} = 192.00$$

$$b_{i2,2} = 147456.00$$

$$p_{sh,min} * F_{ywe} = \text{Min}(p_{sh,x} * F_{ywe}, p_{sh,y} * F_{ywe}) = 3.00635$$

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

$$p_{sh,x} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{sh2} * F_{ywe2} = 3.00635$$

$$p_{sh1} \text{ (external)} = (A_{sh1} * h_1 / s_1) / A_{sec} = 0.00392699$$

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

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

$$h_1 = 400.00$$

$$p_{sh2} \text{ (internal)} = (A_{sh2} * h_2 / s_2) / A_{sec} = 0.00050265$$

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

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

$$h_2 = 200.00$$

$$p_{sh,y} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{sh2} * F_{ywe2} = 3.00635$$

$$p_{sh1} \text{ (external)} = (A_{sh1} * h_1 / s_1) / A_{sec} = 0.00392699$$

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

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

h1 = 400.00
ps2 (internal) = (Ash2*h2/s2)/Asec = 0.00050265
Ash2 = Astir_2*ns_2 = 100.531
No stirups, ns_2 = 2.00
h2 = 200.00

Asec = 160000.00
s1 = 100.00
s2 = 250.00
fywe1 = 694.45
fywe2 = 555.55
fce = 33.00

From ((5.A.5), TBDY), TBDY: cc = 0.00332119
c = confinement factor = 1.13212

y1 = 0.00184318
sh1 = 0.00589816
ft1 = 580.8818
fy1 = 484.0682
su1 = 0.01099427

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

lo/lou,min = lb/d = 0.45297586
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 = 484.0682

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

y2 = 0.00184318
sh2 = 0.00589816
ft2 = 580.8818
fy2 = 484.0682
su2 = 0.01099427

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

lo/lou,min = lb/lb,min = 0.45297586
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 = 484.0682

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

yv = 0.00184318
shv = 0.00589816
ftv = 614.3968
fyv = 511.9973
suv = 0.01099427

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

lo/lou,min = lb/d = 0.45297586
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 = 511.9973

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

1 = Asl,ten/(b*d)*(fs1/fc) = 0.0851958

2 = Asl,com/(b*d)*(fs2/fc) = 0.0851958

v = Asl,mid/(b*d)*(fsv/fc) = 0.04369034

and confined core properties:

$b = 340.00$
 $d = 327.00$
 $d' = 13.00$
 $f_{cc} (5A.2, TBDY) = 37.35991$
 $cc (5A.5, TBDY) = 0.00332119$
 $c = \text{confinement factor} = 1.13212$
 $1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.1094258$
 $2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.1094258$
 $v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.05611603$
 Case/Assumption: Unconfined full section - Steel rupture
 ' satisfies Eq. (4.3)

--->
 $v < v_{s,y2}$ - LHS eq.(4.5) is satisfied
 --->
 $su (4.9) = 0.16193824$
 $Mu = MRc (4.14) = 1.8194E+008$
 $u = su (4.1) = 3.6747033E-005$

 Calculation of ratio l_b/l_d

 Lap Length: $l_b/l_d = 0.45297586$

$l_b = 300.00$
 $l_d = 662.2869$

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

$db = 14.66667$
 Mean strength value of all re-bars: $f_y = 656.5682$
 Mean concrete strength: $f'_c = (f'_{c,jacket} * Area_{jacket} + f'_{c,core} * Area_{core}) / Area_{section} = 29.75$, but $f_c^{0.5} \leq 8.3$
 MPa (22.5.3.1, ACI 318-14)

$t = 1.00$
 $s = 0.80$
 $e = 1.00$

$cb = 25.00$
 $K_{tr} = 3.43481$

$A_{tr} = \text{Min}(A_{tr,x}, A_{tr,y}) = 257.6106$
 where $A_{tr,x}, A_{tr,y}$ are the sum of the area of all stirrup legs along X and Y local axis
 $s = \text{Max}(s_{external}, s_{internal}) = 250.00$
 $n = 12.00$

 Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 633062.661$

 Calculation of Shear Strength at edge 1, $V_{r1} = 633062.661$

$V_{r1} = V_{CoI} ((10.3), ASCE 41-17) = k_{nl} * V_{CoI0}$
 $V_{CoI0} = 633062.661$
 $k_{nl} = 1$ (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: $f'_c = (f'_{c,jacket} * Area_{jacket} + f'_{c,core} * Area_{core}) / Area_{section} = 29.75$, but $f_c^{0.5} \leq 8.3$
 MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$
 $Mu = 4.3445556E-012$
 $Vu = 2.8976040E-031$

$d = 0.8 * h = 320.00$
 $Nu = 5926.932$

$Ag = 160000.00$
 From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 279254.914$

where:
 $V_{s1} = 279254.914$ is calculated for jacket, with:
 $d = 320.00$
 $A_v = 157079.633$

$f_y = 555.56$
 $s = 100.00$
 V_{s1} is multiplied by $Col1 = 1.00$
 $s/d = 0.3125$
 $V_{s2} = 0.00$ is calculated for core, with:
 $d = 160.00$
 $A_v = 100530.965$
 $f_y = 444.44$
 $s = 250.00$
 V_{s2} is multiplied by $Col2 = 0.00$
 $s/d = 1.5625$
 V_f ((11-3)-(11.4), ACI 440) = 188111.148
 $f = 0.95$, for fully-wrapped sections
 $w_f/s_f = 1$ (FRP strips adjacent to one another).
 In (11.3) $\sin \theta + \cos \theta$ is replaced with $(\cot \theta + \csc \theta) \sin \alpha$ which is more a generalised expression,
 where θ is the angle of the crack direction (see KANEPE).
 This later relation, considered as a function $V_f(\theta, \alpha)$, is implemented for every different fiber orientation α_i ,
 as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.
 orientation 1: $\theta = b1 + 90^\circ = 90.00$
 $V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, \theta)|)$, with:
 total thickness per orientation, $t_{f1} = NL * t / \text{NoDir} = 1.016$
 $d_{fv} = d$ (figure 11.2, ACI 440) = 357.00
 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: $V_s + V_f \leq 463788.751$
 $b_w = 400.00$

Calculation of Shear Strength at edge 2, $V_{r2} = 633062.661$
 $V_{r2} = V_{Col}$ ((10.3), ASCE 41-17) = $k_{nl} * V_{Col0}$
 $V_{Col0} = 633062.661$
 $k_{nl} = 1$ (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).

$\gamma_c = 1$ (normal-weight concrete)
 Mean concrete strength: $f'_c = (f'_{c,jacket} * Area_{jacket} + f'_{c,core} * Area_{core}) / Area_{section} = 29.75$, but $f'_c^{0.5} \leq 8.3$
 MPa (22.5.3.1, ACI 318-14)
 $M_u / d = 2.00$
 $M_u = 4.3445556E-012$
 $V_u = 2.8976040E-031$
 $d = 0.8 * h = 320.00$
 $N_u = 5926.932$
 $A_g = 160000.00$
 From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 279254.914$
 where:
 $V_{s1} = 279254.914$ is calculated for jacket, with:
 $d = 320.00$
 $A_v = 157079.633$
 $f_y = 555.56$
 $s = 100.00$
 V_{s1} is multiplied by $Col1 = 1.00$
 $s/d = 0.3125$
 $V_{s2} = 0.00$ is calculated for core, with:
 $d = 160.00$
 $A_v = 100530.965$
 $f_y = 444.44$
 $s = 250.00$
 V_{s2} is multiplied by $Col2 = 0.00$
 $s/d = 1.5625$
 V_f ((11-3)-(11.4), ACI 440) = 188111.148
 $f = 0.95$, 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 $V_f(\theta, a_i)$, is implemented for every different fiber orientation a_i , as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.

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

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

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

$d_{fv} = d$ (figure 11.2, ACI 440) = 357.00

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: $V_s + V_f \leq 463788.751$

$b_w = 400.00$

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

At local axis: 3

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

At Shear local axis: 2

(Bending local axis: 3)

Section Type: rcjrs

Constant Properties

Knowledge Factor, $\phi = 0.80$

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

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

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

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

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

Jacket

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

Existing Column

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

#####

External Height, $H = 400.00$

External Width, $W = 400.00$

Internal Height, $H = 200.00$

Internal Width, $W = 200.00$

Cover Thickness, $c = 25.00$

Mean Confinement Factor overall section = 1.13212

Element Length, $L = 3000.00$

Secondary Member

Ribbed Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

Lap Length $l_o = 300.00$

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$
Elongation, $e_{fu} = 0.01$
Number of directions, $NoDir = 1$
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, $V_a = -6.6805695E-033$
EDGE -B-
Shear Force, $V_b = 6.6805695E-033$
BOTH EDGES
Axial Force, $F = -5926.932$
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: $As_{lt} = 0.00$
-Compression: $As_{lc} = 2060.885$
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension: $As_{l,ten} = 829.3805$
-Compression: $As_{l,com} = 829.3805$
-Middle: $As_{l,mid} = 402.1239$

Calculation of Shear Capacity ratio, $V_e/V_r = 0.19159777$
Member Controlled by Flexure ($V_e/V_r < 1$)
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 121293.391$
with

$M_{pr1} = \text{Max}(\mu_{1+}, \mu_{1-}) = 1.8194E+008$
 $\mu_{1+} = 1.8194E+008$, is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination
 $\mu_{1-} = 1.8194E+008$, is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination
 $M_{pr2} = \text{Max}(\mu_{2+}, \mu_{2-}) = 1.8194E+008$
 $\mu_{2+} = 1.8194E+008$, is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the the static loading combination
 $\mu_{2-} = 1.8194E+008$, is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the the static loading combination

Calculation of μ_{1+}

Calculation of ultimate curvature μ according to 4.1, Biskinis/Fardis 2013:
 $\mu = 3.6747033E-005$
 $\mu_u = 1.8194E+008$

with full section properties:

$$b = 400.00$$

$$d = 357.00$$

$$d' = 43.00$$

$$v = 0.00125773$$

$$N = 5926.932$$

$$f_c = 33.00$$

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

$$\text{Final value of } \mu_c: \mu_c^* = \text{shear_factor} * \text{Max}(\mu_c, \mu_{cc}) = 0.01505571$$

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

$$\text{From (5.4b), TBDY: } \mu_c = 0.01505571$$

$$\mu_c \text{ ((5.4c), TBDY)} = a_s e^* \text{ sh}_{, \min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.08345896$$

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

$$f_x = 0.07683125$$

af = 0.57333333
b = 400.00
h = 400.00
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 = 0.07683125
af = 0.57333333
b = 400.00
h = 400.00
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) = $(ase1*Aext+ase2*Aint)/Asec = 0.24250288$
ase1 = 0.24250288
bo_1 = 340.00
ho_1 = 340.00
bi2_1 = 462400.00
ase2 = $Max(ase1,ase2) = 0.24250288$
bo_2 = 192.00
ho_2 = 192.00
bi2_2 = 147456.00

psh,min*Fywe = $Min(psh,x*Fywe, psh,y*Fywe) = 3.00635$
Expression ((5.4d), TBDY) for psh,min*Fywe has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

psh_x*Fywe = $psh1*Fywe1+ps2*Fywe2 = 3.00635$
ps1 (external) = $(Ash1*h1/s1)/Asec = 0.00392699$
Ash1 = $Astir_1*ns_1 = 157.0796$
No stirrups, ns_1 = 2.00
h1 = 400.00
ps2 (internal) = $(Ash2*h2/s2)/Asec = 0.00050265$
Ash2 = $Astir_2*ns_2 = 100.531$
No stirrups, ns_2 = 2.00
h2 = 200.00

psh_y*Fywe = $psh1*Fywe1+ps2*Fywe2 = 3.00635$
ps1 (external) = $(Ash1*h1/s1)/Asec = 0.00392699$
Ash1 = $Astir_1*ns_1 = 157.0796$
No stirrups, ns_1 = 2.00
h1 = 400.00
ps2 (internal) = $(Ash2*h2/s2)/Asec = 0.00050265$
Ash2 = $Astir_2*ns_2 = 100.531$
No stirrups, ns_2 = 2.00
h2 = 200.00

Asec = 160000.00
s1 = 100.00
s2 = 250.00
fywe1 = 694.45
fywe2 = 555.55
fce = 33.00

From ((5.A5), TBDY), TBDY: $cc = 0.00332119$
c = confinement factor = 1.13212

y1 = 0.00184318
sh1 = 0.00589816
ft1 = 580.8818
fy1 = 484.0682
su1 = 0.01099427

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

and also multiplied by the shear_factor according to 15.7.1.4, with

Shear_factor = 1.00

$l_o/l_{ou,min} = l_b/l_d = 0.45297586$

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

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

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

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

with $fs_1 = (f_s,jacket * A_{s,ten,jacket} + f_s,core * A_{s,ten,core}) / A_{s,ten} = 484.0682$

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

$y_2 = 0.00184318$

$sh_2 = 0.00589816$

$ft_2 = 580.8818$

$fy_2 = 484.0682$

$su_2 = 0.01099427$

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

and also multiplied by the shear_factor according to 15.7.1.4, with

Shear_factor = 1.00

$l_o/l_{ou,min} = l_b/l_{b,min} = 0.45297586$

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

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

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

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

with $fs_2 = (f_s,jacket * A_{s,com,jacket} + f_s,core * A_{s,com,core}) / A_{s,com} = 484.0682$

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

$y_v = 0.00184318$

$sh_v = 0.00589816$

$ft_v = 614.3968$

$fy_v = 511.9973$

$suv = 0.01099427$

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

and also multiplied by the shear_factor according to 15.7.1.4, with

Shear_factor = 1.00

$l_o/l_{ou,min} = l_b/l_d = 0.45297586$

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

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

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

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

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

with $f_{sv} = (f_s,jacket * A_{s,mid,jacket} + f_s,mid * A_{s,mid,core}) / A_{s,mid} = 511.9973$

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

$1 = A_{s,ten} / (b * d) * (f_{s1} / f_c) = 0.0851958$

$2 = A_{s,com} / (b * d) * (f_{s2} / f_c) = 0.0851958$

$v = A_{s,mid} / (b * d) * (f_{sv} / f_c) = 0.04369034$

and confined core properties:

$b = 340.00$

$d = 327.00$

$d' = 13.00$

$f_{cc} (5A.2, TBDY) = 37.35991$

$cc (5A.5, TBDY) = 0.00332119$

$c = \text{confinement factor} = 1.13212$

$1 = A_{s,ten} / (b * d) * (f_{s1} / f_c) = 0.1094258$

$2 = A_{s,com} / (b * d) * (f_{s2} / f_c) = 0.1094258$

$v = A_{s,mid} / (b * d) * (f_{sv} / f_c) = 0.05611603$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

$su (4.9) = 0.16193824$

$Mu = MRc (4.14) = 1.8194E+008$

$u = su (4.1) = 3.6747033E-005$

Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.45297586$

$l_b = 300.00$

$l_d = 662.2869$

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

$= 1$

$db = 14.66667$

Mean strength value of all re-bars: $f_y = 656.5682$

Mean concrete strength: $f_c' = (f_c'_{jacket} \cdot Area_{jacket} + f_c'_{core} \cdot Area_{core}) / Area_{section} = 29.75$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 3.43481$

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

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

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

$n = 12.00$

Calculation of μ_{u1} -

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

$\mu = 3.6747033E-005$

$\mu_u = 1.8194E+008$

with full section properties:

$b = 400.00$

$d = 357.00$

$d' = 43.00$

$v = 0.00125773$

$N = 5926.932$

$f_c = 33.00$

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

Final value of μ_u : $\mu_u^* = \text{shear_factor} \cdot \text{Max}(\mu_u, \mu_c) = 0.01505571$

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

From (5.4b), TBDY: $\mu_u = 0.01505571$

where ((5.4c), TBDY) = $\alpha_1 \cdot \text{sh}_{min} \cdot f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.08345896$

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

$f_x = 0.07683125$

$\alpha_f = 0.57333333$

$b = 400.00$

$h = 400.00$

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

$bw = 400.00$

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

$f_y = 0.07683125$

$\alpha_f = 0.57333333$

$b = 400.00$

$h = 400.00$

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

$bw = 400.00$

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

$R = 40.00$

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

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{,f} = 0.015$

$\alpha_{se} ((5.4d), TBDY) = (\alpha_{se1} \cdot A_{ext} + \alpha_{se2} \cdot A_{int}) / A_{sec} = 0.24250288$

$\alpha_{se1} = 0.24250288$

bo_1 = 340.00
ho_1 = 340.00
bi2_1 = 462400.00
ase2 = Max(ase1,ase2) = 0.24250288
bo_2 = 192.00
ho_2 = 192.00
bi2_2 = 147456.00

psh,min*Fywe = Min(psh,x*Fywe , psh,y*Fywe) = 3.00635

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

psh_x*Fywe = psh1*Fywe1+ps2*Fywe2 = 3.00635
ps1 (external) = (Ash1*h1/s1)/Asec = 0.00392699
Ash1 = Astir_1*ns_1 = 157.0796
No stirrups, ns_1 = 2.00
h1 = 400.00
ps2 (internal) = (Ash2*h2/s2)/Asec = 0.00050265
Ash2 = Astir_2*ns_2 = 100.531
No stirrups, ns_2 = 2.00
h2 = 200.00

psh_y*Fywe = psh1*Fywe1+ps2*Fywe2 = 3.00635
ps1 (external) = (Ash1*h1/s1)/Asec = 0.00392699
Ash1 = Astir_1*ns_1 = 157.0796
No stirrups, ns_1 = 2.00
h1 = 400.00
ps2 (internal) = (Ash2*h2/s2)/Asec = 0.00050265
Ash2 = Astir_2*ns_2 = 100.531
No stirrups, ns_2 = 2.00
h2 = 200.00

Asec = 160000.00

s1 = 100.00

s2 = 250.00

fywe1 = 694.45

fywe2 = 555.55

fce = 33.00

From ((5.A5), TBDY), TBDY: cc = 0.00332119

c = confinement factor = 1.13212

y1 = 0.00184318

sh1 = 0.00589816

ft1 = 580.8818

fy1 = 484.0682

su1 = 0.01099427

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

lo/lou,min = lb/lb = 0.45297586

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

From table 5A.1, TBDY: esu1_nominal = 0.08,

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

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

with fs1 = (fs,jacket*Asl,ten,jacket + fs,core*Asl,ten,core)/Asl,ten = 484.0682

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

y2 = 0.00184318

sh2 = 0.00589816

ft2 = 580.8818

fy2 = 484.0682

su2 = 0.01099427

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

lo/lou,min = lb/lb,min = 0.45297586

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 $fs_2 = fs_2/1.2$, from table 5.1, TBDY.

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

with $fs_2 = (fs_{jacket} \cdot Asl_{com,jacket} + fs_{core} \cdot Asl_{com,core}) / Asl_{com} = 484.0682$

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

$y_v = 0.00184318$

$sh_v = 0.00589816$

$ft_v = 614.3968$

$fy_v = 511.9973$

$suv = 0.01099427$

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

and also multiplied by the shear_factor according to 15.7.1.4, with

Shear_factor = 1.00

$lo/lo_{u,min} = lb/ld = 0.45297586$

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

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

considering characteristic value $fs_{yv} = fs_v/1.2$, from table 5.1, TBDY

For calculation of $esuv_{nominal}$ and y_v, sh_v, ft_v, fy_v , it is considered

characteristic value $fs_{yv} = fs_v/1.2$, from table 5.1, TBDY.

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

with $fs_v = (fs_{jacket} \cdot Asl_{mid,jacket} + fs_{mid} \cdot Asl_{mid,core}) / Asl_{mid} = 511.9973$

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

$1 = Asl_{ten} / (b \cdot d) \cdot (fs_1 / fc) = 0.0851958$

$2 = Asl_{com} / (b \cdot d) \cdot (fs_2 / fc) = 0.0851958$

$v = Asl_{mid} / (b \cdot d) \cdot (fs_v / fc) = 0.04369034$

and confined core properties:

$b = 340.00$

$d = 327.00$

$d' = 13.00$

$fcc (5A.2, TBDY) = 37.35991$

$cc (5A.5, TBDY) = 0.00332119$

$c = \text{confinement factor} = 1.13212$

$1 = Asl_{ten} / (b \cdot d) \cdot (fs_1 / fc) = 0.1094258$

$2 = Asl_{com} / (b \cdot d) \cdot (fs_2 / fc) = 0.1094258$

$v = Asl_{mid} / (b \cdot d) \cdot (fs_v / fc) = 0.05611603$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

$su (4.9) = 0.16193824$

$Mu = MRc (4.14) = 1.8194E+008$

$u = su (4.1) = 3.6747033E-005$

Calculation of ratio lb/ld

Lap Length: $lb/ld = 0.45297586$

$lb = 300.00$

$ld = 662.2869$

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

= 1

$db = 14.66667$

Mean strength value of all re-bars: $fy = 656.5682$

Mean concrete strength: $fc' = (fc'_{jacket} \cdot Area_{jacket} + fc'_{core} \cdot Area_{core}) / Area_{section} = 29.75$, but $fc'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 3.43481$

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

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

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

$n = 12.00$

Calculation of μ_{2+}

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

$$\mu = 3.6747033E-005$$

$$\mu = 1.8194E+008$$

with full section properties:

$$b = 400.00$$

$$d = 357.00$$

$$d' = 43.00$$

$$v = 0.00125773$$

$$N = 5926.932$$

$$f_c = 33.00$$

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

$$\text{Final value of } \mu: \mu^* = \text{shear_factor} * \text{Max}(\mu, c_c) = 0.01505571$$

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

$$\text{From (5.4b), TBDY: } \mu = 0.01505571$$

$$\mu \text{ ((5.4c), TBDY)} = a_s * \text{sh}_{,\min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.08345896$$

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

$$f_x = 0.07683125$$

$$a_f = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

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

$$b_w = 400.00$$

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

$$f_y = 0.07683125$$

$$a_f = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

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

$$b_w = 400.00$$

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

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$\mu \text{ ((5.4d), TBDY)} = (a_{se1} * A_{ext} + a_{se2} * A_{int}) / A_{sec} = 0.24250288$$

$$a_{se1} = 0.24250288$$

$$b_{o,1} = 340.00$$

$$h_{o,1} = 340.00$$

$$b_{i,1} = 462400.00$$

$$a_{se2} = \text{Max}(a_{se1}, a_{se2}) = 0.24250288$$

$$b_{o,2} = 192.00$$

$$h_{o,2} = 192.00$$

$$b_{i,2} = 147456.00$$

$$p_{sh,\min} * F_{ywe} = \text{Min}(p_{sh,x} * F_{ywe}, p_{sh,y} * F_{ywe}) = 3.00635$$

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

$$p_{sh,x} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{sh2} * F_{ywe2} = 3.00635$$

$$p_{sh1} \text{ (external)} = (A_{sh1} * h_1 / s_1) / A_{sec} = 0.00392699$$

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

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

$$h_1 = 400.00$$

$$p_{sh2} \text{ (internal)} = (A_{sh2} * h_2 / s_2) / A_{sec} = 0.00050265$$

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

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

$$h_2 = 200.00$$

$$p_{sh,y} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{sh2} * F_{ywe2} = 3.00635$$

$$ps1 \text{ (external)} = (Ash1 \cdot h1 / s1) / Asec = 0.00392699$$

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

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

$$h1 = 400.00$$

$$ps2 \text{ (internal)} = (Ash2 \cdot h2 / s2) / Asec = 0.00050265$$

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

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

$$h2 = 200.00$$

$$Asec = 160000.00$$

$$s1 = 100.00$$

$$s2 = 250.00$$

$$fywe1 = 694.45$$

$$fywe2 = 555.55$$

$$fce = 33.00$$

$$\text{From } ((5.A5), \text{ TBDY}), \text{ TBDY: } cc = 0.00332119$$

$$c = \text{confinement factor} = 1.13212$$

$$y1 = 0.00184318$$

$$sh1 = 0.00589816$$

$$ft1 = 580.8818$$

$$fy1 = 484.0682$$

$$su1 = 0.01099427$$

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

$$lo/lou, \text{min} = lb/d = 0.45297586$$

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

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

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

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

$$\text{with } fs1 = (fs_{\text{jacket}} \cdot Asl, \text{ten, jacket} + fs_{\text{core}} \cdot Asl, \text{ten, core}) / Asl, \text{ten} = 484.0682$$

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

$$y2 = 0.00184318$$

$$sh2 = 0.00589816$$

$$ft2 = 580.8818$$

$$fy2 = 484.0682$$

$$su2 = 0.01099427$$

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

$$lo/lou, \text{min} = lb/lb, \text{min} = 0.45297586$$

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

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

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

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

$$\text{with } fs2 = (fs_{\text{jacket}} \cdot Asl, \text{com, jacket} + fs_{\text{core}} \cdot Asl, \text{com, core}) / Asl, \text{com} = 484.0682$$

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

$$yv = 0.00184318$$

$$shv = 0.00589816$$

$$ftv = 614.3968$$

$$fyv = 511.9973$$

$$suv = 0.01099427$$

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

$$lo/lou, \text{min} = lb/d = 0.45297586$$

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

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

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

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

$$\text{with } fsv = (fs_{\text{jacket}} \cdot Asl, \text{mid, jacket} + fs_{\text{mid}} \cdot Asl, \text{mid, core}) / Asl, \text{mid} = 511.9973$$

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

$$1 = Asl, \text{ten} / (b \cdot d) \cdot (fs1 / fce) = 0.0851958$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.0851958$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.04369034$$

and confined core properties:

$$b = 340.00$$

$$d = 327.00$$

$$d' = 13.00$$

$$f_{cc} (5A.2, TBDY) = 37.35991$$

$$c_c (5A.5, TBDY) = 0.00332119$$

$$c = \text{confinement factor} = 1.13212$$

$$1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.1094258$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.1094258$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.05611603$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

$$s_u (4.9) = 0.16193824$$

$$M_u = M_{Rc} (4.14) = 1.8194E+008$$

$$u = s_u (4.1) = 3.6747033E-005$$

Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.45297586$

$$l_b = 300.00$$

$$l_d = 662.2869$$

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

$$= 1$$

$$d_b = 14.66667$$

$$\text{Mean strength value of all re-bars: } f_y = 656.5682$$

Mean concrete strength: $f_c' = (f_c'_{jacket} * \text{Area}_{jacket} + f_c'_{core} * \text{Area}_{core}) / \text{Area}_{section} = 29.75$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 25.00$$

$$K_{tr} = 3.43481$$

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

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

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

$$n = 12.00$$

Calculation of M_u2 -

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

$$u = 3.6747033E-005$$

$$M_u = 1.8194E+008$$

with full section properties:

$$b = 400.00$$

$$d = 357.00$$

$$d' = 43.00$$

$$v = 0.00125773$$

$$N = 5926.932$$

$$f_c = 33.00$$

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

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.01505571$$

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

$$\text{From (5.4b), TBDY: } c_u = 0.01505571$$

$$w_e ((5.4c), TBDY) = a_{se} * s_{h,min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.08345896$$

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

fx = 0.07683125
af = 0.57333333
b = 400.00
h = 400.00
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 = 0.07683125
af = 0.57333333
b = 400.00
h = 400.00
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 = 0.24250288
ase1 = 0.24250288
bo_1 = 340.00
ho_1 = 340.00
bi2_1 = 462400.00
ase2 = Max(ase1,ase2) = 0.24250288
bo_2 = 192.00
ho_2 = 192.00
bi2_2 = 147456.00

psh,min*Fywe = Min(psh,x*Fywe , psh,y*Fywe) = 3.00635
Expression ((5.4d), TBDY) for psh,min*Fywe has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

psh_x*Fywe = psh1*Fywe1+ps2*Fywe2 = 3.00635
ps1 (external) = (Ash1*h1/s1)/Asec = 0.00392699
Ash1 = Astir_1*ns_1 = 157.0796
No stirrups, ns_1 = 2.00
h1 = 400.00
ps2 (internal) = (Ash2*h2/s2)/Asec = 0.00050265
Ash2 = Astir_2*ns_2 = 100.531
No stirrups, ns_2 = 2.00
h2 = 200.00

psh_y*Fywe = psh1*Fywe1+ps2*Fywe2 = 3.00635
ps1 (external) = (Ash1*h1/s1)/Asec = 0.00392699
Ash1 = Astir_1*ns_1 = 157.0796
No stirrups, ns_1 = 2.00
h1 = 400.00
ps2 (internal) = (Ash2*h2/s2)/Asec = 0.00050265
Ash2 = Astir_2*ns_2 = 100.531
No stirrups, ns_2 = 2.00
h2 = 200.00

Asec = 160000.00
s1 = 100.00
s2 = 250.00
fywe1 = 694.45
fywe2 = 555.55
fce = 33.00

From ((5.A5), TBDY), TBDY: cc = 0.00332119
c = confinement factor = 1.13212

y1 = 0.00184318
sh1 = 0.00589816
ft1 = 580.8818
fy1 = 484.0682
su1 = 0.01099427

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

$$l_o/l_{o,u,min} = l_b/l_d = 0.45297586$$

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

From table 5A.1, TBDY: $e_{s_u1,nominal} = 0.08$,

For calculation of $e_{s_u1,nominal}$ and y_1, sh_1, ft_1, fy_1 , it is considered
characteristic value $f_{s_y1} = f_{s_1}/1.2$, 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.

$$\text{with } f_{s_1} = (f_{s,jacket} * A_{s,ten,jacket} + f_{s,core} * A_{s,ten,core}) / A_{s,ten} = 484.0682$$

$$\text{with } E_{s_1} = (E_{s,jacket} * A_{s,ten,jacket} + E_{s,core} * A_{s,ten,core}) / A_{s,ten} = 200000.00$$

$$y_2 = 0.00184318$$

$$sh_2 = 0.00589816$$

$$ft_2 = 580.8818$$

$$fy_2 = 484.0682$$

$$s_u2 = 0.01099427$$

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

$$l_o/l_{o,u,min} = l_b/l_{b,min} = 0.45297586$$

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

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

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

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

$$\text{with } f_{s_2} = (f_{s,jacket} * A_{s,com,jacket} + f_{s,core} * A_{s,com,core}) / A_{s,com} = 484.0682$$

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

$$y_v = 0.00184318$$

$$sh_v = 0.00589816$$

$$ft_v = 614.3968$$

$$fy_v = 511.9973$$

$$s_uv = 0.01099427$$

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

$$l_o/l_{o,u,min} = l_b/l_d = 0.45297586$$

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

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

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

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

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

$$\text{with } f_{s_v} = (f_{s,jacket} * A_{s,mid,jacket} + f_{s,mid} * A_{s,mid,core}) / A_{s,mid} = 511.9973$$

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

$$1 = A_{s,ten} / (b * d) * (f_{s_1} / f_c) = 0.0851958$$

$$2 = A_{s,com} / (b * d) * (f_{s_2} / f_c) = 0.0851958$$

$$v = A_{s,mid} / (b * d) * (f_{s_v} / f_c) = 0.04369034$$

and confined core properties:

$$b = 340.00$$

$$d = 327.00$$

$$d' = 13.00$$

$$f_{cc} (5A.2, TBDY) = 37.35991$$

$$c_c (5A.5, TBDY) = 0.00332119$$

$$c = \text{confinement factor} = 1.13212$$

$$1 = A_{s,ten} / (b * d) * (f_{s_1} / f_c) = 0.1094258$$

$$2 = A_{s,com} / (b * d) * (f_{s_2} / f_c) = 0.1094258$$

$$v = A_{s,mid} / (b * d) * (f_{s_v} / f_c) = 0.05611603$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

$$s_u (4.9) = 0.16193824$$

$$\mu_u = M_{Rc} (4.14) = 1.8194E+008$$

$$u = s_u (4.1) = 3.6747033E-005$$

Calculation of ratio l_b/d

Lap Length: $l_b/d = 0.45297586$

$l_b = 300.00$

$d = 662.2869$

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

$= 1$

$d_b = 14.66667$

Mean strength value of all re-bars: $f_y = 656.5682$

Mean concrete strength: $f'_c = (f'_{c_jacket} \cdot Area_{jacket} + f'_{c_core} \cdot Area_{core}) / Area_{section} = 29.75$, but $f'_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$c_b = 25.00$

$K_{tr} = 3.43481$

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

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

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

$n = 12.00$

Calculation of Shear Strength $V_r = \min(V_{r1}, V_{r2}) = 633062.661$

Calculation of Shear Strength at edge 1, $V_{r1} = 633062.661$

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

$V_{Col0} = 633062.661$

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

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

$= 1$ (normal-weight concrete)

Mean concrete strength: $f'_c = (f'_{c_jacket} \cdot Area_{jacket} + f'_{c_core} \cdot Area_{core}) / Area_{section} = 29.75$, but $f'_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$\mu_u = 4.6931004E-013$

$\nu_u = 6.6805695E-033$

$d = 0.8 \cdot h = 320.00$

$N_u = 5926.932$

$A_g = 160000.00$

From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 279254.914$

where:

$V_{s1} = 279254.914$ is calculated for jacket, with:

$d = 320.00$

$A_v = 157079.633$

$f_y = 555.56$

$s = 100.00$

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

$s/d = 0.3125$

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

$d = 160.00$

$A_v = 100530.965$

$f_y = 444.44$

$s = 250.00$

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

$s/d = 1.5625$

$V_f ((11-3)-(11.4), ACI 440) = 188111.148$

$f = 0.95$, for fully-wrapped sections

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

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

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

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

$V_f = \text{Min}(|V_f(45, 1)|, |V_f(-45, a1)|)$, with:
total thickness per orientation, $tf1 = NL*t/\text{NoDir} = 1.016$
 $dfv = d$ (figure 11.2, ACI 440) = 357.00
 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: $V_s + V_f \leq 463788.751$
 $bw = 400.00$

Calculation of Shear Strength at edge 2, $V_{r2} = 633062.661$
 $V_{r2} = V_{Col}$ ((10.3), ASCE 41-17) = $knl*V_{Col0}$
 $V_{Col0} = 633062.661$
 $knl = 1$ (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: $f_c' = (f_c'_{jacket}*Area_{jacket} + f_c'_{core}*Area_{core})/Area_{section} = 29.75$, but $f_c'^{0.5} \leq 8.3$
MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$
 $M_u = 4.6931004E-013$
 $V_u = 6.6805695E-033$
 $d = 0.8*h = 320.00$
 $N_u = 5926.932$
 $A_g = 160000.00$
From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 279254.914$

where:

$V_{s1} = 279254.914$ is calculated for jacket, with:

$d = 320.00$
 $A_v = 157079.633$
 $f_y = 555.56$
 $s = 100.00$

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

$s/d = 0.3125$

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

$d = 160.00$
 $A_v = 100530.965$
 $f_y = 444.44$
 $s = 250.00$

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

$s/d = 1.5625$

V_f ((11-3)-(11.4), ACI 440) = 188111.148

$f = 0.95$, 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 $V_f(\alpha, a_i)$, is implemented for every different fiber orientation a_i , as well as for 2 crack directions, $\alpha = 45^\circ$ and $\alpha = -45^\circ$ to take into consideration the cyclic seismic loading.

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

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

total thickness per orientation, $tf1 = NL*t/\text{NoDir} = 1.016$

$dfv = d$ (figure 11.2, ACI 440) = 357.00

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: $V_s + V_f \leq 463788.751$

$bw = 400.00$

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

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

At local axis: 2

Integration Section: (a)

Section Type: rcjrs

Constant Properties

Knowledge Factor, $\gamma = 0.80$

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

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

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

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

External Height, $H = 400.00$

External Width, $W = 400.00$

Internal Height, $H = 200.00$

Internal Width, $W = 200.00$

Cover Thickness, $c = 25.00$

Element Length, $L = 3000.00$

Secondary Member

Ribbed Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

Lap Length $l_b = 300.00$

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $ε_{fu} = 0.01$

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

Fiber orientations, $b_i = 0.00^\circ$

Number of layers, $N_L = 1$

Radius of rounding corners, $R = 40.00$

Stepwise Properties

Bending Moment, $M = 3.6608976E-012$

Shear Force, $V_2 = -7481.276$

Shear Force, $V_3 = 1.2884777E-015$

Axial Force, $F = -6438.97$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: $As_t = 829.3805$

-Compression: $As_c = 1231.504$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

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

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

-Middle: $As_{mid} = 402.1239$

Longitudinal External Reinforcement Area Distribution (in 3 divisions)

-Tension: $As_{t,ten,jacket} = 603.1858$

-Compression: $As_{c,com,jacket} = 603.1858$

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

Longitudinal Internal Reinforcement Area Distribution (in 3 divisions)

-Tension: $As_{t,ten,core} = 226.1947$

-Compression: $A_{sl,com,core} = 226.1947$

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

Mean Diameter of Tension Reinforcement, $DbL = 14.40$

Existing component: From table 7-7, ASCE 41_17: Final chord rotation Capacity $u_{,R} = u = 0.00332297$
 $u = y + p = 0.00415372$

- Calculation of y -

$y = (My * L_s / 3) / E_{eff} = 0.00415372$ ((4.29), Biskinis Phd))

$My = 1.4156E+008$

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

From table 10.5, ASCE 41_17: $E_{eff} = factor * E_c * I_g = 1.7040E+013$

factor = 0.30

$A_g = 160000.00$

Mean concrete strength: $f_c' = (f_c'_{jacket} * Area_{jacket} + f_c'_{core} * Area_{core}) / Area_{section} = 29.75$

$N = 6438.97$

$E_c * I_g = E_c * I_{g,jacket} + E_c * I_{g,core} = 5.6801E+013$

Calculation of Yielding Moment My

Calculation of y and My according to Annex 7 -

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

$y_{ten} = 8.5640402E-006$

with ((10.1), ASCE 41-17) $f_y = \text{Min}(f_y, 1.25 * f_y * (I_b / I_d)^{2/3}) = 454.4281$

$d = 357.00$

$y = 0.2568299$

$A = 0.01453119$

$B = 0.00818436$

with $p_t = 0.00680078$

$p_c = 0.00580799$

$p_v = 0.00281599$

$N = 6438.97$

$b = 400.00$

" = 0.12044818

$y_{comp} = 2.5296911E-005$

with $f_c' (12.3, (ACI 440)) = 34.65599$

$f_c = 33.00$

$f_l = 0.93147527$

$b = 400.00$

$h = 400.00$

$A_g = 160000.00$

From (12.9), ACI 440: $k_a = 0.56708553$

$g = p_t + p_c + p_v = 0.01443197$

$r_c = 40.00$

$A_e / A_c = 0.56708553$

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

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

$f_u = 0.01$

$E_f = 64828.00$

$E_c = 26999.444$

$y = 0.25583518$

$A = 0.01433439$

$B = 0.00808514$

with $E_s = 200000.00$

Calculation of ratio I_b / I_d

Lap Length: $l_d/l_{d,min} = 0.56621983$

$l_b = 300.00$

$l_d = 529.8296$

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

$= 1$

$d_b = 14.66667$

Mean strength value of all re-bars: $f_y = 525.2545$

Mean concrete strength: $f_c' = (f_c'_{jacket} \cdot Area_{jacket} + f_c'_{core} \cdot Area_{core}) / Area_{section} = 29.75$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 3.43481$

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

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

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

$n = 12.00$

- Calculation of p -

From table 10-8: $p = 0.00$

with:

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

shear control ratio $V_y E / V_{col} O E = 0.19159777$

$d = d_{external} = 357.00$

$s = s_{external} = 0.00$

$t = s_1 + s_2 + 2 \cdot t_f / b_w \cdot (f_{fe} / f_s) = 0.00680078$

jacket: $s_1 = A_{v1} \cdot h_1 / (s_1 \cdot A_g) = 0.00392699$

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

$h_1 = 400.00$

$s_1 = 100.00$

core: $s_2 = A_{v2} \cdot h_2 / (s_2 \cdot A_g) = 0.00050265$

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

$h_2 = 200.00$

$s_2 = 250.00$

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.

$N_{UD} = 6438.97$

$A_g = 160000.00$

$f_{cE} = (f_{c,jacket} \cdot Area_{jacket} + f_{c,core} \cdot Area_{core}) / section_area = 29.75$

$f_{yIE} = (f_{y,ext_Long_Reinf} \cdot Area_{ext_Long_Reinf} + f_{y,int_Long_Reinf} \cdot Area_{int_Long_Reinf}) / Area_{Tot_Long_Rein} = 531.1678$

$f_{yTE} = (f_{y,ext_Trans_Reinf} \cdot Area_{ext_Trans_Reinf} + f_{y,int_Trans_Reinf} \cdot Area_{int_Trans_Reinf}) / Area_{Tot_Trans_Rein} = 542.9506$

$p_l = Area_{Tot_Long_Rein} / (b \cdot d) = 0.01443197$

$b = 400.00$

$d = 357.00$

$f_{cE} = 29.75$

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

At local axis: 2

Integration Section: (a)

Calculation No. 3

column C1, Floor 1

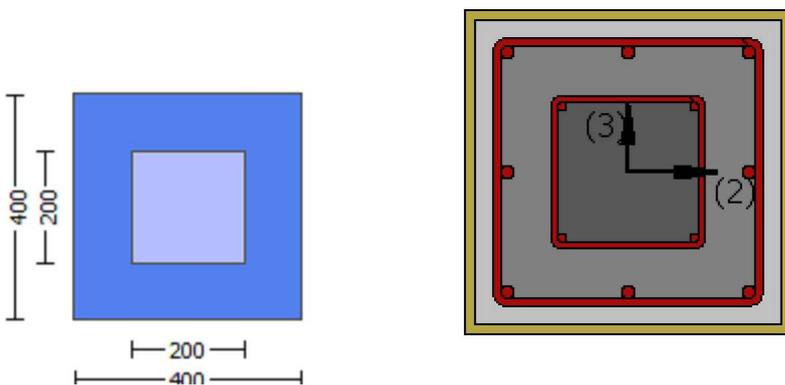
Limit State: Immediate Occupancy (data interpolation between analysis steps 2 and 3)

Analysis: Uniform +X

Check: Shear capacity VRd

Edge: Start

Local Axis: (3)



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

At local axis: 3

Integration Section: (a)

Section Type: rcjrs

Constant Properties

Knowledge Factor, $\gamma = 0.80$

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

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

Consequently:

Jacket

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

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

Concrete Elasticity, $E_c = 26999.444$

Steel Elasticity, $E_s = 200000.00$

Existing Column

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

Existing material of Secondary Member: Steel Strength, $f_s = f_{s_lower_bound} = 400.00$

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

#####

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

Jacket

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

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

Existing Column

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

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

#####

External Height, H = 400.00
External Width, W = 400.00
Internal Height, H = 200.00
Internal Width, W = 200.00
Cover Thickness, c = 25.00
Element Length, L = 3000.00
Secondary Member
Ribbed Bars
Ductile Steel
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
Lap Length $l_o = l_b = 300.00$
FRP Wrapping Data
Type: Carbon
Cured laminate properties (design values)
Thickness, t = 1.016
Tensile Strength, $f_{fu} = 1055.00$
Tensile Modulus, $E_f = 64828.00$
Elongation, $e_{fu} = 0.01$
Number of directions, NoDir = 1
Fiber orientations, $b_i: 0.00^\circ$
Number of layers, NL = 1
Radius of rounding corners, R = 40.00

Stepwise Properties

EDGE -A-
Bending Moment, $M_a = 3.6608976E-012$
Shear Force, $V_a = 1.2884777E-015$
EDGE -B-
Bending Moment, $M_b = -7.5332205E-012$
Shear Force, $V_b = -1.2884777E-015$
BOTH EDGES
Axial Force, F = -6438.97
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: $A_{sl} = 829.3805$
-Compression: $A_{sc} = 1231.504$
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension: $A_{sl,ten} = 829.3805$
-Compression: $A_{sl,com} = 829.3805$
-Middle: $A_{sl,mid} = 402.1239$
Mean Diameter of Tension Reinforcement, $D_{bL,ten} = 14.40$

Existing component: From table 7-7, ASCE 41_17: Final Shear Capacity $V_R = V_n = 447154.557$
 $V_n ((10.3), ASCE 41-17) = k_n \cdot V_{CoI} = 558943.196$
 $V_{CoI} = 558943.196$
 $k_n = 1.00$
displacement_ductility_demand = 0.00

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

= 1 (normal-weight concrete)
Mean concrete strength: $f_c' = (f_c'_{jacket} \cdot Area_{jacket} + f_c'_{core} \cdot Area_{core}) / Area_{section} = 22.75$, but $f_c'^{0.5} \leq 8.3$
MPa (22.5.3.1, ACI 318-14)
 $M / Vd = 2.00$
 $M_u = 3.6608976E-012$
 $V_u = 1.2884777E-015$
 $d = 0.8 \cdot h = 320.00$
 $N_u = 6438.97$
 $A_g = 160000.00$
From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 251327.412$
where:

Vs1 = 251327.412 is calculated for jacket, with:

$$d = 320.00$$

$$A_v = 157079.633$$

$$f_y = 500.00$$

$$s = 100.00$$

Vs1 is multiplied by Col1 = 1.00

$$s/d = 0.3125$$

Vs2 = 0.00 is calculated for core, with:

$$d = 160.00$$

$$A_v = 100530.965$$

$$f_y = 400.00$$

$$s = 250.00$$

Vs2 is multiplied by Col2 = 0.00

$$s/d = 1.5625$$

Vf ((11-3)-(11.4), ACI 440) = 188111.148

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

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

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

$d_{fv} = d$ (figure 11.2, ACI 440) = 357.00

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: $V_s + V_f \leq 405571.497$

$$b_w = 400.00$$

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 $\theta = 5.9665892E-022$

$$y = (M_y \cdot L_s / 3) / E_{eff} = 0.00415372 \text{ ((4.29), Biskinis Phd)}$$

$$M_y = 1.4156E+008$$

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

From table 10.5, ASCE 41_17: $E_{eff} = \text{factor} \cdot E_c \cdot I_g = 1.7040E+013$

$$\text{factor} = 0.30$$

$$A_g = 160000.00$$

$$\text{Mean concrete strength: } f_c' = (f_c'_{\text{jacket}} \cdot \text{Area}_{\text{jacket}} + f_c'_{\text{core}} \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 29.75$$

$$N = 6438.97$$

$$E_c \cdot I_g = E_{c_{\text{jacket}}} \cdot I_{g_{\text{jacket}}} + E_{c_{\text{core}}} \cdot I_{g_{\text{core}}} = 5.6801E+013$$

Calculation of Yielding Moment M_y

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

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

$$y_{\text{ten}} = 8.5640402E-006$$

$$\text{with ((10.1), ASCE 41-17) } f_y = \text{Min}(f_y, 1.25 \cdot f_y \cdot (I_b / I_d)^{2/3}) = 454.4281$$

$$d = 357.00$$

$$y = 0.2568299$$

$$A = 0.01453119$$

$$B = 0.00818436$$

$$\text{with } p_t = 0.00580799$$

$$p_c = 0.00580799$$

$$p_v = 0.00281599$$

$$N = 6438.97$$

$b = 400.00$
 $\rho = 0.12044818$
 $y_{comp} = 2.5296911E-005$
 with f_c^* (12.3, (ACI 440)) = 34.65599
 $f_c = 33.00$
 $f_l = 0.93147527$
 $b = 400.00$
 $h = 400.00$
 $A_g = 160000.00$
 From (12.9), ACI 440: $k_a = 0.56708553$
 $g = p_t + p_c + p_v = 0.01443197$
 $rc = 40.00$
 $A_e/A_c = 0.56708553$
 Effective FRP thickness, $t_f = NL*t*\cos(b1) = 1.016$
 effective strain from (12.5) and (12.12), $\epsilon_{fe} = 0.004$
 $f_u = 0.01$
 $E_f = 64828.00$
 $E_c = 26999.444$
 $y = 0.25583518$
 $A = 0.01433439$
 $B = 0.00808514$
 with $E_s = 200000.00$

 Calculation of ratio l_b/l_d

 Lap Length: $l_d/l_{d,min} = 0.56621983$

$l_b = 300.00$

$l_d = 529.8296$

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

$= 1$

$d_b = 14.66667$

Mean strength value of all re-bars: $f_y = 525.2545$

Mean concrete strength: $f_c' = (f_c'_{jacket} * Area_{jacket} + f_c'_{core} * Area_{core}) / Area_{section} = 29.75$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 3.43481$

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

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

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

$n = 12.00$

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

At local axis: 3

Integration Section: (a)

Calculation No. 4

column C1, Floor 1

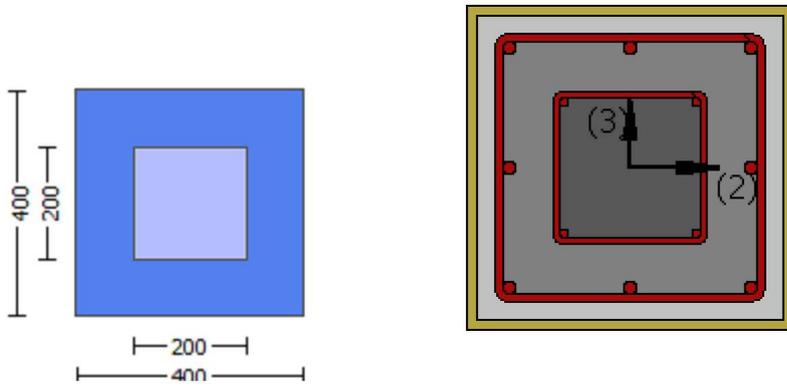
Limit State: Immediate Occupancy (data interpolation between analysis steps 2 and 3)

Analysis: Uniform +X

Check: Chord rotation capacity (θ_u)

Edge: Start

Local Axis: (3)



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

At Shear local axis: 3

(Bending local axis: 2)

Section Type: rcjrs

Constant Properties

Knowledge Factor, $\gamma = 0.80$

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

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

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

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

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

Jacket

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

Existing Column

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

#####

External Height, $H = 400.00$

External Width, $W = 400.00$

Internal Height, $H = 200.00$

Internal Width, $W = 200.00$

Cover Thickness, $c = 25.00$

Mean Confinement Factor overall section = 1.13212

Element Length, $L = 3000.00$

Secondary Member

Ribbed Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

Lap Length $l_o = 300.00$

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $\epsilon_{fu} = 0.01$

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

Fiber orientations, $b_i = 0.00^\circ$

Number of layers, $N_L = 1$

Radius of rounding corners, $R = 40.00$

Stepwise Properties

At local axis: 3

EDGE -A-

Shear Force, $V_a = 2.8976040E-031$

EDGE -B-

Shear Force, $V_b = -2.8976040E-031$

BOTH EDGES

Axial Force, $F = -5926.932$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

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

-Compression: $A_{sl,c} = 2060.885$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

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

-Compression: $A_{sl,com} = 829.3805$

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

Calculation of Shear Capacity ratio, $V_e/V_r = 0.19159777$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 121293.391$

with

$M_{pr1} = \text{Max}(M_{u1+}, M_{u1-}) = 1.8194E+008$

$M_{u1+} = 1.8194E+008$, is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination

$M_{u1-} = 1.8194E+008$, is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination

$M_{pr2} = \text{Max}(M_{u2+}, M_{u2-}) = 1.8194E+008$

$M_{u2+} = 1.8194E+008$, is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the the static loading combination

$M_{u2-} = 1.8194E+008$, is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the the static loading combination

Calculation of M_{u1+}

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

$\phi_u = 3.6747033E-005$

$M_u = 1.8194E+008$

with full section properties:

$b = 400.00$

$d = 357.00$

$d' = 43.00$

$v = 0.00125773$

$N = 5926.932$

$f_c = 33.00$

α_0 (5A.5, TBDY) = 0.002

Final value of c_u : $c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.01505571$

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

From (5.4b), TBDY: $c_u = 0.01505571$

w_e ((5.4c), TBDY) = $ase * \text{sh_min} * fy_{we} / f_{ce} + \text{Min}(f_x, f_y) = 0.08345896$

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

 $f_x = 0.07683125$

$af = 0.57333333$

$b = 400.00$

$h = 400.00$

From EC8 A.4.4.3(6), $pf = 2tf/bw = 0.00508$

$bw = 400.00$

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

 $f_y = 0.07683125$

$af = 0.57333333$

$b = 400.00$

$h = 400.00$

From EC8 A.4.4.3(6), $pf = 2tf/bw = 0.00508$

$bw = 400.00$

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

 $R = 40.00$

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

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{f} = 0.015$

ase ((5.4d), TBDY) = $(ase1 * A_{ext} + ase2 * A_{int}) / A_{sec} = 0.24250288$

$ase1 = 0.24250288$

$bo_1 = 340.00$

$ho_1 = 340.00$

$bi2_1 = 462400.00$

$ase2 = \text{Max}(ase1, ase2) = 0.24250288$

$bo_2 = 192.00$

$ho_2 = 192.00$

$bi2_2 = 147456.00$

$psh_{min} * fy_{we} = \text{Min}(psh_x * fy_{we}, psh_y * fy_{we}) = 3.00635$

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

 $psh_x * fy_{we} = psh1 * fy_{we1} + ps2 * fy_{we2} = 3.00635$

$ps1$ (external) = $(Ash1 * h1 / s1) / A_{sec} = 0.00392699$

$Ash1 = Astir_1 * ns_1 = 157.0796$

No stirrups, $ns_1 = 2.00$

$h1 = 400.00$

$ps2$ (internal) = $(Ash2 * h2 / s2) / A_{sec} = 0.00050265$

$Ash2 = Astir_2 * ns_2 = 100.531$

No stirrups, $ns_2 = 2.00$

$h2 = 200.00$

 $psh_y * fy_{we} = psh1 * fy_{we1} + ps2 * fy_{we2} = 3.00635$

$ps1$ (external) = $(Ash1 * h1 / s1) / A_{sec} = 0.00392699$

$Ash1 = Astir_1 * ns_1 = 157.0796$

No stirrups, $ns_1 = 2.00$

$h1 = 400.00$

$ps2$ (internal) = $(Ash2 * h2 / s2) / A_{sec} = 0.00050265$

$Ash2 = Astir_2 * ns_2 = 100.531$

No stirrups, $ns_2 = 2.00$

$h2 = 200.00$

 $A_{sec} = 160000.00$

$s1 = 100.00$

$s2 = 250.00$

$fy_{we1} = 694.45$

$fy_{we2} = 555.55$

$f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY: $cc = 0.00332119$

$c = \text{confinement factor} = 1.13212$
 $y1 = 0.00184318$
 $sh1 = 0.00589816$
 $ft1 = 580.8818$
 $fy1 = 484.0682$
 $su1 = 0.01099427$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 $\text{Shear_factor} = 1.00$
 $lo/lou,min = lb/ld = 0.45297586$
 $su1 = 0.4 * esu1_nominal ((5.5), \text{TBDY}) = 0.032$
 From table 5A.1, TBDY: $esu1_nominal = 0.08$,
 For calculation of $esu1_nominal$ and $y1, sh1, ft1, fy1$, it is considered
 characteristic value $fsy1 = fs1/1.2$, from table 5.1, TBDY.
 $y1, sh1, ft1, fy1$, are also multiplied by $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE 41-17.
 with $fs1 = (fs,jacket * Asl,ten,jacket + fs,core * Asl,ten,core) / Asl,ten = 484.0682$
 with $Es1 = (Es,jacket * Asl,ten,jacket + Es,core * Asl,ten,core) / Asl,ten = 200000.00$
 $y2 = 0.00184318$
 $sh2 = 0.00589816$
 $ft2 = 580.8818$
 $fy2 = 484.0682$
 $su2 = 0.01099427$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 $\text{Shear_factor} = 1.00$
 $lo/lou,min = lb/lb,min = 0.45297586$
 $su2 = 0.4 * esu2_nominal ((5.5), \text{TBDY}) = 0.032$
 From table 5A.1, TBDY: $esu2_nominal = 0.08$,
 For calculation of $esu2_nominal$ and $y2, sh2, ft2, fy2$, it is considered
 characteristic value $fsy2 = fs2/1.2$, from table 5.1, TBDY.
 $y1, sh1, ft1, fy1$, are also multiplied by $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE 41-17.
 with $fs2 = (fs,jacket * Asl,com,jacket + fs,core * Asl,com,core) / Asl,com = 484.0682$
 with $Es2 = (Es,jacket * Asl,com,jacket + Es,core * Asl,com,core) / Asl,com = 200000.00$
 $yv = 0.00184318$
 $shv = 0.00589816$
 $ftv = 614.3968$
 $fyv = 511.9973$
 $suv = 0.01099427$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 $\text{Shear_factor} = 1.00$
 $lo/lou,min = lb/ld = 0.45297586$
 $suv = 0.4 * esuv_nominal ((5.5), \text{TBDY}) = 0.032$
 From table 5A.1, TBDY: $esuv_nominal = 0.08$,
 considering characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY
 For calculation of $esuv_nominal$ and yv, shv, ftv, fyv , it is considered
 characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY.
 $y1, sh1, ft1, fy1$, are also multiplied by $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE 41-17.
 with $fsv = (fs,jacket * Asl,mid,jacket + fs,mid * Asl,mid,core) / Asl,mid = 511.9973$
 with $Es_v = (Es,jacket * Asl,mid,jacket + Es,mid * Asl,mid,core) / Asl,mid = 200000.00$
 $1 = Asl,ten / (b * d) * (fs1 / fc) = 0.0851958$
 $2 = Asl,com / (b * d) * (fs2 / fc) = 0.0851958$
 $v = Asl,mid / (b * d) * (fsv / fc) = 0.04369034$
 and confined core properties:
 $b = 340.00$
 $d = 327.00$
 $d' = 13.00$
 $fcc (5A.2, \text{TBDY}) = 37.35991$
 $cc (5A.5, \text{TBDY}) = 0.00332119$
 $c = \text{confinement factor} = 1.13212$
 $1 = Asl,ten / (b * d) * (fs1 / fc) = 0.1094258$
 $2 = Asl,com / (b * d) * (fs2 / fc) = 0.1094258$
 $v = Asl,mid / (b * d) * (fsv / fc) = 0.05611603$
 Case/Assumption: Unconfined full section - Steel rupture
 ' satisfies Eq. (4.3)
 --->
 $v < vs,y2$ - LHS eq.(4.5) is satisfied

--->

su (4.9) = 0.16193824
Mu = MRc (4.14) = 1.8194E+008
u = su (4.1) = 3.6747033E-005

Calculation of ratio lb/l_d

Lap Length: lb/l_d = 0.45297586

lb = 300.00

l_d = 662.2869

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

= 1

db = 14.66667

Mean strength value of all re-bars: f_y = 656.5682

Mean concrete strength: f_c' = (f_c'_{jacket}*Area_{jacket} + f_c'_{core}*Area_{core})/Area_{section} = 29.75, but f_c'^{0.5} ≤ 8.3 MPa (22.5.3.1, ACI 318-14)

t = 1.00

s = 0.80

e = 1.00

cb = 25.00

K_{tr} = 3.43481

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

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

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

n = 12.00

Calculation of Mu1-

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

u = 3.6747033E-005

Mu = 1.8194E+008

with full section properties:

b = 400.00

d = 357.00

d' = 43.00

v = 0.00125773

N = 5926.932

f_c = 33.00

co (5A.5, TBDY) = 0.002

Final value of ϕ_u : $\phi_u^* = \text{shear_factor} * \text{Max}(\phi_u, \phi_c) = 0.01505571$

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

From (5.4b), TBDY: $\phi_u = 0.01505571$

we ((5.4c), TBDY) = $\text{ase} * \text{sh}_{\min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.08345896$

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

f_x = 0.07683125

af = 0.57333333

b = 400.00

h = 400.00

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 = 0.07683125

af = 0.57333333

b = 400.00

h = 400.00

From EC8 A.4.4.3(6), pf = 2tf/bw = 0.00508

bw = 400.00

effective stress from (A.35), ff,e = 870.5244

$R = 40.00$
 Effective FRP thickness, $t_f = NL * t * \cos(b_1) = 1.016$
 $f_{u,f} = 1055.00$
 $E_f = 64828.00$
 $u_{,f} = 0.015$
 $ase((5.4d), TBDY) = (ase_1 * A_{ext} + ase_2 * A_{int}) / A_{sec} = 0.24250288$
 $ase_1 = 0.24250288$
 $bo_1 = 340.00$
 $ho_1 = 340.00$
 $bi_2_1 = 462400.00$
 $ase_2 = \text{Max}(ase_1, ase_2) = 0.24250288$
 $bo_2 = 192.00$
 $ho_2 = 192.00$
 $bi_2_2 = 147456.00$

$psh_{,min} * F_{ywe} = \text{Min}(psh_{,x} * F_{ywe}, psh_{,y} * F_{ywe}) = 3.00635$
 Expression ((5.4d), TBDY) for $psh_{,min} * F_{ywe}$ has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$psh_{,x} * F_{ywe} = psh_1 * F_{ywe1} + ps_2 * F_{ywe2} = 3.00635$
 $ps_1 \text{ (external)} = (A_{sh1} * h_1 / s_1) / A_{sec} = 0.00392699$
 $A_{sh1} = A_{stir_1} * ns_1 = 157.0796$
 No stirrups, $ns_1 = 2.00$
 $h_1 = 400.00$
 $ps_2 \text{ (internal)} = (A_{sh2} * h_2 / s_2) / A_{sec} = 0.00050265$
 $A_{sh2} = A_{stir_2} * ns_2 = 100.531$
 No stirrups, $ns_2 = 2.00$
 $h_2 = 200.00$

$psh_{,y} * F_{ywe} = psh_1 * F_{ywe1} + ps_2 * F_{ywe2} = 3.00635$
 $ps_1 \text{ (external)} = (A_{sh1} * h_1 / s_1) / A_{sec} = 0.00392699$
 $A_{sh1} = A_{stir_1} * ns_1 = 157.0796$
 No stirrups, $ns_1 = 2.00$
 $h_1 = 400.00$
 $ps_2 \text{ (internal)} = (A_{sh2} * h_2 / s_2) / A_{sec} = 0.00050265$
 $A_{sh2} = A_{stir_2} * ns_2 = 100.531$
 No stirrups, $ns_2 = 2.00$
 $h_2 = 200.00$

$A_{sec} = 160000.00$
 $s_1 = 100.00$
 $s_2 = 250.00$
 $f_{ywe1} = 694.45$
 $f_{ywe2} = 555.55$
 $f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY: $cc = 0.00332119$
 $c = \text{confinement factor} = 1.13212$

$y_1 = 0.00184318$
 $sh_1 = 0.00589816$
 $ft_1 = 580.8818$
 $fy_1 = 484.0682$
 $su_1 = 0.01099427$

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

$lo/lo_{,min} = lb/ld = 0.45297586$
 $su_1 = 0.4 * esu_1_{nominal} \text{ ((5.5), TBDY)} = 0.032$

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

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

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

with $fs_1 = (f_{s,jacket} * A_{sl,ten,jacket} + f_{s,core} * A_{sl,ten,core}) / A_{sl,ten} = 484.0682$

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

$y_2 = 0.00184318$
 $sh_2 = 0.00589816$
 $ft_2 = 580.8818$
 $fy_2 = 484.0682$
 $su_2 = 0.01099427$

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

$$l_o/l_{o,u,min} = l_b/l_{b,min} = 0.45297586$$

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

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

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

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

$$\text{with } f_{s_2} = (f_{s,jacket} * A_{s_l,com,jacket} + f_{s,core} * A_{s_l,com,core}) / A_{s_l,com} = 484.0682$$

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

$$y_v = 0.00184318$$

$$sh_v = 0.00589816$$

$$ft_v = 614.3968$$

$$fy_v = 511.9973$$

$$s_{u_v} = 0.01099427$$

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

$$l_o/l_{o,u,min} = l_b/l_d = 0.45297586$$

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

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

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

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

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

$$\text{with } f_{s_v} = (f_{s,jacket} * A_{s_l,mid,jacket} + f_{s,mid} * A_{s_l,mid,core}) / A_{s_l,mid} = 511.9973$$

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

$$1 = A_{s_l,ten} / (b * d) * (f_{s_1} / f_c) = 0.0851958$$

$$2 = A_{s_l,com} / (b * d) * (f_{s_2} / f_c) = 0.0851958$$

$$v = A_{s_l,mid} / (b * d) * (f_{s_v} / f_c) = 0.04369034$$

and confined core properties:

$$b = 340.00$$

$$d = 327.00$$

$$d' = 13.00$$

$$f_{cc} (5A.2, TBDY) = 37.35991$$

$$cc (5A.5, TBDY) = 0.00332119$$

$$c = \text{confinement factor} = 1.13212$$

$$1 = A_{s_l,ten} / (b * d) * (f_{s_1} / f_c) = 0.1094258$$

$$2 = A_{s_l,com} / (b * d) * (f_{s_2} / f_c) = 0.1094258$$

$$v = A_{s_l,mid} / (b * d) * (f_{s_v} / f_c) = 0.05611603$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

$$s_u (4.9) = 0.16193824$$

$$\mu = MR_c (4.14) = 1.8194E+008$$

$$u = s_u (4.1) = 3.6747033E-005$$

Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.45297586$

$$l_b = 300.00$$

$$l_d = 662.2869$$

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

$$= 1$$

$$d_b = 14.66667$$

Mean strength value of all re-bars: $f_y = 656.5682$

Mean concrete strength: $f'_c = (f'_c_{jacket} * Area_{jacket} + f'_c_{core} * Area_{core}) / Area_{section} = 29.75$, but $f'_c^{0.5} \leq 8.3$
MPa (22.5.3.1, ACI 318-14)

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 25.00$$

$$K_{tr} = 3.43481$$

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

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

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

$$n = 12.00$$

Calculation of μ_{2+}

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

$$u = 3.6747033E-005$$

$$\mu = 1.8194E+008$$

with full section properties:

$$b = 400.00$$

$$d = 357.00$$

$$d' = 43.00$$

$$v = 0.00125773$$

$$N = 5926.932$$

$$f_c = 33.00$$

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

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.01505571$$

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

$$\text{From (5.4b), TBDY: } c_u = 0.01505571$$

$$w_e \text{ ((5.4c), TBDY)} = a_{se} * s_{h,\text{min}} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.08345896$$

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

$$f_x = 0.07683125$$

$$a_f = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

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

$$b_w = 400.00$$

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

$$f_y = 0.07683125$$

$$a_f = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

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

$$b_w = 400.00$$

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

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u_{f} = 0.015$$

$$a_{se} \text{ ((5.4d), TBDY)} = (a_{se1} * A_{ext} + a_{se2} * A_{int}) / A_{sec} = 0.24250288$$

$$a_{se1} = 0.24250288$$

$$b_{o,1} = 340.00$$

$$h_{o,1} = 340.00$$

$$b_{i,1} = 462400.00$$

$$a_{se2} = \text{Max}(a_{se1}, a_{se2}) = 0.24250288$$

$$b_{o,2} = 192.00$$

$$h_{o,2} = 192.00$$

$$b_{i,2} = 147456.00$$

$$p_{sh,\text{min}} * f_{ywe} = \text{Min}(p_{sh,x} * f_{ywe}, p_{sh,y} * f_{ywe}) = 3.00635$$

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

$$p_{sh_x} * f_{ywe} = p_{sh1} * f_{ywe1} + p_{sh2} * f_{ywe2} = 3.00635$$

$$p_{s1} \text{ (external)} = (A_{sh1} * h_1 / s_1) / A_{sec} = 0.00392699$$

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

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

h1 = 400.00
ps2 (internal) = (Ash2*h2/s2)/Asec = 0.00050265
Ash2 = Astir_2*ns_2 = 100.531
No stirups, ns_2 = 2.00
h2 = 200.00

psh_y*Fywe = psh1*Fywe1+ps2*Fywe2 = 3.00635
ps1 (external) = (Ash1*h1/s1)/Asec = 0.00392699
Ash1 = Astir_1*ns_1 = 157.0796
No stirups, ns_1 = 2.00
h1 = 400.00
ps2 (internal) = (Ash2*h2/s2)/Asec = 0.00050265
Ash2 = Astir_2*ns_2 = 100.531
No stirups, ns_2 = 2.00
h2 = 200.00

Asec = 160000.00
s1 = 100.00
s2 = 250.00
fywe1 = 694.45
fywe2 = 555.55
fce = 33.00

From ((5.A5), TBDY), TBDY: cc = 0.00332119
c = confinement factor = 1.13212

y1 = 0.00184318
sh1 = 0.00589816
ft1 = 580.8818
fy1 = 484.0682
su1 = 0.01099427

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

lo/lou,min = lb/d = 0.45297586

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 = 484.0682

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

y2 = 0.00184318
sh2 = 0.00589816
ft2 = 580.8818
fy2 = 484.0682
su2 = 0.01099427

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

lo/lou,min = lb/lb,min = 0.45297586

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 = 484.0682

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

yv = 0.00184318
shv = 0.00589816
ftv = 614.3968
fyv = 511.9973
suv = 0.01099427

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

lo/lou,min = lb/d = 0.45297586

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

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

considering characteristic value $f_{sv} = f_{sv}/1.2$, from table 5.1, TBDY
For calculation of $e_{suv_nominal}$ and y_v , sh_v , ft_v , f_{yv} , it is considered characteristic value $f_{sv} = f_{sv}/1.2$, from table 5.1, TBDY.

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

with $f_{sv} = (f_{s,jacket} \cdot A_{s,mid,jacket} + f_{s,mid} \cdot A_{s,mid,core}) / A_{s,mid} = 511.9973$

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

$1 = A_{s,ten} / (b \cdot d) \cdot (f_{s1} / f_c) = 0.0851958$

$2 = A_{s,com} / (b \cdot d) \cdot (f_{s2} / f_c) = 0.0851958$

$v = A_{s,mid} / (b \cdot d) \cdot (f_{sv} / f_c) = 0.04369034$

and confined core properties:

$b = 340.00$

$d = 327.00$

$d' = 13.00$

f_{cc} (5A.2, TBDY) = 37.35991

cc (5A.5, TBDY) = 0.00332119

c = confinement factor = 1.13212

$1 = A_{s,ten} / (b \cdot d) \cdot (f_{s1} / f_c) = 0.1094258$

$2 = A_{s,com} / (b \cdot d) \cdot (f_{s2} / f_c) = 0.1094258$

$v = A_{s,mid} / (b \cdot d) \cdot (f_{sv} / f_c) = 0.05611603$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

su (4.9) = 0.16193824

$\mu_u = MR_c$ (4.14) = 1.8194E+008

$u = su$ (4.1) = 3.6747033E-005

Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.45297586$

$l_b = 300.00$

$l_d = 662.2869$

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

= 1

$db = 14.66667$

Mean strength value of all re-bars: $f_y = 656.5682$

Mean concrete strength: $f'_c = (f'_{c,jacket} \cdot Area_{jacket} + f'_{c,core} \cdot Area_{core}) / Area_{section} = 29.75$, but $f_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 3.43481$

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

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

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

$n = 12.00$

Calculation of μ_u

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

$u = 3.6747033E-005$

$\mu_u = 1.8194E+008$

with full section properties:

$b = 400.00$

$d = 357.00$

$d' = 43.00$

$v = 0.00125773$

$N = 5926.932$

$f_c = 33.00$

co (5A.5, TBDY) = 0.002

Final value of cu: $cu^* = \text{shear_factor} * \text{Max}(cu, cc) = 0.01505571$

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

From (5.4b), TBDY: $cu = 0.01505571$

we ((5.4c), TBDY) = $ase^* sh_{\min} * fy_{we} / f_{ce} + \text{Min}(fx, fy) = 0.08345896$

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

 $fx = 0.07683125$

$af = 0.57333333$

$b = 400.00$

$h = 400.00$

From EC8 A.4.4.3(6), $pf = 2tf/bw = 0.00508$

$bw = 400.00$

effective stress from (A.35), $ff,e = 870.5244$

 $fy = 0.07683125$

$af = 0.57333333$

$b = 400.00$

$h = 400.00$

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) = $(ase1 * A_{ext} + ase2 * A_{int}) / A_{sec} = 0.24250288$

$ase1 = 0.24250288$

$bo_1 = 340.00$

$ho_1 = 340.00$

$bi2_1 = 462400.00$

$ase2 = \text{Max}(ase1, ase2) = 0.24250288$

$bo_2 = 192.00$

$ho_2 = 192.00$

$bi2_2 = 147456.00$

$psh_{\min} * fy_{we} = \text{Min}(psh_x * fy_{we}, psh_y * fy_{we}) = 3.00635$

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

 $psh_x * fy_{we} = psh1 * fy_{we1} + ps2 * fy_{we2} = 3.00635$

$ps1$ (external) = $(Ash1 * h1 / s1) / A_{sec} = 0.00392699$

$Ash1 = Astir_1 * ns_1 = 157.0796$

No stirrups, $ns_1 = 2.00$

$h1 = 400.00$

$ps2$ (internal) = $(Ash2 * h2 / s2) / A_{sec} = 0.00050265$

$Ash2 = Astir_2 * ns_2 = 100.531$

No stirrups, $ns_2 = 2.00$

$h2 = 200.00$

 $psh_y * fy_{we} = psh1 * fy_{we1} + ps2 * fy_{we2} = 3.00635$

$ps1$ (external) = $(Ash1 * h1 / s1) / A_{sec} = 0.00392699$

$Ash1 = Astir_1 * ns_1 = 157.0796$

No stirrups, $ns_1 = 2.00$

$h1 = 400.00$

$ps2$ (internal) = $(Ash2 * h2 / s2) / A_{sec} = 0.00050265$

$Ash2 = Astir_2 * ns_2 = 100.531$

No stirrups, $ns_2 = 2.00$

$h2 = 200.00$

 $A_{sec} = 160000.00$

$s1 = 100.00$

$s2 = 250.00$

$fy_{we1} = 694.45$

$fy_{we2} = 555.55$

$f_{ce} = 33.00$

From ((5.A.5), TBDY), TBDY: $cc = 0.00332119$
 $c = \text{confinement factor} = 1.13212$
 $y1 = 0.00184318$
 $sh1 = 0.00589816$
 $ft1 = 580.8818$
 $fy1 = 484.0682$
 $su1 = 0.01099427$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 $\text{Shear_factor} = 1.00$
 $lo/lou,min = lb/ld = 0.45297586$
 $su1 = 0.4 * esu1_nominal ((5.5), TBDY) = 0.032$
 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 $fs1 = (fs,jacket * Asl,ten,jacket + fs,core * Asl,ten,core) / Asl,ten = 484.0682$
 with $Es1 = (Es,jacket * Asl,ten,jacket + Es,core * Asl,ten,core) / Asl,ten = 200000.00$
 $y2 = 0.00184318$
 $sh2 = 0.00589816$
 $ft2 = 580.8818$
 $fy2 = 484.0682$
 $su2 = 0.01099427$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 $\text{Shear_factor} = 1.00$
 $lo/lou,min = lb/lb,min = 0.45297586$
 $su2 = 0.4 * esu2_nominal ((5.5), TBDY) = 0.032$
 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 $fs2 = (fs,jacket * Asl,com,jacket + fs,core * Asl,com,core) / Asl,com = 484.0682$
 with $Es2 = (Es,jacket * Asl,com,jacket + Es,core * Asl,com,core) / Asl,com = 200000.00$
 $yv = 0.00184318$
 $shv = 0.00589816$
 $ftv = 614.3968$
 $fyv = 511.9973$
 $suv = 0.01099427$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 $\text{Shear_factor} = 1.00$
 $lo/lou,min = lb/ld = 0.45297586$
 $suv = 0.4 * esuv_nominal ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $esuv_nominal = 0.08$,
 considering characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY
 For calculation of $esuv_nominal$ and yv, shv, ftv, fyv , it is considered
 characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY.
 $y1, sh1, ft1, fy1$, are also multiplied by $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE 41-17.
 with $fsv = (fs,jacket * Asl,mid,jacket + fs,mid * Asl,mid,core) / Asl,mid = 511.9973$
 with $Es_v = (Es,jacket * Asl,mid,jacket + Es,mid * Asl,mid,core) / Asl,mid = 200000.00$
 $1 = Asl,ten / (b * d) * (fs1 / fc) = 0.0851958$
 $2 = Asl,com / (b * d) * (fs2 / fc) = 0.0851958$
 $v = Asl,mid / (b * d) * (fsv / fc) = 0.04369034$
 and confined core properties:
 $b = 340.00$
 $d = 327.00$
 $d' = 13.00$
 $fcc (5A.2, TBDY) = 37.35991$
 $cc (5A.5, TBDY) = 0.00332119$
 $c = \text{confinement factor} = 1.13212$
 $1 = Asl,ten / (b * d) * (fs1 / fc) = 0.1094258$
 $2 = Asl,com / (b * d) * (fs2 / fc) = 0.1094258$
 $v = Asl,mid / (b * d) * (fsv / fc) = 0.05611603$
 Case/Assumption: Unconfined full section - Steel rupture
 ' satisfies Eq. (4.3)

--->

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

--->

$$\mu_u(4.9) = 0.16193824$$

$$\mu_u = M/R_c(4.14) = 1.8194E+008$$

$$u = \mu_u(4.1) = 3.6747033E-005$$

Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.45297586$

$$l_b = 300.00$$

$$l_d = 662.2869$$

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

$$= 1$$

$$d_b = 14.66667$$

Mean strength value of all re-bars: $f_y = 656.5682$

Mean concrete strength: $f_c' = (f_c'_{\text{jacket}} \cdot \text{Area}_{\text{jacket}} + f_c'_{\text{core}} \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 29.75$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 25.00$$

$$K_{tr} = 3.43481$$

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

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

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

$$n = 12.00$$

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 633062.661$

Calculation of Shear Strength at edge 1, $V_{r1} = 633062.661$

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

$$V_{\text{Col}0} = 633062.661$$

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

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

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

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

Mean concrete strength: $f_c' = (f_c'_{\text{jacket}} \cdot \text{Area}_{\text{jacket}} + f_c'_{\text{core}} \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 29.75$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$$M/V_d = 2.00$$

$$\mu_u = 4.3445556E-012$$

$$\mu_v = 2.8976040E-031$$

$$d = 0.8 \cdot h = 320.00$$

$$N_u = 5926.932$$

$$A_g = 160000.00$$

$$\text{From (11.5.4.8), ACI 318-14: } V_s = V_{s1} + V_{s2} = 279254.914$$

where:

$V_{s1} = 279254.914$ is calculated for jacket, with:

$$d = 320.00$$

$$A_v = 157079.633$$

$$f_y = 555.56$$

$$s = 100.00$$

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

$$s/d = 0.3125$$

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

$$d = 160.00$$

$$A_v = 100530.965$$

$$f_y = 444.44$$

$$s = 250.00$$

V_{s2} is multiplied by $\text{Col}2 = 0.00$

$$s/d = 1.5625$$

$$V_f \text{ ((11-3)-(11.4), ACI 440)} = 188111.148$$

$f = 0.95$, 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, $\alpha_1 = 45^\circ$ and $\alpha_2 = -45^\circ$ to take into consideration the cyclic seismic loading.
 orientation 1: $\alpha_1 = b_1 + 90^\circ = 90.00$
 $V_f = \text{Min}(|V_f(45, 1)|, |V_f(-45, a1)|)$, with:
 total thickness per orientation, $tf_1 = NL \cdot t / \text{NoDir} = 1.016$
 $df_v = d$ (figure 11.2, ACI 440) = 357.00
 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: $V_s + V_f \leq 463788.751$
 $bw = 400.00$

Calculation of Shear Strength at edge 2, $V_{r2} = 633062.661$
 $V_{r2} = V_{Col}$ ((10.3), ASCE 41-17) = $k_{nl} \cdot V_{Col0}$
 $V_{Col0} = 633062.661$
 $k_{nl} = 1$ (zero step-static loading)

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

$\gamma = 1$ (normal-weight concrete)
 Mean concrete strength: $f'_c = (f'_{c_jacket} \cdot \text{Area}_{jacket} + f'_{c_core} \cdot \text{Area}_{core}) / \text{Area}_{section} = 29.75$, but $f'_c^{0.5} \leq 8.3$
 MPa (22.5.3.1, ACI 318-14)
 $M/d = 2.00$
 $\mu_u = 4.3445556E-012$
 $\nu_u = 2.8976040E-031$
 $d = 0.8 \cdot h = 320.00$
 $N_u = 5926.932$
 $A_g = 160000.00$
 From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 279254.914$
 where:
 $V_{s1} = 279254.914$ is calculated for jacket, with:
 $d = 320.00$
 $A_v = 157079.633$
 $f_y = 555.56$
 $s = 100.00$
 V_{s1} is multiplied by $Col1 = 1.00$
 $s/d = 0.3125$
 $V_{s2} = 0.00$ is calculated for core, with:
 $d = 160.00$
 $A_v = 100530.965$
 $f_y = 444.44$
 $s = 250.00$
 V_{s2} is multiplied by $Col2 = 0.00$
 $s/d = 1.5625$
 V_f ((11-3)-(11.4), ACI 440) = 188111.148
 $f = 0.95$, 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, $\alpha_1 = 45^\circ$ and $\alpha_2 = -45^\circ$ to take into consideration the cyclic seismic loading.
 orientation 1: $\alpha_1 = b_1 + 90^\circ = 90.00$
 $V_f = \text{Min}(|V_f(45, 1)|, |V_f(-45, a1)|)$, with:
 total thickness per orientation, $tf_1 = NL \cdot t / \text{NoDir} = 1.016$
 $df_v = d$ (figure 11.2, ACI 440) = 357.00
 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: $V_s + V_f \leq 463788.751$

bw = 400.00

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

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

Constant Properties

Knowledge Factor, $\gamma = 0.80$

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

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

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

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

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

Jacket

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

Existing Column

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

#####

External Height, $H = 400.00$

External Width, $W = 400.00$

Internal Height, $H = 200.00$

Internal Width, $W = 200.00$

Cover Thickness, $c = 25.00$

Mean Confinement Factor overall section = 1.13212

Element Length, $L = 3000.00$

Secondary Member

Ribbed Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

Lap Length $l_o = 300.00$

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $e_{fu} = 0.01$

Number of directions, $NoDir = 1$

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, $V_a = -6.6805695E-033$

EDGE -B-

Shear Force, $V_b = 6.6805695E-033$

BOTH EDGES

Axial Force, $F = -5926.932$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: $As_{lt} = 0.00$

-Compression: $As_{lc} = 2060.885$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension: $As_{l,ten} = 829.3805$

-Compression: $As_{l,com} = 829.3805$

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

Calculation of Shear Capacity ratio, $V_e/V_r = 0.19159777$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 121293.391$

with

$M_{pr1} = \text{Max}(Mu_{1+}, Mu_{1-}) = 1.8194E+008$

$Mu_{1+} = 1.8194E+008$, is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination

$Mu_{1-} = 1.8194E+008$, is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination

$M_{pr2} = \text{Max}(Mu_{2+}, Mu_{2-}) = 1.8194E+008$

$Mu_{2+} = 1.8194E+008$, is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the the static loading combination

$Mu_{2-} = 1.8194E+008$, is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the the static loading combination

Calculation of Mu_{1+}

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

$\phi_u = 3.6747033E-005$

$M_u = 1.8194E+008$

with full section properties:

$b = 400.00$

$d = 357.00$

$d' = 43.00$

$v = 0.00125773$

$N = 5926.932$

$f_c = 33.00$

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

Final value of ϕ_u : $\phi_u^* = \text{shear_factor} * \text{Max}(\phi_u, \phi_c) = 0.01505571$

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

From (5.4b), TBDY: $\phi_u = 0.01505571$

$\phi_{we} ((5.4c), TBDY) = \alpha_{se} * \phi_{sh,min} * f_{ywe}/f_{ce} + \text{Min}(\phi_x, \phi_y) = 0.08345896$

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

$\phi_x = 0.07683125$

$\alpha_{pf} = 0.57333333$

$b = 400.00$

$h = 400.00$

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

$b_w = 400.00$

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

$\phi_y = 0.07683125$

$\alpha_{pf} = 0.57333333$

$b = 400.00$

$h = 400.00$

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

bw = 400.00
effective stress from (A.35), $f_{f,e} = 870.5244$

R = 40.00
Effective FRP thickness, $t_f = NL * t * \cos(b1) = 1.016$
 $f_{u,f} = 1055.00$
 $E_f = 64828.00$
 $u_{,f} = 0.015$
 $ase((5.4d), TBDY) = (ase1 * A_{ext} + ase2 * A_{int}) / A_{sec} = 0.24250288$
 $ase1 = 0.24250288$
 $bo_1 = 340.00$
 $ho_1 = 340.00$
 $bi2_1 = 462400.00$
 $ase2 = \text{Max}(ase1, ase2) = 0.24250288$
 $bo_2 = 192.00$
 $ho_2 = 192.00$
 $bi2_2 = 147456.00$

$psh_{,min} * F_{ywe} = \text{Min}(psh_{,x} * F_{ywe}, psh_{,y} * F_{ywe}) = 3.00635$
Expression ((5.4d), TBDY) for $psh_{,min} * F_{ywe}$ has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$psh_{,x} * F_{ywe} = psh1 * F_{ywe1} + ps2 * F_{ywe2} = 3.00635$
 $ps1$ (external) = $(Ash1 * h1 / s1) / A_{sec} = 0.00392699$
 $Ash1 = Astir_1 * ns_1 = 157.0796$
No stirrups, $ns_1 = 2.00$
 $h1 = 400.00$
 $ps2$ (internal) = $(Ash2 * h2 / s2) / A_{sec} = 0.00050265$
 $Ash2 = Astir_2 * ns_2 = 100.531$
No stirrups, $ns_2 = 2.00$
 $h2 = 200.00$

$psh_{,y} * F_{ywe} = psh1 * F_{ywe1} + ps2 * F_{ywe2} = 3.00635$
 $ps1$ (external) = $(Ash1 * h1 / s1) / A_{sec} = 0.00392699$
 $Ash1 = Astir_1 * ns_1 = 157.0796$
No stirrups, $ns_1 = 2.00$
 $h1 = 400.00$
 $ps2$ (internal) = $(Ash2 * h2 / s2) / A_{sec} = 0.00050265$
 $Ash2 = Astir_2 * ns_2 = 100.531$
No stirrups, $ns_2 = 2.00$
 $h2 = 200.00$

$A_{sec} = 160000.00$
 $s1 = 100.00$
 $s2 = 250.00$
 $f_{ywe1} = 694.45$
 $f_{ywe2} = 555.55$
 $f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY: $cc = 0.00332119$
 $c = \text{confinement factor} = 1.13212$

$y1 = 0.00184318$
 $sh1 = 0.00589816$
 $ft1 = 580.8818$
 $fy1 = 484.0682$
 $su1 = 0.01099427$

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

$lo/lo_{u,min} = lb/ld = 0.45297586$
 $su1 = 0.4 * esu1_{nominal}((5.5), TBDY) = 0.032$

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

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

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

with $fs1 = (fs_{jacket} * A_{sl,ten,jacket} + fs_{core} * A_{sl,ten,core}) / A_{sl,ten} = 484.0682$

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

$y2 = 0.00184318$
 $sh2 = 0.00589816$

$$ft2 = 580.8818$$

$$fy2 = 484.0682$$

$$su2 = 0.01099427$$

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

$$lo/lo_{u,min} = lb/lb_{u,min} = 0.45297586$$

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

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

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

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

$$\text{with } fs2 = (fs_{jacket} * Asl_{com,jacket} + fs_{core} * Asl_{com,core}) / Asl_{com} = 484.0682$$

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

$$yv = 0.00184318$$

$$shv = 0.00589816$$

$$ftv = 614.3968$$

$$fyv = 511.9973$$

$$suv = 0.01099427$$

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

$$lo/lo_{u,min} = lb/ld = 0.45297586$$

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

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

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

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

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

$$\text{with } fsv = (fs_{jacket} * Asl_{mid,jacket} + fs_{mid} * Asl_{mid,core}) / Asl_{mid} = 511.9973$$

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

$$1 = Asl_{ten} / (b * d) * (fs1 / fc) = 0.0851958$$

$$2 = Asl_{com} / (b * d) * (fs2 / fc) = 0.0851958$$

$$v = Asl_{mid} / (b * d) * (fsv / fc) = 0.04369034$$

and confined core properties:

$$b = 340.00$$

$$d = 327.00$$

$$d' = 13.00$$

$$fcc (5A.2, TBDY) = 37.35991$$

$$cc (5A.5, TBDY) = 0.00332119$$

$$c = \text{confinement factor} = 1.13212$$

$$1 = Asl_{ten} / (b * d) * (fs1 / fc) = 0.1094258$$

$$2 = Asl_{com} / (b * d) * (fs2 / fc) = 0.1094258$$

$$v = Asl_{mid} / (b * d) * (fsv / fc) = 0.05611603$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

---->

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

---->

$$su (4.9) = 0.16193824$$

$$Mu = MRc (4.14) = 1.8194E+008$$

$$u = su (4.1) = 3.6747033E-005$$

Calculation of ratio lb/ld

Lap Length: $lb/ld = 0.45297586$

$$lb = 300.00$$

$$ld = 662.2869$$

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

$$= 1$$

$$db = 14.66667$$

Mean strength value of all re-bars: $fy = 656.5682$

Mean concrete strength: $fc' = (fc'_{jacket} * Area_{jacket} + fc'_{core} * Area_{core}) / Area_{section} = 29.75$, but $fc'^{0.5} \leq 8.3$

MPa (22.5.3.1, ACI 318-14)

$$t = 1.00$$

$$s = 0.80$$

e = 1.00
cb = 25.00
Ktr = 3.43481
Atr = Min(Atr_x,Atr_y) = 257.6106
where Atr_x, Atr_y are the sum of the area of all stirrup legs along X and Y loxal axis
s = Max(s_external,s_internal) = 250.00
n = 12.00

Calculation of Mu1-

Calculation of ultimate curvature ϕ_u according to 4.1, Biskinis/Fardis 2013:
u = 3.6747033E-005
Mu = 1.8194E+008

with full section properties:

b = 400.00
d = 357.00
d' = 43.00
v = 0.00125773
N = 5926.932
fc = 33.00
co (5A.5, TBDY) = 0.002
Final value of ϕ_u : $\phi_u^* = \text{shear_factor} * \text{Max}(\phi_u, \phi_c) = 0.01505571$
The Shear_factor is considered equal to 1 (pure moment strength)
From (5.4b), TBDY: $\phi_u = 0.01505571$
 ϕ_{we} ((5.4c), TBDY) = $\text{ase} * \text{sh}_{\min} * \text{fy}_{we} / \text{f}_{ce} + \text{Min}(\phi_x, \phi_y) = 0.08345896$
where $\phi = \text{af} * \text{pf} * \text{ff}_e / \text{f}_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

 $\phi_x = 0.07683125$
 $\text{af} = 0.57333333$
b = 400.00
h = 400.00
From EC8 A.4.4.3(6), $\text{pf} = 2\text{tf}/\text{bw} = 0.00508$
bw = 400.00
effective stress from (A.35), $\text{ff}_e = 870.5244$

 $\phi_y = 0.07683125$
 $\text{af} = 0.57333333$
b = 400.00
h = 400.00
From EC8 A.4.4.3(6), $\text{pf} = 2\text{tf}/\text{bw} = 0.00508$
bw = 400.00
effective stress from (A.35), $\text{ff}_e = 870.5244$

R = 40.00
Effective FRP thickness, $\text{tf} = \text{NL} * \text{t} * \text{Cos}(b1) = 1.016$
 $\text{fu}_f = 1055.00$
 $E_f = 64828.00$
 $u_{f} = 0.015$
 ase ((5.4d), TBDY) = $(\text{ase1} * \text{A}_{\text{ext}} + \text{ase2} * \text{A}_{\text{int}}) / \text{A}_{\text{sec}} = 0.24250288$
 $\text{ase1} = 0.24250288$
 $\text{bo}_1 = 340.00$
 $\text{ho}_1 = 340.00$
 $\text{bi2}_1 = 462400.00$
 $\text{ase2} = \text{Max}(\text{ase1}, \text{ase2}) = 0.24250288$
 $\text{bo}_2 = 192.00$
 $\text{ho}_2 = 192.00$
 $\text{bi2}_2 = 147456.00$

$\text{psh}_{\min} * \text{Fy}_{we} = \text{Min}(\text{psh}_x * \text{Fy}_{we}, \text{psh}_y * \text{Fy}_{we}) = 3.00635$
Expression ((5.4d), TBDY) for $\text{psh}_{\min} * \text{Fy}_{we}$ has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

 $\text{psh}_x * \text{Fy}_{we} = \text{psh1} * \text{Fy}_{we1} + \text{ps2} * \text{Fy}_{we2} = 3.00635$

ps1 (external) = $(Ash1 \cdot h1 / s1) / Asec = 0.00392699$
Ash1 = Astir_1 * ns_1 = 157.0796
No stirups, ns_1 = 2.00
h1 = 400.00
ps2 (internal) = $(Ash2 \cdot h2 / s2) / Asec = 0.00050265$
Ash2 = Astir_2 * ns_2 = 100.531
No stirups, ns_2 = 2.00
h2 = 200.00

psh_y * Fywe = psh1 * Fywe1 + ps2 * Fywe2 = 3.00635
ps1 (external) = $(Ash1 \cdot h1 / s1) / Asec = 0.00392699$
Ash1 = Astir_1 * ns_1 = 157.0796
No stirups, ns_1 = 2.00
h1 = 400.00
ps2 (internal) = $(Ash2 \cdot h2 / s2) / Asec = 0.00050265$
Ash2 = Astir_2 * ns_2 = 100.531
No stirups, ns_2 = 2.00
h2 = 200.00

Asec = 160000.00
s1 = 100.00
s2 = 250.00
fywe1 = 694.45
fywe2 = 555.55
fce = 33.00

From ((5.A5), TBDY), TBDY: cc = 0.00332119
c = confinement factor = 1.13212

y1 = 0.00184318
sh1 = 0.00589816
ft1 = 580.8818
fy1 = 484.0682
su1 = 0.01099427

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

lo/lou,min = lb/lb = 0.45297586
su1 = $0.4 \cdot esu1_nominal$ ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu1_nominal = 0.08,
For calculation of esu1_nominal and y1, sh1, ft1, fy1, it is considered
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1, ft1, fy1, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/lb)^{2/3})$, from 10.3.5, ASCE 41-17.
with fs1 = $(fs_jacket \cdot Asl,ten,jacket + fs_core \cdot Asl,ten,core) / Asl,ten = 484.0682$
with Es1 = $(Es_jacket \cdot Asl,ten,jacket + Es_core \cdot Asl,ten,core) / Asl,ten = 200000.00$

y2 = 0.00184318
sh2 = 0.00589816
ft2 = 580.8818
fy2 = 484.0682
su2 = 0.01099427

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

lo/lou,min = lb/lb,min = 0.45297586
su2 = $0.4 \cdot esu2_nominal$ ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu2_nominal = 0.08,
For calculation of esu2_nominal and y2, sh2, ft2, fy2, it is considered
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

y1, sh1, ft1, fy1, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/lb)^{2/3})$, from 10.3.5, ASCE 41-17.
with fs2 = $(fs_jacket \cdot Asl,com,jacket + fs_core \cdot Asl,com,core) / Asl,com = 484.0682$
with Es2 = $(Es_jacket \cdot Asl,com,jacket + Es_core \cdot Asl,com,core) / Asl,com = 200000.00$

yv = 0.00184318
shv = 0.00589816
ftv = 614.3968
fyv = 511.9973
suv = 0.01099427

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

$$l_0/l_{ou,min} = l_b/l_d = 0.45297586$$

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

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

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

For calculation of $e_{suv_nominal}$ and γ_v , sh_v, ft_v, fy_v , it is considered

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

$$\gamma_1, sh_1, ft_1, fy_1, \text{ are also multiplied by } \text{Min}(1, 1.25 * (l_b/l_d)^{2/3}), \text{ from 10.3.5, ASCE 41-17.}$$

$$\text{with } f_{sv} = (f_{s,jacket} * A_{s,mid,jacket} + f_{s,mid} * A_{s,mid,core}) / A_{s,mid} = 511.9973$$

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

$$1 = A_{s,ten} / (b * d) * (f_{s1} / f_c) = 0.0851958$$

$$2 = A_{s,com} / (b * d) * (f_{s2} / f_c) = 0.0851958$$

$$v = A_{s,mid} / (b * d) * (f_{sv} / f_c) = 0.04369034$$

and confined core properties:

$$b = 340.00$$

$$d = 327.00$$

$$d' = 13.00$$

$$f_{cc} (5A.2, TBDY) = 37.35991$$

$$c_c (5A.5, TBDY) = 0.00332119$$

$$c = \text{confinement factor} = 1.13212$$

$$1 = A_{s,ten} / (b * d) * (f_{s1} / f_c) = 0.1094258$$

$$2 = A_{s,com} / (b * d) * (f_{s2} / f_c) = 0.1094258$$

$$v = A_{s,mid} / (b * d) * (f_{sv} / f_c) = 0.05611603$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

$$s_u (4.9) = 0.16193824$$

$$M_u = M_{Rc} (4.14) = 1.8194E+008$$

$$u = s_u (4.1) = 3.6747033E-005$$

Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.45297586$

$$l_b = 300.00$$

$$l_d = 662.2869$$

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

$$= 1$$

$$d_b = 14.66667$$

Mean strength value of all re-bars: $f_y = 656.5682$

Mean concrete strength: $f'_c = (f'_{c,jacket} * Area_{jacket} + f'_{c,core} * Area_{core}) / Area_{section} = 29.75$, but $f_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 25.00$$

$$K_{tr} = 3.43481$$

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

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

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

$$n = 12.00$$

Calculation of M_u

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

$$u = 3.6747033E-005$$

$$M_u = 1.8194E+008$$

with full section properties:

$$b = 400.00$$

$$d = 357.00$$

$$d' = 43.00$$

$$v = 0.00125773$$

$$N = 5926.932$$

$$f_c = 33.00$$

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

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.01505571$$

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

$$\text{From (5.4b), TBDY: } c_u = 0.01505571$$

$$\text{we ((5.4c), TBDY)} = a_{se} * s_{h,\min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.08345896$$

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

$$f_x = 0.07683125$$

$$a_f = 0.573333333$$

$$b = 400.00$$

$$h = 400.00$$

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

$$b_w = 400.00$$

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

$$f_y = 0.07683125$$

$$a_f = 0.573333333$$

$$b = 400.00$$

$$h = 400.00$$

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

$$b_w = 400.00$$

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

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$a_{se} \text{ ((5.4d), TBDY)} = (a_{se1} * A_{ext} + a_{se2} * A_{int}) / A_{sec} = 0.24250288$$

$$a_{se1} = 0.24250288$$

$$b_{o,1} = 340.00$$

$$h_{o,1} = 340.00$$

$$b_{i,2,1} = 462400.00$$

$$a_{se2} = \text{Max}(a_{se1}, a_{se2}) = 0.24250288$$

$$b_{o,2} = 192.00$$

$$h_{o,2} = 192.00$$

$$b_{i,2,2} = 147456.00$$

$$p_{sh,\min} * F_{ywe} = \text{Min}(p_{sh,x} * F_{ywe}, p_{sh,y} * F_{ywe}) = 3.00635$$

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

$$p_{sh,x} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{sh2} * F_{ywe2} = 3.00635$$

$$p_{s1} \text{ (external)} = (A_{sh1} * h_1 / s_1) / A_{sec} = 0.00392699$$

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

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

$$h_1 = 400.00$$

$$p_{s2} \text{ (internal)} = (A_{sh2} * h_2 / s_2) / A_{sec} = 0.00050265$$

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

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

$$h_2 = 200.00$$

$$p_{sh,y} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{sh2} * F_{ywe2} = 3.00635$$

$$p_{s1} \text{ (external)} = (A_{sh1} * h_1 / s_1) / A_{sec} = 0.00392699$$

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

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

$$h_1 = 400.00$$

$$p_{s2} \text{ (internal)} = (A_{sh2} * h_2 / s_2) / A_{sec} = 0.00050265$$

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

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

$$h_2 = 200.00$$

$$A_{sec} = 160000.00$$

$$s_1 = 100.00$$

$$s_2 = 250.00$$

fywe1 = 694.45
fywe2 = 555.55
fce = 33.00

From ((5.A.5), TBDY), TBDY: cc = 0.00332119
c = confinement factor = 1.13212

y1 = 0.00184318
sh1 = 0.00589816
ft1 = 580.8818
fy1 = 484.0682
su1 = 0.01099427

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

lo/lou,min = lb/ld = 0.45297586

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 = 484.0682

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

y2 = 0.00184318
sh2 = 0.00589816
ft2 = 580.8818
fy2 = 484.0682
su2 = 0.01099427

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

lo/lou,min = lb/lb,min = 0.45297586

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 = 484.0682

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

yv = 0.00184318
shv = 0.00589816
ftv = 614.3968
fyv = 511.9973
suv = 0.01099427

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

lo/lou,min = lb/ld = 0.45297586

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 = 511.9973

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

1 = Asl,ten/(b*d)*(fs1/fc) = 0.0851958

2 = Asl,com/(b*d)*(fs2/fc) = 0.0851958

v = Asl,mid/(b*d)*(fsv/fc) = 0.04369034

and confined core properties:

b = 340.00
d = 327.00
d' = 13.00

fcc (5A.2, TBDY) = 37.35991

cc (5A.5, TBDY) = 0.00332119

c = confinement factor = 1.13212

1 = Asl,ten/(b*d)*(fs1/fc) = 0.1094258

2 = Asl,com/(b*d)*(fs2/fc) = 0.1094258

v = Asl,mid/(b*d)*(fsv/fc) = 0.05611603

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

--->
v < vs,y2 - LHS eq.(4.5) is satisfied
--->
su (4.9) = 0.16193824
Mu = MRc (4.14) = 1.8194E+008
u = su (4.1) = 3.6747033E-005

Calculation of ratio lb/l_d

Lap Length: lb/l_d = 0.45297586
lb = 300.00
l_d = 662.2869
Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
= 1
db = 14.66667
Mean strength value of all re-bars: fy = 656.5682
Mean concrete strength: fc' = (fc'_jacket*Area_jacket + fc'_core*Area_core)/Area_section = 29.75, but fc'^0.5 <= 8.3
MPa (22.5.3.1, ACI 318-14)
t = 1.00
s = 0.80
e = 1.00
cb = 25.00
Ktr = 3.43481
Atr = Min(Atr_x,Atr_y) = 257.6106
where Atr_x, Atr_y are the sum of the area of all stirrup legs along X and Y local axis
s = Max(s_external,s_internal) = 250.00
n = 12.00

Calculation of Mu2-

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:
u = 3.6747033E-005
Mu = 1.8194E+008

with full section properties:

b = 400.00
d = 357.00
d' = 43.00
v = 0.00125773
N = 5926.932
fc = 33.00
co (5A.5, TBDY) = 0.002
Final value of cu: cu* = shear_factor * Max(cu, cc) = 0.01505571
The Shear_factor is considered equal to 1 (pure moment strength)
From (5.4b), TBDY: cu = 0.01505571
we ((5.4c), TBDY) = ase* sh,min*fywe/fce+Min(fx, fy) = 0.08345896
where f = af*pf*ffe/fce is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

fx = 0.07683125
af = 0.57333333
b = 400.00
h = 400.00
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 = 0.07683125
af = 0.57333333
b = 400.00
h = 400.00

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, $tf = NL*t*\text{Cos}(b1) = 1.016$
 $f_{u,f} = 1055.00$
 $E_f = 64828.00$
 $u_{,f} = 0.015$
 $ase((5.4d), \text{TBDY}) = (ase1*A_{ext} + ase2*A_{int})/A_{sec} = 0.24250288$
 $ase1 = 0.24250288$
 $bo_1 = 340.00$
 $ho_1 = 340.00$
 $bi2_1 = 462400.00$
 $ase2 = \text{Max}(ase1, ase2) = 0.24250288$
 $bo_2 = 192.00$
 $ho_2 = 192.00$
 $bi2_2 = 147456.00$

$psh_{,min}*F_{ywe} = \text{Min}(psh_{,x}*F_{ywe}, psh_{,y}*F_{ywe}) = 3.00635$
Expression ((5.4d), TBDY) for $psh_{,min}*F_{ywe}$ has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$psh_{,x}*F_{ywe} = psh1*F_{ywe1} + ps2*F_{ywe2} = 3.00635$
 $ps1$ (external) = $(Ash1*h1/s1)/A_{sec} = 0.00392699$
 $Ash1 = Astir_1*ns_1 = 157.0796$
No stirrups, $ns_1 = 2.00$
 $h1 = 400.00$
 $ps2$ (internal) = $(Ash2*h2/s2)/A_{sec} = 0.00050265$
 $Ash2 = Astir_2*ns_2 = 100.531$
No stirrups, $ns_2 = 2.00$
 $h2 = 200.00$

$psh_{,y}*F_{ywe} = psh1*F_{ywe1} + ps2*F_{ywe2} = 3.00635$
 $ps1$ (external) = $(Ash1*h1/s1)/A_{sec} = 0.00392699$
 $Ash1 = Astir_1*ns_1 = 157.0796$
No stirrups, $ns_1 = 2.00$
 $h1 = 400.00$
 $ps2$ (internal) = $(Ash2*h2/s2)/A_{sec} = 0.00050265$
 $Ash2 = Astir_2*ns_2 = 100.531$
No stirrups, $ns_2 = 2.00$
 $h2 = 200.00$

$A_{sec} = 160000.00$
 $s1 = 100.00$
 $s2 = 250.00$
 $f_{ywe1} = 694.45$
 $f_{ywe2} = 555.55$
 $f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY: $cc = 0.00332119$
 $c = \text{confinement factor} = 1.13212$

$y1 = 0.00184318$
 $sh1 = 0.00589816$
 $ft1 = 580.8818$
 $fy1 = 484.0682$
 $su1 = 0.01099427$

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

$lo/lou_{,min} = lb/d = 0.45297586$
 $su1 = 0.4*esu1_{,nominal}((5.5), \text{TBDY}) = 0.032$

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

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

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

with $fs1 = (fs_{,jacket}*A_{sl,ten,jacket} + fs_{,core}*A_{sl,ten,core})/A_{sl,ten} = 484.0682$

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

$y2 = 0.00184318$

$sh_2 = 0.00589816$
 $ft_2 = 580.8818$
 $fy_2 = 484.0682$
 $su_2 = 0.01099427$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $lo/lo_{min} = lb/lb_{min} = 0.45297586$
 $su_2 = 0.4 * esu_{2,nominal} ((5.5), TBDY) = 0.032$
 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 $Min(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE 41-17.
 with $fs_2 = (fs_{jacket} * Asl_{com,jacket} + fs_{core} * Asl_{com,core}) / Asl_{com} = 484.0682$
 with $Es_2 = (Es_{jacket} * Asl_{com,jacket} + Es_{core} * Asl_{com,core}) / Asl_{com} = 200000.00$
 $yv = 0.00184318$
 $shv = 0.00589816$
 $ftv = 614.3968$
 $fyv = 511.9973$
 $suv = 0.01099427$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $lo/lo_{min} = lb/ld = 0.45297586$
 $suv = 0.4 * esuv_{nominal} ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $esuv_{nominal} = 0.08$,
 considering characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY
 For calculation of $esuv_{nominal}$ and yv, shv, ftv, fyv , it is considered
 characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $Min(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE 41-17.
 with $fsv = (fs_{jacket} * Asl_{mid,jacket} + fs_{mid} * Asl_{mid,core}) / Asl_{mid} = 511.9973$
 with $Es_v = (Es_{jacket} * Asl_{mid,jacket} + Es_{mid} * Asl_{mid,core}) / Asl_{mid} = 200000.00$
 $1 = Asl_{ten} / (b * d) * (fs_1 / fc) = 0.0851958$
 $2 = Asl_{com} / (b * d) * (fs_2 / fc) = 0.0851958$
 $v = Asl_{mid} / (b * d) * (fsv / fc) = 0.04369034$

and confined core properties:

$b = 340.00$
 $d = 327.00$
 $d' = 13.00$
 $fcc (5A.2, TBDY) = 37.35991$
 $cc (5A.5, TBDY) = 0.00332119$
 $c = \text{confinement factor} = 1.13212$
 $1 = Asl_{ten} / (b * d) * (fs_1 / fc) = 0.1094258$
 $2 = Asl_{com} / (b * d) * (fs_2 / fc) = 0.1094258$
 $v = Asl_{mid} / (b * d) * (fsv / fc) = 0.05611603$

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

--->
 $v < v_{s,y_2}$ - LHS eq.(4.5) is satisfied
 --->
 $su (4.9) = 0.16193824$
 $Mu = MRc (4.14) = 1.8194E+008$
 $u = su (4.1) = 3.6747033E-005$

Calculation of ratio lb/ld

Lap Length: $lb/ld = 0.45297586$
 $lb = 300.00$
 $ld = 662.2869$
 Calculation of lb_{min} according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
 $= 1$
 $db = 14.66667$
 Mean strength value of all re-bars: $fy = 656.5682$
 Mean concrete strength: $fc' = (fc'_{jacket} * Area_{jacket} + fc'_{core} * Area_{core}) / Area_{section} = 29.75$, but $fc'^{0.5} \leq 8.3$
 MPa (22.5.3.1, ACI 318-14)
 $t = 1.00$

$s = 0.80$
 $e = 1.00$
 $cb = 25.00$
 $K_{tr} = 3.43481$
 $A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 257.6106$
 where A_{tr_x} , A_{tr_y} are the sum of the area of all stirrup legs along X and Y loxal axis
 $s = \text{Max}(s_{\text{external}}, s_{\text{internal}}) = 250.00$
 $n = 12.00$

 Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 633062.661$

Calculation of Shear Strength at edge 1, $V_{r1} = 633062.661$
 $V_{r1} = V_{Col} \text{ ((10.3), ASCE 41-17)} = k_{nl} * V_{Col0}$
 $V_{Col0} = 633062.661$
 $k_{nl} = 1$ (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: $f_c' = (f_c'_{\text{jacket}} * \text{Area}_{\text{jacket}} + f_c'_{\text{core}} * \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 29.75$, but $f_c'^{0.5} \leq 8.3$
 MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$
 $\mu_u = 4.6931004E-013$
 $\nu_u = 6.6805695E-033$
 $d = 0.8 * h = 320.00$
 $N_u = 5926.932$
 $A_g = 160000.00$
 From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 279254.914$
 where:

$V_{s1} = 279254.914$ is calculated for jacket, with:
 $d = 320.00$
 $A_v = 157079.633$
 $f_y = 555.56$
 $s = 100.00$

V_{s1} is multiplied by $\text{Col1} = 1.00$
 $s/d = 0.3125$

$V_{s2} = 0.00$ is calculated for core, with:
 $d = 160.00$
 $A_v = 100530.965$
 $f_y = 444.44$
 $s = 250.00$

V_{s2} is multiplied by $\text{Col2} = 0.00$
 $s/d = 1.5625$

$V_f \text{ ((11-3)-(11.4), ACI 440)} = 188111.148$
 $f = 0.95$, 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 $V_f(\alpha, a_i)$, is implemented for every different fiber orientation a_i ,
 as well as for 2 crack directions, $\alpha = 45^\circ$ and $\alpha = -45^\circ$ to take into consideration the cyclic seismic loading.

orientation 1: $\alpha = b1 + 90^\circ = 90.00$
 $V_f = \text{Min}(|V_f(45, 1)|, |V_f(-45, a1)|)$, with:
 total thickness per orientation, $t_{f1} = N_L * t / N_{oDir} = 1.016$

$d_{fv} = d$ (figure 11.2, ACI 440) = 357.00
 $f_{fe} \text{ ((11-5), ACI 440)} = 259.312$

$E_f = 64828.00$
 $f_e = 0.004$, from (11.6a), ACI 440
 with $f_u = 0.01$

From (11-11), ACI 440: $V_s + V_f \leq 463788.751$
 $b_w = 400.00$

 Calculation of Shear Strength at edge 2, $V_{r2} = 633062.661$

Vr2 = VCol ((10.3), ASCE 41-17) = knl*VCol0

VCol0 = 633062.661

kn1 = 1 (zero step-static loading)

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

= 1 (normal-weight concrete)

Mean concrete strength: fc' = (fc'_jacket*Area_jacket + fc'_core*Area_core)/Area_section = 29.75, but fc'^0.5 <= 8.3 MPa (22.5.3.1, ACI 318-14)

M/Vd = 2.00

Mu = 4.6931004E-013

Vu = 6.6805695E-033

d = 0.8*h = 320.00

Nu = 5926.932

Ag = 160000.00

From (11.5.4.8), ACI 318-14: Vs = Vs1 + Vs2 = 279254.914

where:

Vs1 = 279254.914 is calculated for jacket, with:

d = 320.00

Av = 157079.633

fy = 555.56

s = 100.00

Vs1 is multiplied by Col1 = 1.00

s/d = 0.3125

Vs2 = 0.00 is calculated for core, with:

d = 160.00

Av = 100530.965

fy = 444.44

s = 250.00

Vs2 is multiplied by Col2 = 0.00

s/d = 1.5625

Vf ((11-3)-(11.4), ACI 440) = 188111.148

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) = 357.00

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 <= 463788.751

bw = 400.00

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

At local axis: 2

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

At local axis: 3

Integration Section: (a)

Section Type: rcjrs

Constant Properties

Knowledge Factor, = 0.80

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

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

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

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

External Height, $H = 400.00$

External Width, $W = 400.00$

Internal Height, $H = 200.00$

Internal Width, $W = 200.00$

Cover Thickness, $c = 25.00$

Element Length, $L = 3000.00$

Secondary Member

Ribbed Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

Lap Length $l_b = 300.00$

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $e_{fu} = 0.01$

Number of directions, $NoDir = 1$

Fiber orientations, $b_i = 0.00^\circ$

Number of layers, $NL = 1$

Radius of rounding corners, $R = 40.00$

Stepwise Properties

Bending Moment, $M = -2.2502E+007$

Shear Force, $V_2 = -7481.276$

Shear Force, $V_3 = 1.2884777E-015$

Axial Force, $F = -6438.97$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: $As_t = 829.3805$

-Compression: $As_c = 1231.504$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

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

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

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

Longitudinal External Reinforcement Area Distribution (in 3 divisions)

-Tension: $As_{,ten,jacket} = 603.1858$

-Compression: $As_{,com,jacket} = 603.1858$

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

Longitudinal Internal Reinforcement Area Distribution (in 3 divisions)

-Tension: $As_{,ten,core} = 226.1947$

-Compression: $As_{,com,core} = 226.1947$

-Middle: $As_{,mid,core} = 0.00$

Mean Diameter of Tension Reinforcement, $Db_L = 14.40$

Existing component: From table 7-7, ASCE 41_17: Final chord rotation Capacity $u_{,R} = * u = 0.00666306$

$u = y + p = 0.00832882$

- Calculation of y -

$y = (M_y * L_s / 3) / E_{eff} = 0.00832882$ ((4.29), Biskinis Phd)
 $M_y = 1.4156E+008$
 $L_s = M/V$ (with $L_s > 0.1 * L$ and $L_s < 2 * L$) = 3007.725
 From table 10.5, ASCE 41_17: $E_{eff} = factor * E_c * I_g = 1.7040E+013$
 $factor = 0.30$
 $A_g = 160000.00$
 Mean concrete strength: $f'_c = (f'_{c_jacket} * Area_{jacket} + f'_{c_core} * Area_{core}) / Area_{section} = 29.75$
 $N = 6438.97$
 $E_c * I_g = E_{c_jacket} * I_{g_jacket} + E_{c_core} * I_{g_core} = 5.6801E+013$

Calculation of Yielding Moment M_y

Calculation of y and M_y according to Annex 7 -

$y = \text{Min}(y_{ten}, y_{com})$
 $y_{ten} = 8.5640402E-006$
 with ((10.1), ASCE 41-17) $f_y = \text{Min}(f_y, 1.25 * f_y * (I_b / I_d)^{2/3}) = 454.4281$
 $d = 357.00$
 $y = 0.2568299$
 $A = 0.01453119$
 $B = 0.00818436$
 with $pt = 0.00680078$
 $pc = 0.00580799$
 $pv = 0.00281599$
 $N = 6438.97$
 $b = 400.00$
 $" = 0.12044818$
 $y_{comp} = 2.5296911E-005$
 with f'_c (12.3, (ACI 440)) = 34.65599
 $f_c = 33.00$
 $f_l = 0.93147527$
 $b = 400.00$
 $h = 400.00$
 $A_g = 160000.00$
 From (12.9), ACI 440: $k_a = 0.56708553$
 $g = pt + pc + pv = 0.01443197$
 $rc = 40.00$
 $A_e / A_c = 0.56708553$
 Effective FRP thickness, $t_f = N L * t * \text{Cos}(b_1) = 1.016$
 effective strain from (12.5) and (12.12), $\epsilon_{fe} = 0.004$
 $f_u = 0.01$
 $E_f = 64828.00$
 $E_c = 26999.444$
 $y = 0.25583518$
 $A = 0.01433439$
 $B = 0.00808514$
 with $E_s = 200000.00$

Calculation of ratio I_b / I_d

Lap Length: $I_d / I_{d,min} = 0.56621983$

$I_b = 300.00$

$I_d = 529.8296$

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

= 1

$db = 14.66667$

Mean strength value of all re-bars: $f_y = 525.2545$

Mean concrete strength: $f'_c = (f'_{c_jacket} * Area_{jacket} + f'_{c_core} * Area_{core}) / Area_{section} = 29.75$, but $f_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

cb = 25.00
Ktr = 3.43481
Atr = Min(Atr_x,Atr_y) = 257.6106
where Atr_x, Atr_y are the sum of the area of all stirrup legs along X and Y loxal axis
s = Max(s_external,s_internal) = 250.00
n = 12.00

- Calculation of p -

From table 10-8: p = 0.00

with:

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

shear control ratio $V_y E / V_{CoI} O E = 0.19159777$

d = d_external = 357.00

s = s_external = 0.00

t = s1 + s2 + 2*tf/bw*(ffe/fs) = 0.00680078

jacket: s1 = Av1*h1/(s1*Ag) = 0.00392699

Av1 = 157.0796, is the total area of all stirrups parallel to loading (shear) direction

h1 = 400.00

s1 = 100.00

core: s2 = Av2*h2/(s2*Ag) = 0.00050265

Av2 = 100.531, is the total area of all stirrups parallel to loading (shear) direction

h2 = 200.00

s2 = 250.00

The term $2*tf/bw*(ffe/fs)$ is implemented to account for FRP contribution

where $f = 2*tf/bw$ is FRP ratio (EC8 - 3, A.4.4.3(6)) and ffe/fs normalises f to steel strength

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

For the normalisation fs of jacket is used.

NUD = 6438.97

Ag = 160000.00

f_{cE} = (f_{c,jacket}*Area_{jacket}+ f_{c,core}*Area_{core})/section_area = 29.75

f_{yI}E = (f_{y,ext}_Long_Reinf*Area_ext_Long_Reinf+ f_{y,int}_Long_Reinf*Area_int_Long_Reinf)/Area_Tot_Long_Rein = 531.1678

f_{yT}E = (f_{y,ext}_Trans_Reinf*Area_ext_Trans_Reinf+ f_{y,int}_Trans_Reinf*Area_int_Trans_Reinf)/Area_Tot_Trans_Rein = 542.9506

p_l = Area_Tot_Long_Rein/(b*d) = 0.01443197

b = 400.00

d = 357.00

f_{cE} = 29.75

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

At local axis: 3

Integration Section: (a)

Calculation No. 5

column C1, Floor 1

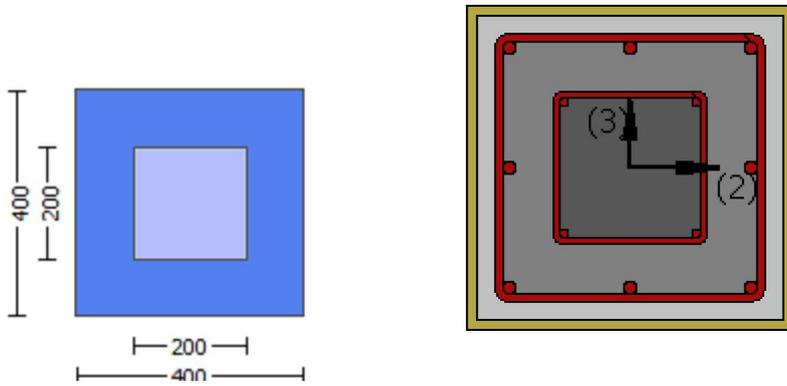
Limit State: Immediate Occupancy (data interpolation between analysis steps 2 and 3)

Analysis: Uniform +X

Check: Shear capacity VRd

Edge: End

Local Axis: (2)



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

At local axis: 2

Integration Section: (b)

Section Type: rcjrs

Constant Properties

Knowledge Factor, $\gamma = 0.80$

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

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

Consequently:

Jacket

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

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

Concrete Elasticity, $E_c = 26999.444$

Steel Elasticity, $E_s = 200000.00$

Existing Column

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

Existing material of Secondary Member: Steel Strength, $f_s = f_{s_lower_bound} = 400.00$

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

#####

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

Jacket

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

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

Existing Column

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

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

#####

External Height, $H = 400.00$

External Width, $W = 400.00$

Internal Height, $H = 200.00$

Internal Width, $W = 200.00$

Cover Thickness, $c = 25.00$

Element Length, $L = 3000.00$

Secondary Member

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

Stepwise Properties

EDGE -A-
Bending Moment, $M_a = -2.2502E+007$
Shear Force, $V_a = -7481.276$
EDGE -B-
Bending Moment, $M_b = 46945.948$
Shear Force, $V_b = 7481.276$
BOTH EDGES
Axial Force, $F = -6438.97$
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: $A_{sl,t} = 0.00$
-Compression: $A_{sl,c} = 2060.885$
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension: $A_{sl,ten} = 829.3805$
-Compression: $A_{sl,com} = 829.3805$
-Middle: $A_{sl,mid} = 402.1239$
Mean Diameter of Tension Reinforcement, $Db_{L,ten} = 14.40$

Existing component: From table 7-7, ASCE 41_17: Final Shear Capacity $V_R = \phi V_n = 447154.557$
 V_n ((10.3), ASCE 41-17) = $k_n l^* V_{CoI0} = 558943.196$
 $V_{CoI} = 558943.196$
 $k_n l = 1.00$
displacement_ductility_demand = 0.23936023

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

= 1 (normal-weight concrete)
Mean concrete strength: $f_c' = (f_c'_{jacket} * Area_{jacket} + f_c'_{core} * Area_{core}) / Area_{section} = 22.75$, but $f_c'^{0.5} \leq 8.3$
MPa (22.5.3.1, ACI 318-14)
 $M / Vd = 2.00$
 $M_u = 46945.948$
 $V_u = 7481.276$
 $d = 0.8 * h = 320.00$
 $N_u = 6438.97$
 $A_g = 160000.00$
From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 251327.412$
where:
 $V_{s1} = 251327.412$ is calculated for jacket, with:
 $d = 320.00$
 $A_v = 157079.633$
 $f_y = 500.00$
 $s = 100.00$
 V_{s1} is multiplied by $CoI1 = 1.00$
 $s/d = 0.3125$

Vs2 = 0.00 is calculated for core, with:

$$d = 160.00$$

$$A_v = 100530.965$$

$$f_y = 400.00$$

$$s = 250.00$$

Vs2 is multiplied by Col2 = 0.00

$$s/d = 1.5625$$

Vf ((11-3)-(11.4), ACI 440) = 188111.148

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

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

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

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

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

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

Vf = Min(|Vf(45, θ)|, |Vf(-45, θ)|), with:

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

dfv = d (figure 11.2, ACI 440) = 357.00

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

$$E_f = 64828.00$$

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

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

From (11-11), ACI 440: Vs + Vf <= 405571.497

$$b_w = 400.00$$

displacement ductility demand is calculated as δ / y

- Calculation of δ / y for END B -

for rotation axis 3 and integ. section (b)

From analysis, chord rotation $\theta = 0.00019885$

$$y = (M_y * L_s / 3) / E_{\text{eff}} = 0.00083074 \text{ ((4.29), Biskinis Phd)}$$

$$M_y = 1.4156E+008$$

$$L_s = M/V \text{ (with } L_s > 0.1 * L \text{ and } L_s < 2 * L) = 300.00$$

From table 10.5, ASCE 41_17: $E_{\text{eff}} = \text{factor} * E_c * I_g = 1.7040E+013$

$$\text{factor} = 0.30$$

$$A_g = 160000.00$$

$$\text{Mean concrete strength: } f_c' = (f_c'_{\text{jacket}} * \text{Area}_{\text{jacket}} + f_c'_{\text{core}} * \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 29.75$$

$$N = 6438.97$$

$$E_c * I_g = E_c_{\text{jacket}} * I_{g_{\text{jacket}}} + E_c_{\text{core}} * I_{g_{\text{core}}} = 5.6801E+013$$

Calculation of Yielding Moment My

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

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

$$y_{\text{ten}} = 8.5640402E-006$$

$$\text{with ((10.1), ASCE 41-17) } f_y = \text{Min}(f_y, 1.25 * f_y * (I_b / d)^{2/3}) = 454.4281$$

$$d = 357.00$$

$$y = 0.2568299$$

$$A = 0.01453119$$

$$B = 0.00818436$$

$$\text{with } p_t = 0.00580799$$

$$p_c = 0.00580799$$

$$p_v = 0.00281599$$

$$N = 6438.97$$

$$b = 400.00$$

$$" = 0.12044818$$

$$y_{\text{comp}} = 2.5296911E-005$$

with $f_c' * (12.3, \text{ (ACI 440)}) = 34.65599$

$$f_c = 33.00$$

$$f_l = 0.93147527$$

$$b = 400.00$$

h = 400.00
Ag = 160000.00
From (12.9), ACI 440: ka = 0.56708553
g = pt + pc + pv = 0.01443197
rc = 40.00
Ae/Ac = 0.56708553
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 = 0.25583518
A = 0.01433439
B = 0.00808514
with Es = 200000.00

Calculation of ratio lb/ld

Lap Length: ld/ld,min = 0.56621983

lb = 300.00

ld = 529.8296

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

= 1

db = 14.66667

Mean strength value of all re-bars: fy = 525.2545

Mean concrete strength: fc' = (fc'_jacket*Area_jacket + fc'_core*Area_core)/Area_section = 29.75, but fc'^0.5 <= 8.3 MPa (22.5.3.1, ACI 318-14)

t = 1.00

s = 0.80

e = 1.00

cb = 25.00

Ktr = 3.43481

Atr = Min(Atr_x,Atr_y) = 257.6106

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

s = Max(s_external,s_internal) = 250.00

n = 12.00

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

At local axis: 2

Integration Section: (b)

Calculation No. 6

column C1, Floor 1

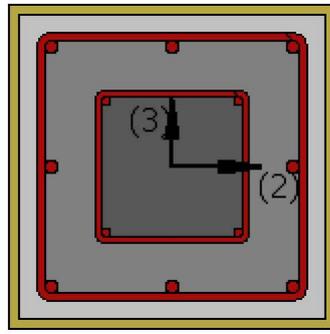
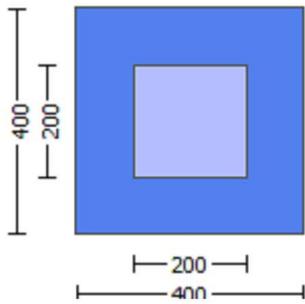
Limit State: Immediate Occupancy (data interpolation between analysis steps 2 and 3)

Analysis: Uniform +X

Check: Chord rotation capacity (u)

Edge: End

Local Axis: (2)



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

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

Constant Properties

Knowledge Factor, $\gamma = 0.80$

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

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

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

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

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

Jacket

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

Existing Column

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

#####

External Height, $H = 400.00$

External Width, $W = 400.00$

Internal Height, $H = 200.00$

Internal Width, $W = 200.00$

Cover Thickness, $c = 25.00$

Mean Confinement Factor overall section = 1.13212

Element Length, $L = 3000.00$

Secondary Member

Ribbed Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

Lap Length $l_o = 300.00$

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $e_{fu} = 0.01$

Number of directions, $NoDir = 1$

Fiber orientations, $b_i = 0.00^\circ$

Number of layers, $NL = 1$

Radius of rounding corners, $R = 40.00$

Stepwise Properties

At local axis: 3

EDGE -A-

Shear Force, $V_a = 2.8976040E-031$

EDGE -B-

Shear Force, $V_b = -2.8976040E-031$

BOTH EDGES

Axial Force, $F = -5926.932$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: $As_t = 0.00$

-Compression: $As_c = 2060.885$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

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

-Compression: $As_{l,com} = 829.3805$

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

Calculation of Shear Capacity ratio, $V_e/V_r = 0.19159777$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 121293.391$

with

$M_{pr1} = \text{Max}(M_{u1+}, M_{u1-}) = 1.8194E+008$

$M_{u1+} = 1.8194E+008$, is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination

$M_{u1-} = 1.8194E+008$, is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination

$M_{pr2} = \text{Max}(M_{u2+}, M_{u2-}) = 1.8194E+008$

$M_{u2+} = 1.8194E+008$, is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the static loading combination

$M_{u2-} = 1.8194E+008$, is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the static loading combination

Calculation of M_{u1+}

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

$\phi_u = 3.6747033E-005$

$M_u = 1.8194E+008$

with full section properties:

$b = 400.00$

$d = 357.00$

$d' = 43.00$

$v = 0.00125773$

$N = 5926.932$

$f_c = 33.00$

α (5A.5, TBDY) = 0.002

Final value of ϕ_u : $\phi_u^* = \text{shear_factor} * \text{Max}(\phi_u, \phi_c) = 0.01505571$

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

From (5.4b), TBDY: $\phi_u = 0.01505571$

where ϕ_u ((5.4c), TBDY) = $\alpha s_e * \text{sh}_{\min} * f_{ywe}/f_{ce} + \text{Min}(\phi_x, \phi_y) = 0.08345896$

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

$\phi_x = 0.07683125$

$\alpha s_e = 0.573333333$

$b = 400.00$

$h = 400.00$

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

$b_w = 400.00$

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

fy = 0.07683125
af = 0.57333333
b = 400.00
h = 400.00
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 = 0.24250288
ase1 = 0.24250288
bo_1 = 340.00
ho_1 = 340.00
bi2_1 = 462400.00
ase2 = Max(ase1,ase2) = 0.24250288
bo_2 = 192.00
ho_2 = 192.00
bi2_2 = 147456.00
psh,min*Fywe = Min(psh,x*Fywe , psh,y*Fywe) = 3.00635

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

psh_x*Fywe = psh1*Fywe1+ps2*Fywe2 = 3.00635
ps1 (external) = (Ash1*h1/s1)/Asec = 0.00392699
Ash1 = Astir_1*ns_1 = 157.0796
No stirrups, ns_1 = 2.00
h1 = 400.00
ps2 (internal) = (Ash2*h2/s2)/Asec = 0.00050265
Ash2 = Astir_2*ns_2 = 100.531
No stirrups, ns_2 = 2.00
h2 = 200.00

psh_y*Fywe = psh1*Fywe1+ps2*Fywe2 = 3.00635
ps1 (external) = (Ash1*h1/s1)/Asec = 0.00392699
Ash1 = Astir_1*ns_1 = 157.0796
No stirrups, ns_1 = 2.00
h1 = 400.00
ps2 (internal) = (Ash2*h2/s2)/Asec = 0.00050265
Ash2 = Astir_2*ns_2 = 100.531
No stirrups, ns_2 = 2.00
h2 = 200.00

Asec = 160000.00
s1 = 100.00
s2 = 250.00
fywe1 = 694.45
fywe2 = 555.55
fce = 33.00

From ((5.A5), TBDY), TBDY: cc = 0.00332119
c = confinement factor = 1.13212

y1 = 0.00184318
sh1 = 0.00589816
ft1 = 580.8818
fy1 = 484.0682
su1 = 0.01099427

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

lo/lou,min = lb/d = 0.45297586
su1 = 0.4*esu1_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu1_nominal = 0.08,

For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered

characteristic value $f_{sy1} = f_{s1}/1.2$, from table 5.1, TBDY.

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

with $f_{s1} = (f_{s,jacket} \cdot A_{s,ten,jacket} + f_{s,core} \cdot A_{s,ten,core})/A_{s,ten} = 484.0682$

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

$y_2 = 0.00184318$

$sh_2 = 0.00589816$

$ft_2 = 580.8818$

$fy_2 = 484.0682$

$su_2 = 0.01099427$

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

and also multiplied by the shear_factor according to 15.7.1.4, with

Shear_factor = 1.00

$l_o/l_{o,min} = l_b/l_{b,min} = 0.45297586$

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

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 $f_{s2} = (f_{s,jacket} \cdot A_{s,com,jacket} + f_{s,core} \cdot A_{s,com,core})/A_{s,com} = 484.0682$

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

$y_v = 0.00184318$

$sh_v = 0.00589816$

$ft_v = 614.3968$

$fy_v = 511.9973$

$su_v = 0.01099427$

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

and also multiplied by the shear_factor according to 15.7.1.4, with

Shear_factor = 1.00

$l_o/l_{o,min} = l_b/l_d = 0.45297586$

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

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 $f_{sv} = (f_{s,jacket} \cdot A_{s,mid,jacket} + f_{s,mid} \cdot A_{s,mid,core})/A_{s,mid} = 511.9973$

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

$1 = A_{s,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.0851958$

$2 = A_{s,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.0851958$

$v = A_{s,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.04369034$

and confined core properties:

$b = 340.00$

$d = 327.00$

$d' = 13.00$

$f_{cc} (5A.2, TBDY) = 37.35991$

$cc (5A.5, TBDY) = 0.00332119$

$c = \text{confinement factor} = 1.13212$

$1 = A_{s,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.1094258$

$2 = A_{s,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.1094258$

$v = A_{s,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.05611603$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

---->

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

---->

$su (4.9) = 0.16193824$

$Mu = MRc (4.14) = 1.8194E+008$

$u = su (4.1) = 3.6747033E-005$

Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.45297586$

$l_b = 300.00$

$l_d = 662.2869$

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

= 1

$db = 14.66667$
 Mean strength value of all re-bars: $f_y = 656.5682$
 Mean concrete strength: $f_c' = (f_c'_{jacket} \cdot Area_{jacket} + f_c'_{core} \cdot Area_{core}) / Area_{section} = 29.75$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $t = 1.00$
 $s = 0.80$
 $e = 1.00$
 $cb = 25.00$
 $K_{tr} = 3.43481$
 $A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 257.6106$
 where A_{tr_x} , A_{tr_y} are the sum of the area of all stirrup legs along X and Y local axis
 $s = \text{Max}(s_{external}, s_{internal}) = 250.00$
 $n = 12.00$

 Calculation of μ_1 -

Calculation of ultimate curvature μ according to 4.1, Biskinis/Fardis 2013:
 $\mu = 3.6747033E-005$
 $\mu_u = 1.8194E+008$

 with full section properties:

$b = 400.00$
 $d = 357.00$
 $d' = 43.00$
 $v = 0.00125773$
 $N = 5926.932$
 $f_c = 33.00$
 α_1 (5A.5, TBDY) = 0.002

Final value of μ_u : $\mu_u^* = \text{shear_factor} \cdot \text{Max}(\mu_u, \mu_c) = 0.01505571$

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

From (5.4b), TBDY: $\mu_u = 0.01505571$

where $\mu_u = \alpha_1 \cdot \mu_{u,FRP} \cdot \text{Min}(f_x, f_y) = 0.08345896$

where $f_x = \alpha_1 \cdot \mu_{u,FRP} \cdot f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

 $f_x = 0.07683125$
 $\alpha_1 = 0.57333333$
 $b = 400.00$
 $h = 400.00$

From EC8 A.4.4.3(6), $\mu_{u,FRP} = 2t_f/bw = 0.00508$
 $bw = 400.00$
 effective stress from (A.35), $f_{fe} = 870.5244$

 $f_y = 0.07683125$
 $\alpha_1 = 0.57333333$
 $b = 400.00$
 $h = 400.00$

From EC8 A.4.4.3(6), $\mu_{u,FRP} = 2t_f/bw = 0.00508$
 $bw = 400.00$
 effective stress from (A.35), $f_{fe} = 870.5244$

 $R = 40.00$
 Effective FRP thickness, $t_f = NL \cdot t \cdot \text{Cos}(\beta_1) = 1.016$
 $f_{u,f} = 1055.00$
 $E_f = 64828.00$
 $u_{,f} = 0.015$
 α_{se} ((5.4d), TBDY) = $(\alpha_{se1} \cdot A_{ext} + \alpha_{se2} \cdot A_{int}) / A_{sec} = 0.24250288$
 $\alpha_{se1} = 0.24250288$
 $b_{o,1} = 340.00$
 $h_{o,1} = 340.00$
 $b_{i,1} = 462400.00$
 $\alpha_{se2} = \text{Max}(\alpha_{se1}, \alpha_{se2}) = 0.24250288$
 $b_{o,2} = 192.00$
 $h_{o,2} = 192.00$

$$bi2_2 = 147456.00$$

$$psh,min*Fywe = \text{Min}(psh,x*Fywe, psh,y*Fywe) = 3.00635$$

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

$$psh_x*Fywe = psh1*Fywe1 + ps2*Fywe2 = 3.00635$$

$$ps1 \text{ (external)} = (Ash1*h1/s1)/Asec = 0.00392699$$

$$Ash1 = Astir_1*ns_1 = 157.0796$$

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

$$h1 = 400.00$$

$$ps2 \text{ (internal)} = (Ash2*h2/s2)/Asec = 0.00050265$$

$$Ash2 = Astir_2*ns_2 = 100.531$$

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

$$h2 = 200.00$$

$$psh_y*Fywe = psh1*Fywe1 + ps2*Fywe2 = 3.00635$$

$$ps1 \text{ (external)} = (Ash1*h1/s1)/Asec = 0.00392699$$

$$Ash1 = Astir_1*ns_1 = 157.0796$$

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

$$h1 = 400.00$$

$$ps2 \text{ (internal)} = (Ash2*h2/s2)/Asec = 0.00050265$$

$$Ash2 = Astir_2*ns_2 = 100.531$$

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

$$h2 = 200.00$$

$$Asec = 160000.00$$

$$s1 = 100.00$$

$$s2 = 250.00$$

$$fywe1 = 694.45$$

$$fywe2 = 555.55$$

$$fce = 33.00$$

$$\text{From ((5.A5), TBDY), TBDY: } cc = 0.00332119$$

$$c = \text{confinement factor} = 1.13212$$

$$y1 = 0.00184318$$

$$sh1 = 0.00589816$$

$$ft1 = 580.8818$$

$$fy1 = 484.0682$$

$$su1 = 0.01099427$$

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

$$lo/lou,min = lb/l_d = 0.45297586$$

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

$$\text{From table 5A.1, TBDY: } esu1_nominal = 0.08,$$

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

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

$$\text{with } fs1 = (fs,jacket*Asl,ten,jacket + fs,core*Asl,ten,core)/Asl,ten = 484.0682$$

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

$$y2 = 0.00184318$$

$$sh2 = 0.00589816$$

$$ft2 = 580.8818$$

$$fy2 = 484.0682$$

$$su2 = 0.01099427$$

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

$$lo/lou,min = lb/l_b,min = 0.45297586$$

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

$$\text{From table 5A.1, TBDY: } esu2_nominal = 0.08,$$

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

$y2, sh2, ft2, fy2$, are also multiplied by $\text{Min}(1, 1.25*(lb/l_d)^{2/3})$, from 10.3.5, ASCE 41-17.

$$\text{with } fs2 = (fs,jacket*Asl,com,jacket + fs,core*Asl,com,core)/Asl,com = 484.0682$$

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

$$yv = 0.00184318$$

$$shv = 0.00589816$$

$$f_{tv} = 614.3968$$

$$f_{yv} = 511.9973$$

$$s_{uv} = 0.01099427$$

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

$$l_o/l_{ou,min} = l_b/l_d = 0.45297586$$

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

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

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

For calculation of $e_{suv,nominal}$ and γ_v , sh_v, f_{tv}, f_{yv} , it is considered
characteristic value $f_{sv} = f_{sv}/1.2$, from table 5.1, TBDY.

γ_1 , sh_1, f_{t1}, f_{y1} , are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE 41-17.

with $f_{sv} = (f_{s,jacket} * A_{s,mid,jacket} + f_{s,mid} * A_{s,mid,core}) / A_{s,mid} = 511.9973$

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

$$1 = A_{s,ten} / (b * d) * (f_{s1} / f_c) = 0.0851958$$

$$2 = A_{s,com} / (b * d) * (f_{s2} / f_c) = 0.0851958$$

$$v = A_{s,mid} / (b * d) * (f_{sv} / f_c) = 0.04369034$$

and confined core properties:

$$b = 340.00$$

$$d = 327.00$$

$$d' = 13.00$$

$$f_{cc} (5A.2, TBDY) = 37.35991$$

$$c_c (5A.5, TBDY) = 0.00332119$$

c = confinement factor = 1.13212

$$1 = A_{s,ten} / (b * d) * (f_{s1} / f_c) = 0.1094258$$

$$2 = A_{s,com} / (b * d) * (f_{s2} / f_c) = 0.1094258$$

$$v = A_{s,mid} / (b * d) * (f_{sv} / f_c) = 0.05611603$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

$$s_u (4.9) = 0.16193824$$

$$\mu_u = M_{Rc} (4.14) = 1.8194E+008$$

$$u = s_u (4.1) = 3.6747033E-005$$

Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.45297586$

$$l_b = 300.00$$

$$l_d = 662.2869$$

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

$$= 1$$

$$d_b = 14.66667$$

Mean strength value of all re-bars: $f_y = 656.5682$

Mean concrete strength: $f_c' = (f_c',jacket * Area_{jacket} + f_c',core * Area_{core}) / Area_{section} = 29.75$, but $f_c'^{0.5} \leq 8.3$

MPa (22.5.3.1, ACI 318-14)

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 25.00$$

$$K_{tr} = 3.43481$$

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

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

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

$$n = 12.00$$

Calculation of μ_{u2+}

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

$$u = 3.6747033E-005$$

Mu = 1.8194E+008

with full section properties:

b = 400.00

d = 357.00

d' = 43.00

v = 0.00125773

N = 5926.932

fc = 33.00

co (5A.5, TBDY) = 0.002

Final value of cu: cu* = shear_factor * Max(cu, cc) = 0.01505571

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

From (5.4b), TBDY: cu = 0.01505571

we ((5.4c), TBDY) = ase* sh,min*fywe/fce+ Min(fx, fy) = 0.08345896

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

fx = 0.07683125

af = 0.57333333

b = 400.00

h = 400.00

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 = 0.07683125

af = 0.57333333

b = 400.00

h = 400.00

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 = 0.24250288

ase1 = 0.24250288

bo_1 = 340.00

ho_1 = 340.00

bi2_1 = 462400.00

ase2 = Max(ase1,ase2) = 0.24250288

bo_2 = 192.00

ho_2 = 192.00

bi2_2 = 147456.00

psh,min*Fywe = Min(psh,x*Fywe , psh,y*Fywe) = 3.00635

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

psh_x*Fywe = psh1*Fywe1+ps2*Fywe2 = 3.00635

ps1 (external) = (Ash1*h1/s1)/Asec = 0.00392699

Ash1 = Astir_1*ns_1 = 157.0796

No stirrups, ns_1 = 2.00

h1 = 400.00

ps2 (internal) = (Ash2*h2/s2)/Asec = 0.00050265

Ash2 = Astir_2*ns_2 = 100.531

No stirrups, ns_2 = 2.00

h2 = 200.00

psh_y*Fywe = psh1*Fywe1+ps2*Fywe2 = 3.00635

ps1 (external) = (Ash1*h1/s1)/Asec = 0.00392699

Ash1 = Astir_1*ns_1 = 157.0796

No stirrups, ns_1 = 2.00

h1 = 400.00

ps2 (internal) = (Ash2*h2/s2)/Asec = 0.00050265

Ash2 = Astir_2*ns_2 = 100.531

No stirrups, ns_2 = 2.00
h2 = 200.00

Asec = 160000.00

s1 = 100.00

s2 = 250.00

fywe1 = 694.45

fywe2 = 555.55

fce = 33.00

From ((5.A.5), TBDY), TBDY: cc = 0.00332119

c = confinement factor = 1.13212

y1 = 0.00184318

sh1 = 0.00589816

ft1 = 580.8818

fy1 = 484.0682

su1 = 0.01099427

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

lo/lou,min = lb/lc = 0.45297586

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

From table 5A.1, TBDY: esu1_nominal = 0.08,

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

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

with fs1 = (fs,jacket*Asl,ten,jacket + fs,core*Asl,ten,core)/Asl,ten = 484.0682

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

y2 = 0.00184318

sh2 = 0.00589816

ft2 = 580.8818

fy2 = 484.0682

su2 = 0.01099427

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

lo/lou,min = lb/lb,min = 0.45297586

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

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

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

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

with fs2 = (fs,jacket*Asl,com,jacket + fs,core*Asl,com,core)/Asl,com = 484.0682

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

yv = 0.00184318

shv = 0.00589816

ftv = 614.3968

fyv = 511.9973

suv = 0.01099427

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

lo/lou,min = lb/lc = 0.45297586

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

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

considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY
For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered

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

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

with fsv = (fs,jacket*Asl,mid,jacket + fs,mid*Asl,mid,core)/Asl,mid = 511.9973

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

1 = Asl,ten/(b*d)*(fs1/fc) = 0.0851958

2 = Asl,com/(b*d)*(fs2/fc) = 0.0851958

v = Asl,mid/(b*d)*(fsv/fc) = 0.04369034

and confined core properties:

b = 340.00

d = 327.00

d' = 13.00

fcc (5A.2, TBDY) = 37.35991
cc (5A.5, TBDY) = 0.00332119
c = confinement factor = 1.13212
1 = $Asl,ten/(b*d)*(fs1/fc)$ = 0.1094258
2 = $Asl,com/(b*d)*(fs2/fc)$ = 0.1094258
v = $Asl,mid/(b*d)*(fsv/fc)$ = 0.05611603
Case/Assumption: Unconfined full section - Steel rupture
' satisfies Eq. (4.3)

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

--->
su (4.9) = 0.16193824
Mu = MRc (4.14) = 1.8194E+008
u = su (4.1) = 3.6747033E-005

Calculation of ratio lb/ld

Lap Length: lb/ld = 0.45297586

lb = 300.00

ld = 662.2869

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

db = 14.66667

Mean strength value of all re-bars: fy = 656.5682

Mean concrete strength: fc' = $(fc'_jacket*Area_jacket + fc'_core*Area_core)/Area_section$ = 29.75, but $fc'^{0.5} \leq 8.3$
MPa (22.5.3.1, ACI 318-14)

t = 1.00

s = 0.80

e = 1.00

cb = 25.00

Ktr = 3.43481

Atr = $\text{Min}(Atr_x, Atr_y)$ = 257.6106

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

s = $\text{Max}(s_external, s_internal)$ = 250.00

n = 12.00

Calculation of Mu2-

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

u = 3.6747033E-005

Mu = 1.8194E+008

with full section properties:

b = 400.00

d = 357.00

d' = 43.00

v = 0.00125773

N = 5926.932

fc = 33.00

co (5A.5, TBDY) = 0.002

Final value of cu: $cu^* = \text{shear_factor} * \text{Max}(cu, cc)$ = 0.01505571

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

From (5.4b), TBDY: cu = 0.01505571

we ((5.4c), TBDY) = $ase * sh, \text{min}(fywe/fce + \text{Min}(fx, fy))$ = 0.08345896

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

fx = 0.07683125

af = 0.573333333

b = 400.00

h = 400.00

From EC8 A.4.4.3(6), pf = $2tf/bw$ = 0.00508

bw = 400.00

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

$f_y = 0.07683125$

$a_f = 0.57333333$

$b = 400.00$

$h = 400.00$

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, $t_f = NL*t*\cos(b_1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{,f} = 0.015$

$a_{se} ((5.4d), TBDY) = (a_{se1}*A_{ext} + a_{se2}*A_{int})/A_{sec} = 0.24250288$

$a_{se1} = 0.24250288$

$b_{o,1} = 340.00$

$h_{o,1} = 340.00$

$b_{i2,1} = 462400.00$

$a_{se2} = \text{Max}(a_{se1}, a_{se2}) = 0.24250288$

$b_{o,2} = 192.00$

$h_{o,2} = 192.00$

$b_{i2,2} = 147456.00$

$p_{sh,min}*F_{ywe} = \text{Min}(p_{sh,x}*F_{ywe}, p_{sh,y}*F_{ywe}) = 3.00635$

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

$p_{sh,x}*F_{ywe} = p_{sh1}*F_{ywe1} + p_{s2}*F_{ywe2} = 3.00635$

$p_{s1} \text{ (external)} = (A_{sh1}*h_1/s_1)/A_{sec} = 0.00392699$

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

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

$h_1 = 400.00$

$p_{s2} \text{ (internal)} = (A_{sh2}*h_2/s_2)/A_{sec} = 0.00050265$

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

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

$h_2 = 200.00$

$p_{sh,y}*F_{ywe} = p_{sh1}*F_{ywe1} + p_{s2}*F_{ywe2} = 3.00635$

$p_{s1} \text{ (external)} = (A_{sh1}*h_1/s_1)/A_{sec} = 0.00392699$

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

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

$h_1 = 400.00$

$p_{s2} \text{ (internal)} = (A_{sh2}*h_2/s_2)/A_{sec} = 0.00050265$

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

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

$h_2 = 200.00$

$A_{sec} = 160000.00$

$s_1 = 100.00$

$s_2 = 250.00$

$f_{ywe1} = 694.45$

$f_{ywe2} = 555.55$

$f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY: $c_c = 0.00332119$

$c = \text{confinement factor} = 1.13212$

$y_1 = 0.00184318$

$sh_1 = 0.00589816$

$ft_1 = 580.8818$

$fy_1 = 484.0682$

$su_1 = 0.01099427$

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

$l_o/l_{o,min} = l_b/d = 0.45297586$

$su_1 = 0.4*es_{u1,nominal} ((5.5), TBDY) = 0.032$

From table 5A.1, TBDY: $es_{u1,nominal} = 0.08$,

For calculation of $esu1_nominal$ 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 $fs1 = (fs_{jacket} \cdot Asl_{ten,jacket} + fs_{core} \cdot Asl_{ten,core}) / Asl_{ten} = 484.0682$

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

$y2 = 0.00184318$

$sh2 = 0.00589816$

$ft2 = 580.8818$

$fy2 = 484.0682$

$su2 = 0.01099427$

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

$lo/lo_{ou,min} = lb/lb_{,min} = 0.45297586$

$su2 = 0.4 \cdot esu2_nominal$ ((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 $fs2 = (fs_{jacket} \cdot Asl_{com,jacket} + fs_{core} \cdot Asl_{com,core}) / Asl_{com} = 484.0682$

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

$yv = 0.00184318$

$shv = 0.00589816$

$ftv = 614.3968$

$fyv = 511.9973$

$suv = 0.01099427$

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

$lo/lo_{ou,min} = lb/ld = 0.45297586$

$suv = 0.4 \cdot esuv_nominal$ ((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 $fsv = (fs_{jacket} \cdot Asl_{mid,jacket} + fs_{mid} \cdot Asl_{mid,core}) / Asl_{mid} = 511.9973$

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

1 = $Asl_{ten} / (b \cdot d) \cdot (fs1 / fc) = 0.0851958$

2 = $Asl_{com} / (b \cdot d) \cdot (fs2 / fc) = 0.0851958$

v = $Asl_{mid} / (b \cdot d) \cdot (fsv / fc) = 0.04369034$

and confined core properties:

b = 340.00

d = 327.00

d' = 13.00

fcc (5A.2, TBDY) = 37.35991

cc (5A.5, TBDY) = 0.00332119

c = confinement factor = 1.13212

1 = $Asl_{ten} / (b \cdot d) \cdot (fs1 / fc) = 0.1094258$

2 = $Asl_{com} / (b \cdot d) \cdot (fs2 / fc) = 0.1094258$

v = $Asl_{mid} / (b \cdot d) \cdot (fsv / fc) = 0.05611603$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < vs_{y2}$ - LHS eq.(4.5) is satisfied

--->

su (4.9) = 0.16193824

$Mu = MRc$ (4.14) = 1.8194E+008

u = su (4.1) = 3.6747033E-005

Calculation of ratio lb/ld

Lap Length: $lb/ld = 0.45297586$

$lb = 300.00$

$ld = 662.2869$

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

$$= 1$$

$$db = 14.66667$$

Mean strength value of all re-bars: $f_y = 656.5682$

Mean concrete strength: $f_c' = (f_c'_{\text{jacket}} \cdot \text{Area}_{\text{jacket}} + f_c'_{\text{core}} \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 29.75$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$cb = 25.00$$

$$K_{tr} = 3.43481$$

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

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

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

$$n = 12.00$$

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 633062.661$

Calculation of Shear Strength at edge 1, $V_{r1} = 633062.661$

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

$$V_{\text{Col}0} = 633062.661$$

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

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

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

Mean concrete strength: $f_c' = (f_c'_{\text{jacket}} \cdot \text{Area}_{\text{jacket}} + f_c'_{\text{core}} \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 29.75$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$$M/Vd = 2.00$$

$$\mu_u = 4.3445556E-012$$

$$\nu_u = 2.8976040E-031$$

$$d = 0.8 \cdot h = 320.00$$

$$N_u = 5926.932$$

$$A_g = 160000.00$$

From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 279254.914$

where:

$V_{s1} = 279254.914$ is calculated for jacket, with:

$$d = 320.00$$

$$A_v = 157079.633$$

$$f_y = 555.56$$

$$s = 100.00$$

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

$$s/d = 0.3125$$

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

$$d = 160.00$$

$$A_v = 100530.965$$

$$f_y = 444.44$$

$$s = 250.00$$

V_{s2} is multiplied by $\text{Col}2 = 0.00$

$$s/d = 1.5625$$

V_f ((11-3)-(11.4), ACI 440) = 188111.148

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

$w_f/s_f = 1$ (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: $\theta = 90^\circ = 90.00$

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

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

$d_{fv} = d$ (figure 11.2, ACI 440) = 357.00

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

$$E_f = 64828.00$$

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

with $f_u = 0.01$

From (11-11), ACI 440: $V_s + V_f \leq 463788.751$

$b_w = 400.00$

Calculation of Shear Strength at edge 2, $V_{r2} = 633062.661$

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

$V_{Col0} = 633062.661$

$knl = 1$ (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: $f_c' = (f_c'_{jacket} * Area_{jacket} + f_c'_{core} * Area_{core}) / Area_{section} = 29.75$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M / Vd = 2.00$

$\mu_u = 4.3445556E-012$

$V_u = 2.8976040E-031$

$d = 0.8 * h = 320.00$

$N_u = 5926.932$

$A_g = 160000.00$

From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 279254.914$

where:

$V_{s1} = 279254.914$ is calculated for jacket, with:

$d = 320.00$

$A_v = 157079.633$

$f_y = 555.56$

$s = 100.00$

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

$s/d = 0.3125$

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

$d = 160.00$

$A_v = 100530.965$

$f_y = 444.44$

$s = 250.00$

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

$s/d = 1.5625$

$V_f ((11-3)-(11.4), ACI 440) = 188111.148$

$f = 0.95$, for fully-wrapped sections

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

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

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

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

orientation 1: $\alpha_1 = b_1 + 90^\circ = 90.00$

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

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

$d_{fv} = d$ (figure 11.2, ACI 440) = 357.00

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

$E_f = 64828.00$

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

with $f_u = 0.01$

From (11-11), ACI 440: $V_s + V_f \leq 463788.751$

$b_w = 400.00$

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

At local axis: 3

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

At Shear local axis: 2

(Bending local axis: 3)

Section Type: rcjrs

Constant Properties

Knowledge Factor, $\gamma = 0.80$

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

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

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

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

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

Jacket

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

Existing Column

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

#####

External Height, $H = 400.00$

External Width, $W = 400.00$

Internal Height, $H = 200.00$

Internal Width, $W = 200.00$

Cover Thickness, $c = 25.00$

Mean Confinement Factor overall section = 1.13212

Element Length, $L = 3000.00$

Secondary Member

Ribbed Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

Lap Length $l_o = 300.00$

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $\epsilon_{fu} = 0.01$

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

Fiber orientations, $b_i = 0.00^\circ$

Number of layers, $N_L = 1$

Radius of rounding corners, $R = 40.00$

Stepwise Properties

At local axis: 2

EDGE -A-

Shear Force, $V_a = -6.6805695E-033$

EDGE -B-

Shear Force, $V_b = 6.6805695E-033$

BOTH EDGES

Axial Force, $F = -5926.932$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

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

-Compression: $A_{sl,c} = 2060.885$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

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

-Compression: $A_{sl,com} = 829.3805$

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

Calculation of Shear Capacity ratio , $V_e/V_r = 0.19159777$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 121293.391$

with
 $M_{pr1} = \text{Max}(M_{u1+}, M_{u1-}) = 1.8194E+008$
 $M_{u1+} = 1.8194E+008$, is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination
 $M_{u1-} = 1.8194E+008$, is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination
 $M_{pr2} = \text{Max}(M_{u2+}, M_{u2-}) = 1.8194E+008$
 $M_{u2+} = 1.8194E+008$, is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the the static loading combination
 $M_{u2-} = 1.8194E+008$, is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the the static loading combination

Calculation of M_{u1+}

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

$\phi_u = 3.6747033E-005$

$M_u = 1.8194E+008$

with full section properties:

$b = 400.00$

$d = 357.00$

$d' = 43.00$

$v = 0.00125773$

$N = 5926.932$

$f_c = 33.00$

α_1 (5A.5, TBDY) = 0.002

Final value of ϕ_{cu} : $\phi_{cu}^* = \text{shear_factor} * \text{Max}(\phi_{cu}, \phi_{cc}) = 0.01505571$

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

From (5.4b), TBDY: $\phi_{cu} = 0.01505571$

ϕ_{we} ((5.4c), TBDY) = $\alpha_1 * \phi_{cu} * \text{Min}(\phi_{fx}, \phi_{fy}) = 0.08345896$

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

$\phi_{fx} = 0.07683125$

$\alpha_1 = 0.57333333$

$b = 400.00$

$h = 400.00$

From EC8 A.4.4.3(6), $\phi_{fx} = 2t_f/bw = 0.00508$

$bw = 400.00$

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

$\phi_{fy} = 0.07683125$

$\alpha_1 = 0.57333333$

$b = 400.00$

$h = 400.00$

From EC8 A.4.4.3(6), $\phi_{fy} = 2t_f/bw = 0.00508$

$bw = 400.00$

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

$R = 40.00$

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

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{f} = 0.015$

α_{se} ((5.4d), TBDY) = $(\alpha_{se1} * A_{ext} + \alpha_{se2} * A_{int}) / A_{sec} = 0.24250288$

$\alpha_{se1} = 0.24250288$

$b_{o,1} = 340.00$

$h_{o,1} = 340.00$

$b_{i,1} = 462400.00$

$$ase2 = \text{Max}(ase1, ase2) = 0.24250288$$

$$bo_2 = 192.00$$

$$ho_2 = 192.00$$

$$bi2_2 = 147456.00$$

$$psh, \min * Fywe = \text{Min}(psh, x * Fywe, psh, y * Fywe) = 3.00635$$

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

$$psh_x * Fywe = psh1 * Fywe1 + ps2 * Fywe2 = 3.00635$$

$$ps1 \text{ (external)} = (Ash1 * h1 / s1) / Asec = 0.00392699$$

$$Ash1 = Astir_1 * ns_1 = 157.0796$$

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

$$h1 = 400.00$$

$$ps2 \text{ (internal)} = (Ash2 * h2 / s2) / Asec = 0.00050265$$

$$Ash2 = Astir_2 * ns_2 = 100.531$$

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

$$h2 = 200.00$$

$$psh_y * Fywe = psh1 * Fywe1 + ps2 * Fywe2 = 3.00635$$

$$ps1 \text{ (external)} = (Ash1 * h1 / s1) / Asec = 0.00392699$$

$$Ash1 = Astir_1 * ns_1 = 157.0796$$

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

$$h1 = 400.00$$

$$ps2 \text{ (internal)} = (Ash2 * h2 / s2) / Asec = 0.00050265$$

$$Ash2 = Astir_2 * ns_2 = 100.531$$

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

$$h2 = 200.00$$

$$Asec = 160000.00$$

$$s1 = 100.00$$

$$s2 = 250.00$$

$$fywe1 = 694.45$$

$$fywe2 = 555.55$$

$$fce = 33.00$$

From ((5.A5), TBDY), TBDY: $cc = 0.00332119$

$$c = \text{confinement factor} = 1.13212$$

$$y1 = 0.00184318$$

$$sh1 = 0.00589816$$

$$ft1 = 580.8818$$

$$fy1 = 484.0682$$

$$su1 = 0.01099427$$

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

$$lo/lou, \min = lb/ld = 0.45297586$$

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

From table 5A.1, TBDY: $esu1_nominal = 0.08$,

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

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

$$\text{with } fs1 = (fs, \text{jacket} * Asl, \text{ten, jacket} + fs, \text{core} * Asl, \text{ten, core}) / Asl, \text{ten} = 484.0682$$

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

$$y2 = 0.00184318$$

$$sh2 = 0.00589816$$

$$ft2 = 580.8818$$

$$fy2 = 484.0682$$

$$su2 = 0.01099427$$

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

$$lo/lou, \min = lb/lb, \min = 0.45297586$$

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

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

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

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

$$\text{with } fs2 = (fs, \text{jacket} * Asl, \text{com, jacket} + fs, \text{core} * Asl, \text{com, core}) / Asl, \text{com} = 484.0682$$

with $E_s2 = (E_{s,jacket} \cdot A_{s,com,jacket} + E_{s,core} \cdot A_{s,com,core}) / A_{s,com} = 200000.00$
 $y_v = 0.00184318$
 $sh_v = 0.00589816$
 $ft_v = 614.3968$
 $fy_v = 511.9973$
 $su_v = 0.01099427$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $l_o/l_{o,min} = l_b/l_d = 0.45297586$
 $su_v = 0.4 \cdot esuv_nominal((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $esuv_nominal = 0.08$,
 considering characteristic value $fs_v = fsv/1.2$, from table 5.1, TBDY
 For calculation of $esuv_nominal$ and y_v, sh_v, ft_v, fy_v , it is considered
 characteristic value $fs_v = fsv/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$, from 10.3.5, ASCE 41-17.
 with $fsv = (f_{s,jacket} \cdot A_{s,mid,jacket} + f_{s,mid} \cdot A_{s,mid,core}) / A_{s,mid} = 511.9973$
 with $E_{sv} = (E_{s,jacket} \cdot A_{s,mid,jacket} + E_{s,mid} \cdot A_{s,mid,core}) / A_{s,mid} = 200000.00$
 $1 = A_{s,ten} / (b \cdot d) \cdot (f_{s1} / f_c) = 0.0851958$
 $2 = A_{s,com} / (b \cdot d) \cdot (f_{s2} / f_c) = 0.0851958$
 $v = A_{s,mid} / (b \cdot d) \cdot (f_{sv} / f_c) = 0.04369034$
 and confined core properties:
 $b = 340.00$
 $d = 327.00$
 $d' = 13.00$
 $f_{cc}(5A.2, TBDY) = 37.35991$
 $cc(5A.5, TBDY) = 0.00332119$
 $c = \text{confinement factor} = 1.13212$
 $1 = A_{s,ten} / (b \cdot d) \cdot (f_{s1} / f_c) = 0.1094258$
 $2 = A_{s,com} / (b \cdot d) \cdot (f_{s2} / f_c) = 0.1094258$
 $v = A_{s,mid} / (b \cdot d) \cdot (f_{sv} / f_c) = 0.05611603$
 Case/Assumption: Unconfined full section - Steel rupture
 ' satisfies Eq. (4.3)
 --->
 $v < v_{s,y2}$ - LHS eq.(4.5) is satisfied
 --->
 $su(4.9) = 0.16193824$
 $Mu = MRc(4.14) = 1.8194E+008$
 $u = su(4.1) = 3.6747033E-005$

 Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.45297586$
 $l_b = 300.00$
 $l_d = 662.2869$
 Calculation of l_b,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
 $= 1$
 $db = 14.66667$
 Mean strength value of all re-bars: $fy = 656.5682$
 Mean concrete strength: $fc' = (fc'_{jacket} \cdot Area_{jacket} + fc'_{core} \cdot Area_{core}) / Area_{section} = 29.75$, but $fc'^{0.5} \leq 8.3$
 MPa (22.5.3.1, ACI 318-14)
 $t = 1.00$
 $s = 0.80$
 $e = 1.00$
 $cb = 25.00$
 $K_{tr} = 3.43481$
 $A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 257.6106$
 where A_{tr_x}, A_{tr_y} are the sum of the area of all stirrup legs along X and Y loxal axis
 $s = \text{Max}(s_{external}, s_{internal}) = 250.00$
 $n = 12.00$

 Calculation of $Mu1$ -

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

$$u = 3.6747033E-005$$

$$Mu = 1.8194E+008$$

with full section properties:

$$b = 400.00$$

$$d = 357.00$$

$$d' = 43.00$$

$$v = 0.00125773$$

$$N = 5926.932$$

$$f_c = 33.00$$

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

$$\text{Final value of } \phi_u: \phi_u^* = \text{shear_factor} * \text{Max}(\phi_{cu}, \phi_{cc}) = 0.01505571$$

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

$$\text{From (5.4b), TBDY: } \phi_{cu} = 0.01505571$$

$$\phi_{cc} ((5.4c), TBDY) = \alpha_{se} * \text{sh}_{,min} * f_{ywe} / f_{ce} + \text{Min}(\phi_{fx}, \phi_{fy}) = 0.08345896$$

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

$$\phi_{fx} = 0.07683125$$

$$\alpha_f = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

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

$$b_w = 400.00$$

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

$$\phi_{fy} = 0.07683125$$

$$\alpha_f = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

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

$$b_w = 400.00$$

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

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$\alpha_{se} ((5.4d), TBDY) = (\alpha_{se1} * A_{ext} + \alpha_{se2} * A_{int}) / A_{sec} = 0.24250288$$

$$\alpha_{se1} = 0.24250288$$

$$b_{o,1} = 340.00$$

$$h_{o,1} = 340.00$$

$$b_{i2,1} = 462400.00$$

$$\alpha_{se2} = \text{Max}(\alpha_{se1}, \alpha_{se2}) = 0.24250288$$

$$b_{o,2} = 192.00$$

$$h_{o,2} = 192.00$$

$$b_{i2,2} = 147456.00$$

$$p_{sh,min} * F_{ywe} = \text{Min}(p_{sh,x} * F_{ywe}, p_{sh,y} * F_{ywe}) = 3.00635$$

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

$$p_{sh,x} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{sh2} * F_{ywe2} = 3.00635$$

$$p_{sh1} \text{ (external)} = (A_{sh1} * h_1 / s_1) / A_{sec} = 0.00392699$$

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

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

$$h_1 = 400.00$$

$$p_{sh2} \text{ (internal)} = (A_{sh2} * h_2 / s_2) / A_{sec} = 0.00050265$$

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

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

$$h_2 = 200.00$$

$$p_{sh,y} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{sh2} * F_{ywe2} = 3.00635$$

$$p_{sh1} \text{ (external)} = (A_{sh1} * h_1 / s_1) / A_{sec} = 0.00392699$$

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

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

h1 = 400.00
ps2 (internal) = (Ash2*h2/s2)/Asec = 0.00050265
Ash2 = Astir_2*ns_2 = 100.531
No stirups, ns_2 = 2.00
h2 = 200.00

Asec = 160000.00
s1 = 100.00
s2 = 250.00
fywe1 = 694.45
fywe2 = 555.55
fce = 33.00

From ((5.A.5), TBDY), TBDY: cc = 0.00332119
c = confinement factor = 1.13212

y1 = 0.00184318
sh1 = 0.00589816
ft1 = 580.8818
fy1 = 484.0682
su1 = 0.01099427

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

lo/lou,min = lb/d = 0.45297586
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 = 484.0682

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

y2 = 0.00184318
sh2 = 0.00589816
ft2 = 580.8818
fy2 = 484.0682
su2 = 0.01099427

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

lo/lou,min = lb/lb,min = 0.45297586
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 = 484.0682

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

yv = 0.00184318
shv = 0.00589816
ftv = 614.3968
fyv = 511.9973
suv = 0.01099427

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

lo/lou,min = lb/d = 0.45297586
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 = 511.9973

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

1 = Asl,ten/(b*d)*(fs1/fc) = 0.0851958

2 = Asl,com/(b*d)*(fs2/fc) = 0.0851958

v = Asl,mid/(b*d)*(fsv/fc) = 0.04369034

and confined core properties:

$b = 340.00$
 $d = 327.00$
 $d' = 13.00$
 $f_{cc} (5A.2, TBDY) = 37.35991$
 $cc (5A.5, TBDY) = 0.00332119$
 $c = \text{confinement factor} = 1.13212$
 $1 = A_{s1,ten}/(b*d)*(f_{s1}/f_c) = 0.1094258$
 $2 = A_{s2,com}/(b*d)*(f_{s2}/f_c) = 0.1094258$
 $v = A_{s,mid}/(b*d)*(f_{sv}/f_c) = 0.05611603$
 Case/Assumption: Unconfined full section - Steel rupture
 ' satisfies Eq. (4.3)

--->
 $v < v_{s,y2}$ - LHS eq.(4.5) is satisfied
 --->
 $su (4.9) = 0.16193824$
 $Mu = MRc (4.14) = 1.8194E+008$
 $u = su (4.1) = 3.6747033E-005$

 Calculation of ratio l_b/l_d

 Lap Length: $l_b/l_d = 0.45297586$
 $l_b = 300.00$
 $l_d = 662.2869$
 Calculation of l_b, \min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
 $= 1$
 $db = 14.66667$
 Mean strength value of all re-bars: $f_y = 656.5682$
 Mean concrete strength: $f'_c = (f'_{c,jacket} * Area_{jacket} + f'_{c,core} * Area_{core}) / Area_{section} = 29.75$, but $f_c^{0.5} \leq 8.3$
 MPa (22.5.3.1, ACI 318-14)
 $t = 1.00$
 $s = 0.80$
 $e = 1.00$
 $cb = 25.00$
 $K_{tr} = 3.43481$
 $A_{tr} = \text{Min}(A_{tr,x}, A_{tr,y}) = 257.6106$
 where $A_{tr,x}, A_{tr,y}$ are the sum of the area of all stirrup legs along X and Y loxal axis
 $s = \text{Max}(s_{external}, s_{internal}) = 250.00$
 $n = 12.00$

 Calculation of Mu_{2+}

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

$u = 3.6747033E-005$
 $Mu = 1.8194E+008$

 with full section properties:

$b = 400.00$
 $d = 357.00$
 $d' = 43.00$
 $v = 0.00125773$
 $N = 5926.932$
 $f_c = 33.00$
 $co (5A.5, TBDY) = 0.002$
 Final value of cu : $cu^* = \text{shear_factor} * \text{Max}(cu, cc) = 0.01505571$
 The Shear_factor is considered equal to 1 (pure moment strength)
 From (5.4b), TBDY: $cu = 0.01505571$
 $we ((5.4c), TBDY) = ase * sh_{,min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.08345896$
 where $f = af * pf * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

 $f_x = 0.07683125$
 $af = 0.57333333$
 $b = 400.00$

h = 400.00
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 = 0.07683125
af = 0.57333333
b = 400.00
h = 400.00
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
 $ase ((5.4d), TBDY) = (ase1*Aext+ase2*Aint)/Asec = 0.24250288$
ase1 = 0.24250288
bo_1 = 340.00
ho_1 = 340.00
bi2_1 = 462400.00
ase2 = Max(ase1,ase2) = 0.24250288
bo_2 = 192.00
ho_2 = 192.00
bi2_2 = 147456.00

psh,min*Fywe = Min(psh,x*Fywe , psh,y*Fywe) = 3.00635
Expression ((5.4d), TBDY) for psh,min*Fywe has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

psh_x*Fywe = psh1*Fywe1+ps2*Fywe2 = 3.00635
ps1 (external) = (Ash1*h1/s1)/Asec = 0.00392699
Ash1 = Astir_1*ns_1 = 157.0796
No stirrups, ns_1 = 2.00
h1 = 400.00
ps2 (internal) = (Ash2*h2/s2)/Asec = 0.00050265
Ash2 = Astir_2*ns_2 = 100.531
No stirrups, ns_2 = 2.00
h2 = 200.00

psh_y*Fywe = psh1*Fywe1+ps2*Fywe2 = 3.00635
ps1 (external) = (Ash1*h1/s1)/Asec = 0.00392699
Ash1 = Astir_1*ns_1 = 157.0796
No stirrups, ns_1 = 2.00
h1 = 400.00
ps2 (internal) = (Ash2*h2/s2)/Asec = 0.00050265
Ash2 = Astir_2*ns_2 = 100.531
No stirrups, ns_2 = 2.00
h2 = 200.00

Asec = 160000.00
s1 = 100.00
s2 = 250.00
fywe1 = 694.45
fywe2 = 555.55
fce = 33.00

From ((5.A5), TBDY), TBDY: cc = 0.00332119
c = confinement factor = 1.13212

y1 = 0.00184318
sh1 = 0.00589816
ft1 = 580.8818
fy1 = 484.0682
su1 = 0.01099427

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

$$l_0/l_{ou,min} = l_b/l_d = 0.45297586$$

$$s_u1 = 0.4 * e_{su1_nominal} ((5.5), TBDY) = 0.032$$

$$\text{From table 5A.1, TBDY: } e_{su1_nominal} = 0.08,$$

For calculation of $e_{su1_nominal}$ and y_1, sh_1, ft_1, fy_1 , it is considered characteristic value $f_{sy1} = f_{s1}/1.2$, from table 5.1, TBDY.

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

$$\text{with } f_{s1} = (f_{s,jacket} * A_{sl,ten,jacket} + f_{s,core} * A_{sl,ten,core}) / A_{sl,ten} = 484.0682$$

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

$$y_2 = 0.00184318$$

$$sh_2 = 0.00589816$$

$$ft_2 = 580.8818$$

$$fy_2 = 484.0682$$

$$s_u2 = 0.01099427$$

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

$$l_0/l_{ou,min} = l_b/l_{b,min} = 0.45297586$$

$$s_u2 = 0.4 * e_{su2_nominal} ((5.5), TBDY) = 0.032$$

$$\text{From table 5A.1, TBDY: } e_{su2_nominal} = 0.08,$$

For calculation of $e_{su2_nominal}$ and y_2, sh_2, ft_2, fy_2 , it is considered characteristic value $f_{sy2} = f_{s2}/1.2$, from table 5.1, TBDY.

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

$$\text{with } f_{s2} = (f_{s,jacket} * A_{sl,com,jacket} + f_{s,core} * A_{sl,com,core}) / A_{sl,com} = 484.0682$$

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

$$y_v = 0.00184318$$

$$sh_v = 0.00589816$$

$$ft_v = 614.3968$$

$$fy_v = 511.9973$$

$$s_{uv} = 0.01099427$$

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

$$l_0/l_{ou,min} = l_b/l_d = 0.45297586$$

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

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

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

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

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

$$\text{with } f_{sv} = (f_{s,jacket} * A_{sl,mid,jacket} + f_{s,mid} * A_{sl,mid,core}) / A_{sl,mid} = 511.9973$$

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

$$1 = A_{sl,ten} / (b * d) * (f_{s1} / f_c) = 0.0851958$$

$$2 = A_{sl,com} / (b * d) * (f_{s2} / f_c) = 0.0851958$$

$$v = A_{sl,mid} / (b * d) * (f_{sv} / f_c) = 0.04369034$$

and confined core properties:

$$b = 340.00$$

$$d = 327.00$$

$$d' = 13.00$$

$$f_{cc} (5A.2, TBDY) = 37.35991$$

$$c_c (5A.5, TBDY) = 0.00332119$$

$$c = \text{confinement factor} = 1.13212$$

$$1 = A_{sl,ten} / (b * d) * (f_{s1} / f_c) = 0.1094258$$

$$2 = A_{sl,com} / (b * d) * (f_{s2} / f_c) = 0.1094258$$

$$v = A_{sl,mid} / (b * d) * (f_{sv} / f_c) = 0.05611603$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

$$s_u (4.9) = 0.16193824$$

$$\mu = M_{Rc} (4.14) = 1.8194E+008$$

$$u = s_u (4.1) = 3.6747033E-005$$

Calculation of ratio l_b/l_d

$$\text{Lap Length: } l_b/l_d = 0.45297586$$

$$I_b = 300.00$$

$$I_d = 662.2869$$

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

$$= 1$$

$$d_b = 14.66667$$

$$\text{Mean strength value of all re-bars: } f_y = 656.5682$$

$$\text{Mean concrete strength: } f_c' = (f_c'_{\text{jacket}} \cdot \text{Area}_{\text{jacket}} + f_c'_{\text{core}} \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 29.75, \text{ but } f_c'^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 25.00$$

$$K_{tr} = 3.43481$$

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

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

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

$$n = 12.00$$

Calculation of μ_2 -

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

$$\mu = 3.6747033E-005$$

$$\mu_2 = 1.8194E+008$$

with full section properties:

$$b = 400.00$$

$$d = 357.00$$

$$d' = 43.00$$

$$v = 0.00125773$$

$$N = 5926.932$$

$$f_c = 33.00$$

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

$$\text{Final value of } \mu: \mu^* = \text{shear_factor} \cdot \text{Max}(\mu, \mu_c) = 0.01505571$$

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

$$\text{From (5.4b), TBDY: } \mu = 0.01505571$$

$$\mu_e \text{ ((5.4c), TBDY)} = a_{se} \cdot \text{sh}_{\text{min}} \cdot f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.08345896$$

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)

$$f_x = 0.07683125$$

$$a_f = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

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

$$b_w = 400.00$$

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

$$f_y = 0.07683125$$

$$a_f = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

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

$$b_w = 400.00$$

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

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$a_{se} \text{ ((5.4d), TBDY)} = (a_{se1} \cdot A_{ext} + a_{se2} \cdot A_{int}) / A_{sec} = 0.24250288$$

$$a_{se1} = 0.24250288$$

$$b_{o,1} = 340.00$$

$$h_{o,1} = 340.00$$

bi2_1 = 462400.00
ase2 = Max(ase1,ase2) = 0.24250288
bo_2 = 192.00
ho_2 = 192.00
bi2_2 = 147456.00

psh,min*Fywe = Min(psh,x*Fywe , psh,y*Fywe) = 3.00635

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

psh_x*Fywe = psh1*Fywe1+ps2*Fywe2 = 3.00635
ps1 (external) = (Ash1*h1/s1)/Asec = 0.00392699
Ash1 = Astir_1*ns_1 = 157.0796
No stirrups, ns_1 = 2.00
h1 = 400.00
ps2 (internal) = (Ash2*h2/s2)/Asec = 0.00050265
Ash2 = Astir_2*ns_2 = 100.531
No stirrups, ns_2 = 2.00
h2 = 200.00

psh_y*Fywe = psh1*Fywe1+ps2*Fywe2 = 3.00635
ps1 (external) = (Ash1*h1/s1)/Asec = 0.00392699
Ash1 = Astir_1*ns_1 = 157.0796
No stirrups, ns_1 = 2.00
h1 = 400.00
ps2 (internal) = (Ash2*h2/s2)/Asec = 0.00050265
Ash2 = Astir_2*ns_2 = 100.531
No stirrups, ns_2 = 2.00
h2 = 200.00

Asec = 160000.00
s1 = 100.00
s2 = 250.00
fywe1 = 694.45
fywe2 = 555.55
fce = 33.00

From ((5.A5), TBDY), TBDY: cc = 0.00332119
c = confinement factor = 1.13212

y1 = 0.00184318
sh1 = 0.00589816
ft1 = 580.8818
fy1 = 484.0682
su1 = 0.01099427

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

lo/lou,min = lb/lb,min = 0.45297586

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

From table 5A.1, TBDY: esu1_nominal = 0.08,

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

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

with fs1 = (fs,jacket*Asl,ten,jacket + fs,core*Asl,ten,core)/Asl,ten = 484.0682

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

y2 = 0.00184318
sh2 = 0.00589816
ft2 = 580.8818
fy2 = 484.0682
su2 = 0.01099427

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

lo/lou,min = lb/lb,min = 0.45297586

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

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

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

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

$with fs2 = (fs,jacket*Asl,com,jacket + fs,core*Asl,com,core)/Asl,com = 484.0682$
 $with Es2 = (Es,jacket*Asl,com,jacket + Es,core*Asl,com,core)/Asl,com = 200000.00$
 $yv = 0.00184318$
 $shv = 0.00589816$
 $ftv = 614.3968$
 $fyv = 511.9973$
 $suv = 0.01099427$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 $Shear_factor = 1.00$
 $lo/lou,min = lb/ld = 0.45297586$
 $suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032$
 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.
 $with fsv = (fs,jacket*Asl,mid,jacket + fs,mid*Asl,mid,core)/Asl,mid = 511.9973$
 $with Esv = (Es,jacket*Asl,mid,jacket + Es,mid*Asl,mid,core)/Asl,mid = 200000.00$
 $1 = Asl,ten/(b*d)*(fs1/fc) = 0.0851958$
 $2 = Asl,com/(b*d)*(fs2/fc) = 0.0851958$
 $v = Asl,mid/(b*d)*(fsv/fc) = 0.04369034$

and confined core properties:

$b = 340.00$
 $d = 327.00$
 $d' = 13.00$
 $fcc (5A.2, TBDY) = 37.35991$
 $cc (5A.5, TBDY) = 0.00332119$
 $c = \text{confinement factor} = 1.13212$
 $1 = Asl,ten/(b*d)*(fs1/fc) = 0.1094258$
 $2 = Asl,com/(b*d)*(fs2/fc) = 0.1094258$
 $v = Asl,mid/(b*d)*(fsv/fc) = 0.05611603$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

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

$su (4.9) = 0.16193824$
 $Mu = MRc (4.14) = 1.8194E+008$
 $u = su (4.1) = 3.6747033E-005$

Calculation of ratio lb/ld

Lap Length: $lb/ld = 0.45297586$

$lb = 300.00$

$ld = 662.2869$

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

= 1

$db = 14.66667$

Mean strength value of all re-bars: $fy = 656.5682$

Mean concrete strength: $fc' = (fc'_jacket*Area_jacket + fc'_core*Area_core)/Area_section = 29.75$, but $fc'^{0.5} <= 8.3$ MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$Ktr = 3.43481$

$Atr = Min(Atr_x,Atr_y) = 257.6106$

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

$s = Max(s_external,s_internal) = 250.00$

$n = 12.00$

Calculation of Shear Strength $Vr = Min(Vr1,Vr2) = 633062.661$

Calculation of Shear Strength at edge 1, $Vr1 = 633062.661$

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

$VColO = 633062.661$

$knl = 1$ (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: $fc' = (fc'_{jacket} * Area_{jacket} + fc'_{core} * Area_{core}) / Area_{section} = 29.75$, but $fc'^{0.5} \leq 8.3$
MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$Mu = 4.6931004E-013$

$Vu = 6.6805695E-033$

$d = 0.8 * h = 320.00$

$Nu = 5926.932$

$Ag = 160000.00$

From (11.5.4.8), ACI 318-14: $Vs = Vs1 + Vs2 = 279254.914$

where:

$Vs1 = 279254.914$ is calculated for jacket, with:

$d = 320.00$

$Av = 157079.633$

$fy = 555.56$

$s = 100.00$

$Vs1$ is multiplied by $Col1 = 1.00$

$s/d = 0.3125$

$Vs2 = 0.00$ is calculated for core, with:

$d = 160.00$

$Av = 100530.965$

$fy = 444.44$

$s = 250.00$

$Vs2$ is multiplied by $Col2 = 0.00$

$s/d = 1.5625$

Vf ((11-3)-(11.4), ACI 440) = 188111.148

$f = 0.95$, for fully-wrapped sections

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

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

This later relation, considered as a function $Vf(\alpha, a1)$, is implemented for every different fiber orientation $a1$,
as well as for 2 crack directions, $\alpha = 45^\circ$ and $\alpha = -45^\circ$ to take into consideration the cyclic seismic loading.

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

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

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

$dfv = d$ (figure 11.2, ACI 440) = 357.00

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

$Ef = 64828.00$

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

with $fu = 0.01$

From (11-11), ACI 440: $Vs + Vf \leq 463788.751$

$bw = 400.00$

Calculation of Shear Strength at edge 2, $Vr2 = 633062.661$

$Vr2 = VCol$ ((10.3), ASCE 41-17) = $knl * VColO$

$VColO = 633062.661$

$knl = 1$ (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: $fc' = (fc'_{jacket} * Area_{jacket} + fc'_{core} * Area_{core}) / Area_{section} = 29.75$, but $fc'^{0.5} \leq 8.3$
MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$Mu = 4.6931004E-013$

$Vu = 6.6805695E-033$

$d = 0.8 \cdot h = 320.00$
 $Nu = 5926.932$
 $Ag = 160000.00$
 From (11.5.4.8), ACI 318-14: $Vs = Vs1 + Vs2 = 279254.914$
 where:
 $Vs1 = 279254.914$ is calculated for jacket, with:
 $d = 320.00$
 $Av = 157079.633$
 $fy = 555.56$
 $s = 100.00$
 $Vs1$ is multiplied by $Col1 = 1.00$
 $s/d = 0.3125$
 $Vs2 = 0.00$ is calculated for core, with:
 $d = 160.00$
 $Av = 100530.965$
 $fy = 444.44$
 $s = 250.00$
 $Vs2$ is multiplied by $Col2 = 0.00$
 $s/d = 1.5625$
 Vf ((11-3)-(11.4), ACI 440) = 188111.148
 $f = 0.95$, for fully-wrapped sections
 $wf/sf = 1$ (FRP strips adjacent to one another).
 In (11.3) $\sin + \cos$ is replaced with $(\cot + \cot a) \sin a$ which is more a generalised expression,
 where a is the angle of the crack direction (see KANEPE).
 This later relation, considered as a function $Vf(,)$, is implemented for every different fiber orientation a_i ,
 as well as for 2 crack directions, $a = 45^\circ$ and $a = -45^\circ$ to take into consideration the cyclic seismic loading.
 orientation 1: $a = b1 + 90^\circ = 90.00$
 $Vf = \text{Min}(|Vf(45, 1)|, |Vf(-45, a1)|)$, with:
 total thickness per orientation, $tf1 = NL \cdot t / \text{NoDir} = 1.016$
 $dfv = d$ (figure 11.2, ACI 440) = 357.00
 ffe ((11-5), ACI 440) = 259.312
 $Ef = 64828.00$
 $fe = 0.004$, from (11.6a), ACI 440
 with $fu = 0.01$
 From (11-11), ACI 440: $Vs + Vf \leq 463788.751$
 $bw = 400.00$

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

 Start Of Calculation of Chord Rotation Capacity for element: column JC1 of floor 1
 At local axis: 2
 Integration Section: (b)
 Section Type: rcjrs

Constant Properties

 Knowledge Factor, $\lambda = 0.80$
 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
 Existing material of Secondary Member: Concrete Strength, $f_c = f_{cm} = 20.00$
 Existing material of Secondary Member: Steel Strength, $f_s = f_{sm} = 444.44$
 Concrete Elasticity, $E_c = 21019.039$
 Steel Elasticity, $E_s = 200000.00$
 External Height, $H = 400.00$
 External Width, $W = 400.00$

Internal Height, H = 200.00
Internal Width, W = 200.00
Cover Thickness, c = 25.00
Element Length, L = 3000.00
Secondary Member
Ribbed Bars
Ductile Steel
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
Lap Length l_b = 300.00
FRP Wrapping Data
Type: Carbon
Cured laminate properties (design values)
Thickness, t = 1.016
Tensile Strength, f_{fu} = 1055.00
Tensile Modulus, E_f = 64828.00
Elongation, e_{fu} = 0.01
Number of directions, NoDir = 1
Fiber orientations, b_i : 0.00°
Number of layers, NL = 1
Radius of rounding corners, R = 40.00

Stepwise Properties

Bending Moment, M = -7.5332205E-012
Shear Force, V2 = 7481.276
Shear Force, V3 = -1.2884777E-015
Axial Force, F = -6438.97
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: $A_{sl,t}$ = 0.00
-Compression: $A_{sl,c}$ = 2060.885
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension: $A_{sl,ten}$ = 829.3805
-Compression: $A_{sl,com}$ = 829.3805
-Middle: $A_{sl,mid}$ = 402.1239
Longitudinal External Reinforcement Area Distribution (in 3 divisions)
-Tension: $A_{sl,ten,jacket}$ = 603.1858
-Compression: $A_{sl,com,jacket}$ = 603.1858
-Middle: $A_{sl,mid,jacket}$ = 402.1239
Longitudinal Internal Reinforcement Area Distribution (in 3 divisions)
-Tension: $A_{sl,ten,core}$ = 226.1947
-Compression: $A_{sl,com,core}$ = 226.1947
-Middle: $A_{sl,mid,core}$ = 0.00
Mean Diameter of Tension Reinforcement, DbL = 14.40

Existing component: From table 7-7, ASCE 41_17: Final chord rotation Capacity $u_{,R} = u = 0.00332297$
 $u = y + p = 0.00415372$

- Calculation of y -

$y = (My * L_s / 3) / E_{eff} = 0.00415372$ ((4.29), Biskinis Phd))
 $My = 1.4156E+008$
 $L_s = M/V$ (with $L_s > 0.1 * L$ and $L_s < 2 * L$) = 1500.00
From table 10.5, ASCE 41_17: $E_{eff} = factor * E_c * I_g = 1.7040E+013$
factor = 0.30
 $A_g = 160000.00$
Mean concrete strength: $fc' = (fc'_{jacket} * Area_{jacket} + fc'_{core} * Area_{core}) / Area_{section} = 29.75$
 $N = 6438.97$
 $Ec * I_g = Ec_{jacket} * I_{g,jacket} + Ec_{core} * I_{g,core} = 5.6801E+013$

Calculation of Yielding Moment M_y

Calculation of y and M_y according to Annex 7 -

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

$$y_{\text{ten}} = 8.5640402\text{E-}006$$

$$\text{with } ((10.1), \text{ASCE 41-17}) f_y = \text{Min}(f_y, 1.25 \cdot f_y \cdot (l_b/d)^{2/3}) = 454.4281$$

$$d = 357.00$$

$$y = 0.2568299$$

$$A = 0.01453119$$

$$B = 0.00818436$$

$$\text{with } p_t = 0.00680078$$

$$p_c = 0.00580799$$

$$p_v = 0.00281599$$

$$N = 6438.97$$

$$b = 400.00$$

$$" = 0.12044818$$

$$y_{\text{comp}} = 2.5296911\text{E-}005$$

$$\text{with } f_c^* (12.3, (\text{ACI 440})) = 34.65599$$

$$f_c = 33.00$$

$$f_l = 0.93147527$$

$$b = 400.00$$

$$h = 400.00$$

$$A_g = 160000.00$$

$$\text{From } (12.9), \text{ACI 440: } k_a = 0.56708553$$

$$g = p_t + p_c + p_v = 0.01443197$$

$$r_c = 40.00$$

$$A_e/A_c = 0.56708553$$

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

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

$$f_u = 0.01$$

$$E_f = 64828.00$$

$$E_c = 26999.444$$

$$y = 0.25583518$$

$$A = 0.01433439$$

$$B = 0.00808514$$

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

Calculation of ratio l_b/d

$$\text{Lap Length: } l_d/d, \text{min} = 0.56621983$$

$$l_b = 300.00$$

$$l_d = 529.8296$$

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

$$= 1$$

$$d_b = 14.66667$$

$$\text{Mean strength value of all re-bars: } f_y = 525.2545$$

$$\text{Mean concrete strength: } f_c' = (f_c'_{\text{jacket}} \cdot \text{Area}_{\text{jacket}} + f_c'_{\text{core}} \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 29.75, \text{ but } f_c'^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 25.00$$

$$K_{tr} = 3.43481$$

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

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

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

$$n = 12.00$$

- Calculation of p -

From table 10-8: $p = 0.00$

with:

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

shear control ratio $V_y E / V_{CoI} E = 0.19159777$

$d = d_{\text{external}} = 357.00$

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

$t = s_1 + s_2 + 2 \cdot t_f / b_w \cdot (f_{fe} / f_s) = 0.00680078$

jacket: $s_1 = A_{v1} \cdot h_1 / (s_1 \cdot A_g) = 0.00392699$

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

$h_1 = 400.00$

$s_1 = 100.00$

core: $s_2 = A_{v2} \cdot h_2 / (s_2 \cdot A_g) = 0.00050265$

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

$h_2 = 200.00$

$s_2 = 250.00$

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

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

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

For the normalisation f_s of jacket is used.

$NUD = 6438.97$

$A_g = 160000.00$

$f_{cE} = (f_{c_jacket} \cdot \text{Area_jacket} + f_{c_core} \cdot \text{Area_core}) / \text{section_area} = 29.75$

$f_{yIE} = (f_{y_ext_Long_Reinf} \cdot \text{Area_ext_Long_Reinf} + f_{y_int_Long_Reinf} \cdot \text{Area_int_Long_Reinf}) / \text{Area_Tot_Long_Rein} = 531.1678$

$f_{yTE} = (f_{y_ext_Trans_Reinf} \cdot \text{Area_ext_Trans_Reinf} + f_{y_int_Trans_Reinf} \cdot \text{Area_int_Trans_Reinf}) / \text{Area_Tot_Trans_Rein} = 542.9506$

$\rho_l = \text{Area_Tot_Long_Rein} / (b \cdot d) = 0.01443197$

$b = 400.00$

$d = 357.00$

$f_{cE} = 29.75$

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

At local axis: 2

Integration Section: (b)

Calculation No. 7

column C1, Floor 1

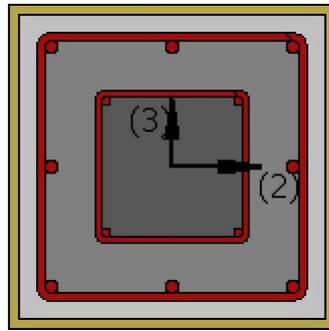
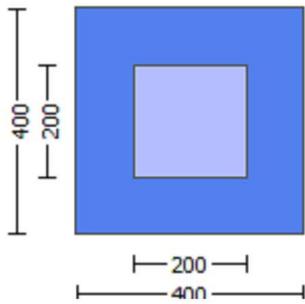
Limit State: Immediate Occupancy (data interpolation between analysis steps 2 and 3)

Analysis: Uniform +X

Check: Shear capacity V_{Rd}

Edge: End

Local Axis: (3)



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

At local axis: 3

Integration Section: (b)

Section Type: rcjrs

Constant Properties

Knowledge Factor, $\gamma = 0.80$

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

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

Consequently:

Jacket

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

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

Concrete Elasticity, $E_c = 26999.444$

Steel Elasticity, $E_s = 200000.00$

Existing Column

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

Existing material of Secondary Member: Steel Strength, $f_s = f_{s_lower_bound} = 400.00$

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

#####

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

Jacket

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

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

Existing Column

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

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

#####

External Height, $H = 400.00$

External Width, $W = 400.00$

Internal Height, $H = 200.00$

Internal Width, $W = 200.00$

Cover Thickness, $c = 25.00$

Element Length, $L = 3000.00$

Secondary Member

Ribbed Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

Lap Length $l_o = l_b = 300.00$

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $e_{fu} = 0.01$

Number of directions, $NoDir = 1$

Fiber orientations, θ_i : 0.00°
Number of layers, NL = 1
Radius of rounding corners, R = 40.00

Stepwise Properties

EDGE -A-
Bending Moment, M_a = 3.6608976E-012
Shear Force, V_a = 1.2884777E-015
EDGE -B-
Bending Moment, M_b = -7.5332205E-012
Shear Force, V_b = -1.2884777E-015
BOTH EDGES
Axial Force, F = -6438.97
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: A_{st} = 0.00
-Compression: A_{sc} = 2060.885
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension: $A_{st,ten}$ = 829.3805
-Compression: $A_{sc,com}$ = 829.3805
-Middle: $A_{st,mid}$ = 402.1239
Mean Diameter of Tension Reinforcement, $D_{bL,ten}$ = 14.40

Existing component: From table 7-7, ASCE 41_17: Final Shear Capacity $V_R = \phi V_n = 447154.557$
 V_n ((10.3), ASCE 41-17) = $k_n \phi V_{Co10} = 558943.196$
 $V_{Co10} = 558943.196$
 $k_n = 1.00$
displacement_ductility_demand = 0.00

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

= 1 (normal-weight concrete)
Mean concrete strength: $f_c' = (f_c'_{jacket} \cdot Area_{jacket} + f_c'_{core} \cdot Area_{core}) / Area_{section} = 22.75$, but $f_c'^{0.5} \leq 8.3$
MPa (22.5.3.1, ACI 318-14)
 $M / Vd = 2.00$
 $M_u = 7.5332205E-012$
 $V_u = 1.2884777E-015$
 $d = 0.8 \cdot h = 320.00$
 $N_u = 6438.97$
 $A_g = 160000.00$
From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 251327.412$
where:
 $V_{s1} = 251327.412$ is calculated for jacket, with:
 $d = 320.00$
 $A_v = 157079.633$
 $f_y = 500.00$
 $s = 100.00$
 V_{s1} is multiplied by $Col1 = 1.00$
 $s/d = 0.3125$
 $V_{s2} = 0.00$ is calculated for core, with:
 $d = 160.00$
 $A_v = 100530.965$
 $f_y = 400.00$
 $s = 250.00$
 V_{s2} is multiplied by $Col2 = 0.00$
 $s/d = 1.5625$
 V_f ((11-3)-(11.4), ACI 440) = 188111.148
 $\phi = 0.95$, for fully-wrapped sections
 $w_f / s_f = 1$ (FRP strips adjacent to one another).
In (11.3) $\sin \theta + \cos \theta$ is replaced with $(\cot \theta + \csc \theta) \sin \alpha$ which is more a generalised expression,
where α 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 θ_i ,

as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.
orientation 1: $\theta = b1 + 90^\circ = 90.00$
 $V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, \theta)|)$, with:
total thickness per orientation, $t_{f1} = NL \cdot t / \text{NoDir} = 1.016$
 $d_{fv} = d$ (figure 11.2, ACI 440) = 357.00
 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: $V_s + V_f \leq 405571.497$
 $b_w = 400.00$

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 $\theta = 6.3775258E-023$
 $y = (M_y \cdot L_s / 3) / E_{eff} = 0.00415372$ ((4.29), Biskinis Phd)
 $M_y = 1.4156E+008$
 $L_s = M/V$ (with $L_s > 0.1 \cdot L$ and $L_s < 2 \cdot L$) = 1500.00
From table 10.5, ASCE 41_17: $E_{eff} = \text{factor} \cdot E_c \cdot I_g = 1.7040E+013$
factor = 0.30
 $A_g = 160000.00$
Mean concrete strength: $f_c' = (f_c'_{jacket} \cdot \text{Area}_{jacket} + f_c'_{core} \cdot \text{Area}_{core}) / \text{Area}_{section} = 29.75$
 $N = 6438.97$
 $E_c \cdot I_g = E_{c,jacket} \cdot I_{g,jacket} + E_{c,core} \cdot I_{g,core} = 5.6801E+013$

Calculation of Yielding Moment M_y

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

$y = \text{Min}(y_{ten}, y_{com})$
 $y_{ten} = 8.5640402E-006$
with ((10.1), ASCE 41-17) $f_y = \text{Min}(f_y, 1.25 \cdot f_y \cdot (I_b / I_d)^{2/3}) = 454.4281$
 $d = 357.00$
 $y = 0.2568299$
 $A = 0.01453119$
 $B = 0.00818436$
with $p_t = 0.00580799$
 $p_c = 0.00580799$
 $p_v = 0.00281599$
 $N = 6438.97$
 $b = 400.00$
 $\theta = 0.12044818$
 $y_{comp} = 2.5296911E-005$
with f_c^* (12.3, (ACI 440)) = 34.65599
 $f_c = 33.00$
 $f_l = 0.93147527$
 $b = 400.00$
 $h = 400.00$
 $A_g = 160000.00$
From (12.9), ACI 440: $k_a = 0.56708553$
 $g = p_t + p_c + p_v = 0.01443197$
 $r_c = 40.00$
 $A_e / A_c = 0.56708553$
Effective FRP thickness, $t_f = NL \cdot t \cdot \text{Cos}(b1) = 1.016$
effective strain from (12.5) and (12.12), $\epsilon_{fe} = 0.004$
 $f_u = 0.01$
 $E_f = 64828.00$
 $E_c = 26999.444$
 $y = 0.25583518$
 $A = 0.01433439$

B = 0.00808514
with $E_s = 200000.00$

Calculation of ratio l_b/d

Lap Length: $l_d/l_{d,min} = 0.56621983$

$l_b = 300.00$

$l_d = 529.8296$

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

$= 1$

$d_b = 14.66667$

Mean strength value of all re-bars: $f_y = 525.2545$

Mean concrete strength: $f_c' = (f_c'_{jacket} \cdot Area_{jacket} + f_c'_{core} \cdot Area_{core}) / Area_{section} = 29.75$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 3.43481$

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

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

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

$n = 12.00$

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

At local axis: 3

Integration Section: (b)

Calculation No. 8

column C1, Floor 1

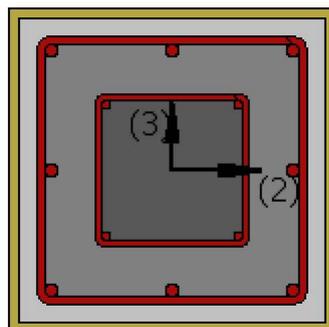
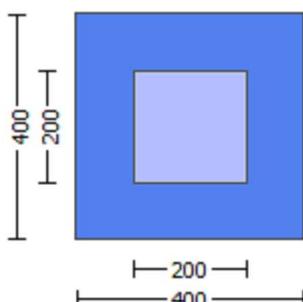
Limit State: Immediate Occupancy (data interpolation between analysis steps 2 and 3)

Analysis: Uniform +X

Check: Chord rotation capacity (θ)

Edge: End

Local Axis: (3)



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

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

Constant Properties

Knowledge Factor, $\gamma = 0.80$

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

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

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

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

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

Jacket

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

Existing Column

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

#####

External Height, $H = 400.00$

External Width, $W = 400.00$

Internal Height, $H = 200.00$

Internal Width, $W = 200.00$

Cover Thickness, $c = 25.00$

Mean Confinement Factor overall section = 1.13212

Element Length, $L = 3000.00$

Secondary Member

Ribbed Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

Lap Length $l_o = 300.00$

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $e_{fu} = 0.01$

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

Fiber orientations, $b_i = 0.00^\circ$

Number of layers, $N_L = 1$

Radius of rounding corners, $R = 40.00$

Stepwise Properties

At local axis: 3

EDGE -A-

Shear Force, $V_a = 2.8976040E-031$

EDGE -B-

Shear Force, $V_b = -2.8976040E-031$

BOTH EDGES

Axial Force, $F = -5926.932$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: $A_{st} = 0.00$

-Compression: $A_{s,c} = 2060.885$
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension: $A_{s,t} = 829.3805$
-Compression: $A_{s,c} = 829.3805$
-Middle: $A_{s,m} = 402.1239$

Calculation of Shear Capacity ratio, $V_e/V_r = 0.19159777$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 121293.391$
with

$M_{pr1} = \text{Max}(M_{u1+}, M_{u1-}) = 1.8194E+008$

$M_{u1+} = 1.8194E+008$, is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination

$M_{u1-} = 1.8194E+008$, is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination

$M_{pr2} = \text{Max}(M_{u2+}, M_{u2-}) = 1.8194E+008$

$M_{u2+} = 1.8194E+008$, is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the the static loading combination

$M_{u2-} = 1.8194E+008$, is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the the static loading combination

Calculation of M_{u1+}

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

$\phi_u = 3.6747033E-005$

$M_u = 1.8194E+008$

with full section properties:

$b = 400.00$

$d = 357.00$

$d' = 43.00$

$v = 0.00125773$

$N = 5926.932$

$f_c = 33.00$

ϕ_c (5A.5, TBDY) = 0.002

Final value of ϕ_u : $\phi_u^* = \text{shear_factor} * \text{Max}(\phi_c, \phi_c) = 0.01505571$

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

From (5.4b), TBDY: $\phi_u = 0.01505571$

ϕ_{we} ((5.4c), TBDY) = $a_s * \phi_{u, \min} * f_{ywe} / f_{ce} + \text{Min}(\phi_x, \phi_y) = 0.08345896$

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

$\phi_x = 0.07683125$

$a_f = 0.57333333$

$b = 400.00$

$h = 400.00$

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

$b_w = 400.00$

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

$\phi_y = 0.07683125$

$a_f = 0.57333333$

$b = 400.00$

$h = 400.00$

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

$b_w = 400.00$

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

$R = 40.00$

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 ((5.4d), TBDY) = (ase1*Aext+ase2*Aint)/Asec = 0.24250288

ase1 = 0.24250288

bo_1 = 340.00

ho_1 = 340.00

bi2_1 = 462400.00

ase2 = Max(ase1,ase2) = 0.24250288

bo_2 = 192.00

ho_2 = 192.00

bi2_2 = 147456.00

psh,min*Fywe = Min(psh,x*Fywe , psh,y*Fywe) = 3.00635

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

psh_x*Fywe = psh1*Fywe1+ps2*Fywe2 = 3.00635

ps1 (external) = (Ash1*h1/s1)/Asec = 0.00392699

Ash1 = Astir_1*ns_1 = 157.0796

No stirrups, ns_1 = 2.00

h1 = 400.00

ps2 (internal) = (Ash2*h2/s2)/Asec = 0.00050265

Ash2 = Astir_2*ns_2 = 100.531

No stirrups, ns_2 = 2.00

h2 = 200.00

psh_y*Fywe = psh1*Fywe1+ps2*Fywe2 = 3.00635

ps1 (external) = (Ash1*h1/s1)/Asec = 0.00392699

Ash1 = Astir_1*ns_1 = 157.0796

No stirrups, ns_1 = 2.00

h1 = 400.00

ps2 (internal) = (Ash2*h2/s2)/Asec = 0.00050265

Ash2 = Astir_2*ns_2 = 100.531

No stirrups, ns_2 = 2.00

h2 = 200.00

Asec = 160000.00

s1 = 100.00

s2 = 250.00

fywe1 = 694.45

fywe2 = 555.55

fce = 33.00

From ((5.A5), TBDY), TBDY: cc = 0.00332119

c = confinement factor = 1.13212

y1 = 0.00184318

sh1 = 0.00589816

ft1 = 580.8818

fy1 = 484.0682

su1 = 0.01099427

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

lo/lou,min = lb/lb = 0.45297586

su1 = 0.4*esu1_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu1_nominal = 0.08,

For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/lb)^2/3), from 10.3.5, ASCE 41-17.

with fs1 = (fs,jacket*Asl,ten,jacket + fs,core*Asl,ten,core)/Asl,ten = 484.0682

with Es1 = (Es,jacket*Asl,ten,jacket + Es,core*Asl,ten,core)/Asl,ten = 200000.00

y2 = 0.00184318

sh2 = 0.00589816

ft2 = 580.8818

fy2 = 484.0682

su2 = 0.01099427

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

lo/lou,min = lb/lb,min = 0.45297586

$$su_2 = 0.4 * esu_2_nominal ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: $esu_2_nominal = 0.08$,

For calculation of $esu_2_nominal$ and y_2, sh_2, ft_2, fy_2 , it is considered characteristic value $fsy_2 = fs_2/1.2$, from table 5.1, TBDY.

y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE 41-17.

$$\text{with } fs_2 = (fs_jacket * Asl_com_jacket + fs_core * Asl_com_core) / Asl_com = 484.0682$$

$$\text{with } Es_2 = (Es_jacket * Asl_com_jacket + Es_core * Asl_com_core) / Asl_com = 200000.00$$

$$y_v = 0.00184318$$

$$sh_v = 0.00589816$$

$$ft_v = 614.3968$$

$$fy_v = 511.9973$$

$$suv = 0.01099427$$

using (30) in Biskinis/Fardis (2013) multiplied with $shear_factor$

and also multiplied by the $shear_factor$ according to 15.7.1.4, with

$$Shear_factor = 1.00$$

$$lo/lo_{u,min} = lb/ld = 0.45297586$$

$$suv = 0.4 * esuv_nominal ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: $esuv_nominal = 0.08$,

considering characteristic value $fsv = fs_v/1.2$, from table 5.1, TBDY

For calculation of $esuv_nominal$ and y_v, sh_v, ft_v, fy_v , it is considered characteristic value $fsv = fs_v/1.2$, 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.

$$\text{with } fs_v = (fs_jacket * Asl_mid_jacket + fs_mid * Asl_mid_core) / Asl_mid = 511.9973$$

$$\text{with } Es_v = (Es_jacket * Asl_mid_jacket + Es_mid * Asl_mid_core) / Asl_mid = 200000.00$$

$$1 = Asl_ten / (b * d) * (fs_1 / fc) = 0.0851958$$

$$2 = Asl_com / (b * d) * (fs_2 / fc) = 0.0851958$$

$$v = Asl_mid / (b * d) * (fs_v / fc) = 0.04369034$$

and confined core properties:

$$b = 340.00$$

$$d = 327.00$$

$$d' = 13.00$$

$$fcc (5A.2, TBDY) = 37.35991$$

$$cc (5A.5, TBDY) = 0.00332119$$

$$c = \text{confinement factor} = 1.13212$$

$$1 = Asl_ten / (b * d) * (fs_1 / fc) = 0.1094258$$

$$2 = Asl_com / (b * d) * (fs_2 / fc) = 0.1094258$$

$$v = Asl_mid / (b * d) * (fs_v / fc) = 0.05611603$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < v_{s,y_2}$ - LHS eq.(4.5) is satisfied

--->

$$su (4.9) = 0.16193824$$

$$\mu_u = MR_c (4.14) = 1.8194E+008$$

$$u = su (4.1) = 3.6747033E-005$$

Calculation of ratio lb/ld

Lap Length: $lb/ld = 0.45297586$

$$lb = 300.00$$

$$ld = 662.2869$$

Calculation of lb_{min} according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

$$= 1$$

$$db = 14.66667$$

Mean strength value of all re-bars: $fy = 656.5682$

Mean concrete strength: $fc' = (fc'_jacket * Area_jacket + fc'_core * Area_core) / Area_section = 29.75$, but $fc'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$cb = 25.00$$

$$K_{tr} = 3.43481$$

$$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 257.6106$$

where A_{tr_x}, A_{tr_y} are the sum of the area of all stirrup legs along X and Y local axis

$$s = \text{Max}(s_{external}, s_{internal}) = 250.00$$

$$n = 12.00$$

Calculation of Mu1-

Calculation of ultimate curvature μ according to 4.1, Biskinis/Fardis 2013:

$$\mu = 3.6747033E-005$$

$$Mu = 1.8194E+008$$

with full section properties:

$$b = 400.00$$

$$d = 357.00$$

$$d' = 43.00$$

$$v = 0.00125773$$

$$N = 5926.932$$

$$f_c = 33.00$$

$$c_o \text{ (5A.5, TBDY)} = 0.002$$

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_o) = 0.01505571$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } c_u = 0.01505571$$

$$w_e \text{ ((5.4c), TBDY)} = a_{se} * s_{h,min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.08345896$$

where $f = a_f * p_f * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.07683125$$

$$a_f = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 870.5244$$

$$f_y = 0.07683125$$

$$a_f = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 870.5244$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L * t * \text{Cos}(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$a_{se} \text{ ((5.4d), TBDY)} = (a_{se1} * A_{ext} + a_{se2} * A_{int}) / A_{sec} = 0.24250288$$

$$a_{se1} = 0.24250288$$

$$b_{o,1} = 340.00$$

$$h_{o,1} = 340.00$$

$$b_{i,2,1} = 462400.00$$

$$a_{se2} = \text{Max}(a_{se1}, a_{se2}) = 0.24250288$$

$$b_{o,2} = 192.00$$

$$h_{o,2} = 192.00$$

$$b_{i,2,2} = 147456.00$$

$$p_{sh,min} * F_{ywe} = \text{Min}(p_{sh,x} * F_{ywe}, p_{sh,y} * F_{ywe}) = 3.00635$$

Expression ((5.4d), TBDY) for $p_{sh,min} * F_{ywe}$ has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$$p_{sh,x} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{sh2} * F_{ywe2} = 3.00635$$

$$p_{s1} \text{ (external)} = (A_{sh1} * h_1 / s_1) / A_{sec} = 0.00392699$$

$$A_{sh1} = A_{stir,1} * n_{s,1} = 157.0796$$

$$\text{No stirrups, } n_{s,1} = 2.00$$

$$h_1 = 400.00$$

$$p_{s2} \text{ (internal)} = (A_{sh2} * h_2 / s_2) / A_{sec} = 0.00050265$$

$$A_{sh2} = A_{stir,2} * n_{s,2} = 100.531$$

$$\text{No stirrups, } n_{s,2} = 2.00$$

$$h2 = 200.00$$

$$\begin{aligned} psh_y * Fywe &= psh1 * Fywe1 + ps2 * Fywe2 = 3.00635 \\ ps1 \text{ (external)} &= (Ash1 * h1 / s1) / Asec = 0.00392699 \\ Ash1 &= Astir_1 * ns_1 = 157.0796 \\ \text{No stirups, } ns_1 &= 2.00 \\ h1 &= 400.00 \\ ps2 \text{ (internal)} &= (Ash2 * h2 / s2) / Asec = 0.00050265 \\ Ash2 &= Astir_2 * ns_2 = 100.531 \\ \text{No stirups, } ns_2 &= 2.00 \\ h2 &= 200.00 \end{aligned}$$

$$Asec = 160000.00$$

$$s1 = 100.00$$

$$s2 = 250.00$$

$$fywe1 = 694.45$$

$$fywe2 = 555.55$$

$$fce = 33.00$$

$$\text{From } ((5.A.5), \text{ TBDY}), \text{ TBDY: } cc = 0.00332119$$

$$c = \text{confinement factor} = 1.13212$$

$$y1 = 0.00184318$$

$$sh1 = 0.00589816$$

$$ft1 = 580.8818$$

$$fy1 = 484.0682$$

$$su1 = 0.01099427$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$lo/lou, \text{min} = lb/ld = 0.45297586$$

$$su1 = 0.4 * esu1_nominal \text{ ((5.5), TBDY)} = 0.032$$

From table 5A.1, TBDY: esu1_nominal = 0.08,

For calculation of esu1_nominal and y1, sh1, ft1, fy1, it is considered
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1, ft1, fy1, are also multiplied by $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE 41-17.

$$\text{with } fs1 = (fs_jacket * Asl, \text{ten, jacket} + fs_core * Asl, \text{ten, core}) / Asl, \text{ten} = 484.0682$$

$$\text{with } Es1 = (Es_jacket * Asl, \text{ten, jacket} + Es_core * Asl, \text{ten, core}) / Asl, \text{ten} = 200000.00$$

$$y2 = 0.00184318$$

$$sh2 = 0.00589816$$

$$ft2 = 580.8818$$

$$fy2 = 484.0682$$

$$su2 = 0.01099427$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$lo/lou, \text{min} = lb/lb, \text{min} = 0.45297586$$

$$su2 = 0.4 * esu2_nominal \text{ ((5.5), TBDY)} = 0.032$$

From table 5A.1, TBDY: esu2_nominal = 0.08,

For calculation of esu2_nominal and y2, sh2, ft2, fy2, it is considered
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

y1, sh1, ft1, fy1, are also multiplied by $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE 41-17.

$$\text{with } fs2 = (fs_jacket * Asl, \text{com, jacket} + fs_core * Asl, \text{com, core}) / Asl, \text{com} = 484.0682$$

$$\text{with } Es2 = (Es_jacket * Asl, \text{com, jacket} + Es_core * Asl, \text{com, core}) / Asl, \text{com} = 200000.00$$

$$yv = 0.00184318$$

$$shv = 0.00589816$$

$$ftv = 614.3968$$

$$fyv = 511.9973$$

$$suv = 0.01099427$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$lo/lou, \text{min} = lb/ld = 0.45297586$$

$$suv = 0.4 * esuv_nominal \text{ ((5.5), TBDY)} = 0.032$$

From table 5A.1, TBDY: esuv_nominal = 0.08,

considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY
For calculation of esuv_nominal and yv, shv, ftv, fyv, it is considered

characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.

y1, sh1, ft1, fy1, are also multiplied by $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE 41-17.

with $f_{sv} = (f_{s,jacket} \cdot A_{s,mid,jacket} + f_{s,mid} \cdot A_{s,mid,core}) / A_{s,mid} = 511.9973$
with $E_{sv} = (E_{s,jacket} \cdot A_{s,mid,jacket} + E_{s,mid} \cdot A_{s,mid,core}) / A_{s,mid} = 200000.00$
 $1 = A_{s,ten} / (b \cdot d) \cdot (f_{s1} / f_c) = 0.0851958$
 $2 = A_{s,com} / (b \cdot d) \cdot (f_{s2} / f_c) = 0.0851958$
 $v = A_{s,mid} / (b \cdot d) \cdot (f_{sv} / f_c) = 0.04369034$

and confined core properties:

$b = 340.00$
 $d = 327.00$
 $d' = 13.00$
 $f_{cc} (5A.2, TBDY) = 37.35991$
 $cc (5A.5, TBDY) = 0.00332119$
 $c = \text{confinement factor} = 1.13212$
 $1 = A_{s,ten} / (b \cdot d) \cdot (f_{s1} / f_c) = 0.1094258$
 $2 = A_{s,com} / (b \cdot d) \cdot (f_{s2} / f_c) = 0.1094258$
 $v = A_{s,mid} / (b \cdot d) \cdot (f_{sv} / f_c) = 0.05611603$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < v_{s,y2}$ - LHS eq.(4.5) is satisfied

--->

$\mu_u (4.9) = 0.16193824$
 $M_u = M_{Rc} (4.14) = 1.8194E+008$
 $u = \mu_u (4.1) = 3.6747033E-005$

Calculation of ratio l_b/d

Lap Length: $l_b/d = 0.45297586$

$l_b = 300.00$
 $l_d = 662.2869$

Calculation of l_b, \min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

= 1

$d_b = 14.66667$
Mean strength value of all re-bars: $f_y = 656.5682$
Mean concrete strength: $f_c' = (f_c'_{jacket} \cdot \text{Area}_{jacket} + f_c'_{core} \cdot \text{Area}_{core}) / \text{Area}_{section} = 29.75$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $t = 1.00$
 $s = 0.80$
 $e = 1.00$
 $cb = 25.00$
 $K_{tr} = 3.43481$
 $A_{tr} = \text{Min}(A_{tr,x}, A_{tr,y}) = 257.6106$
where $A_{tr,x}$, $A_{tr,y}$ are the sum of the area of all stirrup legs along X and Y local axis
 $s = \text{Max}(s_{external}, s_{internal}) = 250.00$
 $n = 12.00$

Calculation of μ_{u2+}

Calculation of ultimate curvature μ_u according to 4.1, Biskinis/Fardis 2013:

$u = 3.6747033E-005$
 $M_u = 1.8194E+008$

with full section properties:

$b = 400.00$
 $d = 357.00$
 $d' = 43.00$
 $v = 0.00125773$
 $N = 5926.932$
 $f_c = 33.00$
 $co (5A.5, TBDY) = 0.002$
Final value of μ_u : $\mu_u^* = \text{shear_factor} \cdot \text{Max}(\mu_u, cc) = 0.01505571$
The Shear_factor is considered equal to 1 (pure moment strength)
From (5.4b), TBDY: $\mu_u = 0.01505571$

w_e ((5.4c), TBDY) = $a_{se} \cdot \min(f_{ywe}/f_{ce} + \min(f_x, f_y)) = 0.08345896$
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)

$f_x = 0.07683125$
 $a_f = 0.57333333$
 $b = 400.00$
 $h = 400.00$
From EC8 A.4.4.3(6), $p_f = 2t_f/bw = 0.00508$
 $bw = 400.00$
effective stress from (A.35), $f_{f,e} = 870.5244$

$f_y = 0.07683125$
 $a_f = 0.57333333$
 $b = 400.00$
 $h = 400.00$
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, $t_f = NL \cdot t \cdot \cos(b_1) = 1.016$
 $f_{u,f} = 1055.00$
 $E_f = 64828.00$
 $u_{,f} = 0.015$
 a_{se} ((5.4d), TBDY) = $(a_{se1} \cdot A_{ext} + a_{se2} \cdot A_{int})/A_{sec} = 0.24250288$
 $a_{se1} = 0.24250288$
 $bo_{,1} = 340.00$
 $ho_{,1} = 340.00$
 $bi_{2,1} = 462400.00$
 $a_{se2} = \max(a_{se1}, a_{se2}) = 0.24250288$
 $bo_{,2} = 192.00$
 $ho_{,2} = 192.00$
 $bi_{2,2} = 147456.00$

$p_{sh, \min} \cdot F_{ywe} = \min(p_{sh,x} \cdot F_{ywe}, p_{sh,y} \cdot F_{ywe}) = 3.00635$

Expression ((5.4d), TBDY) for $p_{sh, \min} \cdot F_{ywe}$ has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$p_{sh,x} \cdot F_{ywe} = p_{sh1} \cdot F_{ywe1} + p_{sh2} \cdot F_{ywe2} = 3.00635$
 ps_1 (external) = $(A_{sh1} \cdot h_1/s_1)/A_{sec} = 0.00392699$
 $A_{sh1} = A_{stir,1} \cdot ns_1 = 157.0796$
No stirrups, $ns_1 = 2.00$
 $h_1 = 400.00$
 ps_2 (internal) = $(A_{sh2} \cdot h_2/s_2)/A_{sec} = 0.00050265$
 $A_{sh2} = A_{stir,2} \cdot ns_2 = 100.531$
No stirrups, $ns_2 = 2.00$
 $h_2 = 200.00$

$p_{sh,y} \cdot F_{ywe} = p_{sh1} \cdot F_{ywe1} + p_{sh2} \cdot F_{ywe2} = 3.00635$
 ps_1 (external) = $(A_{sh1} \cdot h_1/s_1)/A_{sec} = 0.00392699$
 $A_{sh1} = A_{stir,1} \cdot ns_1 = 157.0796$
No stirrups, $ns_1 = 2.00$
 $h_1 = 400.00$
 ps_2 (internal) = $(A_{sh2} \cdot h_2/s_2)/A_{sec} = 0.00050265$
 $A_{sh2} = A_{stir,2} \cdot ns_2 = 100.531$
No stirrups, $ns_2 = 2.00$
 $h_2 = 200.00$

$A_{sec} = 160000.00$

$s_1 = 100.00$

$s_2 = 250.00$

$f_{ywe1} = 694.45$

$f_{ywe2} = 555.55$

$f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY: $cc = 0.00332119$

$c =$ confinement factor = 1.13212

$y_1 = 0.00184318$

$sh_1 = 0.00589816$

$ft1 = 580.8818$
 $fy1 = 484.0682$
 $su1 = 0.01099427$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $lo/lou,min = lb/ld = 0.45297586$
 $su1 = 0.4*esu1_nominal ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $esu1_nominal = 0.08$,
 For calculation of $esu1_nominal$ and $y1, sh1,ft1,fy1$, it is considered
 characteristic value $fsy1 = fs1/1.2$, from table 5.1, TBDY.
 $y1, sh1,ft1,fy1$, are also multiplied by $Min(1,1.25*(lb/ld)^{2/3})$, from 10.3.5, ASCE 41-17.
 with $fs1 = (fs,jacket*Asl,ten,jacket + fs,core*Asl,ten,core)/Asl,ten = 484.0682$
 with $Es1 = (Es,jacket*Asl,ten,jacket + Es,core*Asl,ten,core)/Asl,ten = 200000.00$
 $y2 = 0.00184318$
 $sh2 = 0.00589816$
 $ft2 = 580.8818$
 $fy2 = 484.0682$
 $su2 = 0.01099427$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $lo/lou,min = lb/lb,min = 0.45297586$
 $su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $esu2_nominal = 0.08$,
 For calculation of $esu2_nominal$ and $y2, sh2,ft2,fy2$, it is considered
 characteristic value $fsy2 = fs2/1.2$, from table 5.1, TBDY.
 $y1, sh1,ft1,fy1$, are also multiplied by $Min(1,1.25*(lb/ld)^{2/3})$, from 10.3.5, ASCE 41-17.
 with $fs2 = (fs,jacket*Asl,com,jacket + fs,core*Asl,com,core)/Asl,com = 484.0682$
 with $Es2 = (Es,jacket*Asl,com,jacket + Es,core*Asl,com,core)/Asl,com = 200000.00$
 $yv = 0.00184318$
 $shv = 0.00589816$
 $ftv = 614.3968$
 $fyv = 511.9973$
 $suv = 0.01099427$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $lo/lou,min = lb/ld = 0.45297586$
 $suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032$
 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 $fsv = (fs,jacket*Asl,mid,jacket + fs,mid*Asl,mid,core)/Asl,mid = 511.9973$
 with $Es_v = (Es,jacket*Asl,mid,jacket + Es,mid*Asl,mid,core)/Asl,mid = 200000.00$
 $1 = Asl,ten/(b*d)*(fs1/fc) = 0.0851958$
 $2 = Asl,com/(b*d)*(fs2/fc) = 0.0851958$
 $v = Asl,mid/(b*d)*(fsv/fc) = 0.04369034$
 and confined core properties:
 $b = 340.00$
 $d = 327.00$
 $d' = 13.00$
 $fcc (5A.2, TBDY) = 37.35991$
 $cc (5A.5, TBDY) = 0.00332119$
 $c = \text{confinement factor} = 1.13212$
 $1 = Asl,ten/(b*d)*(fs1/fc) = 0.1094258$
 $2 = Asl,com/(b*d)*(fs2/fc) = 0.1094258$
 $v = Asl,mid/(b*d)*(fsv/fc) = 0.05611603$
 Case/Assumption: Unconfined full section - Steel rupture
 ' satisfies Eq. (4.3)
 --->
 $v < vs,y2$ - LHS eq.(4.5) is satisfied
 --->
 $su (4.9) = 0.16193824$
 $Mu = MRc (4.14) = 1.8194E+008$

$$u = s_u(4.1) = 3.6747033E-005$$

Calculation of ratio l_b/d

$$\text{Lap Length: } l_b/d = 0.45297586$$

$$l_b = 300.00$$

$$d = 662.2869$$

Calculation of l_b, \min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

$$= 1$$

$$d_b = 14.66667$$

$$\text{Mean strength value of all re-bars: } f_y = 656.5682$$

$$\text{Mean concrete strength: } f_c' = (f_c'_{\text{jacket}} \cdot \text{Area}_{\text{jacket}} + f_c'_{\text{core}} \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 29.75, \text{ but } f_c'^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 25.00$$

$$K_{tr} = 3.43481$$

$$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 257.6106$$

where A_{tr_x}, A_{tr_y} are the sum of the area of all stirrup legs along X and Y local axis

$$s = \text{Max}(s_{\text{external}}, s_{\text{internal}}) = 250.00$$

$$n = 12.00$$

Calculation of μ_2

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

$$u = 3.6747033E-005$$

$$\mu_u = 1.8194E+008$$

with full section properties:

$$b = 400.00$$

$$d = 357.00$$

$$d' = 43.00$$

$$v = 0.00125773$$

$$N = 5926.932$$

$$f_c = 33.00$$

$$c_o \text{ (5A.5, TBDY)} = 0.002$$

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.01505571$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } c_u = 0.01505571$$

$$w_e \text{ ((5.4c), TBDY)} = a_s c * s_{h, \min} * f_{y, w} / f_{c, e} + \text{Min}(f_x, f_y) = 0.08345896$$

where $f = a_f * p_f * f_{f, e} / f_{c, e}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.07683125$$

$$a_f = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{f, e} = 870.5244$$

$$f_y = 0.07683125$$

$$a_f = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{f, e} = 870.5244$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L * t * \text{Cos}(b_1) = 1.016$$

$$f_{u, f} = 1055.00$$

Ef = 64828.00

u,f = 0.015

ase ((5.4d), TBDY) = (ase1*Aext+ase2*Aint)/Asec = 0.24250288

ase1 = 0.24250288

bo_1 = 340.00

ho_1 = 340.00

bi2_1 = 462400.00

ase2 = Max(ase1,ase2) = 0.24250288

bo_2 = 192.00

ho_2 = 192.00

bi2_2 = 147456.00

psh,min*Fywe = Min(psh,x*Fywe , psh,y*Fywe) = 3.00635

Expression ((5.4d), TBDY) for psh,min*Fywe has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

psh_x*Fywe = psh1*Fywe1+ps2*Fywe2 = 3.00635

ps1 (external) = (Ash1*h1/s1)/Asec = 0.00392699

Ash1 = Astir_1*ns_1 = 157.0796

No stirrups, ns_1 = 2.00

h1 = 400.00

ps2 (internal) = (Ash2*h2/s2)/Asec = 0.00050265

Ash2 = Astir_2*ns_2 = 100.531

No stirrups, ns_2 = 2.00

h2 = 200.00

psh_y*Fywe = psh1*Fywe1+ps2*Fywe2 = 3.00635

ps1 (external) = (Ash1*h1/s1)/Asec = 0.00392699

Ash1 = Astir_1*ns_1 = 157.0796

No stirrups, ns_1 = 2.00

h1 = 400.00

ps2 (internal) = (Ash2*h2/s2)/Asec = 0.00050265

Ash2 = Astir_2*ns_2 = 100.531

No stirrups, ns_2 = 2.00

h2 = 200.00

Asec = 160000.00

s1 = 100.00

s2 = 250.00

fywe1 = 694.45

fywe2 = 555.55

fce = 33.00

From ((5.A5), TBDY), TBDY: cc = 0.00332119

c = confinement factor = 1.13212

y1 = 0.00184318

sh1 = 0.00589816

ft1 = 580.8818

fy1 = 484.0682

su1 = 0.01099427

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

lo/lou,min = lb/ld = 0.45297586

su1 = 0.4*esu1_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu1_nominal = 0.08,

For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/ld)^2/3), from 10.3.5, ASCE 41-17.

with fs1 = (fs,jacket*Asl,ten,jacket + fs,core*Asl,ten,core)/Asl,ten = 484.0682

with Es1 = (Es,jacket*Asl,ten,jacket + Es,core*Asl,ten,core)/Asl,ten = 200000.00

y2 = 0.00184318

sh2 = 0.00589816

ft2 = 580.8818

fy2 = 484.0682

su2 = 0.01099427

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$$l_0/l_{0u,min} = l_b/l_{b,min} = 0.45297586$$

$$s_u = 0.4 \cdot e_{su2,nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: $e_{su2,nominal} = 0.08$,

For calculation of $e_{su2,nominal}$ and y_2 , sh_2 , ft_2 , fy_2 , it is considered characteristic value $f_{sy2} = f_{s2}/1.2$, from table 5.1, TBDY.

y_1 , sh_1 , ft_1 , fy_1 , are also multiplied by $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$, from 10.3.5, ASCE 41-17.

$$\text{with } f_{s2} = (f_{s,jacket} \cdot A_{s1,com,jacket} + f_{s,core} \cdot A_{s1,com,core}) / A_{s1,com} = 484.0682$$

$$\text{with } E_{s2} = (E_{s,jacket} \cdot A_{s1,com,jacket} + E_{s,core} \cdot A_{s1,com,core}) / A_{s1,com} = 200000.00$$

$$y_v = 0.00184318$$

$$sh_v = 0.00589816$$

$$ft_v = 614.3968$$

$$fy_v = 511.9973$$

$$s_{uv} = 0.01099427$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor

and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$$l_0/l_{0u,min} = l_b/l_d = 0.45297586$$

$$s_{uv} = 0.4 \cdot e_{suv,nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: $e_{suv,nominal} = 0.08$,

considering characteristic value $f_{sv} = f_{sv}/1.2$, from table 5.1, TBDY

For calculation of $e_{suv,nominal}$ and y_v , sh_v , ft_v , fy_v , it is considered characteristic value $f_{sv} = f_{sv}/1.2$, from table 5.1, TBDY.

y_1 , sh_1 , ft_1 , fy_1 , are also multiplied by $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$, from 10.3.5, ASCE 41-17.

$$\text{with } f_{sv} = (f_{s,jacket} \cdot A_{s,mid,jacket} + f_{s,mid} \cdot A_{s,mid,core}) / A_{s,mid} = 511.9973$$

$$\text{with } E_{sv} = (E_{s,jacket} \cdot A_{s,mid,jacket} + E_{s,mid} \cdot A_{s,mid,core}) / A_{s,mid} = 200000.00$$

$$1 = A_{s1,ten} / (b \cdot d) \cdot (f_{s1} / f_c) = 0.0851958$$

$$2 = A_{s1,com} / (b \cdot d) \cdot (f_{s2} / f_c) = 0.0851958$$

$$v = A_{s1,mid} / (b \cdot d) \cdot (f_{sv} / f_c) = 0.04369034$$

and confined core properties:

$$b = 340.00$$

$$d = 327.00$$

$$d' = 13.00$$

$$f_{cc} (5A.2, TBDY) = 37.35991$$

$$c_c (5A.5, TBDY) = 0.00332119$$

$$c = \text{confinement factor} = 1.13212$$

$$1 = A_{s1,ten} / (b \cdot d) \cdot (f_{s1} / f_c) = 0.1094258$$

$$2 = A_{s1,com} / (b \cdot d) \cdot (f_{s2} / f_c) = 0.1094258$$

$$v = A_{s1,mid} / (b \cdot d) \cdot (f_{sv} / f_c) = 0.05611603$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

---->

$v < v_{s,y2}$ - LHS eq.(4.5) is satisfied

---->

$$s_u (4.9) = 0.16193824$$

$$\mu_u = M_{Rc} (4.14) = 1.8194E+008$$

$$u = s_u (4.1) = 3.6747033E-005$$

Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.45297586$

$$l_b = 300.00$$

$$l_d = 662.2869$$

Calculation of $l_{b,min}$ according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

$$= 1$$

$$d_b = 14.66667$$

Mean strength value of all re-bars: $f_y = 656.5682$

Mean concrete strength: $f'_c = (f'_{c,jacket} \cdot \text{Area}_{jacket} + f'_{c,core} \cdot \text{Area}_{core}) / \text{Area}_{section} = 29.75$, but $f'_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 25.00$$

$$K_{tr} = 3.43481$$

$$A_{tr} = \text{Min}(A_{tr,x}, A_{tr,y}) = 257.6106$$

where $A_{tr,x}$, $A_{tr,y}$ are the sum of the area of all stirrup legs along X and Y local axis

$$s = \text{Max}(s_{external}, s_{internal}) = 250.00$$

n = 12.00

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 633062.661$

Calculation of Shear Strength at edge 1, $V_{r1} = 633062.661$

$V_{r1} = V_{Co1} \text{ ((10.3), ASCE 41-17)} = knl * V_{Co10}$

$V_{Co10} = 633062.661$

$knl = 1$ (zero step-static loading)

NOTE: In expression (10-3) ' $V_s = A_v * f_y * d / s$ ' is replaced by ' $V_s + f * V_f$ ' where V_f is the contribution of FRPs (11.3), ACI 440).

= 1 (normal-weight concrete)

Mean concrete strength: $f_c' = (f_c'_{\text{jacket}} * \text{Area}_{\text{jacket}} + f_c'_{\text{core}} * \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 29.75$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M / Vd = 2.00$

$\mu_u = 4.3445556E-012$

$V_u = 2.8976040E-031$

$d = 0.8 * h = 320.00$

$N_u = 5926.932$

$A_g = 160000.00$

From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 279254.914$

where:

$V_{s1} = 279254.914$ is calculated for jacket, with:

$d = 320.00$

$A_v = 157079.633$

$f_y = 555.56$

$s = 100.00$

V_{s1} is multiplied by $Col1 = 1.00$

$s/d = 0.3125$

$V_{s2} = 0.00$ is calculated for core, with:

$d = 160.00$

$A_v = 100530.965$

$f_y = 444.44$

$s = 250.00$

V_{s2} is multiplied by $Col2 = 0.00$

$s/d = 1.5625$

$V_f \text{ ((11-3)-(11.4), ACI 440)} = 188111.148$

$f = 0.95$, for fully-wrapped sections

$wf / sf = 1$ (FRP strips adjacent to one another).

In (11.3) $\sin \theta + \cos \theta$ is replaced with $(\cot \theta + \csc \theta) \sin \alpha$ which is more a generalised expression,

where θ is the angle of the crack direction (see KANEPE).

This later relation, considered as a function $V_f(\theta, \alpha)$, is implemented for every different fiber orientation α_i , as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.

orientation 1: $\theta = b1 + 90^\circ = 90.00$

$V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, \theta)|)$, with:

total thickness per orientation, $tf1 = NL * t / \text{NoDir} = 1.016$

$d_{fv} = d$ (figure 11.2, ACI 440) = 357.00

$f_{fe} \text{ ((11-5), ACI 440)} = 259.312$

$E_f = 64828.00$

$f_e = 0.004$, from (11.6a), ACI 440

with $f_u = 0.01$

From (11-11), ACI 440: $V_s + V_f \leq 463788.751$

$bw = 400.00$

Calculation of Shear Strength at edge 2, $V_{r2} = 633062.661$

$V_{r2} = V_{Co2} \text{ ((10.3), ASCE 41-17)} = knl * V_{Co10}$

$V_{Co10} = 633062.661$

$knl = 1$ (zero step-static loading)

NOTE: In expression (10-3) ' $V_s = A_v * f_y * d / s$ ' is replaced by ' $V_s + f * V_f$ ' where V_f is the contribution of FRPs (11.3), ACI 440).

= 1 (normal-weight concrete)

Mean concrete strength: $f_c' = (f_c'_{\text{jacket}} \cdot \text{Area}_{\text{jacket}} + f_c'_{\text{core}} \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 29.75$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$\mu_u = 4.3445556E-012$

$\nu_u = 2.8976040E-031$

$d = 0.8 \cdot h = 320.00$

$N_u = 5926.932$

$A_g = 160000.00$

From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 279254.914$

where:

$V_{s1} = 279254.914$ is calculated for jacket, with:

$d = 320.00$

$A_v = 157079.633$

$f_y = 555.56$

$s = 100.00$

V_{s1} is multiplied by $\text{Col1} = 1.00$

$s/d = 0.3125$

$V_{s2} = 0.00$ is calculated for core, with:

$d = 160.00$

$A_v = 100530.965$

$f_y = 444.44$

$s = 250.00$

V_{s2} is multiplied by $\text{Col2} = 0.00$

$s/d = 1.5625$

V_f ((11-3)-(11.4), ACI 440) = 188111.148

$f = 0.95$, for fully-wrapped sections

$w_f/s_f = 1$ (FRP strips adjacent to one another).

In (11.3) $\sin + \cos$ is replaced with $(\cot + \cot a) \sin a$ which is more a generalised expression, where a is the angle of the crack direction (see KANEPE).

This later relation, considered as a function $V_f(\theta)$, is implemented for every different fiber orientation a_i , as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.

orientation 1: $\theta = b1 + 90^\circ = 90.00$

$V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, a1)|)$, with:

total thickness per orientation, $t_{f1} = NL \cdot t / \text{NoDir} = 1.016$

$d_{fv} = d$ (figure 11.2, ACI 440) = 357.00

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: $V_s + V_f \leq 463788.751$

$b_w = 400.00$

End Of Calculation of Shear Capacity ratio for element: column JC1 of floor 1
At local axis: 3

Start Of Calculation of Shear Capacity ratio for element: column JC1 of floor 1
At Shear local axis: 2
(Bending local axis: 3)
Section Type: rcjrs

Constant Properties

Knowledge Factor, $\gamma = 0.80$

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

Existing material of Secondary Member: Concrete Strength, $f_c = f_{cm} = 20.00$

```

Existing material of Secondary Member: Steel Strength,  $f_s = f_{sm} = 444.44$ 
Concrete Elasticity,  $E_c = 21019.039$ 
Steel Elasticity,  $E_s = 200000.00$ 
#####
Note: Especially for the calculation of moment strengths,
the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14
Jacket
New material: Steel Strength,  $f_s = 1.25 * f_{sm} = 694.45$ 
Existing Column
Existing material: Steel Strength,  $f_s = 1.25 * f_{sm} = 555.55$ 
#####
External Height,  $H = 400.00$ 
External Width,  $W = 400.00$ 
Internal Height,  $H = 200.00$ 
Internal Width,  $W = 200.00$ 
Cover Thickness,  $c = 25.00$ 
Mean Confinement Factor overall section = 1.13212
Element Length,  $L = 3000.00$ 
Secondary Member
Ribbed Bars
Ductile Steel
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
Lap Length  $l_o = 300.00$ 
FRP Wrapping Data
Type: Carbon
Cured laminate properties (design values)
Thickness,  $t = 1.016$ 
Tensile Strength,  $f_{fu} = 1055.00$ 
Tensile Modulus,  $E_f = 64828.00$ 
Elongation,  $e_{fu} = 0.01$ 
Number of directions,  $N_{oDir} = 1$ 
Fiber orientations,  $b_i: 0.00^\circ$ 
Number of layers,  $N_L = 1$ 
Radius of rounding corners,  $R = 40.00$ 
-----

Stepwise Properties
-----
At local axis: 2
EDGE -A-
Shear Force,  $V_a = -6.6805695E-033$ 
EDGE -B-
Shear Force,  $V_b = 6.6805695E-033$ 
BOTH EDGES
Axial Force,  $F = -5926.932$ 
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension:  $A_{sl,t} = 0.00$ 
-Compression:  $A_{sl,c} = 2060.885$ 
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension:  $A_{sl,ten} = 829.3805$ 
-Compression:  $A_{sl,com} = 829.3805$ 
-Middle:  $A_{sl,mid} = 402.1239$ 
-----
-----

Calculation of Shear Capacity ratio ,  $V_e/V_r = 0.19159777$ 
Member Controlled by Flexure ( $V_e/V_r < 1$ )
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 121293.391$ 
with
 $M_{pr1} = \text{Max}(M_{u1+} , M_{u1-}) = 1.8194E+008$ 
 $M_{u1+} = 1.8194E+008$ , is the ultimate moment strength at the edge 1 of the member in the actual moment direction
which is defined for the static loading combination
 $M_{u1-} = 1.8194E+008$ , is the ultimate moment strength at the edge 1 of the member in the opposite moment
direction which is defined for the static loading combination
 $M_{pr2} = \text{Max}(M_{u2+} , M_{u2-}) = 1.8194E+008$ 

```

Mu2+ = 1.8194E+008, is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the the static loading combination

Mu2- = 1.8194E+008, is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the the static loading combination

Calculation of Mu1+

Calculation of ultimate curvature κ_u according to 4.1, Biskinis/Fardis 2013:

$$\kappa_u = 3.6747033E-005$$

$$Mu = 1.8194E+008$$

with full section properties:

$$b = 400.00$$

$$d = 357.00$$

$$d' = 43.00$$

$$v = 0.00125773$$

$$N = 5926.932$$

$$f_c = 33.00$$

$$\kappa_{co} \text{ (5A.5, TBDY)} = 0.002$$

$$\text{Final value of } \kappa_u: \kappa_u^* = \text{shear_factor} * \text{Max}(\kappa_u, \kappa_{co}) = 0.01505571$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \kappa_u = 0.01505571$$

$$\text{we ((5.4c), TBDY) } = a_{se} * \text{sh}_{, \min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.08345896$$

where $f = a_f * p_f * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.07683125$$

$$a_f = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 870.5244$$

$$f_y = 0.07683125$$

$$a_f = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 870.5244$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L * t * \text{Cos}(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$a_{se} \text{ ((5.4d), TBDY)} = (a_{se1} * A_{ext} + a_{se2} * A_{int}) / A_{sec} = 0.24250288$$

$$a_{se1} = 0.24250288$$

$$b_{o,1} = 340.00$$

$$h_{o,1} = 340.00$$

$$b_{i,1} = 462400.00$$

$$a_{se2} = \text{Max}(a_{se1}, a_{se2}) = 0.24250288$$

$$b_{o,2} = 192.00$$

$$h_{o,2} = 192.00$$

$$b_{i,2} = 147456.00$$

$$p_{sh, \min} * f_{ywe} = \text{Min}(p_{sh,x} * f_{ywe}, p_{sh,y} * f_{ywe}) = 3.00635$$

Expression ((5.4d), TBDY) for $p_{sh, \min} * f_{ywe}$ has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$$p_{sh,x} * f_{ywe} = p_{sh1} * f_{ywe1} + p_{sh2} * f_{ywe2} = 3.00635$$

$$p_{s1} \text{ (external)} = (A_{sh1} * h_1 / s_1) / A_{sec} = 0.00392699$$

$$A_{sh1} = A_{stir,1} * n_{s,1} = 157.0796$$

$$\text{No stirrups, } n_{s,1} = 2.00$$

$$h_1 = 400.00$$

$$ps_2 \text{ (internal)} = (Ash_2 * h_2 / s_2) / A_{sec} = 0.00050265$$

$$Ash_2 = Astir_2 * ns_2 = 100.531$$

$$\text{No stirups, } ns_2 = 2.00$$

$$h_2 = 200.00$$

$$psh_y * Fywe = psh_1 * Fywe_1 + ps_2 * Fywe_2 = 3.00635$$

$$ps_1 \text{ (external)} = (Ash_1 * h_1 / s_1) / A_{sec} = 0.00392699$$

$$Ash_1 = Astir_1 * ns_1 = 157.0796$$

$$\text{No stirups, } ns_1 = 2.00$$

$$h_1 = 400.00$$

$$ps_2 \text{ (internal)} = (Ash_2 * h_2 / s_2) / A_{sec} = 0.00050265$$

$$Ash_2 = Astir_2 * ns_2 = 100.531$$

$$\text{No stirups, } ns_2 = 2.00$$

$$h_2 = 200.00$$

$$A_{sec} = 160000.00$$

$$s_1 = 100.00$$

$$s_2 = 250.00$$

$$fywe_1 = 694.45$$

$$fywe_2 = 555.55$$

$$f_{ce} = 33.00$$

$$\text{From ((5.A.5), TBDY), TBDY: } cc = 0.00332119$$

$$c = \text{confinement factor} = 1.13212$$

$$y_1 = 0.00184318$$

$$sh_1 = 0.00589816$$

$$ft_1 = 580.8818$$

$$fy_1 = 484.0682$$

$$su_1 = 0.01099427$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$lo/lou, \min = lb/ld = 0.45297586$$

$$su_1 = 0.4 * esu_1 \text{ nominal ((5.5), TBDY)} = 0.032$$

$$\text{From table 5A.1, TBDY: } esu_1 \text{ nominal} = 0.08,$$

For calculation of esu_1 nominal and y_1, sh_1, ft_1, fy_1, it is considered
characteristic value fsy_1 = fs_1 / 1.2, from table 5.1, TBDY.

$$y_1, sh_1, ft_1, fy_1, \text{ are also multiplied by } \text{Min}(1, 1.25 * (lb/ld)^{2/3}), \text{ from 10.3.5, ASCE 41-17.}$$

$$\text{with } fs_1 = (fs_{jacket} * A_{sl, ten, jacket} + fs_{core} * A_{sl, ten, core}) / A_{sl, ten} = 484.0682$$

$$\text{with } Es_1 = (Es_{jacket} * A_{sl, ten, jacket} + Es_{core} * A_{sl, ten, core}) / A_{sl, ten} = 200000.00$$

$$y_2 = 0.00184318$$

$$sh_2 = 0.00589816$$

$$ft_2 = 580.8818$$

$$fy_2 = 484.0682$$

$$su_2 = 0.01099427$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$lo/lou, \min = lb/lb, \min = 0.45297586$$

$$su_2 = 0.4 * esu_2 \text{ nominal ((5.5), TBDY)} = 0.032$$

$$\text{From table 5A.1, TBDY: } esu_2 \text{ nominal} = 0.08,$$

For calculation of esu_2 nominal and y_2, sh_2, ft_2, fy_2, it is considered
characteristic value fsy_2 = fs_2 / 1.2, from table 5.1, TBDY.

$$y_2, sh_2, ft_2, fy_2, \text{ are also multiplied by } \text{Min}(1, 1.25 * (lb/ld)^{2/3}), \text{ from 10.3.5, ASCE 41-17.}$$

$$\text{with } fs_2 = (fs_{jacket} * A_{sl, com, jacket} + fs_{core} * A_{sl, com, core}) / A_{sl, com} = 484.0682$$

$$\text{with } Es_2 = (Es_{jacket} * A_{sl, com, jacket} + Es_{core} * A_{sl, com, core}) / A_{sl, com} = 200000.00$$

$$y_v = 0.00184318$$

$$sh_v = 0.00589816$$

$$ft_v = 614.3968$$

$$fy_v = 511.9973$$

$$su_v = 0.01099427$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$lo/lou, \min = lb/ld = 0.45297586$$

$$su_v = 0.4 * esuv \text{ nominal ((5.5), TBDY)} = 0.032$$

$$\text{From table 5A.1, TBDY: } esuv \text{ nominal} = 0.08,$$

considering characteristic value fsyv = fsv / 1.2, from table 5.1, TBDY

For calculation of $\epsilon_{sv_nominal}$ and γ_v , γ_{shv} , γ_{ftv} , γ_{fyv} , it is considered characteristic value $f_{sv} = f_{sv}/1.2$, from table 5.1, TBDY.

γ_1 , γ_{sh1} , γ_{ft1} , γ_{fy1} , are also multiplied by $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$, from 10.3.5, ASCE 41-17.

with $f_{sv} = (f_{s,jacket} \cdot A_{s,mid,jacket} + f_{s,mid} \cdot A_{s,mid,core})/A_{s,mid} = 511.9973$

with $E_{sv} = (E_{s,jacket} \cdot A_{s,mid,jacket} + E_{s,mid} \cdot A_{s,mid,core})/A_{s,mid} = 200000.00$

$1 = A_{s,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.0851958$

$2 = A_{s,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.0851958$

$v = A_{s,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.04369034$

and confined core properties:

$b = 340.00$

$d = 327.00$

$d' = 13.00$

f_{cc} (5A.2, TBDY) = 37.35991

c_c (5A.5, TBDY) = 0.00332119

$c = \text{confinement factor} = 1.13212$

$1 = A_{s,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.1094258$

$2 = A_{s,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.1094258$

$v = A_{s,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.05611603$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < v_{s,y2}$ - LHS eq.(4.5) is satisfied

--->

μ_u (4.9) = 0.16193824

$\mu_u = M_{Rc}$ (4.14) = 1.8194E+008

$u = \mu_u$ (4.1) = 3.6747033E-005

Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.45297586$

$l_b = 300.00$

$l_d = 662.2869$

Calculation of $l_{b,min}$ according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

= 1

$d_b = 14.66667$

Mean strength value of all re-bars: $f_y = 656.5682$

Mean concrete strength: $f'_c = (f'_{c,jacket} \cdot \text{Area}_{jacket} + f'_{c,core} \cdot \text{Area}_{core})/\text{Area}_{section} = 29.75$, but $f_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 3.43481$

$A_{tr} = \text{Min}(A_{tr,x}, A_{tr,y}) = 257.6106$

where $A_{tr,x}$, $A_{tr,y}$ are the sum of the area of all stirrup legs along X and Y local axis

$s = \text{Max}(s_{external}, s_{internal}) = 250.00$

$n = 12.00$

Calculation of μ_{u1} -

Calculation of ultimate curvature μ_u according to 4.1, Biskinis/Fardis 2013:

$u = 3.6747033E-005$

$\mu_u = 1.8194E+008$

with full section properties:

$b = 400.00$

$d = 357.00$

$d' = 43.00$

$v = 0.00125773$

$N = 5926.932$

$f_c = 33.00$

c_c (5A.5, TBDY) = 0.002

Final value of c_u : $c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.01505571$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $c_u = 0.01505571$

w_e ((5.4c), TBDY) = $ase * \text{sh_min} * fy_{we} / f_{ce} + \text{Min}(f_x, f_y) = 0.08345896$

where $f = af * pf * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

 $f_x = 0.07683125$

$af = 0.57333333$

$b = 400.00$

$h = 400.00$

From EC8 A.4.4.3(6), $pf = 2tf/bw = 0.00508$

$bw = 400.00$

effective stress from (A.35), $f_{f,e} = 870.5244$

 $f_y = 0.07683125$

$af = 0.57333333$

$b = 400.00$

$h = 400.00$

From EC8 A.4.4.3(6), $pf = 2tf/bw = 0.00508$

$bw = 400.00$

effective stress from (A.35), $f_{f,e} = 870.5244$

 $R = 40.00$

Effective FRP thickness, $tf = NL * t * \text{Cos}(b1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{,f} = 0.015$

ase ((5.4d), TBDY) = $(ase1 * A_{ext} + ase2 * A_{int}) / A_{sec} = 0.24250288$

$ase1 = 0.24250288$

$bo_1 = 340.00$

$ho_1 = 340.00$

$bi2_1 = 462400.00$

$ase2 = \text{Max}(ase1, ase2) = 0.24250288$

$bo_2 = 192.00$

$ho_2 = 192.00$

$bi2_2 = 147456.00$

$psh_{,min} * F_{ywe} = \text{Min}(psh_{,x} * F_{ywe}, psh_{,y} * F_{ywe}) = 3.00635$

Expression ((5.4d), TBDY) for $psh_{,min} * F_{ywe}$ has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

 $psh_{,x} * F_{ywe} = psh1 * F_{ywe1} + ps2 * F_{ywe2} = 3.00635$

$ps1$ (external) = $(Ash1 * h1 / s1) / A_{sec} = 0.00392699$

$Ash1 = Astir_1 * ns_1 = 157.0796$

No stirrups, $ns_1 = 2.00$

$h1 = 400.00$

$ps2$ (internal) = $(Ash2 * h2 / s2) / A_{sec} = 0.00050265$

$Ash2 = Astir_2 * ns_2 = 100.531$

No stirrups, $ns_2 = 2.00$

$h2 = 200.00$

 $psh_{,y} * F_{ywe} = psh1 * F_{ywe1} + ps2 * F_{ywe2} = 3.00635$

$ps1$ (external) = $(Ash1 * h1 / s1) / A_{sec} = 0.00392699$

$Ash1 = Astir_1 * ns_1 = 157.0796$

No stirrups, $ns_1 = 2.00$

$h1 = 400.00$

$ps2$ (internal) = $(Ash2 * h2 / s2) / A_{sec} = 0.00050265$

$Ash2 = Astir_2 * ns_2 = 100.531$

No stirrups, $ns_2 = 2.00$

$h2 = 200.00$

 $A_{sec} = 160000.00$

$s1 = 100.00$

$s2 = 250.00$

$fy_{we1} = 694.45$

$fy_{we2} = 555.55$

$f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY: $cc = 0.00332119$

$c = \text{confinement factor} = 1.13212$
 $y1 = 0.00184318$
 $sh1 = 0.00589816$
 $ft1 = 580.8818$
 $fy1 = 484.0682$
 $su1 = 0.01099427$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 $\text{Shear_factor} = 1.00$
 $lo/lou,min = lb/ld = 0.45297586$
 $su1 = 0.4 * esu1_nominal ((5.5), \text{TBDY}) = 0.032$
 From table 5A.1, TBDY: $esu1_nominal = 0.08$,
 For calculation of $esu1_nominal$ and $y1, sh1, ft1, fy1$, it is considered
 characteristic value $fsy1 = fs1/1.2$, from table 5.1, TBDY.
 $y1, sh1, ft1, fy1$, are also multiplied by $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE 41-17.
 with $fs1 = (fs,jacket * Asl,ten,jacket + fs,core * Asl,ten,core) / Asl,ten = 484.0682$
 with $Es1 = (Es,jacket * Asl,ten,jacket + Es,core * Asl,ten,core) / Asl,ten = 200000.00$
 $y2 = 0.00184318$
 $sh2 = 0.00589816$
 $ft2 = 580.8818$
 $fy2 = 484.0682$
 $su2 = 0.01099427$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 $\text{Shear_factor} = 1.00$
 $lo/lou,min = lb/lb,min = 0.45297586$
 $su2 = 0.4 * esu2_nominal ((5.5), \text{TBDY}) = 0.032$
 From table 5A.1, TBDY: $esu2_nominal = 0.08$,
 For calculation of $esu2_nominal$ and $y2, sh2, ft2, fy2$, it is considered
 characteristic value $fsy2 = fs2/1.2$, from table 5.1, TBDY.
 $y1, sh1, ft1, fy1$, are also multiplied by $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE 41-17.
 with $fs2 = (fs,jacket * Asl,com,jacket + fs,core * Asl,com,core) / Asl,com = 484.0682$
 with $Es2 = (Es,jacket * Asl,com,jacket + Es,core * Asl,com,core) / Asl,com = 200000.00$
 $yv = 0.00184318$
 $shv = 0.00589816$
 $ftv = 614.3968$
 $fyv = 511.9973$
 $suv = 0.01099427$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 $\text{Shear_factor} = 1.00$
 $lo/lou,min = lb/ld = 0.45297586$
 $suv = 0.4 * esuv_nominal ((5.5), \text{TBDY}) = 0.032$
 From table 5A.1, TBDY: $esuv_nominal = 0.08$,
 considering characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY
 For calculation of $esuv_nominal$ and yv, shv, ftv, fyv , it is considered
 characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY.
 $y1, sh1, ft1, fy1$, are also multiplied by $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE 41-17.
 with $fsv = (fs,jacket * Asl,mid,jacket + fs,mid * Asl,mid,core) / Asl,mid = 511.9973$
 with $Es_v = (Es,jacket * Asl,mid,jacket + Es,mid * Asl,mid,core) / Asl,mid = 200000.00$
 $1 = Asl,ten / (b * d) * (fs1 / fc) = 0.0851958$
 $2 = Asl,com / (b * d) * (fs2 / fc) = 0.0851958$
 $v = Asl,mid / (b * d) * (fsv / fc) = 0.04369034$
 and confined core properties:
 $b = 340.00$
 $d = 327.00$
 $d' = 13.00$
 $fcc (5A.2, \text{TBDY}) = 37.35991$
 $cc (5A.5, \text{TBDY}) = 0.00332119$
 $c = \text{confinement factor} = 1.13212$
 $1 = Asl,ten / (b * d) * (fs1 / fc) = 0.1094258$
 $2 = Asl,com / (b * d) * (fs2 / fc) = 0.1094258$
 $v = Asl,mid / (b * d) * (fsv / fc) = 0.05611603$
 Case/Assumption: Unconfined full section - Steel rupture
 ' satisfies Eq. (4.3)

--->
 $v < vs,y2$ - LHS eq.(4.5) is satisfied

--->

su (4.9) = 0.16193824
Mu = MRc (4.14) = 1.8194E+008
u = su (4.1) = 3.6747033E-005

Calculation of ratio lb/l_d

Lap Length: lb/l_d = 0.45297586

lb = 300.00

l_d = 662.2869

Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

= 1

db = 14.66667

Mean strength value of all re-bars: f_y = 656.5682

Mean concrete strength: f_c' = (f_c'_{jacket}*Area_{jacket} + f_c'_{core}*Area_{core})/Area_{section} = 29.75, but f_c'^{0.5} ≤ 8.3

MPa (22.5.3.1, ACI 318-14)

t = 1.00

s = 0.80

e = 1.00

cb = 25.00

K_{tr} = 3.43481

A_{tr} = Min(A_{tr_x}, A_{tr_y}) = 257.6106

where A_{tr_x}, A_{tr_y} are the sum of the area of all stirrup legs along X and Y local axis

s = Max(s_{external}, s_{internal}) = 250.00

n = 12.00

Calculation of Mu₂₊

Calculation of ultimate curvature ϕ_u according to 4.1, Biskinis/Fardis 2013:

u = 3.6747033E-005

Mu = 1.8194E+008

with full section properties:

b = 400.00

d = 357.00

d' = 43.00

v = 0.00125773

N = 5926.932

f_c = 33.00

co (5A.5, TBDY) = 0.002

Final value of ϕ_u : $\phi_u^* = \text{shear_factor} * \text{Max}(\phi_u, \phi_c) = 0.01505571$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $\phi_u = 0.01505571$

we ((5.4c), TBDY) = $\text{ase} * \text{sh}_{\min} * f_{ywe} / f_{ce} + \text{Min}(\phi_x, \phi_y) = 0.08345896$

where $f = \text{af} * \text{pf} * \text{ffe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

 $\phi_x = 0.07683125$

$\text{af} = 0.57333333$

b = 400.00

h = 400.00

From EC8 A.4.4.3(6), $\text{pf} = 2t_f / b_w = 0.00508$

$b_w = 400.00$

effective stress from (A.35), $\text{ff}, e = 870.5244$

 $\phi_y = 0.07683125$

$\text{af} = 0.57333333$

b = 400.00

h = 400.00

From EC8 A.4.4.3(6), $\text{pf} = 2t_f / b_w = 0.00508$

$b_w = 400.00$

effective stress from (A.35), $\text{ff}, e = 870.5244$

$R = 40.00$
 Effective FRP thickness, $t_f = NL * t * \cos(b_1) = 1.016$
 $f_{u,f} = 1055.00$
 $E_f = 64828.00$
 $u_{,f} = 0.015$
 $ase((5.4d), TBDY) = (ase_1 * A_{ext} + ase_2 * A_{int}) / A_{sec} = 0.24250288$
 $ase_1 = 0.24250288$
 $bo_1 = 340.00$
 $ho_1 = 340.00$
 $bi_2_1 = 462400.00$
 $ase_2 = \text{Max}(ase_1, ase_2) = 0.24250288$
 $bo_2 = 192.00$
 $ho_2 = 192.00$
 $bi_2_2 = 147456.00$

$psh_{,min} * F_{ywe} = \text{Min}(psh_{,x} * F_{ywe}, psh_{,y} * F_{ywe}) = 3.00635$
 Expression ((5.4d), TBDY) for $psh_{,min} * F_{ywe}$ has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$psh_{,x} * F_{ywe} = psh_1 * F_{ywe1} + ps_2 * F_{ywe2} = 3.00635$
 $ps_1 \text{ (external)} = (A_{sh1} * h_1 / s_1) / A_{sec} = 0.00392699$
 $A_{sh1} = A_{stir_1} * ns_1 = 157.0796$
 No stirrups, $ns_1 = 2.00$
 $h_1 = 400.00$
 $ps_2 \text{ (internal)} = (A_{sh2} * h_2 / s_2) / A_{sec} = 0.00050265$
 $A_{sh2} = A_{stir_2} * ns_2 = 100.531$
 No stirrups, $ns_2 = 2.00$
 $h_2 = 200.00$

$psh_{,y} * F_{ywe} = psh_1 * F_{ywe1} + ps_2 * F_{ywe2} = 3.00635$
 $ps_1 \text{ (external)} = (A_{sh1} * h_1 / s_1) / A_{sec} = 0.00392699$
 $A_{sh1} = A_{stir_1} * ns_1 = 157.0796$
 No stirrups, $ns_1 = 2.00$
 $h_1 = 400.00$
 $ps_2 \text{ (internal)} = (A_{sh2} * h_2 / s_2) / A_{sec} = 0.00050265$
 $A_{sh2} = A_{stir_2} * ns_2 = 100.531$
 No stirrups, $ns_2 = 2.00$
 $h_2 = 200.00$

$A_{sec} = 160000.00$
 $s_1 = 100.00$
 $s_2 = 250.00$
 $f_{ywe1} = 694.45$
 $f_{ywe2} = 555.55$
 $f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY: $cc = 0.00332119$
 $c = \text{confinement factor} = 1.13212$

$y_1 = 0.00184318$
 $sh_1 = 0.00589816$
 $ft_1 = 580.8818$
 $fy_1 = 484.0682$
 $su_1 = 0.01099427$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 $\text{Shear_factor} = 1.00$

$lo/lo_{,min} = lb/ld = 0.45297586$
 $su_1 = 0.4 * esu_1_{,nominal} \text{ ((5.5), TBDY)} = 0.032$

From table 5A.1, TBDY: $esu_1_{,nominal} = 0.08$,

For calculation of $esu_1_{,nominal}$ and y_1, sh_1, ft_1, fy_1 , it is considered
 characteristic value $fsy_1 = fs_1 / 1.2$, from table 5.1, TBDY.

y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE 41-17.

with $fs_1 = (fs_{,jacket} * A_{sl,ten,jacket} + fs_{,core} * A_{sl,ten,core}) / A_{sl,ten} = 484.0682$

with $Es_1 = (Es_{,jacket} * A_{sl,ten,jacket} + Es_{,core} * A_{sl,ten,core}) / A_{sl,ten} = 200000.00$

$y_2 = 0.00184318$
 $sh_2 = 0.00589816$
 $ft_2 = 580.8818$
 $fy_2 = 484.0682$
 $su_2 = 0.01099427$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$l_0/l_{ou,min} = l_b/l_{b,min} = 0.45297586$$

$$s_u2 = 0.4 * e_{su2,nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: $e_{su2,nominal} = 0.08$,

For calculation of $e_{su2,nominal}$ and y_2, sh_2, ft_2, fy_2 , it is considered
characteristic value $f_{sy2} = f_{s2}/1.2$, from table 5.1, TBDY.

y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE 41-17.

$$\text{with } f_{s2} = (f_{s,jacket} * A_{sl,com,jacket} + f_{s,core} * A_{sl,com,core}) / A_{sl,com} = 484.0682$$

$$\text{with } E_{s2} = (E_{s,jacket} * A_{sl,com,jacket} + E_{s,core} * A_{sl,com,core}) / A_{sl,com} = 200000.00$$

$$y_v = 0.00184318$$

$$sh_v = 0.00589816$$

$$ft_v = 614.3968$$

$$fy_v = 511.9973$$

$$s_{uv} = 0.01099427$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$l_0/l_{ou,min} = l_b/l_d = 0.45297586$$

$$s_{uv} = 0.4 * e_{suv,nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: $e_{suv,nominal} = 0.08$,

considering characteristic value $f_{sv} = f_{sv}/1.2$, from table 5.1, TBDY
For calculation of $e_{suv,nominal}$ and y_v, sh_v, ft_v, fy_v , it is considered
characteristic value $f_{sv} = f_{sv}/1.2$, from table 5.1, TBDY.

y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE 41-17.

$$\text{with } f_{sv} = (f_{s,jacket} * A_{sl,mid,jacket} + f_{s,mid} * A_{sl,mid,core}) / A_{sl,mid} = 511.9973$$

$$\text{with } E_{sv} = (E_{s,jacket} * A_{sl,mid,jacket} + E_{s,mid} * A_{sl,mid,core}) / A_{sl,mid} = 200000.00$$

$$1 = A_{sl,ten} / (b * d) * (f_{s1} / f_c) = 0.0851958$$

$$2 = A_{sl,com} / (b * d) * (f_{s2} / f_c) = 0.0851958$$

$$v = A_{sl,mid} / (b * d) * (f_{sv} / f_c) = 0.04369034$$

and confined core properties:

$$b = 340.00$$

$$d = 327.00$$

$$d' = 13.00$$

$$f_{cc} (5A.2, TBDY) = 37.35991$$

$$cc (5A.5, TBDY) = 0.00332119$$

$$c = \text{confinement factor} = 1.13212$$

$$1 = A_{sl,ten} / (b * d) * (f_{s1} / f_c) = 0.1094258$$

$$2 = A_{sl,com} / (b * d) * (f_{s2} / f_c) = 0.1094258$$

$$v = A_{sl,mid} / (b * d) * (f_{sv} / f_c) = 0.05611603$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < v_{s,y2}$ - LHS eq.(4.5) is satisfied

--->

$$s_u (4.9) = 0.16193824$$

$$\mu = MR_c (4.14) = 1.8194E+008$$

$$u = s_u (4.1) = 3.6747033E-005$$

Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.45297586$

$$l_b = 300.00$$

$$l_d = 662.2869$$

Calculation of $l_{b,min}$ according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

$$= 1$$

$$d_b = 14.66667$$

Mean strength value of all re-bars: $f_y = 656.5682$

Mean concrete strength: $f'_c = (f'_c_{jacket} * Area_{jacket} + f'_c_{core} * Area_{core}) / Area_{section} = 29.75$, but $f'_c^{0.5} \leq 8.3$
MPa (22.5.3.1, ACI 318-14)

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 25.00$$

$$K_{tr} = 3.43481$$

$$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 257.6106$$

where A_{tr_x} , A_{tr_y} are the sum of the area of all stirrup legs along X and Y local axis

$$s = \text{Max}(s_{\text{external}}, s_{\text{internal}}) = 250.00$$

$$n = 12.00$$

Calculation of μ_2 -

Calculation of ultimate curvature μ according to 4.1, Biskinis/Fardis 2013:

$$\mu = 3.6747033\text{E-}005$$

$$\mu_2 = 1.8194\text{E+}008$$

with full section properties:

$$b = 400.00$$

$$d = 357.00$$

$$d' = 43.00$$

$$v = 0.00125773$$

$$N = 5926.932$$

$$f_c = 33.00$$

$$c_o \text{ (5A.5, TBDY)} = 0.002$$

$$\text{Final value of } \mu_c: \mu_c^* = \text{shear_factor} * \text{Max}(\mu_c, \mu_{cc}) = 0.01505571$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \mu_c = 0.01505571$$

$$\mu_{cc} \text{ ((5.4c), TBDY)} = a_{se} * s_{h,\text{min}} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.08345896$$

where $f = a_f * p_f * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.07683125$$

$$a_f = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{fe} = 870.5244$$

$$f_y = 0.07683125$$

$$a_f = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{fe} = 870.5244$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L * t * \text{Cos}(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{f} = 0.015$$

$$a_{se} \text{ ((5.4d), TBDY)} = (a_{se1} * A_{ext} + a_{se2} * A_{int}) / A_{sec} = 0.24250288$$

$$a_{se1} = 0.24250288$$

$$b_{o_1} = 340.00$$

$$h_{o_1} = 340.00$$

$$b_{i2_1} = 462400.00$$

$$a_{se2} = \text{Max}(a_{se1}, a_{se2}) = 0.24250288$$

$$b_{o_2} = 192.00$$

$$h_{o_2} = 192.00$$

$$b_{i2_2} = 147456.00$$

$$p_{sh,\text{min}} * f_{ywe} = \text{Min}(p_{sh,x} * f_{ywe}, p_{sh,y} * f_{ywe}) = 3.00635$$

Expression ((5.4d), TBDY) for $p_{sh,\text{min}} * f_{ywe}$ has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$$p_{sh_x} * f_{ywe} = p_{sh1} * f_{ywe1} + p_{sh2} * f_{ywe2} = 3.00635$$

$$p_{s1} \text{ (external)} = (A_{sh1} * h_1 / s_1) / A_{sec} = 0.00392699$$

$$A_{sh1} = A_{stir_1} * n_{s_1} = 157.0796$$

$$\text{No stirrups, } n_{s_1} = 2.00$$

h1 = 400.00
ps2 (internal) = (Ash2*h2/s2)/Asec = 0.00050265
Ash2 = Astir_2*ns_2 = 100.531
No stirups, ns_2 = 2.00
h2 = 200.00

psh_y*Fywe = psh1*Fywe1+ps2*Fywe2 = 3.00635
ps1 (external) = (Ash1*h1/s1)/Asec = 0.00392699
Ash1 = Astir_1*ns_1 = 157.0796
No stirups, ns_1 = 2.00
h1 = 400.00
ps2 (internal) = (Ash2*h2/s2)/Asec = 0.00050265
Ash2 = Astir_2*ns_2 = 100.531
No stirups, ns_2 = 2.00
h2 = 200.00

Asec = 160000.00
s1 = 100.00
s2 = 250.00
fywe1 = 694.45
fywe2 = 555.55
fce = 33.00

From ((5.A5), TBDY), TBDY: cc = 0.00332119
c = confinement factor = 1.13212

y1 = 0.00184318
sh1 = 0.00589816
ft1 = 580.8818
fy1 = 484.0682
su1 = 0.01099427

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/ld = 0.45297586

su1 = 0.4*esu1_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu1_nominal = 0.08,

For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/ld)^ 2/3), from 10.3.5, ASCE 41-17.

with fs1 = (fs,jacket*Asl,ten,jacket + fs,core*Asl,ten,core)/Asl,ten = 484.0682

with Es1 = (Es,jacket*Asl,ten,jacket + Es,core*Asl,ten,core)/Asl,ten = 200000.00

y2 = 0.00184318
sh2 = 0.00589816
ft2 = 580.8818
fy2 = 484.0682
su2 = 0.01099427

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/lb,min = 0.45297586

su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu2_nominal = 0.08,

For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/ld)^ 2/3), from 10.3.5, ASCE 41-17.

with fs2 = (fs,jacket*Asl,com,jacket + fs,core*Asl,com,core)/Asl,com = 484.0682

with Es2 = (Es,jacket*Asl,com,jacket + Es,core*Asl,com,core)/Asl,com = 200000.00

yv = 0.00184318
shv = 0.00589816
ftv = 614.3968
fyv = 511.9973
suv = 0.01099427

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/ld = 0.45297586

suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esuv_nominal = 0.08,

considering characteristic value $f_{sv} = f_{sv}/1.2$, from table 5.1, TBDY

For calculation of $e_{suv_nominal}$ and y_v , sh_v , ft_v , fy_v , it is considered characteristic value $f_{sv} = f_{sv}/1.2$, from table 5.1, TBDY.

y_1 , sh_1 , ft_1 , fy_1 , are also multiplied by $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$, from 10.3.5, ASCE 41-17.

with $f_{sv} = (f_{s,jacket} \cdot A_{s,mid,jacket} + f_{s,mid} \cdot A_{s,mid,core}) / A_{s,mid} = 511.9973$

with $E_{sv} = (E_{s,jacket} \cdot A_{s,mid,jacket} + E_{s,mid} \cdot A_{s,mid,core}) / A_{s,mid} = 200000.00$

$1 = A_{s,ten} / (b \cdot d) \cdot (f_{s1} / f_c) = 0.0851958$

$2 = A_{s,com} / (b \cdot d) \cdot (f_{s2} / f_c) = 0.0851958$

$v = A_{s,mid} / (b \cdot d) \cdot (f_{sv} / f_c) = 0.04369034$

and confined core properties:

$b = 340.00$

$d = 327.00$

$d' = 13.00$

f_{cc} (5A.2, TBDY) = 37.35991

cc (5A.5, TBDY) = 0.00332119

c = confinement factor = 1.13212

$1 = A_{s,ten} / (b \cdot d) \cdot (f_{s1} / f_c) = 0.1094258$

$2 = A_{s,com} / (b \cdot d) \cdot (f_{s2} / f_c) = 0.1094258$

$v = A_{s,mid} / (b \cdot d) \cdot (f_{sv} / f_c) = 0.05611603$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < v_{s,y2}$ - LHS eq.(4.5) is satisfied

--->

su (4.9) = 0.16193824

$Mu = MRc$ (4.14) = 1.8194E+008

$u = su$ (4.1) = 3.6747033E-005

Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.45297586$

$l_b = 300.00$

$l_d = 662.2869$

Calculation of $l_{b,min}$ according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

= 1

$db = 14.66667$

Mean strength value of all re-bars: $f_y = 656.5682$

Mean concrete strength: $f'_c = (f'_{c,jacket} \cdot Area_{jacket} + f'_{c,core} \cdot Area_{core}) / Area_{section} = 29.75$, but $f_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 3.43481$

$A_{tr} = \text{Min}(A_{tr,x}, A_{tr,y}) = 257.6106$

where $A_{tr,x}$, $A_{tr,y}$ are the sum of the area of all stirrup legs along X and Y loxal axis

$s = \text{Max}(s_{external}, s_{internal}) = 250.00$

$n = 12.00$

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 633062.661$

Calculation of Shear Strength at edge 1, $V_{r1} = 633062.661$

$V_{r1} = V_{Col}$ ((10.3), ASCE 41-17) = $k_{nl} \cdot V_{Col0}$

$V_{Col0} = 633062.661$

$k_{nl} = 1$ (zero step-static loading)

NOTE: In expression (10-3) ' $V_s = A_v \cdot f_y \cdot d / s$ ' is replaced by ' $V_s + f \cdot V_f$ '

where V_f is the contribution of FRPs (11.3), ACI 440).

= 1 (normal-weight concrete)

Mean concrete strength: $f'_c = (f'_{c,jacket} \cdot Area_{jacket} + f'_{c,core} \cdot Area_{core}) / Area_{section} = 29.75$, but $f_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$\mu_u = 4.6931004E-013$
 $V_u = 6.6805695E-033$
 $d = 0.8 \cdot h = 320.00$
 $N_u = 5926.932$
 $A_g = 160000.00$
 From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 279254.914$
 where:
 $V_{s1} = 279254.914$ is calculated for jacket, with:
 $d = 320.00$
 $A_v = 157079.633$
 $f_y = 555.56$
 $s = 100.00$
 V_{s1} is multiplied by $Col1 = 1.00$
 $s/d = 0.3125$
 $V_{s2} = 0.00$ is calculated for core, with:
 $d = 160.00$
 $A_v = 100530.965$
 $f_y = 444.44$
 $s = 250.00$
 V_{s2} is multiplied by $Col2 = 0.00$
 $s/d = 1.5625$
 V_f ((11-3)-(11.4), ACI 440) = 188111.148
 $f = 0.95$, for fully-wrapped sections
 $w_f/s_f = 1$ (FRP strips adjacent to one another).
 In (11.3) $\sin \theta + \cos \theta$ is replaced with $(\cot \theta + \cot \alpha) \sin \alpha$ which is more a generalised expression,
 where θ is the angle of the crack direction (see KANEPE).
 This later relation, considered as a function $V_f(\theta, \alpha)$, is implemented for every different fiber orientation α_i ,
 as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.
 orientation 1: $\theta = b_1 + 90^\circ = 90.00$
 $V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, \theta)|)$, with:
 total thickness per orientation, $t_{f1} = N_L \cdot t / N_{oDir} = 1.016$
 $d_{fv} = d$ (figure 11.2, ACI 440) = 357.00
 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: $V_s + V_f \leq 463788.751$
 $b_w = 400.00$

Calculation of Shear Strength at edge 2, $V_{r2} = 633062.661$
 $V_{r2} = V_{Col}$ ((10.3), ASCE 41-17) = $k_{nl} \cdot V_{Col0}$
 $V_{Col0} = 633062.661$
 $k_{nl} = 1$ (zero step-static loading)

NOTE: In expression (10-3) ' $V_s = A_v \cdot f_y \cdot d / s$ ' is replaced by ' $V_s + f \cdot V_f$ '
 where V_f is the contribution of FRPs (11.3), ACI 440).

$\mu = 1$ (normal-weight concrete)
 Mean concrete strength: $f_c' = (f_c'_{jacket} \cdot Area_{jacket} + f_c'_{core} \cdot Area_{core}) / Area_{section} = 29.75$, but $f_c'^{0.5} \leq 8.3$
 MPa (22.5.3.1, ACI 318-14)
 $M/d = 2.00$
 $\mu_u = 4.6931004E-013$
 $V_u = 6.6805695E-033$
 $d = 0.8 \cdot h = 320.00$
 $N_u = 5926.932$
 $A_g = 160000.00$
 From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 279254.914$
 where:
 $V_{s1} = 279254.914$ is calculated for jacket, with:
 $d = 320.00$
 $A_v = 157079.633$
 $f_y = 555.56$
 $s = 100.00$
 V_{s1} is multiplied by $Col1 = 1.00$
 $s/d = 0.3125$
 $V_{s2} = 0.00$ is calculated for core, with:

$d = 160.00$
 $A_v = 100530.965$
 $f_y = 444.44$
 $s = 250.00$
 Vs2 is multiplied by Col2 = 0.00
 $s/d = 1.5625$
 $V_f((11-3)-(11.4), \text{ACI 440}) = 188111.148$
 $f = 0.95$, for fully-wrapped sections
 $w_f/s_f = 1$ (FRP strips adjacent to one another).
 In (11.3) $\sin + \cos$ is replaced with $(\cot + \cot a)\sin a$ which is more a generalised expression,
 where a is the angle of the crack direction (see KANEPE).
 This later relation, considered as a function $V_f(\theta)$, is implemented for every different fiber orientation a_i ,
 as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.
 orientation 1: $\theta_1 = \theta_1 + 90^\circ = 90.00$
 $V_f = \text{Min}(|V_f(45, \theta_1)|, |V_f(-45, a_1)|)$, with:
 total thickness per orientation, $t_{f1} = N_L * t / \text{NoDir} = 1.016$
 $d_{fv} = d$ (figure 11.2, ACI 440) = 357.00
 $f_{fe}((11-5), \text{ACI 440}) = 259.312$
 $E_f = 64828.00$
 $f_e = 0.004$, from (11.6a), ACI 440
 with $f_u = 0.01$
 From (11-11), ACI 440: $V_s + V_f \leq 463788.751$
 $b_w = 400.00$

 End Of Calculation of Shear Capacity ratio for element: column JC1 of floor 1
 At local axis: 2

 Start Of Calculation of Chord Rotation Capacity for element: column JC1 of floor 1
 At local axis: 3

Integration Section: (b)
 Section Type: rcjrs

Constant Properties

 Knowledge Factor, $\gamma = 0.80$
 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
 Existing material of Secondary Member: Concrete Strength, $f_c = f_{cm} = 20.00$
 Existing material of Secondary Member: Steel Strength, $f_s = f_{sm} = 444.44$
 Concrete Elasticity, $E_c = 21019.039$
 Steel Elasticity, $E_s = 200000.00$
 External Height, $H = 400.00$
 External Width, $W = 400.00$
 Internal Height, $H = 200.00$
 Internal Width, $W = 200.00$
 Cover Thickness, $c = 25.00$
 Element Length, $L = 3000.00$
 Secondary Member
 Ribbed Bars
 Ductile Steel
 Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
 Longitudinal Bars With Ends Lapped Starting at the End Sections
 Lap Length $l_b = 300.00$
 FRP Wrapping Data
 Type: Carbon
 Cured laminate properties (design values)

Thickness, $t = 1.016$
Tensile Strength, $f_{fu} = 1055.00$
Tensile Modulus, $E_f = 64828.00$
Elongation, $e_{fu} = 0.01$
Number of directions, $NoDir = 1$
Fiber orientations, $bi = 0.00^\circ$
Number of layers, $NL = 1$
Radius of rounding corners, $R = 40.00$

Stepwise Properties

Bending Moment, $M = 46945.948$
Shear Force, $V_2 = 7481.276$
Shear Force, $V_3 = -1.2884777E-015$
Axial Force, $F = -6438.97$
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: $As_t = 0.00$
-Compression: $As_c = 2060.885$
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension: $As_{ten} = 829.3805$
-Compression: $As_{com} = 829.3805$
-Middle: $As_{mid} = 402.1239$
Longitudinal External Reinforcement Area Distribution (in 3 divisions)
-Tension: $As_{ten,jacket} = 603.1858$
-Compression: $As_{com,jacket} = 603.1858$
-Middle: $As_{mid,jacket} = 402.1239$
Longitudinal Internal Reinforcement Area Distribution (in 3 divisions)
-Tension: $As_{ten,core} = 226.1947$
-Compression: $As_{com,core} = 226.1947$
-Middle: $As_{mid,core} = 0.00$
Mean Diameter of Tension Reinforcement, $Db_L = 14.40$

Existing component: From table 7-7, ASCE 41_17: Final chord rotation Capacity $u_{R} = u = 0.00066459$
 $u = y + p = 0.00083074$

- Calculation of y -

$y = (M_y * L_s / 3) / E_{eff} = 0.00083074$ ((4.29), Biskinis Phd))
 $M_y = 1.4156E+008$
 $L_s = M/V$ (with $L_s > 0.1 * L$ and $L_s < 2 * L$) = 300.00
From table 10.5, ASCE 41_17: $E_{eff} = factor * E_c * I_g = 1.7040E+013$
factor = 0.30
 $A_g = 160000.00$
Mean concrete strength: $f'_c = (f'_{c,jacket} * Area_{jacket} + f'_{c,core} * Area_{core}) / Area_{section} = 29.75$
 $N = 6438.97$
 $E_c * I_g = E_{c,jacket} * I_{g,jacket} + E_{c,core} * I_{g,core} = 5.6801E+013$

Calculation of Yielding Moment M_y

Calculation of y and M_y according to Annex 7 -

$y = \text{Min}(y_{ten}, y_{com})$
 $y_{ten} = 8.5640402E-006$
with ((10.1), ASCE 41-17) $f_y = \text{Min}(f_y, 1.25 * f_y * (I_b / I_d)^{2/3}) = 454.4281$
 $d = 357.00$
 $y = 0.2568299$
 $A = 0.01453119$
 $B = 0.00818436$
with $pt = 0.00680078$
 $pc = 0.00580799$

$p_v = 0.00281599$
 $N = 6438.97$
 $b = 400.00$
 $" = 0.12044818$
 $y_{comp} = 2.5296911E-005$
 with f_c^* (12.3, (ACI 440)) = 34.65599
 $f_c = 33.00$
 $f_l = 0.93147527$
 $b = 400.00$
 $h = 400.00$
 $A_g = 160000.00$
 From (12.9), ACI 440: $k_a = 0.56708553$
 $g = p_t + p_c + p_v = 0.01443197$
 $r_c = 40.00$
 $A_e/A_c = 0.56708553$
 Effective FRP thickness, $t_f = NL*t*\text{Cos}(b_1) = 1.016$
 effective strain from (12.5) and (12.12), $\epsilon_{fe} = 0.004$
 $f_u = 0.01$
 $E_f = 64828.00$
 $E_c = 26999.444$
 $y = 0.25583518$
 $A = 0.01433439$
 $B = 0.00808514$
 with $E_s = 200000.00$

 Calculation of ratio l_b/l_d

Lap Length: $l_d/l_{d,min} = 0.56621983$

$l_b = 300.00$

$l_d = 529.8296$

Calculation of l according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

= 1

$d_b = 14.66667$

Mean strength value of all re-bars: $f_y = 525.2545$

Mean concrete strength: $f_c' = (f_c'_{jacket} * \text{Area}_{jacket} + f_c'_{core} * \text{Area}_{core}) / \text{Area}_{section} = 29.75$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 3.43481$

$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 257.6106$

where A_{tr_x} , A_{tr_y} are the sum of the area of all stirrup legs along X and Y local axis

$s = \text{Max}(s_{external}, s_{internal}) = 250.00$

$n = 12.00$

 - Calculation of ρ_p -

From table 10-8: $\rho_p = 0.00$

with:

- Columns controlled by inadequate development or splicing along the clear height because $l_b/l_d < 1$

shear control ratio $V_y E / V_{col} O E = 0.19159777$

$d = d_{external} = 357.00$

$s = s_{external} = 0.00$

$t = s_1 + s_2 + 2*t_f/bw*(f_{fe}/f_s) = 0.00680078$

jacket: $s_1 = A_{v1}*h_1/(s_1*A_g) = 0.00392699$

$A_{v1} = 157.0796$, is the total area of all stirrups parallel to loading (shear) direction

$h_1 = 400.00$

$s_1 = 100.00$

core: $s_2 = A_{v2}*h_2/(s_2*A_g) = 0.00050265$

$A_{v2} = 100.531$, is the total area of all stirrups parallel to loading (shear) direction

$h_2 = 200.00$

$s_2 = 250.00$

The term $2*t_f/bw*(f_{fe}/f_s)$ 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.

$$N_{UD} = 6438.97$$

$$A_g = 160000.00$$

$$f_{cE} = (f_{c_jacket} \cdot Area_jacket + f_{c_core} \cdot Area_core) / section_area = 29.75$$

$$f_{yE} = (f_{y_ext_Long_Reinf} \cdot Area_ext_Long_Reinf + f_{y_int_Long_Reinf} \cdot Area_int_Long_Reinf) / Area_Tot_Long_Rein = 531.1678$$

$$f_{yE} = (f_{y_ext_Trans_Reinf} \cdot Area_ext_Trans_Reinf + f_{y_int_Trans_Reinf} \cdot Area_int_Trans_Reinf) / Area_Tot_Trans_Rein = 542.9506$$

$$\rho_l = Area_Tot_Long_Rein / (b \cdot d) = 0.01443197$$

$$b = 400.00$$

$$d = 357.00$$

$$f_{cE} = 29.75$$

End Of Calculation of Chord Rotation Capacity for element: column JC1 of floor 1

At local axis: 3

Integration Section: (b)

Calculation No. 9

column C1, Floor 1

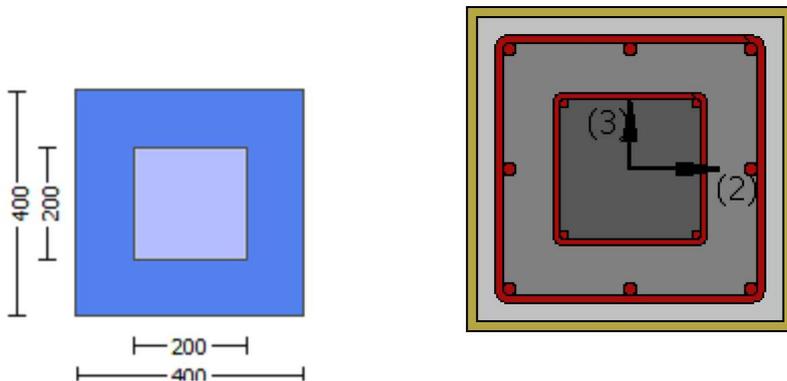
Limit State: Collapse Prevention (data interpolation between analysis steps 2 and 3)

Analysis: Uniform +X

Check: Shear capacity V_{Rd}

Edge: Start

Local Axis: (2)



Start Of Calculation of Shear Capacity for element: column JC1 of floor 1

At local axis: 2

Integration Section: (a)

Section Type: rcjrs

Constant Properties

Knowledge Factor, $\gamma = 0.80$

Member Shear Force is generally considered as Force-Controlled Action according to Table C7-1, ASCE 41-17.

Lower-bound strengths are used for Force-Controlled Actions according to 7.5.1.3, ASCE 41-17

Consequently:

Jacket

New material of Secondary Member: Concrete Strength, $f_c = f_{c_lower_bound} = 25.00$

New material of Secondary Member: Steel Strength, $f_s = f_{s_lower_bound} = 500.00$

Concrete Elasticity, $E_c = 26999.444$

Steel Elasticity, $E_s = 200000.00$

Existing Column

Existing material of Secondary Member: Concrete Strength, $f_c = f_{c_lower_bound} = 16.00$

Existing material of Secondary Member: Steel Strength, $f_s = f_{s_lower_bound} = 400.00$

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of γ for displacement ductility demand, the expected (mean value) strengths are used (7.5.1.3, ASCE 41-17) because bending is considered as Deformation-Controlled Action (Table C7-1, ASCE 41-17).

Jacket

New material: Concrete Strength, $f_c = f_{cm} = 33.00$

New material: Steel Strength, $f_s = f_{sm} = 555.56$

Existing Column

Existing material: Concrete Strength, $f_c = f_{cm} = 20.00$

Existing material: Steel Strength, $f_s = f_{sm} = 444.44$

#####

External Height, $H = 400.00$

External Width, $W = 400.00$

Internal Height, $H = 200.00$

Internal Width, $W = 200.00$

Cover Thickness, $c = 25.00$

Element Length, $L = 3000.00$

Secondary Member

Ribbed Bars

Ductile Steel

Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)

Longitudinal Bars With Ends Lapped Starting at the End Sections

Lap Length $l_o = l_b = 300.00$

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $e_{fu} = 0.01$

Number of directions, $NoDir = 1$

Fiber orientations, $b_i = 0.00^\circ$

Number of layers, $NL = 1$

Radius of rounding corners, $R = 40.00$

Stepwise Properties

EDGE -A-

Bending Moment, $M_a = -2.3276E+007$

Shear Force, $V_a = -7751.185$

EDGE -B-

Bending Moment, $M_b = 14604.754$

Shear Force, $V_b = 7751.185$

BOTH EDGES

Axial Force, $F = -6084.055$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: $As_t = 829.3805$

-Compression: $As_c = 1231.504$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension: $As_{t,ten} = 829.3805$

-Compression: $As_{l,com} = 829.3805$

-Middle: Asl,mid = 402.1239

Mean Diameter of Tension Reinforcement, DbL,ten = 14.40

Existing component: From table 7-7, ASCE 41_17: Final Shear Capacity VR = *Vn = 385777.715

Vn ((10.3), ASCE 41-17) = knl*VColO = 482222.144

VCol = 482222.144

knl = 1.00

displacement_ductility_demand = 0.05320295

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 = 22.75, but fc'^0.5 <= 8.3 MPa (22.5.3.1, ACI 318-14)

M/Vd = 4.00

Mu = 2.3276E+007

Vu = 7751.185

d = 0.8*h = 320.00

Nu = 6084.055

Ag = 160000.00

From (11.5.4.8), ACI 318-14: Vs = Vs1 + Vs2 = 251327.412

where:

Vs1 = 251327.412 is calculated for jacket, with:

d = 320.00

Av = 157079.633

fy = 500.00

s = 100.00

Vs1 is multiplied by Col1 = 1.00

s/d = 0.3125

Vs2 = 0.00 is calculated for core, with:

d = 160.00

Av = 100530.965

fy = 400.00

s = 250.00

Vs2 is multiplied by Col2 = 0.00

s/d = 1.5625

Vf ((11-3)-(11.4), ACI 440) = 188111.148

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) = 357.00

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 <= 405571.497

bw = 400.00

displacement_ductility_demand is calculated as / y

- Calculation of / y for END A -

for rotation axis 3 and integ. section (a)

From analysis, chord rotation = 0.00044224

y = (My*Ls/3)/Eleff = 0.00831241 ((4.29),Biskinis Phd)

My = 1.4151E+008
Ls = M/V (with Ls > 0.1*L and Ls < 2*L) = 3002.949
From table 10.5, ASCE 41_17: Eleff = factor*Ec*Ig = 1.7040E+013
factor = 0.30
Ag = 160000.00
Mean concrete strength: fc' = (fc'_jacket*Area_jacket + fc'_core*Area_core)/Area_section = 29.75
N = 6084.055
Ec*Ig = Ec_jacket*Ig_jacket + Ec_core*Ig_core = 5.6801E+013

Calculation of Yielding Moment My

Calculation of y and My according to Annex 7

y = Min(y_ten, y_com)
y_ten = 8.5630881E-006
with ((10.1), ASCE 41-17) fy = Min(fy, 1.25*fy*(lb/d)^2/3) = 454.4281
d = 357.00
y = 0.25674727
A = 0.01452572
B = 0.00817889
with pt = 0.00580799
pc = 0.00580799
pv = 0.00281599
N = 6084.055
b = 400.00
" = 0.12044818
y_comp = 2.5299695E-005
with fc* (12.3, (ACI 440)) = 34.65599
fc = 33.00
fl = 0.93147527
b = 400.00
h = 400.00
Ag = 160000.00
From (12.9), ACI 440: ka = 0.56708553
g = pt + pc + pv = 0.01443197
rc = 40.00
Ae/Ac = 0.56708553
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 = 0.25580703
A = 0.01433976
B = 0.00808514
with Es = 200000.00

Calculation of ratio lb/d

Lap Length: ld/d,min = 0.56621983
lb = 300.00
ld = 529.8296
Calculation of l according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
= 1
db = 14.66667
Mean strength value of all re-bars: fy = 525.2545
Mean concrete strength: fc' = (fc'_jacket*Area_jacket + fc'_core*Area_core)/Area_section = 29.75, but fc'^0.5 <= 8.3 MPa (22.5.3.1, ACI 318-14)
t = 1.00
s = 0.80
e = 1.00
cb = 25.00
Ktr = 3.43481

$$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 257.6106$$

where A_{tr_x} , A_{tr_y} are the sum of the area of all stirrup legs along X and Y local axis

$$s = \text{Max}(s_{\text{external}}, s_{\text{internal}}) = 250.00$$

$$n = 12.00$$

End Of Calculation of Shear Capacity for element: column JC1 of floor 1

At local axis: 2

Integration Section: (a)

Calculation No. 10

column C1, Floor 1

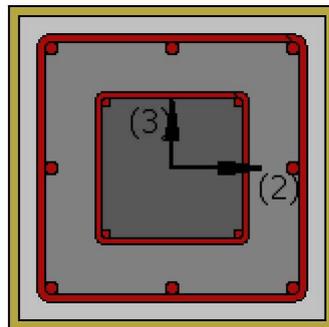
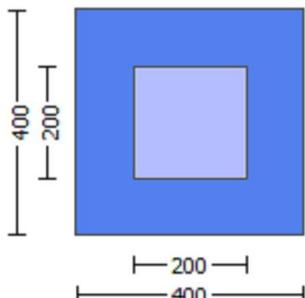
Limit State: Collapse Prevention (data interpolation between analysis steps 2 and 3)

Analysis: Uniform +X

Check: Chord rotation capacity (θ)

Edge: Start

Local Axis: (2)



Start Of Calculation of Shear Capacity ratio for element: column JC1 of floor 1

At Shear local axis: 3

(Bending local axis: 2)

Section Type: rcjrs

Constant Properties

Knowledge Factor, $\gamma = 0.80$

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

Existing material of Secondary Member: Concrete Strength, $f_c = f_{cm} = 20.00$

Existing material of Secondary Member: Steel Strength, $f_s = f_{sm} = 444.44$

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

Note: Especially for the calculation of moment strengths,
the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14
Jacket
New material: Steel Strength, $f_s = 1.25 \cdot f_{sm} = 694.45$
Existing Column
Existing material: Steel Strength, $f_s = 1.25 \cdot f_{sm} = 555.55$

External Height, $H = 400.00$
External Width, $W = 400.00$
Internal Height, $H = 200.00$
Internal Width, $W = 200.00$
Cover Thickness, $c = 25.00$
Mean Confinement Factor overall section = 1.13212
Element Length, $L = 3000.00$
Secondary Member
Ribbed Bars
Ductile Steel
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
Lap Length $l_o = 300.00$
FRP Wrapping Data
Type: Carbon
Cured laminate properties (design values)
Thickness, $t = 1.016$
Tensile Strength, $f_{fu} = 1055.00$
Tensile Modulus, $E_f = 64828.00$
Elongation, $e_{fu} = 0.01$
Number of directions, $N_{oDir} = 1$
Fiber orientations, $b_i: 0.00^\circ$
Number of layers, $N_L = 1$
Radius of rounding corners, $R = 40.00$

Stepwise Properties

At local axis: 3
EDGE -A-
Shear Force, $V_a = 2.8976040E-031$
EDGE -B-
Shear Force, $V_b = -2.8976040E-031$
BOTH EDGES
Axial Force, $F = -5926.932$
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: $A_{sl,t} = 0.00$
-Compression: $A_{sl,c} = 2060.885$
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension: $A_{sl,ten} = 829.3805$
-Compression: $A_{sl,com} = 829.3805$
-Middle: $A_{sl,mid} = 402.1239$

Calculation of Shear Capacity ratio, $V_e/V_r = 0.19159777$
Member Controlled by Flexure ($V_e/V_r < 1$)
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 121293.391$
with
 $M_{pr1} = \text{Max}(M_{u1+}, M_{u1-}) = 1.8194E+008$
 $M_{u1+} = 1.8194E+008$, is the ultimate moment strength at the edge 1 of the member in the actual moment direction
which is defined for the static loading combination
 $M_{u1-} = 1.8194E+008$, is the ultimate moment strength at the edge 1 of the member in the opposite moment
direction which is defined for the static loading combination
 $M_{pr2} = \text{Max}(M_{u2+}, M_{u2-}) = 1.8194E+008$
 $M_{u2+} = 1.8194E+008$, is the ultimate moment strength at the edge 2 of the member in the actual moment direction
which is defined for the the static loading combination

Mu₂₋ = 1.8194E+008, is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the the static loading combination

Calculation of Mu₁₊

Calculation of ultimate curvature ϕ_u according to 4.1, Biskinis/Fardis 2013:

$$\phi_u = 3.6747033E-005$$

$$Mu = 1.8194E+008$$

with full section properties:

$$b = 400.00$$

$$d = 357.00$$

$$d' = 43.00$$

$$v = 0.00125773$$

$$N = 5926.932$$

$$f_c = 33.00$$

$$c_o \text{ (5A.5, TBDY)} = 0.002$$

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.01505571$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } c_u = 0.01505571$$

$$w_e \text{ ((5.4c), TBDY)} = a_{se} * s_{h,\min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.08345896$$

where $f = a_f * p_f * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.07683125$$

$$a_f = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 870.5244$$

$$f_y = 0.07683125$$

$$a_f = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 870.5244$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L * t * \text{Cos}(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$a_{se} \text{ ((5.4d), TBDY)} = (a_{se1} * A_{ext} + a_{se2} * A_{int}) / A_{sec} = 0.24250288$$

$$a_{se1} = 0.24250288$$

$$b_{o,1} = 340.00$$

$$h_{o,1} = 340.00$$

$$b_{i,1} = 462400.00$$

$$a_{se2} = \text{Max}(a_{se1}, a_{se2}) = 0.24250288$$

$$b_{o,2} = 192.00$$

$$h_{o,2} = 192.00$$

$$b_{i,2} = 147456.00$$

$$p_{sh,\min} * F_{ywe} = \text{Min}(p_{sh,x} * F_{ywe}, p_{sh,y} * F_{ywe}) = 3.00635$$

Expression ((5.4d), TBDY) for $p_{sh,\min} * F_{ywe}$ has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$$p_{sh,x} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{sh2} * F_{ywe2} = 3.00635$$

$$p_{s1} \text{ (external)} = (A_{sh1} * h_1 / s_1) / A_{sec} = 0.00392699$$

$$A_{sh1} = A_{stir_1} * n_{s_1} = 157.0796$$

$$\text{No stirrups, } n_{s_1} = 2.00$$

$$h_1 = 400.00$$

$$p_{s2} \text{ (internal)} = (A_{sh2} * h_2 / s_2) / A_{sec} = 0.00050265$$

$$A_{sh2} = A_{stir_2} * n_{s_2} = 100.531$$

No stirups, ns₂ = 2.00
h₂ = 200.00

psh_y*Fywe = psh₁*Fywe₁+ps₂*Fywe₂ = 3.00635
ps₁ (external) = (Ash₁*h₁/s₁)/Asec = 0.00392699
Ash₁ = Astir₁*ns₁ = 157.0796
No stirups, ns₁ = 2.00
h₁ = 400.00
ps₂ (internal) = (Ash₂*h₂/s₂)/Asec = 0.00050265
Ash₂ = Astir₂*ns₂ = 100.531
No stirups, ns₂ = 2.00
h₂ = 200.00

Asec = 160000.00

s₁ = 100.00

s₂ = 250.00

fywe₁ = 694.45

fywe₂ = 555.55

fce = 33.00

From ((5.A.5), TBDY), TBDY: cc = 0.00332119

c = confinement factor = 1.13212

y₁ = 0.00184318

sh₁ = 0.00589816

ft₁ = 580.8818

fy₁ = 484.0682

su₁ = 0.01099427

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/l_d = 0.45297586

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} = 484.0682

with Es₁ = (Es_{jacket}*Asl_{ten,jacket} + Es_{core}*Asl_{ten,core})/Asl_{ten} = 200000.00

y₂ = 0.00184318

sh₂ = 0.00589816

ft₂ = 580.8818

fy₂ = 484.0682

su₂ = 0.01099427

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/l_{b,min} = 0.45297586

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} = 484.0682

with Es₂ = (Es_{jacket}*Asl_{com,jacket} + Es_{core}*Asl_{com,core})/Asl_{com} = 200000.00

y_v = 0.00184318

sh_v = 0.00589816

ft_v = 614.3968

fy_v = 511.9973

suv = 0.01099427

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/l_d = 0.45297586

suv = 0.4*esuv_{nominal} ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esuv_{nominal} = 0.08,

considering characteristic value fsy_v = fsv/1.2, from table 5.1, TBDY
For calculation of esuv_{nominal} and y_v, sh_v,ft_v,fy_v, it is considered
characteristic value fsy_v = fsv/1.2, from table 5.1, TBDY.

y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$, from 10.3.5, ASCE 41-17.

with $f_{sv} = (f_s \cdot \text{jacket} \cdot A_{s, \text{mid, jacket}} + f_s \cdot \text{mid} \cdot A_{s, \text{mid, core}}) / A_{s, \text{mid}} = 511.9973$

with $E_{sv} = (E_s \cdot \text{jacket} \cdot A_{s, \text{mid, jacket}} + E_s \cdot \text{mid} \cdot A_{s, \text{mid, core}}) / A_{s, \text{mid}} = 200000.00$

$1 = A_{s, \text{ten}} / (b \cdot d) \cdot (f_{s1} / f_c) = 0.0851958$

$2 = A_{s, \text{com}} / (b \cdot d) \cdot (f_{s2} / f_c) = 0.0851958$

$v = A_{s, \text{mid}} / (b \cdot d) \cdot (f_{sv} / f_c) = 0.04369034$

and confined core properties:

$b = 340.00$

$d = 327.00$

$d' = 13.00$

$f_{cc} \text{ (5A.2, TBDY)} = 37.35991$

$cc \text{ (5A.5, TBDY)} = 0.00332119$

$c = \text{confinement factor} = 1.13212$

$1 = A_{s, \text{ten}} / (b \cdot d) \cdot (f_{s1} / f_c) = 0.1094258$

$2 = A_{s, \text{com}} / (b \cdot d) \cdot (f_{s2} / f_c) = 0.1094258$

$v = A_{s, \text{mid}} / (b \cdot d) \cdot (f_{sv} / f_c) = 0.05611603$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

$v < v_{s, y2}$ - LHS eq.(4.5) is satisfied

$su \text{ (4.9)} = 0.16193824$

$Mu = MRc \text{ (4.14)} = 1.8194E+008$

$u = su \text{ (4.1)} = 3.6747033E-005$

Calculation of ratio lb/ld

Lap Length: $lb/ld = 0.45297586$

$lb = 300.00$

$ld = 662.2869$

Calculation of lb, min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

$= 1$

$db = 14.66667$

Mean strength value of all re-bars: $fy = 656.5682$

Mean concrete strength: $f_c' = (f_c' \cdot \text{jacket} \cdot \text{Area}_{\text{jacket}} + f_c' \cdot \text{core} \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 29.75$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 3.43481$

$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 257.6106$

where A_{tr_x}, A_{tr_y} are the sum of the area of all stirrup legs along X and Y local axis

$s = \text{Max}(s_{\text{external}}, s_{\text{internal}}) = 250.00$

$n = 12.00$

Calculation of Mu_1 -

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

$u = 3.6747033E-005$

$Mu = 1.8194E+008$

with full section properties:

$b = 400.00$

$d = 357.00$

$d' = 43.00$

$v = 0.00125773$

$N = 5926.932$

$f_c = 33.00$

$co \text{ (5A.5, TBDY)} = 0.002$

Final value of cu : $cu^* = \text{shear_factor} \cdot \text{Max}(cu, cc) = 0.01505571$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $c_u = 0.01505571$

w_e ((5.4c), TBDY) = $ase * sh_{min} * fy_{we} / f_{ce} + \text{Min}(f_x, f_y) = 0.08345896$

where $f = af * pf * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$f_x = 0.07683125$

$af = 0.57333333$

$b = 400.00$

$h = 400.00$

From EC8 A.4.4.3(6), $pf = 2tf/bw = 0.00508$

$bw = 400.00$

effective stress from (A.35), $ff_e = 870.5244$

$f_y = 0.07683125$

$af = 0.57333333$

$b = 400.00$

$h = 400.00$

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, $tf = NL * t * \text{Cos}(b_1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_f = 0.015$

ase ((5.4d), TBDY) = $(ase_1 * A_{ext} + ase_2 * A_{int}) / A_{sec} = 0.24250288$

$ase_1 = 0.24250288$

$bo_1 = 340.00$

$ho_1 = 340.00$

$bi_{2,1} = 462400.00$

$ase_2 = \text{Max}(ase_1, ase_2) = 0.24250288$

$bo_2 = 192.00$

$ho_2 = 192.00$

$bi_{2,2} = 147456.00$

$psh_{min} * Fy_{we} = \text{Min}(psh_x * Fy_{we}, psh_y * Fy_{we}) = 3.00635$

Expression ((5.4d), TBDY) for $psh_{min} * Fy_{we}$ has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$psh_x * Fy_{we} = psh_1 * Fy_{we1} + ps_2 * Fy_{we2} = 3.00635$

ps_1 (external) = $(Ash_1 * h_1 / s_1) / A_{sec} = 0.00392699$

$Ash_1 = Astir_1 * ns_1 = 157.0796$

No stirrups, $ns_1 = 2.00$

$h_1 = 400.00$

ps_2 (internal) = $(Ash_2 * h_2 / s_2) / A_{sec} = 0.00050265$

$Ash_2 = Astir_2 * ns_2 = 100.531$

No stirrups, $ns_2 = 2.00$

$h_2 = 200.00$

$psh_y * Fy_{we} = psh_1 * Fy_{we1} + ps_2 * Fy_{we2} = 3.00635$

ps_1 (external) = $(Ash_1 * h_1 / s_1) / A_{sec} = 0.00392699$

$Ash_1 = Astir_1 * ns_1 = 157.0796$

No stirrups, $ns_1 = 2.00$

$h_1 = 400.00$

ps_2 (internal) = $(Ash_2 * h_2 / s_2) / A_{sec} = 0.00050265$

$Ash_2 = Astir_2 * ns_2 = 100.531$

No stirrups, $ns_2 = 2.00$

$h_2 = 200.00$

$A_{sec} = 160000.00$

$s_1 = 100.00$

$s_2 = 250.00$

$fy_{we1} = 694.45$

$fy_{we2} = 555.55$

$f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY: $cc = 0.00332119$

$c =$ confinement factor = 1.13212

$y_1 = 0.00184318$

$sh1 = 0.00589816$
 $ft1 = 580.8818$
 $fy1 = 484.0682$
 $su1 = 0.01099427$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $lo/lou,min = lb/ld = 0.45297586$
 $su1 = 0.4*esu1_nominal ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $esu1_nominal = 0.08$,
 For calculation of $esu1_nominal$ and $y1, sh1, ft1, fy1$, it is considered
 characteristic value $fsy1 = fs1/1.2$, from table 5.1, TBDY.
 $y1, sh1, ft1, fy1$, are also multiplied by $Min(1, 1.25*(lb/ld)^{2/3})$, from 10.3.5, ASCE 41-17.
 with $fs1 = (fs,jacket*Asl,ten,jacket + fs,core*Asl,ten,core)/Asl,ten = 484.0682$
 with $Es1 = (Es,jacket*Asl,ten,jacket + Es,core*Asl,ten,core)/Asl,ten = 200000.00$
 $y2 = 0.00184318$
 $sh2 = 0.00589816$
 $ft2 = 580.8818$
 $fy2 = 484.0682$
 $su2 = 0.01099427$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $lo/lou,min = lb/lb,min = 0.45297586$
 $su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $esu2_nominal = 0.08$,
 For calculation of $esu2_nominal$ and $y2, sh2, ft2, fy2$, it is considered
 characteristic value $fsy2 = fs2/1.2$, from table 5.1, TBDY.
 $y1, sh1, ft1, fy1$, are also multiplied by $Min(1, 1.25*(lb/ld)^{2/3})$, from 10.3.5, ASCE 41-17.
 with $fs2 = (fs,jacket*Asl,com,jacket + fs,core*Asl,com,core)/Asl,com = 484.0682$
 with $Es2 = (Es,jacket*Asl,com,jacket + Es,core*Asl,com,core)/Asl,com = 200000.00$
 $yv = 0.00184318$
 $shv = 0.00589816$
 $ftv = 614.3968$
 $fyv = 511.9973$
 $suv = 0.01099427$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $lo/lou,min = lb/ld = 0.45297586$
 $suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032$
 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 $fsv = (fs,jacket*Asl,mid,jacket + fs,mid*Asl,mid,core)/Asl,mid = 511.9973$
 with $Es_v = (Es,jacket*Asl,mid,jacket + Es,mid*Asl,mid,core)/Asl,mid = 200000.00$
 $1 = Asl,ten/(b*d)*(fs1/fc) = 0.0851958$
 $2 = Asl,com/(b*d)*(fs2/fc) = 0.0851958$
 $v = Asl,mid/(b*d)*(fsv/fc) = 0.04369034$
 and confined core properties:
 $b = 340.00$
 $d = 327.00$
 $d' = 13.00$
 $fcc (5A.2, TBDY) = 37.35991$
 $cc (5A.5, TBDY) = 0.00332119$
 $c = \text{confinement factor} = 1.13212$
 $1 = Asl,ten/(b*d)*(fs1/fc) = 0.1094258$
 $2 = Asl,com/(b*d)*(fs2/fc) = 0.1094258$
 $v = Asl,mid/(b*d)*(fsv/fc) = 0.05611603$
 Case/Assumption: Unconfined full section - Steel rupture
 ' satisfies Eq. (4.3)
 --->
 $v < vs,y2$ - LHS eq.(4.5) is satisfied
 --->
 $su (4.9) = 0.16193824$

$$\begin{aligned} \mu &= MRC(4.14) = 1.8194E+008 \\ u &= su(4.1) = 3.6747033E-005 \end{aligned}$$

Calculation of ratio l_b/l_d

$$\text{Lap Length: } l_b/l_d = 0.45297586$$

$$l_b = 300.00$$

$$l_d = 662.2869$$

Calculation of l_b, \min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

$$= 1$$

$$d_b = 14.66667$$

$$\text{Mean strength value of all re-bars: } f_y = 656.5682$$

$$\text{Mean concrete strength: } f_c' = (f_c'_{\text{jacket}} \cdot \text{Area}_{\text{jacket}} + f_c'_{\text{core}} \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 29.75, \text{ but } f_c'^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 25.00$$

$$K_{tr} = 3.43481$$

$$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 257.6106$$

where A_{tr_x}, A_{tr_y} are the sum of the area of all stirrup legs along X and Y local axis

$$s = \text{Max}(s_{\text{external}}, s_{\text{internal}}) = 250.00$$

$$n = 12.00$$

Calculation of μ_{2+}

Calculation of ultimate curvature μ according to 4.1, Biskinis/Fardis 2013:

$$u = 3.6747033E-005$$

$$\mu = 1.8194E+008$$

with full section properties:

$$b = 400.00$$

$$d = 357.00$$

$$d' = 43.00$$

$$v = 0.00125773$$

$$N = 5926.932$$

$$f_c = 33.00$$

$$c_o(5A.5, \text{TB DY}) = 0.002$$

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.01505571$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TB DY: } c_u = 0.01505571$$

$$w_e((5.4c), \text{TB DY}) = a_s e * s_{h, \min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.08345896$$

where $f = a_f * p_f * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.07683125$$

$$a_f = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 870.5244$$

$$f_y = 0.07683125$$

$$a_f = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 870.5244$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L * t * \text{Cos}(b_1) = 1.016$$

$f_{u,f} = 1055.00$
 $E_f = 64828.00$
 $u,f = 0.015$
 $ase \text{ ((5.4d), TBDY)} = (ase1 \cdot A_{ext} + ase2 \cdot A_{int}) / A_{sec} = 0.24250288$
 $ase1 = 0.24250288$
 $bo_1 = 340.00$
 $ho_1 = 340.00$
 $bi2_1 = 462400.00$
 $ase2 = \text{Max}(ase1, ase2) = 0.24250288$
 $bo_2 = 192.00$
 $ho_2 = 192.00$
 $bi2_2 = 147456.00$

$psh_{min} \cdot F_{ywe} = \text{Min}(psh_x \cdot F_{ywe}, psh_y \cdot F_{ywe}) = 3.00635$

Expression ((5.4d), TBDY) 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)

$psh_x \cdot F_{ywe} = psh1 \cdot F_{ywe1} + ps2 \cdot F_{ywe2} = 3.00635$
 $ps1 \text{ (external)} = (Ash1 \cdot h1 / s1) / A_{sec} = 0.00392699$
 $Ash1 = Astir_1 \cdot ns_1 = 157.0796$
 No stirrups, $ns_1 = 2.00$
 $h1 = 400.00$
 $ps2 \text{ (internal)} = (Ash2 \cdot h2 / s2) / A_{sec} = 0.00050265$
 $Ash2 = Astir_2 \cdot ns_2 = 100.531$
 No stirrups, $ns_2 = 2.00$
 $h2 = 200.00$

$psh_y \cdot F_{ywe} = psh1 \cdot F_{ywe1} + ps2 \cdot F_{ywe2} = 3.00635$
 $ps1 \text{ (external)} = (Ash1 \cdot h1 / s1) / A_{sec} = 0.00392699$
 $Ash1 = Astir_1 \cdot ns_1 = 157.0796$
 No stirrups, $ns_1 = 2.00$
 $h1 = 400.00$
 $ps2 \text{ (internal)} = (Ash2 \cdot h2 / s2) / A_{sec} = 0.00050265$
 $Ash2 = Astir_2 \cdot ns_2 = 100.531$
 No stirrups, $ns_2 = 2.00$
 $h2 = 200.00$

$A_{sec} = 160000.00$
 $s1 = 100.00$
 $s2 = 250.00$
 $fywe1 = 694.45$
 $fywe2 = 555.55$
 $f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY: $cc = 0.00332119$
 $c = \text{confinement factor} = 1.13212$

$y1 = 0.00184318$
 $sh1 = 0.00589816$
 $ft1 = 580.8818$
 $fy1 = 484.0682$
 $su1 = 0.01099427$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$lo/lou_{min} = lb/ld = 0.45297586$
 $su1 = 0.4 \cdot esu1_{nominal} \text{ ((5.5), TBDY)} = 0.032$

From table 5A.1, TBDY: $esu1_{nominal} = 0.08$,

For calculation of $esu1_{nominal}$ and $y1, sh1, ft1, fy1$, it is considered characteristic value $fsy1 = fs1 / 1.2$, from table 5.1, TBDY.

$y1, sh1, ft1, fy1$, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$, from 10.3.5, ASCE 41-17.

with $fs1 = (fs_{jacket} \cdot A_{sl,ten,jacket} + fs_{core} \cdot A_{sl,ten,core}) / A_{sl,ten} = 484.0682$

with $Es1 = (Es_{jacket} \cdot A_{sl,ten,jacket} + Es_{core} \cdot A_{sl,ten,core}) / A_{sl,ten} = 200000.00$

$y2 = 0.00184318$
 $sh2 = 0.00589816$
 $ft2 = 580.8818$
 $fy2 = 484.0682$
 $su2 = 0.01099427$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with

Shear_factor = 1.00

lo/lou,min = lb/lb,min = 0.45297586

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 = 484.0682

with Es2 = (Es,jacket*Asl,com,jacket + Es,core*Asl,com,core)/Asl,com = 200000.00

yv = 0.00184318

shv = 0.00589816

ftv = 614.3968

fyv = 511.9973

suv = 0.01099427

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor

and also multiplied by the shear_factor according to 15.7.1.4, with

Shear_factor = 1.00

lo/lou,min = lb/ld = 0.45297586

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 = 511.9973

with Esv = (Es,jacket*Asl,mid,jacket + Es,mid*Asl,mid,core)/Asl,mid = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.0851958

2 = Asl,com/(b*d)*(fs2/fc) = 0.0851958

v = Asl,mid/(b*d)*(fsv/fc) = 0.04369034

and confined core properties:

b = 340.00

d = 327.00

d' = 13.00

fcc (5A.2, TBDY) = 37.35991

cc (5A.5, TBDY) = 0.00332119

c = confinement factor = 1.13212

1 = Asl,ten/(b*d)*(fs1/fc) = 0.1094258

2 = Asl,com/(b*d)*(fs2/fc) = 0.1094258

v = Asl,mid/(b*d)*(fsv/fc) = 0.05611603

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

v < vs,y2 - LHS eq.(4.5) is satisfied

--->

su (4.9) = 0.16193824

Mu = MRc (4.14) = 1.8194E+008

u = su (4.1) = 3.6747033E-005

Calculation of ratio lb/ld

Lap Length: lb/ld = 0.45297586

lb = 300.00

ld = 662.2869

Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

= 1

db = 14.66667

Mean strength value of all re-bars: fy = 656.5682

Mean concrete strength: fc' = (fc',jacket*Area_jacket + fc',core*Area_core)/Area_section = 29.75, but $fc'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

t = 1.00

s = 0.80

e = 1.00

cb = 25.00

Ktr = 3.43481

Atr = $\text{Min}(Atr_x, Atr_y)$ = 257.6106

where Atr_x, Atr_y are the sum of the area of all stirrup legs along X and Y local axis

$$s = \text{Max}(s_{\text{external}}, s_{\text{internal}}) = 250.00$$
$$n = 12.00$$

Calculation of μ_2 -

Calculation of ultimate curvature μ according to 4.1, Biskinis/Fardis 2013:

$$\mu = 3.6747033\text{E-}005$$

$$\mu = 1.8194\text{E+}008$$

with full section properties:

$$b = 400.00$$

$$d = 357.00$$

$$d' = 43.00$$

$$v = 0.00125773$$

$$N = 5926.932$$

$$f_c = 33.00$$

$$c_o \text{ (5A.5, TBDY)} = 0.002$$

$$\text{Final value of } \mu: \mu^* = \text{shear_factor} * \text{Max}(\mu, c_o) = 0.01505571$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \mu = 0.01505571$$

$$w_e \text{ ((5.4c), TBDY)} = a_{se} * s_{h,\text{min}} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.08345896$$

where $f = a_f * p_f * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.07683125$$

$$a_f = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 870.5244$$

$$f_y = 0.07683125$$

$$a_f = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 870.5244$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L * t * \text{Cos}(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{f} = 0.015$$

$$a_{se} \text{ ((5.4d), TBDY)} = (a_{se1} * A_{ext} + a_{se2} * A_{int}) / A_{sec} = 0.24250288$$

$$a_{se1} = 0.24250288$$

$$b_{o,1} = 340.00$$

$$h_{o,1} = 340.00$$

$$b_{i,2,1} = 462400.00$$

$$a_{se2} = \text{Max}(a_{se1}, a_{se2}) = 0.24250288$$

$$b_{o,2} = 192.00$$

$$h_{o,2} = 192.00$$

$$b_{i,2,2} = 147456.00$$

$$p_{sh,\text{min}} * F_{ywe} = \text{Min}(p_{sh,x} * F_{ywe}, p_{sh,y} * F_{ywe}) = 3.00635$$

Expression ((5.4d), TBDY) for $p_{sh,\text{min}} * F_{ywe}$ has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$$p_{sh,x} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{sh2} * F_{ywe2} = 3.00635$$

$$p_{s1} \text{ (external)} = (A_{sh1} * h_1 / s_1) / A_{sec} = 0.00392699$$

$$A_{sh1} = A_{stir,1} * n_{s,1} = 157.0796$$

$$\text{No stirrups, } n_{s,1} = 2.00$$

$$h_1 = 400.00$$

$$p_{s2} \text{ (internal)} = (A_{sh2} * h_2 / s_2) / A_{sec} = 0.00050265$$

Ash2 = Astir_2*ns_2 = 100.531
No stirups, ns_2 = 2.00
h2 = 200.00

psh_y*Fywe = psh1*Fywe1+ps2*Fywe2 = 3.00635
ps1 (external) = (Ash1*h1/s1)/Asec = 0.00392699
Ash1 = Astir_1*ns_1 = 157.0796
No stirups, ns_1 = 2.00
h1 = 400.00
ps2 (internal) = (Ash2*h2/s2)/Asec = 0.00050265
Ash2 = Astir_2*ns_2 = 100.531
No stirups, ns_2 = 2.00
h2 = 200.00

Asec = 160000.00

s1 = 100.00

s2 = 250.00

fywe1 = 694.45

fywe2 = 555.55

fce = 33.00

From ((5.A5), TBDY), TBDY: cc = 0.00332119

c = confinement factor = 1.13212

y1 = 0.00184318

sh1 = 0.00589816

ft1 = 580.8818

fy1 = 484.0682

su1 = 0.01099427

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/lb = 0.45297586

su1 = 0.4*esu1_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu1_nominal = 0.08,

For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/lb)^2/3), from 10.3.5, ASCE 41-17.

with fs1 = (fs,jacket*Asl,ten,jacket + fs,core*Asl,ten,core)/Asl,ten = 484.0682

with Es1 = (Es,jacket*Asl,ten,jacket + Es,core*Asl,ten,core)/Asl,ten = 200000.00

y2 = 0.00184318

sh2 = 0.00589816

ft2 = 580.8818

fy2 = 484.0682

su2 = 0.01099427

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/lb,min = 0.45297586

su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu2_nominal = 0.08,

For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/lb)^2/3), from 10.3.5, ASCE 41-17.

with fs2 = (fs,jacket*Asl,com,jacket + fs,core*Asl,com,core)/Asl,com = 484.0682

with Es2 = (Es,jacket*Asl,com,jacket + Es,core*Asl,com,core)/Asl,com = 200000.00

yv = 0.00184318

shv = 0.00589816

ftv = 614.3968

fyv = 511.9973

suv = 0.01099427

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/lb = 0.45297586

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 $f_{sv} = f_{sv}/1.2$, 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 $f_{sv} = (f_{s,jacket} \cdot A_{s,mid,jacket} + f_{s,mid} \cdot A_{s,mid,core})/A_{s,mid} = 511.9973$

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 = $A_{s,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.0851958$

2 = $A_{s,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.0851958$

$v = A_{s,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.04369034$

and confined core properties:

$b = 340.00$

$d = 327.00$

$d' = 13.00$

f_{cc} (5A.2, TBDY) = 37.35991

cc (5A.5, TBDY) = 0.00332119

c = confinement factor = 1.13212

1 = $A_{s,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.1094258$

2 = $A_{s,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.1094258$

$v = A_{s,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.05611603$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

---->

$v < v_{s,y2}$ - LHS eq.(4.5) is satisfied

---->

μ_u (4.9) = 0.16193824

$M_u = M_{Rc}$ (4.14) = 1.8194E+008

$u = \mu_u$ (4.1) = 3.6747033E-005

Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.45297586$

$l_b = 300.00$

$l_d = 662.2869$

Calculation of l_b, \min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

= 1

$d_b = 14.66667$

Mean strength value of all re-bars: $f_y = 656.5682$

Mean concrete strength: $f'_c = (f'_{c,jacket} \cdot \text{Area}_{jacket} + f'_{c,core} \cdot \text{Area}_{core})/\text{Area}_{section} = 29.75$, but $f_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 3.43481$

$A_{tr} = \text{Min}(A_{tr,x}, A_{tr,y}) = 257.6106$

where $A_{tr,x}, A_{tr,y}$ are the sum of the area of all stirrup legs along X and Y local axis

$s = \text{Max}(s_{external}, s_{internal}) = 250.00$

$n = 12.00$

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 633062.661$

Calculation of Shear Strength at edge 1, $V_{r1} = 633062.661$

$V_{r1} = V_{CoI}$ ((10.3), ASCE 41-17) = $k_{nl} \cdot V_{CoI0}$

$V_{CoI0} = 633062.661$

$k_{nl} = 1$ (zero step-static loading)

NOTE: In expression (10-3) ' $V_s = A_v \cdot f_y \cdot d / s$ ' is replaced by ' $V_{s+} + f \cdot V_f$ '

where V_f is the contribution of FRPs (11.3), ACI 440).

= 1 (normal-weight concrete)

Mean concrete strength: $f'_c = (f'_{c,jacket} \cdot \text{Area}_{jacket} + f'_{c,core} \cdot \text{Area}_{core})/\text{Area}_{section} = 29.75$, but $f_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$M_u = 4.3445556E-012$

$V_u = 2.8976040E-031$

$d = 0.8 \cdot h = 320.00$
 $Nu = 5926.932$
 $Ag = 160000.00$
 From (11.5.4.8), ACI 318-14: $Vs = Vs1 + Vs2 = 279254.914$
 where:
 $Vs1 = 279254.914$ is calculated for jacket, with:
 $d = 320.00$
 $Av = 157079.633$
 $fy = 555.56$
 $s = 100.00$
 $Vs1$ is multiplied by $Col1 = 1.00$
 $s/d = 0.3125$
 $Vs2 = 0.00$ is calculated for core, with:
 $d = 160.00$
 $Av = 100530.965$
 $fy = 444.44$
 $s = 250.00$
 $Vs2$ is multiplied by $Col2 = 0.00$
 $s/d = 1.5625$
 Vf ((11-3)-(11.4), ACI 440) = 188111.148
 $f = 0.95$, for fully-wrapped sections
 $wf/sf = 1$ (FRP strips adjacent to one another).
 In (11.3) $\sin \theta + \cos \theta$ is replaced with $(\cot \theta + \cot \alpha) \sin \alpha$ which is more a generalised expression,
 where θ is the angle of the crack direction (see KANEPE).
 This later relation, considered as a function $Vf(\theta, \alpha)$, 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: $\theta = b1 + 90^\circ = 90.00$
 $Vf = \text{Min}(|Vf(45, \theta)|, |Vf(-45, \theta)|)$, with:
 total thickness per orientation, $tf1 = NL \cdot t / NoDir = 1.016$
 $dfv = d$ (figure 11.2, ACI 440) = 357.00
 ffe ((11-5), ACI 440) = 259.312
 $Ef = 64828.00$
 $fe = 0.004$, from (11.6a), ACI 440
 with $fu = 0.01$
 From (11-11), ACI 440: $Vs + Vf \leq 463788.751$
 $bw = 400.00$

Calculation of Shear Strength at edge 2, $Vr2 = 633062.661$
 $Vr2 = VCol$ ((10.3), ASCE 41-17) = $knl \cdot VCol0$
 $VCol0 = 633062.661$
 $knl = 1$ (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).

$\lambda = 1$ (normal-weight concrete)
 Mean concrete strength: $fc' = (fc'_{jacket} \cdot Area_{jacket} + fc'_{core} \cdot Area_{core}) / Area_{section} = 29.75$, but $fc'^{0.5} \leq 8.3$
 MPa (22.5.3.1, ACI 318-14)
 $M/Vd = 2.00$
 $Mu = 4.3445556E-012$
 $Vu = 2.8976040E-031$
 $d = 0.8 \cdot h = 320.00$
 $Nu = 5926.932$
 $Ag = 160000.00$
 From (11.5.4.8), ACI 318-14: $Vs = Vs1 + Vs2 = 279254.914$
 where:
 $Vs1 = 279254.914$ is calculated for jacket, with:
 $d = 320.00$
 $Av = 157079.633$
 $fy = 555.56$
 $s = 100.00$
 $Vs1$ is multiplied by $Col1 = 1.00$
 $s/d = 0.3125$
 $Vs2 = 0.00$ is calculated for core, with:
 $d = 160.00$
 $Av = 100530.965$

$f_y = 444.44$
 $s = 250.00$
 V_{s2} is multiplied by $Col2 = 0.00$
 $s/d = 1.5625$
 $V_f((11-3)-(11.4), ACI 440) = 188111.148$
 $f = 0.95$, 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: $\theta = b1 + 90^\circ = 90.00$
 $V_f = \text{Min}(|V_f(45, 1)|, |V_f(-45, a1)|)$, with:
 total thickness per orientation, $tf1 = NL * t / NoDir = 1.016$
 $dfv = d$ (figure 11.2, ACI 440) = 357.00
 $ffe((11-5), ACI 440) = 259.312$
 $E_f = 64828.00$
 $f_e = 0.004$, from (11.6a), ACI 440
 with $f_u = 0.01$
 From (11-11), ACI 440: $V_s + V_f \leq 463788.751$
 $bw = 400.00$

 End Of Calculation of Shear Capacity ratio for element: column JC1 of floor 1
 At local axis: 3

 Start Of Calculation of Shear Capacity ratio for element: column JC1 of floor 1
 At Shear local axis: 2
 (Bending local axis: 3)
 Section Type: rcjrs

Constant Properties

 Knowledge Factor, $\phi = 0.80$
 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
 Existing material of Secondary Member: Concrete Strength, $f_c = f_{cm} = 20.00$
 Existing material of Secondary Member: Steel Strength, $f_s = f_{sm} = 444.44$
 Concrete Elasticity, $E_c = 21019.039$
 Steel Elasticity, $E_s = 200000.00$
 #####
 Note: Especially for the calculation of moment strengths,
 the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14
 Jacket
 New material: Steel Strength, $f_s = 1.25 * f_{sm} = 694.45$
 Existing Column
 Existing material: Steel Strength, $f_s = 1.25 * f_{sm} = 555.55$
 #####
 External Height, $H = 400.00$
 External Width, $W = 400.00$
 Internal Height, $H = 200.00$
 Internal Width, $W = 200.00$
 Cover Thickness, $c = 25.00$
 Mean Confinement Factor overall section = 1.13212
 Element Length, $L = 3000.00$
 Secondary Member
 Ribbed Bars
 Ductile Steel

Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
Lap Length $l_o = 300.00$
FRP Wrapping Data
Type: Carbon
Cured laminate properties (design values)
Thickness, $t = 1.016$
Tensile Strength, $f_{fu} = 1055.00$
Tensile Modulus, $E_f = 64828.00$
Elongation, $e_{fu} = 0.01$
Number of directions, $N_{oDir} = 1$
Fiber orientations, $b_i = 0.00^\circ$
Number of layers, $N_L = 1$
Radius of rounding corners, $R = 40.00$

Stepwise Properties

At local axis: 2
EDGE -A-
Shear Force, $V_a = -6.6805695E-033$
EDGE -B-
Shear Force, $V_b = 6.6805695E-033$
BOTH EDGES
Axial Force, $F = -5926.932$
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: $A_{sl,t} = 0.00$
-Compression: $A_{sl,c} = 2060.885$
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension: $A_{sl,ten} = 829.3805$
-Compression: $A_{sl,com} = 829.3805$
-Middle: $A_{sl,mid} = 402.1239$

Calculation of Shear Capacity ratio, $V_e/V_r = 0.19159777$
Member Controlled by Flexure ($V_e/V_r < 1$)
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 121293.391$
with
 $M_{pr1} = \text{Max}(Mu_{1+}, Mu_{1-}) = 1.8194E+008$
 $Mu_{1+} = 1.8194E+008$, is the ultimate moment strength at the edge 1 of the member in the actual moment direction
which is defined for the static loading combination
 $Mu_{1-} = 1.8194E+008$, is the ultimate moment strength at the edge 1 of the member in the opposite moment
direction which is defined for the static loading combination
 $M_{pr2} = \text{Max}(Mu_{2+}, Mu_{2-}) = 1.8194E+008$
 $Mu_{2+} = 1.8194E+008$, is the ultimate moment strength at the edge 2 of the member in the actual moment direction
which is defined for the the static loading combination
 $Mu_{2-} = 1.8194E+008$, is the ultimate moment strength at the edge 2 of the member in the opposite moment
direction which is defined for the the static loading combination

Calculation of Mu_{1+}

Calculation of ultimate curvature ϕ_u according to 4.1, Biskinis/Fardis 2013:
 $\phi_u = 3.6747033E-005$
 $M_u = 1.8194E+008$

with full section properties:

$b = 400.00$
 $d = 357.00$
 $d' = 43.00$
 $v = 0.00125773$
 $N = 5926.932$
 $f_c = 33.00$

co (5A.5, TBDY) = 0.002

Final value of cu: $cu^* = \text{shear_factor} * \text{Max}(cu, cc) = 0.01505571$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $cu = 0.01505571$

we ((5.4c), TBDY) = $ase^* sh_{,min} * fy_{we} / f_{ce} + \text{Min}(fx, fy) = 0.08345896$

where $f = af * pf * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

 $fx = 0.07683125$

$af = 0.57333333$

$b = 400.00$

$h = 400.00$

From EC8 A.4.4.3(6), $pf = 2tf/bw = 0.00508$

$bw = 400.00$

effective stress from (A.35), $ff,e = 870.5244$

 $fy = 0.07683125$

$af = 0.57333333$

$b = 400.00$

$h = 400.00$

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) = $(ase1 * A_{ext} + ase2 * A_{int}) / A_{sec} = 0.24250288$

$ase1 = 0.24250288$

$bo_1 = 340.00$

$ho_1 = 340.00$

$bi2_1 = 462400.00$

$ase2 = \text{Max}(ase1, ase2) = 0.24250288$

$bo_2 = 192.00$

$ho_2 = 192.00$

$bi2_2 = 147456.00$

$psh_{,min} * fy_{we} = \text{Min}(psh_x * fy_{we}, psh_y * fy_{we}) = 3.00635$

Expression ((5.4d), TBDY) for $psh_{,min} * fy_{we}$ has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

 $psh_x * fy_{we} = psh1 * fy_{we1} + ps2 * fy_{we2} = 3.00635$

$ps1$ (external) = $(Ash1 * h1 / s1) / A_{sec} = 0.00392699$

$Ash1 = Astir_1 * ns_1 = 157.0796$

No stirrups, $ns_1 = 2.00$

$h1 = 400.00$

$ps2$ (internal) = $(Ash2 * h2 / s2) / A_{sec} = 0.00050265$

$Ash2 = Astir_2 * ns_2 = 100.531$

No stirrups, $ns_2 = 2.00$

$h2 = 200.00$

 $psh_y * fy_{we} = psh1 * fy_{we1} + ps2 * fy_{we2} = 3.00635$

$ps1$ (external) = $(Ash1 * h1 / s1) / A_{sec} = 0.00392699$

$Ash1 = Astir_1 * ns_1 = 157.0796$

No stirrups, $ns_1 = 2.00$

$h1 = 400.00$

$ps2$ (internal) = $(Ash2 * h2 / s2) / A_{sec} = 0.00050265$

$Ash2 = Astir_2 * ns_2 = 100.531$

No stirrups, $ns_2 = 2.00$

$h2 = 200.00$

 $A_{sec} = 160000.00$

$s1 = 100.00$

$s2 = 250.00$

$fy_{we1} = 694.45$

$fy_{we2} = 555.55$

$f_{ce} = 33.00$

From ((5.A.5), TBDY), TBDY: $cc = 0.00332119$
 $c = \text{confinement factor} = 1.13212$
 $y1 = 0.00184318$
 $sh1 = 0.00589816$
 $ft1 = 580.8818$
 $fy1 = 484.0682$
 $su1 = 0.01099427$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 $\text{Shear_factor} = 1.00$
 $lo/lou,min = lb/ld = 0.45297586$
 $su1 = 0.4 * esu1_nominal ((5.5), TBDY) = 0.032$
 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 $fs1 = (fs,jacket * Asl,ten,jacket + fs,core * Asl,ten,core) / Asl,ten = 484.0682$
 with $Es1 = (Es,jacket * Asl,ten,jacket + Es,core * Asl,ten,core) / Asl,ten = 200000.00$
 $y2 = 0.00184318$
 $sh2 = 0.00589816$
 $ft2 = 580.8818$
 $fy2 = 484.0682$
 $su2 = 0.01099427$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 $\text{Shear_factor} = 1.00$
 $lo/lou,min = lb/lb,min = 0.45297586$
 $su2 = 0.4 * esu2_nominal ((5.5), TBDY) = 0.032$
 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 $fs2 = (fs,jacket * Asl,com,jacket + fs,core * Asl,com,core) / Asl,com = 484.0682$
 with $Es2 = (Es,jacket * Asl,com,jacket + Es,core * Asl,com,core) / Asl,com = 200000.00$
 $yv = 0.00184318$
 $shv = 0.00589816$
 $ftv = 614.3968$
 $fyv = 511.9973$
 $suv = 0.01099427$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 $\text{Shear_factor} = 1.00$
 $lo/lou,min = lb/ld = 0.45297586$
 $suv = 0.4 * esuv_nominal ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $esuv_nominal = 0.08$,
 considering characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY
 For calculation of $esuv_nominal$ and yv, shv, ftv, fyv , it is considered
 characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY.
 $y1, sh1, ft1, fy1$, are also multiplied by $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE 41-17.
 with $fsv = (fs,jacket * Asl,mid,jacket + fs,mid * Asl,mid,core) / Asl,mid = 511.9973$
 with $Es_v = (Es,jacket * Asl,mid,jacket + Es,mid * Asl,mid,core) / Asl,mid = 200000.00$
 $1 = Asl,ten / (b * d) * (fs1 / fc) = 0.0851958$
 $2 = Asl,com / (b * d) * (fs2 / fc) = 0.0851958$
 $v = Asl,mid / (b * d) * (fsv / fc) = 0.04369034$
 and confined core properties:
 $b = 340.00$
 $d = 327.00$
 $d' = 13.00$
 $fcc (5A.2, TBDY) = 37.35991$
 $cc (5A.5, TBDY) = 0.00332119$
 $c = \text{confinement factor} = 1.13212$
 $1 = Asl,ten / (b * d) * (fs1 / fc) = 0.1094258$
 $2 = Asl,com / (b * d) * (fs2 / fc) = 0.1094258$
 $v = Asl,mid / (b * d) * (fsv / fc) = 0.05611603$
 Case/Assumption: Unconfined full section - Steel rupture
 ' satisfies Eq. (4.3)

--->

$v < v_{s,y2}$ - LHS eq.(4.5) is satisfied

--->

$$s_u(4.9) = 0.16193824$$

$$M_u = M_{Rc}(4.14) = 1.8194E+008$$

$$u = s_u(4.1) = 3.6747033E-005$$

Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.45297586$

$$l_b = 300.00$$

$$l_d = 662.2869$$

Calculation of l_b, \min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

$$= 1$$

$$d_b = 14.66667$$

$$\text{Mean strength value of all re-bars: } f_y = 656.5682$$

$$\text{Mean concrete strength: } f_c' = (f_c'_{\text{jacket}} \cdot \text{Area}_{\text{jacket}} + f_c'_{\text{core}} \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 29.75, \text{ but } f_c'^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 25.00$$

$$K_{tr} = 3.43481$$

$$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 257.6106$$

where A_{tr_x}, A_{tr_y} are the sum of the area of all stirrup legs along X and Y local axis

$$s = \text{Max}(s_{\text{external}}, s_{\text{internal}}) = 250.00$$

$$n = 12.00$$

Calculation of M_u1 -

Calculation of ultimate curvature ϕ_u according to 4.1, Biskinis/Fardis 2013:

$$u = 3.6747033E-005$$

$$M_u = 1.8194E+008$$

with full section properties:

$$b = 400.00$$

$$d = 357.00$$

$$d' = 43.00$$

$$v = 0.00125773$$

$$N = 5926.932$$

$$f_c = 33.00$$

$$c_o(5A.5, \text{TBDY}) = 0.002$$

$$\text{Final value of } \phi_u: \phi_u^* = \text{shear_factor} \cdot \text{Max}(\phi_u, \phi_c) = 0.01505571$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \phi_u = 0.01505571$$

$$\text{we ((5.4c), TBDY) } = a_s \cdot \text{sh}_{\min} \cdot f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.08345896$$

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)

$$f_x = 0.07683125$$

$$a_f = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{fe} = 870.5244$$

$$f_y = 0.07683125$$

$$a_f = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{fe} = 870.5244$$

R = 40.00
 Effective FRP thickness, $t_f = NL*t*\text{Cos}(b1) = 1.016$
 $f_{u,f} = 1055.00$
 $E_f = 64828.00$
 $u_{,f} = 0.015$
 $\text{ase}((5.4d), \text{TBDY}) = (\text{ase}_1*A_{\text{ext}} + \text{ase}_2*A_{\text{int}})/A_{\text{sec}} = 0.24250288$
 $\text{ase}_1 = 0.24250288$
 $bo_1 = 340.00$
 $ho_1 = 340.00$
 $bi2_1 = 462400.00$
 $\text{ase}_2 = \text{Max}(\text{ase}_1, \text{ase}_2) = 0.24250288$
 $bo_2 = 192.00$
 $ho_2 = 192.00$
 $bi2_2 = 147456.00$
 $\text{psh}_{\text{min}}*F_{ywe} = \text{Min}(\text{psh}_x*F_{ywe}, \text{psh}_y*F_{ywe}) = 3.00635$

Expression ((5.4d), TBDY) for $\text{psh}_{\text{min}}*F_{ywe}$ has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$\text{psh}_x*F_{ywe} = \text{psh}_1*F_{ywe1} + \text{ps}_2*F_{ywe2} = 3.00635$
 $\text{ps}_1(\text{external}) = (A_{sh1}*h_1/s_1)/A_{\text{sec}} = 0.00392699$
 $A_{sh1} = A_{\text{stir}_1}*n_{s1} = 157.0796$
 No stirrups, $n_{s1} = 2.00$
 $h_1 = 400.00$
 $\text{ps}_2(\text{internal}) = (A_{sh2}*h_2/s_2)/A_{\text{sec}} = 0.00050265$
 $A_{sh2} = A_{\text{stir}_2}*n_{s2} = 100.531$
 No stirrups, $n_{s2} = 2.00$
 $h_2 = 200.00$

$\text{psh}_y*F_{ywe} = \text{psh}_1*F_{ywe1} + \text{ps}_2*F_{ywe2} = 3.00635$
 $\text{ps}_1(\text{external}) = (A_{sh1}*h_1/s_1)/A_{\text{sec}} = 0.00392699$
 $A_{sh1} = A_{\text{stir}_1}*n_{s1} = 157.0796$
 No stirrups, $n_{s1} = 2.00$
 $h_1 = 400.00$
 $\text{ps}_2(\text{internal}) = (A_{sh2}*h_2/s_2)/A_{\text{sec}} = 0.00050265$
 $A_{sh2} = A_{\text{stir}_2}*n_{s2} = 100.531$
 No stirrups, $n_{s2} = 2.00$
 $h_2 = 200.00$

$A_{\text{sec}} = 160000.00$
 $s_1 = 100.00$
 $s_2 = 250.00$
 $f_{ywe1} = 694.45$
 $f_{ywe2} = 555.55$
 $f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY: $cc = 0.00332119$
 $c = \text{confinement factor} = 1.13212$

$y_1 = 0.00184318$
 $sh_1 = 0.00589816$
 $ft_1 = 580.8818$
 $fy_1 = 484.0682$
 $su_1 = 0.01099427$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$lo/lo_{\text{min}} = l_b/l_d = 0.45297586$
 $su_1 = 0.4*es_{u1_nominal}((5.5), \text{TBDY}) = 0.032$

From table 5A.1, TBDY: $es_{u1_nominal} = 0.08$,

For calculation of $es_{u1_nominal}$ and y_1, sh_1, ft_1, fy_1 , it is considered characteristic value $fs_{y1} = fs_1/1.2$, from table 5.1, TBDY.

y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25*(l_b/l_d)^{2/3})$, from 10.3.5, ASCE 41-17.

with $fs_1 = (f_{s,jacket}*A_{s1,ten,jacket} + f_{s,core}*A_{s1,ten,core})/A_{s1,ten} = 484.0682$

with $Es_1 = (E_{s,jacket}*A_{s1,ten,jacket} + E_{s,core}*A_{s1,ten,core})/A_{s1,ten} = 200000.00$

$y_2 = 0.00184318$
 $sh_2 = 0.00589816$
 $ft_2 = 580.8818$
 $fy_2 = 484.0682$

$$su_2 = 0.01099427$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$lo/lo_{u,min} = lb/lb_{u,min} = 0.45297586$$

$$su_2 = 0.4 * esu_{2,nominal} ((5.5), TBDY) = 0.032$$

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.

$$\text{with } fs_2 = (fs_{jacket} * A_{sl,com,jacket} + fs_{core} * A_{sl,com,core}) / A_{sl,com} = 484.0682$$

$$\text{with } Es_2 = (Es_{jacket} * A_{sl,com,jacket} + Es_{core} * A_{sl,com,core}) / A_{sl,com} = 200000.00$$

$$yv = 0.00184318$$

$$shv = 0.00589816$$

$$ftv = 614.3968$$

$$fyv = 511.9973$$

$$suv = 0.01099427$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$lo/lo_{u,min} = lb/ld = 0.45297586$$

$$suv = 0.4 * esuv_{nominal} ((5.5), TBDY) = 0.032$$

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.

y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE 41-17.

$$\text{with } fsv = (fs_{jacket} * A_{sl,mid,jacket} + fs_{mid} * A_{sl,mid,core}) / A_{sl,mid} = 511.9973$$

$$\text{with } Esv = (Es_{jacket} * A_{sl,mid,jacket} + Es_{mid} * A_{sl,mid,core}) / A_{sl,mid} = 200000.00$$

$$1 = A_{sl,ten} / (b * d) * (fs_1 / fc) = 0.0851958$$

$$2 = A_{sl,com} / (b * d) * (fs_2 / fc) = 0.0851958$$

$$v = A_{sl,mid} / (b * d) * (fsv / fc) = 0.04369034$$

and confined core properties:

$$b = 340.00$$

$$d = 327.00$$

$$d' = 13.00$$

$$fcc (5A.2, TBDY) = 37.35991$$

$$cc (5A.5, TBDY) = 0.00332119$$

$$c = \text{confinement factor} = 1.13212$$

$$1 = A_{sl,ten} / (b * d) * (fs_1 / fc) = 0.1094258$$

$$2 = A_{sl,com} / (b * d) * (fs_2 / fc) = 0.1094258$$

$$v = A_{sl,mid} / (b * d) * (fsv / fc) = 0.05611603$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < v_{s,y2}$ - LHS eq.(4.5) is satisfied

--->

$$su (4.9) = 0.16193824$$

$$\mu = MRc (4.14) = 1.8194E+008$$

$$u = su (4.1) = 3.6747033E-005$$

Calculation of ratio lb/ld

Lap Length: $lb/ld = 0.45297586$

$$lb = 300.00$$

$$ld = 662.2869$$

Calculation of lb_{min} according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

$$= 1$$

$$db = 14.66667$$

Mean strength value of all re-bars: $fy = 656.5682$

Mean concrete strength: $fc' = (fc'_{jacket} * Area_{jacket} + fc'_{core} * Area_{core}) / Area_{section} = 29.75$, but $fc'^{0.5} \leq 8.3$
MPa (22.5.3.1, ACI 318-14)

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$cb = 25.00$$

$$K_{tr} = 3.43481$$

$$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 257.6106$$

where A_{tr_x} , A_{tr_y} are the sum of the area of all stirrup legs along X and Y local axis

$$s = \text{Max}(s_{\text{external}}, s_{\text{internal}}) = 250.00$$

$$n = 12.00$$

Calculation of μ_{2+}

Calculation of ultimate curvature μ according to 4.1, Biskinis/Fardis 2013:

$$\mu = 3.6747033E-005$$

$$\mu = 1.8194E+008$$

with full section properties:

$$b = 400.00$$

$$d = 357.00$$

$$d' = 43.00$$

$$v = 0.00125773$$

$$N = 5926.932$$

$$f_c = 33.00$$

$$\alpha (5A.5, \text{TBDY}) = 0.002$$

$$\text{Final value of } \mu: \mu^* = \text{shear_factor} * \text{Max}(\mu, \alpha) = 0.01505571$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \mu = 0.01505571$$

$$\mu_e \text{ ((5.4c), TBDY) } = \alpha * \text{sh}_{\text{min}} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.08345896$$

where $f_x = \alpha * p_f * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.07683125$$

$$\alpha_f = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{fe} = 870.5244$$

$$f_y = 0.07683125$$

$$\alpha_f = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{fe} = 870.5244$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L * t * \text{Cos}(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{f} = 0.015$$

$$\alpha_{se} \text{ ((5.4d), TBDY) } = (\alpha_{se1} * A_{ext} + \alpha_{se2} * A_{int}) / A_{sec} = 0.24250288$$

$$\alpha_{se1} = 0.24250288$$

$$b_{o_1} = 340.00$$

$$h_{o_1} = 340.00$$

$$b_{i2_1} = 462400.00$$

$$\alpha_{se2} = \text{Max}(\alpha_{se1}, \alpha_{se2}) = 0.24250288$$

$$b_{o_2} = 192.00$$

$$h_{o_2} = 192.00$$

$$b_{i2_2} = 147456.00$$

$$p_{sh, \text{min}} * f_{ywe} = \text{Min}(p_{sh,x} * f_{ywe}, p_{sh,y} * f_{ywe}) = 3.00635$$

Expression ((5.4d), TBDY) for $p_{sh, \text{min}} * f_{ywe}$ has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$$p_{sh_x} * f_{ywe} = p_{sh1} * f_{ywe1} + p_{sh2} * f_{ywe2} = 3.00635$$

$$p_{s1} \text{ (external) } = (A_{sh1} * h_1 / s_1) / A_{sec} = 0.00392699$$

$$A_{sh1} = A_{stir_1} * n_{s_1} = 157.0796$$

No stirups, ns₁ = 2.00
h₁ = 400.00
ps₂ (internal) = (Ash₂*h₂/s₂)/Asec = 0.00050265
Ash₂ = Astir₂*ns₂ = 100.531
No stirups, ns₂ = 2.00
h₂ = 200.00

psh_y*Fywe = psh₁*Fywe₁+ps₂*Fywe₂ = 3.00635
ps₁ (external) = (Ash₁*h₁/s₁)/Asec = 0.00392699
Ash₁ = Astir₁*ns₁ = 157.0796
No stirups, ns₁ = 2.00
h₁ = 400.00
ps₂ (internal) = (Ash₂*h₂/s₂)/Asec = 0.00050265
Ash₂ = Astir₂*ns₂ = 100.531
No stirups, ns₂ = 2.00
h₂ = 200.00

Asec = 160000.00
s₁ = 100.00
s₂ = 250.00
fywe₁ = 694.45
fywe₂ = 555.55
fce = 33.00

From ((5.A.5), TBDY), TBDY: cc = 0.00332119
c = confinement factor = 1.13212

y₁ = 0.00184318
sh₁ = 0.00589816
ft₁ = 580.8818
fy₁ = 484.0682
su₁ = 0.01099427

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/l_d = 0.45297586

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} = 484.0682

with Es₁ = (Es_{jacket}*Asl_{ten,jacket} + Es_{core}*Asl_{ten,core})/Asl_{ten} = 200000.00

y₂ = 0.00184318
sh₂ = 0.00589816
ft₂ = 580.8818
fy₂ = 484.0682
su₂ = 0.01099427

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/l_{b,min} = 0.45297586

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.

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 fs₂ = (fs_{jacket}*Asl_{com,jacket} + fs_{core}*Asl_{com,core})/Asl_{com} = 484.0682

with Es₂ = (Es_{jacket}*Asl_{com,jacket} + Es_{core}*Asl_{com,core})/Asl_{com} = 200000.00

y_v = 0.00184318
sh_v = 0.00589816
ft_v = 614.3968
fy_v = 511.9973
suv = 0.01099427

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/l_d = 0.45297586

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 $Min(1,1.25*(lb/l_d)^{2/3})$, from 10.3.5, ASCE 41-17.
 with $fsv = (fs_jacket*Asl_mid,jacket + fs_mid*Asl_mid,core)/Asl_mid = 511.9973$
 with $Esv = (Es_jacket*Asl_mid,jacket + Es_mid*Asl_mid,core)/Asl_mid = 200000.00$
 $1 = Asl_ten/(b*d)*(fs1/fc) = 0.0851958$
 $2 = Asl_com/(b*d)*(fs2/fc) = 0.0851958$
 $v = Asl_mid/(b*d)*(fsv/fc) = 0.04369034$

and confined core properties:

$b = 340.00$
 $d = 327.00$
 $d' = 13.00$
 fcc (5A.2, TBDY) = 37.35991
 cc (5A.5, TBDY) = 0.00332119
 $c =$ confinement factor = 1.13212
 $1 = Asl_ten/(b*d)*(fs1/fc) = 0.1094258$
 $2 = Asl_com/(b*d)*(fs2/fc) = 0.1094258$
 $v = Asl_mid/(b*d)*(fsv/fc) = 0.05611603$

Case/Assumption: Unconfined full section - Steel rupture
 ' satisfies Eq. (4.3)

---->
 $v < vs,y2$ - LHS eq.(4.5) is satisfied

---->
 su (4.9) = 0.16193824
 $Mu = MRc$ (4.14) = 1.8194E+008
 $u = su$ (4.1) = 3.6747033E-005

 Calculation of ratio lb/l_d

 Lap Length: $lb/l_d = 0.45297586$

$lb = 300.00$
 $l_d = 662.2869$

Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
 $= 1$

$db = 14.66667$
 Mean strength value of all re-bars: $fy = 656.5682$
 Mean concrete strength: $fc' = (fc'_jacket*Area_jacket + fc'_core*Area_core)/Area_section = 29.75$, but $fc'^{0.5} \leq 8.3$
 MPa (22.5.3.1, ACI 318-14)
 $t = 1.00$
 $s = 0.80$
 $e = 1.00$
 $cb = 25.00$
 $Ktr = 3.43481$
 $Atr = Min(Atr_x,Atr_y) = 257.6106$
 where Atr_x, Atr_y are the sum of the area of all stirrup legs along X and Y loxal axis
 $s = Max(s_external,s_internal) = 250.00$
 $n = 12.00$

 Calculation of $Mu2$ -

 Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

$u = 3.6747033E-005$
 $Mu = 1.8194E+008$

 with full section properties:

$b = 400.00$
 $d = 357.00$
 $d' = 43.00$
 $v = 0.00125773$
 $N = 5926.932$

$$f_c = 33.00$$

$$c_o (5A.5, TBDY) = 0.002$$

$$\text{Final value of } c_u = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.01505571$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } c_u = 0.01505571$$

$$w_e ((5.4c), TBDY) = a_{se} * \text{sh}_{,min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.08345896$$

where $f = a_f * p_f * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.07683125$$

$$a_f = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 870.5244$$

$$f_y = 0.07683125$$

$$a_f = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 870.5244$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N_L * t * \text{Cos}(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$a_{se} ((5.4d), TBDY) = (a_{se1} * A_{ext} + a_{se2} * A_{int}) / A_{sec} = 0.24250288$$

$$a_{se1} = 0.24250288$$

$$b_{o,1} = 340.00$$

$$h_{o,1} = 340.00$$

$$b_{i2,1} = 462400.00$$

$$a_{se2} = \text{Max}(a_{se1}, a_{se2}) = 0.24250288$$

$$b_{o,2} = 192.00$$

$$h_{o,2} = 192.00$$

$$b_{i2,2} = 147456.00$$

$$p_{sh,min} * f_{ywe} = \text{Min}(p_{sh,x} * f_{ywe}, p_{sh,y} * f_{ywe}) = 3.00635$$

Expression ((5.4d), TBDY) for $p_{sh,min} * f_{ywe}$ has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$$p_{sh,x} * f_{ywe} = p_{sh1} * f_{ywe1} + p_{sh2} * f_{ywe2} = 3.00635$$

$$p_{s1} (\text{external}) = (A_{sh1} * h_1 / s_1) / A_{sec} = 0.00392699$$

$$A_{sh1} = A_{stir,1} * n_{s,1} = 157.0796$$

$$\text{No stirrups, } n_{s,1} = 2.00$$

$$h_1 = 400.00$$

$$p_{s2} (\text{internal}) = (A_{sh2} * h_2 / s_2) / A_{sec} = 0.00050265$$

$$A_{sh2} = A_{stir,2} * n_{s,2} = 100.531$$

$$\text{No stirrups, } n_{s,2} = 2.00$$

$$h_2 = 200.00$$

$$p_{sh,y} * f_{ywe} = p_{sh1} * f_{ywe1} + p_{sh2} * f_{ywe2} = 3.00635$$

$$p_{s1} (\text{external}) = (A_{sh1} * h_1 / s_1) / A_{sec} = 0.00392699$$

$$A_{sh1} = A_{stir,1} * n_{s,1} = 157.0796$$

$$\text{No stirrups, } n_{s,1} = 2.00$$

$$h_1 = 400.00$$

$$p_{s2} (\text{internal}) = (A_{sh2} * h_2 / s_2) / A_{sec} = 0.00050265$$

$$A_{sh2} = A_{stir,2} * n_{s,2} = 100.531$$

$$\text{No stirrups, } n_{s,2} = 2.00$$

$$h_2 = 200.00$$

$$A_{sec} = 160000.00$$

$$s_1 = 100.00$$

$$s_2 = 250.00$$

$$f_{ywe1} = 694.45$$

$$f_{ywe2} = 555.55$$

$f_{ce} = 33.00$
 From ((5.A.5), TBDY), TBDY: $cc = 0.00332119$
 $c = \text{confinement factor} = 1.13212$
 $y_1 = 0.00184318$
 $sh_1 = 0.00589816$
 $ft_1 = 580.8818$
 $fy_1 = 484.0682$
 $su_1 = 0.01099427$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $lo/lou, \min = lb/ld = 0.45297586$
 $su_1 = 0.4 * esu_1 \text{ nominal} ((5.5), TBDY) = 0.032$
 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.
 with $fs_1 = (fs_{jacket} * Asl, \text{ten}, \text{jacket} + fs_{core} * Asl, \text{ten}, \text{core}) / Asl, \text{ten} = 484.0682$
 with $Es_1 = (Es_{jacket} * Asl, \text{ten}, \text{jacket} + Es_{core} * Asl, \text{ten}, \text{core}) / Asl, \text{ten} = 200000.00$
 $y_2 = 0.00184318$
 $sh_2 = 0.00589816$
 $ft_2 = 580.8818$
 $fy_2 = 484.0682$
 $su_2 = 0.01099427$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $lo/lou, \min = lb/lb, \min = 0.45297586$
 $su_2 = 0.4 * esu_2 \text{ nominal} ((5.5), TBDY) = 0.032$
 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.
 with $fs_2 = (fs_{jacket} * Asl, \text{com}, \text{jacket} + fs_{core} * Asl, \text{com}, \text{core}) / Asl, \text{com} = 484.0682$
 with $Es_2 = (Es_{jacket} * Asl, \text{com}, \text{jacket} + Es_{core} * Asl, \text{com}, \text{core}) / Asl, \text{com} = 200000.00$
 $y_v = 0.00184318$
 $sh_v = 0.00589816$
 $ft_v = 614.3968$
 $fy_v = 511.9973$
 $suv = 0.01099427$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $lo/lou, \min = lb/ld = 0.45297586$
 $suv = 0.4 * esuv \text{ nominal} ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $esuv \text{ nominal} = 0.08$,
 considering characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY
 For calculation of $esuv \text{ nominal}$ and y_v, sh_v, ft_v, fy_v , it is considered
 characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE 41-17.
 with $fsv = (fs_{jacket} * Asl, \text{mid}, \text{jacket} + fs_{mid} * Asl, \text{mid}, \text{core}) / Asl, \text{mid} = 511.9973$
 with $Es_v = (Es_{jacket} * Asl, \text{mid}, \text{jacket} + Es_{mid} * Asl, \text{mid}, \text{core}) / Asl, \text{mid} = 200000.00$
 $1 = Asl, \text{ten} / (b * d) * (fs_1 / fc) = 0.0851958$
 $2 = Asl, \text{com} / (b * d) * (fs_2 / fc) = 0.0851958$
 $v = Asl, \text{mid} / (b * d) * (fsv / fc) = 0.04369034$
 and confined core properties:
 $b = 340.00$
 $d = 327.00$
 $d' = 13.00$
 $f_{cc} (5A.2, TBDY) = 37.35991$
 $cc (5A.5, TBDY) = 0.00332119$
 $c = \text{confinement factor} = 1.13212$
 $1 = Asl, \text{ten} / (b * d) * (fs_1 / fc) = 0.1094258$
 $2 = Asl, \text{com} / (b * d) * (fs_2 / fc) = 0.1094258$
 $v = Asl, \text{mid} / (b * d) * (fsv / fc) = 0.05611603$
 Case/Assumption: Unconfined full section - Steel rupture
 ' satisfies Eq. (4.3)

--->
v < vs,y2 - LHS eq.(4.5) is satisfied

--->
su (4.9) = 0.16193824
Mu = MRc (4.14) = 1.8194E+008
u = su (4.1) = 3.6747033E-005

Calculation of ratio lb/l_d

Lap Length: lb/l_d = 0.45297586

lb = 300.00

l_d = 662.2869

Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

= 1

db = 14.66667

Mean strength value of all re-bars: fy = 656.5682

Mean concrete strength: fc' = (fc'_jacket*Area_jacket + fc'_core*Area_core)/Area_section = 29.75, but fc'^0.5 <= 8.3 MPa (22.5.3.1, ACI 318-14)

t = 1.00

s = 0.80

e = 1.00

cb = 25.00

Ktr = 3.43481

Atr = Min(Atr_x,Atr_y) = 257.6106

where Atr_x, Atr_y are the sum of the area of all stirrup legs along X and Y loxal axis

s = Max(s_external,s_internal) = 250.00

n = 12.00

Calculation of Shear Strength Vr = Min(Vr1,Vr2) = 633062.661

Calculation of Shear Strength at edge 1, Vr1 = 633062.661

Vr1 = VCol ((10.3), ASCE 41-17) = knl*VCol0

VCol0 = 633062.661

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 = 29.75, but fc'^0.5 <= 8.3 MPa (22.5.3.1, ACI 318-14)

M/Vd = 2.00

Mu = 4.6931004E-013

Vu = 6.6805695E-033

d = 0.8*h = 320.00

Nu = 5926.932

Ag = 160000.00

From (11.5.4.8), ACI 318-14: Vs = Vs1 + Vs2 = 279254.914

where:

Vs1 = 279254.914 is calculated for jacket, with:

d = 320.00

Av = 157079.633

fy = 555.56

s = 100.00

Vs1 is multiplied by Col1 = 1.00

s/d = 0.3125

Vs2 = 0.00 is calculated for core, with:

d = 160.00

Av = 100530.965

fy = 444.44

s = 250.00

Vs2 is multiplied by Col2 = 0.00

s/d = 1.5625

V_f ((11-3)-(11.4), ACI 440) = 188111.148

$f = 0.95$, 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: $\theta = b_1 + 90^\circ = 90.00$

$V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, a)|)$, with:

total thickness per orientation, $t_{f1} = NL \cdot t / \text{NoDir} = 1.016$

$d_{fv} = d$ (figure 11.2, ACI 440) = 357.00

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: $V_s + V_f \leq 463788.751$

$b_w = 400.00$

Calculation of Shear Strength at edge 2, $V_{r2} = 633062.661$

$V_{r2} = V_{Col}$ ((10.3), ASCE 41-17) = $k_{nl} \cdot V_{Col0}$

$V_{Col0} = 633062.661$

$k_{nl} = 1$ (zero step-static loading)

NOTE: In expression (10-3) ' $V_s = A_v \cdot f_y \cdot d / s$ ' is replaced by ' $V_s + f \cdot V_f$ ' where V_f is the contribution of FRPs (11.3), ACI 440).

$f = 1$ (normal-weight concrete)

Mean concrete strength: $f'_c = (f'_c \cdot \text{jacket} \cdot \text{Area}_{\text{jacket}} + f'_c \cdot \text{core} \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 29.75$, but $f'_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$\mu_u = 4.6931004E-013$

$\nu_u = 6.6805695E-033$

$d = 0.8 \cdot h = 320.00$

$N_u = 5926.932$

$A_g = 160000.00$

From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 279254.914$

where:

$V_{s1} = 279254.914$ is calculated for jacket, with:

$d = 320.00$

$A_v = 157079.633$

$f_y = 555.56$

$s = 100.00$

V_{s1} is multiplied by $Col1 = 1.00$

$s/d = 0.3125$

$V_{s2} = 0.00$ is calculated for core, with:

$d = 160.00$

$A_v = 100530.965$

$f_y = 444.44$

$s = 250.00$

V_{s2} is multiplied by $Col2 = 0.00$

$s/d = 1.5625$

V_f ((11-3)-(11.4), ACI 440) = 188111.148

$f = 0.95$, 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: $\theta = b_1 + 90^\circ = 90.00$

$V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, a)|)$, with:

total thickness per orientation, $t_{f1} = NL \cdot t / \text{NoDir} = 1.016$

$d_{fv} = d$ (figure 11.2, ACI 440) = 357.00

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: $V_s + V_f \leq 463788.751$
 $bw = 400.00$

End Of Calculation of Shear Capacity ratio for element: column JC1 of floor 1
At local axis: 2

Start Of Calculation of Chord Rotation Capacity for element: column JC1 of floor 1
At local axis: 2
Integration Section: (a)
Section Type: rcjrs

Constant Properties

Knowledge Factor, $\gamma = 0.80$
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
Existing material of Secondary Member: Concrete Strength, $f_c = f_{cm} = 20.00$
Existing material of Secondary Member: Steel Strength, $f_s = f_{sm} = 444.44$
Concrete Elasticity, $E_c = 21019.039$
Steel Elasticity, $E_s = 200000.00$
External Height, $H = 400.00$
External Width, $W = 400.00$
Internal Height, $H = 200.00$
Internal Width, $W = 200.00$
Cover Thickness, $c = 25.00$
Element Length, $L = 3000.00$
Secondary Member
Ribbed Bars
Ductile Steel
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
Lap Length $l_b = 300.00$
FRP Wrapping Data
Type: Carbon
Cured laminate properties (design values)
Thickness, $t = 1.016$
Tensile Strength, $f_{fu} = 1055.00$
Tensile Modulus, $E_f = 64828.00$
Elongation, $e_{fu} = 0.01$
Number of directions, $N_{oDir} = 1$
Fiber orientations, $b_i: 0.00^\circ$
Number of layers, $N_L = 1$
Radius of rounding corners, $R = 40.00$

Stepwise Properties

Bending Moment, $M = -5.0458668E-011$
Shear Force, $V_2 = -7751.185$
Shear Force, $V_3 = 2.6948337E-014$
Axial Force, $F = -6084.055$
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: $As_t = 829.3805$
-Compression: $As_c = 1231.504$
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension: $As_{t,ten} = 829.3805$

-Compression: $Asl,com = 829.3805$

-Middle: $Asl,mid = 402.1239$

Longitudinal External Reinforcement Area Distribution (in 3 divisions)

-Tension: $Asl,ten,jacket = 603.1858$

-Compression: $Asl,com,jacket = 603.1858$

-Middle: $Asl,mid,jacket = 402.1239$

Longitudinal Internal Reinforcement Area Distribution (in 3 divisions)

-Tension: $Asl,ten,core = 226.1947$

-Compression: $Asl,com,core = 226.1947$

-Middle: $Asl,mid,core = 0.00$

Mean Diameter of Tension Reinforcement, $DbL = 14.40$

Existing component: From table 7-7, ASCE 41_17: Final chord rotation Capacity $u,R = u = 0.0369217$
 $u = y + p = 0.04615212$

- Calculation of y -

$y = (My * Ls / 3) / Eleff = 0.00415212$ ((4.29), Biskinis Phd)

$My = 1.4151E+008$

$Ls = M/V$ (with $Ls > 0.1 * L$ and $Ls < 2 * L$) = 1500.00

From table 10.5, ASCE 41_17: $Eleff = factor * Ec * Ig = 1.7040E+013$

factor = 0.30

$Ag = 160000.00$

Mean concrete strength: $fc' = (fc'_jacket * Area_jacket + fc'_core * Area_core) / Area_section = 29.75$

$N = 6084.055$

$Ec * Ig = Ec_jacket * Ig_jacket + Ec_core * Ig_core = 5.6801E+013$

Calculation of Yielding Moment My

Calculation of y and My according to Annex 7 -

$y = \text{Min}(y_{ten}, y_{com})$

$y_{ten} = 8.5630881E-006$

with ((10.1), ASCE 41-17) $fy = \text{Min}(fy, 1.25 * fy * (lb/d)^{2/3}) = 454.4281$

$d = 357.00$

$y = 0.25674727$

$A = 0.01452572$

$B = 0.00817889$

with $pt = 0.00680078$

$pc = 0.00580799$

$pv = 0.00281599$

$N = 6084.055$

$b = 400.00$

$" = 0.12044818$

$y_{comp} = 2.5299695E-005$

with fc^* (12.3, (ACI 440)) = 34.65599

$fc = 33.00$

$fl = 0.93147527$

$b = 400.00$

$h = 400.00$

$Ag = 160000.00$

From (12.9), ACI 440: $ka = 0.56708553$

$g = pt + pc + pv = 0.01443197$

$rc = 40.00$

$Ae/Ac = 0.56708553$

Effective FRP thickness, $tf = NL * t * \text{Cos}(b1) = 1.016$

effective strain from (12.5) and (12.12), $e_{fe} = 0.004$

$fu = 0.01$

$Ef = 64828.00$

$Ec = 26999.444$

$y = 0.25580703$

A = 0.01433976
B = 0.00808514
with Es = 200000.00

Calculation of ratio l_b/l_d

Lap Length: $l_d/l_{d,min} = 0.56621983$

$l_b = 300.00$

$l_d = 529.8296$

Calculation of I according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

$= 1$

$db = 14.66667$

Mean strength value of all re-bars: $f_y = 525.2545$

Mean concrete strength: $f_c' = (f_c'_{jacket} \cdot Area_{jacket} + f_c'_{core} \cdot Area_{core}) / Area_{section} = 29.75$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 3.43481$

$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 257.6106$

where A_{tr_x} , A_{tr_y} are the sum of the area of all stirrup legs along X and Y local axis

$s = \text{Max}(s_{external}, s_{internal}) = 250.00$

$n = 12.00$

- Calculation of ρ -

From table 10-8: $\rho = 0.042$

with:

- Columns controlled by inadequate development or splicing along the clear height because $l_b/l_d < 1$

shear control ratio $V_y/E/ColOE = 0.19159777$

$d = d_{external} = 357.00$

$s = s_{external} = 0.00$

$t = s_1 + s_2 + 2 \cdot t_f/bw \cdot (f_{fe}/f_s) = 0.00680078$

jacket: $s_1 = A_{v1} \cdot h_1 / (s_1 \cdot A_g) = 0.00392699$

$A_{v1} = 157.0796$, is the total area of all stirrups parallel to loading (shear) direction

$h_1 = 400.00$

$s_1 = 100.00$

core: $s_2 = A_{v2} \cdot h_2 / (s_2 \cdot A_g) = 0.00050265$

$A_{v2} = 100.531$, is the total area of all stirrups parallel to loading (shear) direction

$h_2 = 200.00$

$s_2 = 250.00$

The term $2 \cdot t_f/bw \cdot (f_{fe}/f_s)$ is implemented to account for FRP contribution

where $f = 2 \cdot t_f/bw$ is FRP ratio (EC8 - 3, A.4.4.3(6)) and f_{fe}/f_s normalises f to steel strength

All these variables have already been given in Shear control ratio calculation.

For the normalisation f_s of jacket is used.

$NUD = 6084.055$

$A_g = 160000.00$

$f_{cE} = (f_{c'_{jacket}} \cdot Area_{jacket} + f_{c'_{core}} \cdot Area_{core}) / section_area = 29.75$

$f_{yIE} = (f_{y_{ext_Long_Reinf}} \cdot Area_{ext_Long_Reinf} + f_{y_{int_Long_Reinf}} \cdot Area_{int_Long_Reinf}) / Area_{Tot_Long_Rein} = 531.1678$

$f_{yTE} = (f_{y_{ext_Trans_Reinf}} \cdot Area_{ext_Trans_Reinf} + f_{y_{int_Trans_Reinf}} \cdot Area_{int_Trans_Reinf}) / Area_{Tot_Trans_Rein} = 542.9506$

$\rho_l = Area_{Tot_Long_Rein} / (b \cdot d) = 0.01443197$

$b = 400.00$

$d = 357.00$

$f_{cE} = 29.75$

End Of Calculation of Chord Rotation Capacity for element: column JC1 of floor 1

At local axis: 2

Integration Section: (a)

Calculation No. 11

column C1, Floor 1

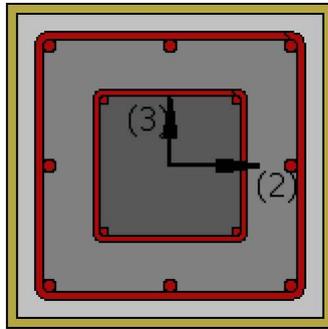
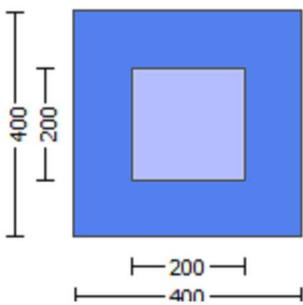
Limit State: Collapse Prevention (data interpolation between analysis steps 2 and 3)

Analysis: Uniform +X

Check: Shear capacity V_{Rd}

Edge: Start

Local Axis: (3)



Start Of Calculation of Shear Capacity for element: column JC1 of floor 1

At local axis: 3

Integration Section: (a)

Section Type: rcjrs

Constant Properties

Knowledge Factor, $\gamma = 0.80$

Member Shear Force is generally considered as Force-Controlled Action according to Table C7-1, ASCE 41-17.

Lower-bound strengths are used for Force-Controlled Actions according to 7.5.1.3, ASCE 41-17

Consequently:

Jacket

New material of Secondary Member: Concrete Strength, $f_c = f_{c_lower_bound} = 25.00$

New material of Secondary Member: Steel Strength, $f_s = f_{s_lower_bound} = 500.00$

Concrete Elasticity, $E_c = 26999.444$

Steel Elasticity, $E_s = 200000.00$

Existing Column

Existing material of Secondary Member: Concrete Strength, $f_c = f_{c_lower_bound} = 16.00$

Existing material of Secondary Member: Steel Strength, $f_s = f_{s_lower_bound} = 400.00$

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of γ for displacement ductility demand, the expected (mean value) strengths are used (7.5.1.3, ASCE 41-17) because bending is considered as Deformation-Controlled Action (Table C7-1, ASCE 41-17).

Jacket

New material: Concrete Strength, $f_c = f_{cm} = 33.00$

New material: Steel Strength, $f_s = f_{sm} = 555.56$
 Existing Column
 Existing material: Concrete Strength, $f_c = f_{cm} = 20.00$
 Existing material: Steel Strength, $f_s = f_{sm} = 444.44$
 #####
 External Height, $H = 400.00$
 External Width, $W = 400.00$
 Internal Height, $H = 200.00$
 Internal Width, $W = 200.00$
 Cover Thickness, $c = 25.00$
 Element Length, $L = 3000.00$
 Secondary Member
 Ribbed Bars
 Ductile Steel
 Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
 Longitudinal Bars With Ends Lapped Starting at the End Sections
 Lap Length $l_o = l_b = 300.00$
 FRP Wrapping Data
 Type: Carbon
 Cured laminate properties (design values)
 Thickness, $t = 1.016$
 Tensile Strength, $f_{fu} = 1055.00$
 Tensile Modulus, $E_f = 64828.00$
 Elongation, $e_{fu} = 0.01$
 Number of directions, $NoDir = 1$
 Fiber orientations, $b_i = 0.00^\circ$
 Number of layers, $NL = 1$
 Radius of rounding corners, $R = 40.00$

 Stepwise Properties

EDGE -A-
 Bending Moment, $M_a = -5.0458668E-011$
 Shear Force, $V_a = 2.6948337E-014$
 EDGE -B-
 Bending Moment, $M_b = -3.0409439E-011$
 Shear Force, $V_b = -2.6948337E-014$
 BOTH EDGES
 Axial Force, $F = -6084.055$
 Longitudinal Reinforcement Area Distribution (in 2 divisions)
 -Tension: $A_{sl,t} = 829.3805$
 -Compression: $A_{sl,c} = 1231.504$
 Longitudinal Reinforcement Area Distribution (in 3 divisions)
 -Tension: $A_{sl,ten} = 829.3805$
 -Compression: $A_{sl,com} = 829.3805$
 -Middle: $A_{sl,mid} = 402.1239$
 Mean Diameter of Tension Reinforcement, $Db_{L,ten} = 14.40$

 Existing component: From table 7-7, ASCE 41_17: Final Shear Capacity $V_R = *V_n = 447098.232$
 V_n ((10.3), ASCE 41-17) = $k_n l * V_{CoI} = 558872.791$
 $V_{CoI} = 558872.791$
 $k_n l = 1.00$
 displacement_ductility_demand = 0.00

NOTE: In expression (10-3) ' $V_s = A_v * f_y * d / s$ ' is replaced by ' $V_s + f * V_f$ '
 where V_f is the contribution of FRPs (11.3), ACI 440).

= 1 (normal-weight concrete)
 Mean concrete strength: $f_c' = (f_c'_{jacket} * Area_{jacket} + f_c'_{core} * Area_{core}) / Area_{section} = 22.75$, but $f_c'^{0.5} \leq 8.3$
 MPa (22.5.3.1, ACI 318-14)
 $M / V d = 2.00$
 $M_u = 5.0458668E-011$
 $V_u = 2.6948337E-014$

$d = 0.8 \cdot h = 320.00$
 $Nu = 6084.055$
 $Ag = 160000.00$
 From (11.5.4.8), ACI 318-14: $Vs = Vs1 + Vs2 = 251327.412$
 where:
 $Vs1 = 251327.412$ is calculated for jacket, with:
 $d = 320.00$
 $Av = 157079.633$
 $fy = 500.00$
 $s = 100.00$
 $Vs1$ is multiplied by $Col1 = 1.00$
 $s/d = 0.3125$
 $Vs2 = 0.00$ is calculated for core, with:
 $d = 160.00$
 $Av = 100530.965$
 $fy = 400.00$
 $s = 250.00$
 $Vs2$ is multiplied by $Col2 = 0.00$
 $s/d = 1.5625$
 Vf ((11-3)-(11.4), ACI 440) = 188111.148
 $f = 0.95$, for fully-wrapped sections
 $wf/sf = 1$ (FRP strips adjacent to one another).
 In (11.3) $\sin + \cos$ is replaced with $(\cot + \cot a) \sin a$ which is more a generalised expression,
 where a is the angle of the crack direction (see KANEPE).
 This later relation, considered as a function $Vf(\theta, a)$, is implemented for every different fiber orientation a_i ,
 as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.
 orientation 1: $\theta = b1 + 90^\circ = 90.00$
 $Vf = \text{Min}(|Vf(45, a1)|, |Vf(-45, a1)|)$, with:
 total thickness per orientation, $tf1 = NL \cdot t / \text{NoDir} = 1.016$
 $dfv = d$ (figure 11.2, ACI 440) = 357.00
 ffe ((11-5), ACI 440) = 259.312
 $Ef = 64828.00$
 $fe = 0.004$, from (11.6a), ACI 440
 with $fu = 0.01$
 From (11-11), ACI 440: $Vs + Vf \leq 405571.497$
 $bw = 400.00$

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 $\theta = 1.3705910E-021$
 $y = (My \cdot Ls / 3) / Eleff = 0.00415212$ ((4.29), Biskinis Phd)
 $My = 1.4151E+008$
 $Ls = M/V$ (with $Ls > 0.1 \cdot L$ and $Ls < 2 \cdot L$) = 1500.00
 From table 10.5, ASCE 41_17: $Eleff = \text{factor} \cdot Ec \cdot Ig = 1.7040E+013$
 $\text{factor} = 0.30$
 $Ag = 160000.00$
 Mean concrete strength: $fc' = (fc'_{\text{jacket}} \cdot \text{Area}_{\text{jacket}} + fc'_{\text{core}} \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 29.75$
 $N = 6084.055$
 $Ec \cdot Ig = Ec_{\text{jacket}} \cdot Ig_{\text{jacket}} + Ec_{\text{core}} \cdot Ig_{\text{core}} = 5.6801E+013$

Calculation of Yielding Moment My

Calculation of δ / y and My according to Annex 7 -

$y = \text{Min}(y_{\text{ten}}, y_{\text{com}})$
 $y_{\text{ten}} = 8.5630881E-006$
 with ((10.1), ASCE 41-17) $fy = \text{Min}(fy, 1.25 \cdot fy \cdot (lb/d)^{2/3}) = 454.4281$
 $d = 357.00$
 $y = 0.25674727$
 $A = 0.01452572$

B = 0.00817889
with pt = 0.00580799
pc = 0.00580799
pv = 0.00281599
N = 6084.055
b = 400.00
" = 0.12044818
y_comp = 2.5299695E-005
with fc* (12.3, (ACI 440)) = 34.65599
fc = 33.00
fl = 0.93147527
b = 400.00
h = 400.00
Ag = 160000.00
From (12.9), ACI 440: ka = 0.56708553
g = pt + pc + pv = 0.01443197
rc = 40.00
Ae/Ac = 0.56708553
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 = 0.25580703
A = 0.01433976
B = 0.00808514
with Es = 200000.00

Calculation of ratio lb/l_d

Lap Length: l_d/l_{d,min} = 0.56621983

lb = 300.00

l_d = 529.8296

Calculation of l according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

= 1

db = 14.66667

Mean strength value of all re-bars: fy = 525.2545

Mean concrete strength: fc' = (fc'_jacket*Area_jacket + fc'_core*Area_core)/Area_section = 29.75, but fc'^0.5 <= 8.3 MPa (22.5.3.1, ACI 318-14)

t = 1.00

s = 0.80

e = 1.00

cb = 25.00

Ktr = 3.43481

Atr = Min(Atr_x, Atr_y) = 257.6106

where Atr_x, Atr_y are the sum of the area of all stirrup legs along X and Y local axis

s = Max(s_external, s_internal) = 250.00

n = 12.00

End Of Calculation of Shear Capacity for element: column JC1 of floor 1

At local axis: 3

Integration Section: (a)

Calculation No. 12

column C1, Floor 1

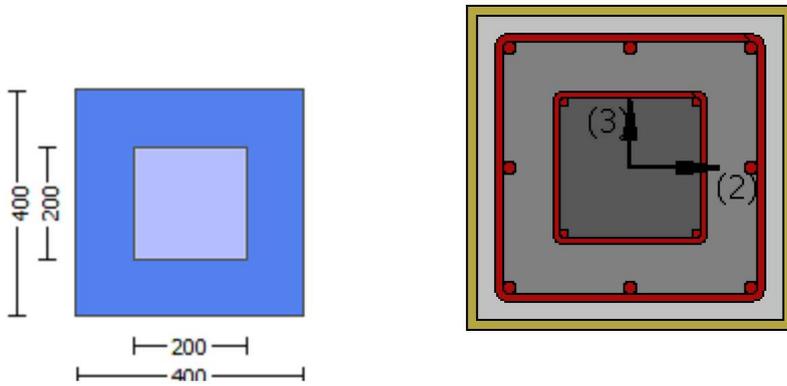
Limit State: Collapse Prevention (data interpolation between analysis steps 2 and 3)

Analysis: Uniform +X

Check: Chord rotation capacity (θ_u)

Edge: Start

Local Axis: (3)



Start Of Calculation of Shear Capacity ratio for element: column JC1 of floor 1

At Shear local axis: 3

(Bending local axis: 2)

Section Type: rcjrs

Constant Properties

Knowledge Factor, $\gamma = 0.80$

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

Existing material of Secondary Member: Concrete Strength, $f_c = f_{cm} = 20.00$

Existing material of Secondary Member: Steel Strength, $f_s = f_{sm} = 444.44$

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14

Jacket

New material: Steel Strength, $f_s = 1.25 \cdot f_{sm} = 694.45$

Existing Column

Existing material: Steel Strength, $f_s = 1.25 \cdot f_{sm} = 555.55$

#####

External Height, $H = 400.00$

External Width, $W = 400.00$

Internal Height, $H = 200.00$

Internal Width, $W = 200.00$

Cover Thickness, $c = 25.00$

Mean Confinement Factor overall section = 1.13212

Element Length, $L = 3000.00$

Secondary Member

Ribbed Bars

Ductile Steel

Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)

Longitudinal Bars With Ends Lapped Starting at the End Sections

Lap Length $l_o = 300.00$

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $\epsilon_{fu} = 0.01$

Number of directions, $N_{oDir} = 1$

Fiber orientations, $b_i = 0.00^\circ$

Number of layers, $N_L = 1$

Radius of rounding corners, $R = 40.00$

Stepwise Properties

At local axis: 3

EDGE -A-

Shear Force, $V_a = 2.8976040E-031$

EDGE -B-

Shear Force, $V_b = -2.8976040E-031$

BOTH EDGES

Axial Force, $F = -5926.932$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: $A_{sl,t} = 0.00$

-Compression: $A_{sl,c} = 2060.885$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension: $A_{sl,ten} = 829.3805$

-Compression: $A_{sl,com} = 829.3805$

-Middle: $A_{sl,mid} = 402.1239$

Calculation of Shear Capacity ratio, $V_e/V_r = 0.19159777$

Member Controlled by Flexure ($V_e/V_r < 1$)

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 121293.391$

with

$M_{pr1} = \text{Max}(M_{u1+}, M_{u1-}) = 1.8194E+008$

$M_{u1+} = 1.8194E+008$, is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination

$M_{u1-} = 1.8194E+008$, is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination

$M_{pr2} = \text{Max}(M_{u2+}, M_{u2-}) = 1.8194E+008$

$M_{u2+} = 1.8194E+008$, is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the the static loading combination

$M_{u2-} = 1.8194E+008$, is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the the static loading combination

Calculation of M_{u1+}

Calculation of ultimate curvature ϕ_u according to 4.1, Biskinis/Fardis 2013:

$\phi_u = 3.6747033E-005$

$M_u = 1.8194E+008$

with full section properties:

$b = 400.00$

$d = 357.00$

$d' = 43.00$

$v = 0.00125773$

$N = 5926.932$

$f_c = 33.00$

α_0 (5A.5, TBDY) = 0.002

Final value of c_u : $c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.01505571$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $c_u = 0.01505571$

w_e ((5.4c), TBDY) = $ase * \text{sh_min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.08345896$

where $f = af * pf * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

 $f_x = 0.07683125$

$af = 0.57333333$

$b = 400.00$

$h = 400.00$

From EC8 A.4.4.3(6), $pf = 2tf/bw = 0.00508$

$bw = 400.00$

effective stress from (A.35), $f_{f,e} = 870.5244$

 $f_y = 0.07683125$

$af = 0.57333333$

$b = 400.00$

$h = 400.00$

From EC8 A.4.4.3(6), $pf = 2tf/bw = 0.00508$

$bw = 400.00$

effective stress from (A.35), $f_{f,e} = 870.5244$

 $R = 40.00$

Effective FRP thickness, $tf = NL * t * \text{Cos}(b1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{,f} = 0.015$

ase ((5.4d), TBDY) = $(ase1 * A_{ext} + ase2 * A_{int}) / A_{sec} = 0.24250288$

$ase1 = 0.24250288$

$bo_1 = 340.00$

$ho_1 = 340.00$

$bi2_1 = 462400.00$

$ase2 = \text{Max}(ase1, ase2) = 0.24250288$

$bo_2 = 192.00$

$ho_2 = 192.00$

$bi2_2 = 147456.00$

$p_{sh,min} * F_{ywe} = \text{Min}(p_{sh,x} * F_{ywe}, p_{sh,y} * F_{ywe}) = 3.00635$

Expression ((5.4d), TBDY) for $p_{sh,min} * F_{ywe}$ has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

 $p_{sh,x} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{sh2} * F_{ywe2} = 3.00635$

$ps1$ (external) = $(Ash1 * h1 / s1) / A_{sec} = 0.00392699$

$Ash1 = Astir_1 * ns_1 = 157.0796$

No stirrups, $ns_1 = 2.00$

$h1 = 400.00$

$ps2$ (internal) = $(Ash2 * h2 / s2) / A_{sec} = 0.00050265$

$Ash2 = Astir_2 * ns_2 = 100.531$

No stirrups, $ns_2 = 2.00$

$h2 = 200.00$

 $p_{sh,y} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{sh2} * F_{ywe2} = 3.00635$

$ps1$ (external) = $(Ash1 * h1 / s1) / A_{sec} = 0.00392699$

$Ash1 = Astir_1 * ns_1 = 157.0796$

No stirrups, $ns_1 = 2.00$

$h1 = 400.00$

$ps2$ (internal) = $(Ash2 * h2 / s2) / A_{sec} = 0.00050265$

$Ash2 = Astir_2 * ns_2 = 100.531$

No stirrups, $ns_2 = 2.00$

$h2 = 200.00$

 $A_{sec} = 160000.00$

$s1 = 100.00$

$s2 = 250.00$

$f_{ywe1} = 694.45$

$f_{ywe2} = 555.55$

$f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY: $cc = 0.00332119$

$c = \text{confinement factor} = 1.13212$
 $y1 = 0.00184318$
 $sh1 = 0.00589816$
 $ft1 = 580.8818$
 $fy1 = 484.0682$
 $su1 = 0.01099427$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 $\text{Shear_factor} = 1.00$
 $lo/lou,min = lb/ld = 0.45297586$
 $su1 = 0.4 * esu1_nominal ((5.5), \text{TBDY}) = 0.032$
 From table 5A.1, TBDY: $esu1_nominal = 0.08$,
 For calculation of $esu1_nominal$ and $y1, sh1, ft1, fy1$, it is considered
 characteristic value $fsy1 = fs1/1.2$, from table 5.1, TBDY.
 $y1, sh1, ft1, fy1$, are also multiplied by $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE 41-17.
 with $fs1 = (fs,jacket * Asl,ten,jacket + fs,core * Asl,ten,core) / Asl,ten = 484.0682$
 with $Es1 = (Es,jacket * Asl,ten,jacket + Es,core * Asl,ten,core) / Asl,ten = 200000.00$
 $y2 = 0.00184318$
 $sh2 = 0.00589816$
 $ft2 = 580.8818$
 $fy2 = 484.0682$
 $su2 = 0.01099427$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 $\text{Shear_factor} = 1.00$
 $lo/lou,min = lb/lb,min = 0.45297586$
 $su2 = 0.4 * esu2_nominal ((5.5), \text{TBDY}) = 0.032$
 From table 5A.1, TBDY: $esu2_nominal = 0.08$,
 For calculation of $esu2_nominal$ and $y2, sh2, ft2, fy2$, it is considered
 characteristic value $fsy2 = fs2/1.2$, from table 5.1, TBDY.
 $y1, sh1, ft1, fy1$, are also multiplied by $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE 41-17.
 with $fs2 = (fs,jacket * Asl,com,jacket + fs,core * Asl,com,core) / Asl,com = 484.0682$
 with $Es2 = (Es,jacket * Asl,com,jacket + Es,core * Asl,com,core) / Asl,com = 200000.00$
 $yv = 0.00184318$
 $shv = 0.00589816$
 $ftv = 614.3968$
 $fyv = 511.9973$
 $suv = 0.01099427$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 $\text{Shear_factor} = 1.00$
 $lo/lou,min = lb/ld = 0.45297586$
 $suv = 0.4 * esuv_nominal ((5.5), \text{TBDY}) = 0.032$
 From table 5A.1, TBDY: $esuv_nominal = 0.08$,
 considering characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY
 For calculation of $esuv_nominal$ and yv, shv, ftv, fyv , it is considered
 characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY.
 $y1, sh1, ft1, fy1$, are also multiplied by $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE 41-17.
 with $fsv = (fs,jacket * Asl,mid,jacket + fs,mid * Asl,mid,core) / Asl,mid = 511.9973$
 with $Es_v = (Es,jacket * Asl,mid,jacket + Es,mid * Asl,mid,core) / Asl,mid = 200000.00$
 $1 = Asl,ten / (b * d) * (fs1 / fc) = 0.0851958$
 $2 = Asl,com / (b * d) * (fs2 / fc) = 0.0851958$
 $v = Asl,mid / (b * d) * (fsv / fc) = 0.04369034$
 and confined core properties:
 $b = 340.00$
 $d = 327.00$
 $d' = 13.00$
 $fcc (5A.2, \text{TBDY}) = 37.35991$
 $cc (5A.5, \text{TBDY}) = 0.00332119$
 $c = \text{confinement factor} = 1.13212$
 $1 = Asl,ten / (b * d) * (fs1 / fc) = 0.1094258$
 $2 = Asl,com / (b * d) * (fs2 / fc) = 0.1094258$
 $v = Asl,mid / (b * d) * (fsv / fc) = 0.05611603$
 Case/Assumption: Unconfined full section - Steel rupture
 ' satisfies Eq. (4.3)
 --->
 $v < vs,y2$ - LHS eq.(4.5) is satisfied

--->

su (4.9) = 0.16193824
Mu = MRc (4.14) = 1.8194E+008
u = su (4.1) = 3.6747033E-005

Calculation of ratio lb/l_d

Lap Length: lb/l_d = 0.45297586

lb = 300.00

l_d = 662.2869

Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

= 1

db = 14.66667

Mean strength value of all re-bars: f_y = 656.5682

Mean concrete strength: f_c' = (f_c'_{jacket}*Area_{jacket} + f_c'_{core}*Area_{core})/Area_{section} = 29.75, but f_c'^{0.5} <= 8.3

MPa (22.5.3.1, ACI 318-14)

t = 1.00

s = 0.80

e = 1.00

cb = 25.00

K_{tr} = 3.43481

A_{tr} = Min(A_{tr_x}, A_{tr_y}) = 257.6106

where A_{tr_x}, A_{tr_y} are the sum of the area of all stirrup legs along X and Y loxal axis

s = Max(s_{external}, s_{internal}) = 250.00

n = 12.00

Calculation of Mu1-

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

u = 3.6747033E-005

Mu = 1.8194E+008

with full section properties:

b = 400.00

d = 357.00

d' = 43.00

v = 0.00125773

N = 5926.932

f_c = 33.00

co (5A.5, TBDY) = 0.002

Final value of cu: cu* = shear_factor * Max(cu, cc) = 0.01505571

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: cu = 0.01505571

we ((5.4c), TBDY) = ase* sh,min*fywe/fce+Min(fx, fy) = 0.08345896

where f = af*pf*ffe/fce is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

fx = 0.07683125

af = 0.57333333

b = 400.00

h = 400.00

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 = 0.07683125

af = 0.57333333

b = 400.00

h = 400.00

From EC8 A.4.4.3(6), pf = 2tf/bw = 0.00508

bw = 400.00

effective stress from (A.35), ff,e = 870.5244

$R = 40.00$
 Effective FRP thickness, $t_f = NL * t * \cos(b_1) = 1.016$
 $f_{u,f} = 1055.00$
 $E_f = 64828.00$
 $u_{,f} = 0.015$
 $ase((5.4d), TBDY) = (ase_1 * A_{ext} + ase_2 * A_{int}) / A_{sec} = 0.24250288$
 $ase_1 = 0.24250288$
 $bo_1 = 340.00$
 $ho_1 = 340.00$
 $bi_2_1 = 462400.00$
 $ase_2 = \text{Max}(ase_1, ase_2) = 0.24250288$
 $bo_2 = 192.00$
 $ho_2 = 192.00$
 $bi_2_2 = 147456.00$

$psh_{,min} * F_{ywe} = \text{Min}(psh_{,x} * F_{ywe}, psh_{,y} * F_{ywe}) = 3.00635$
 Expression ((5.4d), TBDY) for $psh_{,min} * F_{ywe}$ has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$psh_{,x} * F_{ywe} = psh_1 * F_{ywe1} + ps_2 * F_{ywe2} = 3.00635$
 $ps_1 \text{ (external)} = (A_{sh1} * h_1 / s_1) / A_{sec} = 0.00392699$
 $A_{sh1} = A_{stir_1} * ns_1 = 157.0796$
 No stirrups, $ns_1 = 2.00$
 $h_1 = 400.00$
 $ps_2 \text{ (internal)} = (A_{sh2} * h_2 / s_2) / A_{sec} = 0.00050265$
 $A_{sh2} = A_{stir_2} * ns_2 = 100.531$
 No stirrups, $ns_2 = 2.00$
 $h_2 = 200.00$

$psh_{,y} * F_{ywe} = psh_1 * F_{ywe1} + ps_2 * F_{ywe2} = 3.00635$
 $ps_1 \text{ (external)} = (A_{sh1} * h_1 / s_1) / A_{sec} = 0.00392699$
 $A_{sh1} = A_{stir_1} * ns_1 = 157.0796$
 No stirrups, $ns_1 = 2.00$
 $h_1 = 400.00$
 $ps_2 \text{ (internal)} = (A_{sh2} * h_2 / s_2) / A_{sec} = 0.00050265$
 $A_{sh2} = A_{stir_2} * ns_2 = 100.531$
 No stirrups, $ns_2 = 2.00$
 $h_2 = 200.00$

$A_{sec} = 160000.00$
 $s_1 = 100.00$
 $s_2 = 250.00$
 $f_{ywe1} = 694.45$
 $f_{ywe2} = 555.55$
 $f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY: $cc = 0.00332119$
 $c = \text{confinement factor} = 1.13212$

$y_1 = 0.00184318$
 $sh_1 = 0.00589816$
 $ft_1 = 580.8818$
 $fy_1 = 484.0682$
 $su_1 = 0.01099427$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 $\text{Shear_factor} = 1.00$

$lo/lo_{,min} = lb/ld = 0.45297586$
 $su_1 = 0.4 * esu_1_{,nominal} \text{ ((5.5), TBDY)} = 0.032$

From table 5A.1, TBDY: $esu_1_{,nominal} = 0.08$,

For calculation of $esu_1_{,nominal}$ and y_1, sh_1, ft_1, fy_1 , it is considered
 characteristic value $fsy_1 = fs_1 / 1.2$, from table 5.1, TBDY.

y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE 41-17.

with $fs_1 = (f_{s,jacket} * A_{sl,ten,jacket} + f_{s,core} * A_{sl,ten,core}) / A_{sl,ten} = 484.0682$

with $Es_1 = (E_{s,jacket} * A_{sl,ten,jacket} + E_{s,core} * A_{sl,ten,core}) / A_{sl,ten} = 200000.00$

$y_2 = 0.00184318$
 $sh_2 = 0.00589816$
 $ft_2 = 580.8818$
 $fy_2 = 484.0682$
 $su_2 = 0.01099427$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$l_o/l_{o,u,min} = l_b/l_{b,min} = 0.45297586$$

$$s_u2 = 0.4 * e_{s_u2,nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: $e_{s_u2,nominal} = 0.08$,

For calculation of $e_{s_u2,nominal}$ and y_2, sh_2, ft_2, fy_2 , it is considered
characteristic value $f_{s_y2} = f_{s_2}/1.2$, from table 5.1, TBDY.

y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE 41-17.

$$\text{with } f_{s_2} = (f_{s,jacket} * A_{s_l,com,jacket} + f_{s,core} * A_{s_l,com,core}) / A_{s_l,com} = 484.0682$$

$$\text{with } E_{s_2} = (E_{s,jacket} * A_{s_l,com,jacket} + E_{s,core} * A_{s_l,com,core}) / A_{s_l,com} = 200000.00$$

$$y_v = 0.00184318$$

$$sh_v = 0.00589816$$

$$ft_v = 614.3968$$

$$fy_v = 511.9973$$

$$s_{u_v} = 0.01099427$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$l_o/l_{o,u,min} = l_b/l_d = 0.45297586$$

$$s_{u_v} = 0.4 * e_{s_{u_v},nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: $e_{s_{u_v},nominal} = 0.08$,

considering characteristic value $f_{s_{y_v}} = f_{s_v}/1.2$, from table 5.1, TBDY
For calculation of $e_{s_{u_v},nominal}$ and y_v, sh_v, ft_v, fy_v , it is considered
characteristic value $f_{s_{y_v}} = f_{s_v}/1.2$, from table 5.1, TBDY.

y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE 41-17.

$$\text{with } f_{s_v} = (f_{s,jacket} * A_{s_l,mid,jacket} + f_{s,mid} * A_{s_l,mid,core}) / A_{s_l,mid} = 511.9973$$

$$\text{with } E_{s_v} = (E_{s,jacket} * A_{s_l,mid,jacket} + E_{s,mid} * A_{s_l,mid,core}) / A_{s_l,mid} = 200000.00$$

$$1 = A_{s_l,ten} / (b * d) * (f_{s_1} / f_c) = 0.0851958$$

$$2 = A_{s_l,com} / (b * d) * (f_{s_2} / f_c) = 0.0851958$$

$$v = A_{s_l,mid} / (b * d) * (f_{s_v} / f_c) = 0.04369034$$

and confined core properties:

$$b = 340.00$$

$$d = 327.00$$

$$d' = 13.00$$

$$f_{cc} (5A.2, TBDY) = 37.35991$$

$$cc (5A.5, TBDY) = 0.00332119$$

$$c = \text{confinement factor} = 1.13212$$

$$1 = A_{s_l,ten} / (b * d) * (f_{s_1} / f_c) = 0.1094258$$

$$2 = A_{s_l,com} / (b * d) * (f_{s_2} / f_c) = 0.1094258$$

$$v = A_{s_l,mid} / (b * d) * (f_{s_v} / f_c) = 0.05611603$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < v_{s,y_2}$ - LHS eq.(4.5) is satisfied

--->

$$s_u (4.9) = 0.16193824$$

$$\mu = MR_c (4.14) = 1.8194E+008$$

$$u = s_u (4.1) = 3.6747033E-005$$

Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.45297586$

$$l_b = 300.00$$

$$l_d = 662.2869$$

Calculation of $l_{b,min}$ according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

$$= 1$$

$$d_b = 14.66667$$

Mean strength value of all re-bars: $f_y = 656.5682$

Mean concrete strength: $f'_c = (f'_c_{jacket} * Area_{jacket} + f'_c_{core} * Area_{core}) / Area_{section} = 29.75$, but $f'_c^{0.5} \leq 8.3$
MPa (22.5.3.1, ACI 318-14)

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 25.00$$

$$K_{tr} = 3.43481$$

$$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 257.6106$$

where A_{tr_x} , A_{tr_y} are the sum of the area of all stirrup legs along X and Y local axis

$$s = \text{Max}(s_{\text{external}}, s_{\text{internal}}) = 250.00$$

$$n = 12.00$$

Calculation of μ_{2+}

Calculation of ultimate curvature μ according to 4.1, Biskinis/Fardis 2013:

$$u = 3.6747033E-005$$

$$\mu = 1.8194E+008$$

with full section properties:

$$b = 400.00$$

$$d = 357.00$$

$$d' = 43.00$$

$$v = 0.00125773$$

$$N = 5926.932$$

$$f_c = 33.00$$

$$c_o \text{ (5A.5, TBDY)} = 0.002$$

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.01505571$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } c_u = 0.01505571$$

$$w_e \text{ ((5.4c), TBDY)} = a_{se} * s_{h,\text{min}} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.08345896$$

where $f = a_f * p_f * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.07683125$$

$$a_f = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 870.5244$$

$$f_y = 0.07683125$$

$$a_f = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 870.5244$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L * t * \text{Cos}(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{f} = 0.015$$

$$a_{se} \text{ ((5.4d), TBDY)} = (a_{se1} * A_{ext} + a_{se2} * A_{int}) / A_{sec} = 0.24250288$$

$$a_{se1} = 0.24250288$$

$$b_{o,1} = 340.00$$

$$h_{o,1} = 340.00$$

$$b_{i,1} = 462400.00$$

$$a_{se2} = \text{Max}(a_{se1}, a_{se2}) = 0.24250288$$

$$b_{o,2} = 192.00$$

$$h_{o,2} = 192.00$$

$$b_{i,2} = 147456.00$$

$$p_{sh,\text{min}} * f_{ywe} = \text{Min}(p_{sh,x} * f_{ywe}, p_{sh,y} * f_{ywe}) = 3.00635$$

Expression ((5.4d), TBDY) for $p_{sh,\text{min}} * f_{ywe}$ has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$$p_{sh_x} * f_{ywe} = p_{sh1} * f_{ywe1} + p_{sh2} * f_{ywe2} = 3.00635$$

$$p_{s1} \text{ (external)} = (A_{sh1} * h_1 / s_1) / A_{sec} = 0.00392699$$

$$A_{sh1} = A_{stir,1} * n_{s,1} = 157.0796$$

$$\text{No stirrups, } n_{s,1} = 2.00$$

h1 = 400.00
ps2 (internal) = (Ash2*h2/s2)/Asec = 0.00050265
Ash2 = Astir_2*ns_2 = 100.531
No stirups, ns_2 = 2.00
h2 = 200.00

psh_y*Fywe = psh1*Fywe1+ps2*Fywe2 = 3.00635
ps1 (external) = (Ash1*h1/s1)/Asec = 0.00392699
Ash1 = Astir_1*ns_1 = 157.0796
No stirups, ns_1 = 2.00
h1 = 400.00
ps2 (internal) = (Ash2*h2/s2)/Asec = 0.00050265
Ash2 = Astir_2*ns_2 = 100.531
No stirups, ns_2 = 2.00
h2 = 200.00

Asec = 160000.00
s1 = 100.00
s2 = 250.00
fywe1 = 694.45
fywe2 = 555.55
fce = 33.00

From ((5.A5), TBDY), TBDY: cc = 0.00332119
c = confinement factor = 1.13212

y1 = 0.00184318
sh1 = 0.00589816
ft1 = 580.8818
fy1 = 484.0682
su1 = 0.01099427

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/d = 0.45297586

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 = 484.0682

with Es1 = (Es,jacket*Asl,ten,jacket + Es,core*Asl,ten,core)/Asl,ten = 200000.00

y2 = 0.00184318
sh2 = 0.00589816
ft2 = 580.8818
fy2 = 484.0682
su2 = 0.01099427

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/lb,min = 0.45297586

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 = 484.0682

with Es2 = (Es,jacket*Asl,com,jacket + Es,core*Asl,com,core)/Asl,com = 200000.00

yv = 0.00184318
shv = 0.00589816
ftv = 614.3968
fyv = 511.9973
suv = 0.01099427

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/d = 0.45297586

suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esuv_nominal = 0.08,

considering characteristic value $f_{sv} = f_{sv}/1.2$, from table 5.1, TBDY
For calculation of $e_{suv_nominal}$ and y_v , sh_v , ft_v , fy_v , it is considered characteristic value $f_{sv} = f_{sv}/1.2$, from table 5.1, TBDY.

y_1 , sh_1 , ft_1 , fy_1 , are also multiplied by $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$, from 10.3.5, ASCE 41-17.

with $f_{sv} = (f_{s,jacket} \cdot A_{s,mid,jacket} + f_{s,mid} \cdot A_{s,mid,core}) / A_{s,mid} = 511.9973$

with $E_{sv} = (E_{s,jacket} \cdot A_{s,mid,jacket} + E_{s,mid} \cdot A_{s,mid,core}) / A_{s,mid} = 200000.00$

$1 = A_{s,ten} / (b \cdot d) \cdot (f_{s1} / f_c) = 0.0851958$

$2 = A_{s,com} / (b \cdot d) \cdot (f_{s2} / f_c) = 0.0851958$

$v = A_{s,mid} / (b \cdot d) \cdot (f_{sv} / f_c) = 0.04369034$

and confined core properties:

$b = 340.00$

$d = 327.00$

$d' = 13.00$

f_{cc} (5A.2, TBDY) = 37.35991

cc (5A.5, TBDY) = 0.00332119

c = confinement factor = 1.13212

$1 = A_{s,ten} / (b \cdot d) \cdot (f_{s1} / f_c) = 0.1094258$

$2 = A_{s,com} / (b \cdot d) \cdot (f_{s2} / f_c) = 0.1094258$

$v = A_{s,mid} / (b \cdot d) \cdot (f_{sv} / f_c) = 0.05611603$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < v_{s,y2}$ - LHS eq.(4.5) is satisfied

--->

μ_u (4.9) = 0.16193824

$\mu_u = M_{Rc}$ (4.14) = 1.8194E+008

$u = \mu_u$ (4.1) = 3.6747033E-005

Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.45297586$

$l_b = 300.00$

$l_d = 662.2869$

Calculation of $l_{b,min}$ according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

= 1

$d_b = 14.66667$

Mean strength value of all re-bars: $f_y = 656.5682$

Mean concrete strength: $f'_c = (f'_{c,jacket} \cdot Area_{jacket} + f'_{c,core} \cdot Area_{core}) / Area_{section} = 29.75$, but $f_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 3.43481$

$A_{tr} = \text{Min}(A_{tr,x}, A_{tr,y}) = 257.6106$

where $A_{tr,x}$, $A_{tr,y}$ are the sum of the area of all stirrup legs along X and Y loxal axis

$s = \text{Max}(s_{external}, s_{internal}) = 250.00$

$n = 12.00$

Calculation of μ_u

Calculation of ultimate curvature μ_u according to 4.1, Biskinis/Fardis 2013:

$u = 3.6747033E-005$

$\mu_u = 1.8194E+008$

with full section properties:

$b = 400.00$

$d = 357.00$

$d' = 43.00$

$v = 0.00125773$

$N = 5926.932$

$f_c = 33.00$

co (5A.5, TBDY) = 0.002

Final value of cu: $cu^* = \text{shear_factor} * \text{Max}(cu, cc) = 0.01505571$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $cu = 0.01505571$

we ((5.4c), TBDY) = $ase * sh_{,min} * fy_{we} / f_{ce} + \text{Min}(fx, fy) = 0.08345896$

where $f = af * pf * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

 $fx = 0.07683125$

$af = 0.57333333$

$b = 400.00$

$h = 400.00$

From EC8 A.4.4.3(6), $pf = 2tf/bw = 0.00508$

$bw = 400.00$

effective stress from (A.35), $ff_{,e} = 870.5244$

 $fy = 0.07683125$

$af = 0.57333333$

$b = 400.00$

$h = 400.00$

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) = $(ase1 * A_{ext} + ase2 * A_{int}) / A_{sec} = 0.24250288$

$ase1 = 0.24250288$

$bo_{,1} = 340.00$

$ho_{,1} = 340.00$

$bi_{2,1} = 462400.00$

$ase2 = \text{Max}(ase1, ase2) = 0.24250288$

$bo_{,2} = 192.00$

$ho_{,2} = 192.00$

$bi_{2,2} = 147456.00$

$psh_{,min} * fy_{we} = \text{Min}(psh_{,x} * fy_{we}, psh_{,y} * fy_{we}) = 3.00635$

Expression ((5.4d), TBDY) for $psh_{,min} * fy_{we}$ has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

 $psh_{,x} * fy_{we} = psh1 * fy_{we1} + ps2 * fy_{we2} = 3.00635$

$ps1$ (external) = $(Ash1 * h1 / s1) / A_{sec} = 0.00392699$

$Ash1 = Astir_{,1} * ns_{,1} = 157.0796$

No stirrups, $ns_{,1} = 2.00$

$h1 = 400.00$

$ps2$ (internal) = $(Ash2 * h2 / s2) / A_{sec} = 0.00050265$

$Ash2 = Astir_{,2} * ns_{,2} = 100.531$

No stirrups, $ns_{,2} = 2.00$

$h2 = 200.00$

 $psh_{,y} * fy_{we} = psh1 * fy_{we1} + ps2 * fy_{we2} = 3.00635$

$ps1$ (external) = $(Ash1 * h1 / s1) / A_{sec} = 0.00392699$

$Ash1 = Astir_{,1} * ns_{,1} = 157.0796$

No stirrups, $ns_{,1} = 2.00$

$h1 = 400.00$

$ps2$ (internal) = $(Ash2 * h2 / s2) / A_{sec} = 0.00050265$

$Ash2 = Astir_{,2} * ns_{,2} = 100.531$

No stirrups, $ns_{,2} = 2.00$

$h2 = 200.00$

 $A_{sec} = 160000.00$

$s1 = 100.00$

$s2 = 250.00$

$fy_{we1} = 694.45$

$fy_{we2} = 555.55$

$f_{ce} = 33.00$

From ((5.A.5), TBDY), TBDY: $cc = 0.00332119$
 $c = \text{confinement factor} = 1.13212$
 $y1 = 0.00184318$
 $sh1 = 0.00589816$
 $ft1 = 580.8818$
 $fy1 = 484.0682$
 $su1 = 0.01099427$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 $\text{Shear_factor} = 1.00$
 $lo/lou,min = lb/ld = 0.45297586$
 $su1 = 0.4 * esu1_nominal ((5.5), TBDY) = 0.032$
 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 $fs1 = (fs,jacket * Asl,ten,jacket + fs,core * Asl,ten,core) / Asl,ten = 484.0682$
 with $Es1 = (Es,jacket * Asl,ten,jacket + Es,core * Asl,ten,core) / Asl,ten = 200000.00$
 $y2 = 0.00184318$
 $sh2 = 0.00589816$
 $ft2 = 580.8818$
 $fy2 = 484.0682$
 $su2 = 0.01099427$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 $\text{Shear_factor} = 1.00$
 $lo/lou,min = lb/lb,min = 0.45297586$
 $su2 = 0.4 * esu2_nominal ((5.5), TBDY) = 0.032$
 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 $fs2 = (fs,jacket * Asl,com,jacket + fs,core * Asl,com,core) / Asl,com = 484.0682$
 with $Es2 = (Es,jacket * Asl,com,jacket + Es,core * Asl,com,core) / Asl,com = 200000.00$
 $yv = 0.00184318$
 $shv = 0.00589816$
 $ftv = 614.3968$
 $fyv = 511.9973$
 $suv = 0.01099427$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 $\text{Shear_factor} = 1.00$
 $lo/lou,min = lb/ld = 0.45297586$
 $suv = 0.4 * esuv_nominal ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $esuv_nominal = 0.08$,
 considering characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY
 For calculation of $esuv_nominal$ and yv, shv, ftv, fyv , it is considered
 characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY.
 $y1, sh1, ft1, fy1$, are also multiplied by $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE 41-17.
 with $fsv = (fs,jacket * Asl,mid,jacket + fs,mid * Asl,mid,core) / Asl,mid = 511.9973$
 with $Es_v = (Es,jacket * Asl,mid,jacket + Es,mid * Asl,mid,core) / Asl,mid = 200000.00$
 $1 = Asl,ten / (b * d) * (fs1 / fc) = 0.0851958$
 $2 = Asl,com / (b * d) * (fs2 / fc) = 0.0851958$
 $v = Asl,mid / (b * d) * (fsv / fc) = 0.04369034$
 and confined core properties:
 $b = 340.00$
 $d = 327.00$
 $d' = 13.00$
 $fcc (5A.2, TBDY) = 37.35991$
 $cc (5A.5, TBDY) = 0.00332119$
 $c = \text{confinement factor} = 1.13212$
 $1 = Asl,ten / (b * d) * (fs1 / fc) = 0.1094258$
 $2 = Asl,com / (b * d) * (fs2 / fc) = 0.1094258$
 $v = Asl,mid / (b * d) * (fsv / fc) = 0.05611603$
 Case/Assumption: Unconfined full section - Steel rupture
 ' satisfies Eq. (4.3)

$v < v_s, y_2$ - LHS eq.(4.5) is satisfied

--->

$$\mu_u(4.9) = 0.16193824$$

$$\mu_u = M_{Rc}(4.14) = 1.8194E+008$$

$$u = \mu_u(4.1) = 3.6747033E-005$$

Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.45297586$

$$l_b = 300.00$$

$$l_d = 662.2869$$

Calculation of l_b, \min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

$$= 1$$

$$d_b = 14.66667$$

Mean strength value of all re-bars: $f_y = 656.5682$

Mean concrete strength: $f_c' = (f_c'_{jacket} \cdot Area_{jacket} + f_c'_{core} \cdot Area_{core}) / Area_{section} = 29.75$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 25.00$$

$$K_{tr} = 3.43481$$

$$A_{tr} = \min(A_{tr_x}, A_{tr_y}) = 257.6106$$

where A_{tr_x}, A_{tr_y} are the sum of the area of all stirrup legs along X and Y local axis

$$s = \max(s_{external}, s_{internal}) = 250.00$$

$$n = 12.00$$

Calculation of Shear Strength $V_r = \min(V_{r1}, V_{r2}) = 633062.661$

Calculation of Shear Strength at edge 1, $V_{r1} = 633062.661$

$$V_{r1} = V_{Col}((10.3), ASCE 41-17) = k_{nl} \cdot V_{Col0}$$

$$V_{Col0} = 633062.661$$

$$k_{nl} = 1 \text{ (zero step-static loading)}$$

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: $f_c' = (f_c'_{jacket} \cdot Area_{jacket} + f_c'_{core} \cdot Area_{core}) / Area_{section} = 29.75$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$$M/Vd = 2.00$$

$$\mu_u = 4.3445556E-012$$

$$\mu_v = 2.8976040E-031$$

$$d = 0.8 \cdot h = 320.00$$

$$N_u = 5926.932$$

$$A_g = 160000.00$$

$$\text{From (11.5.4.8), ACI 318-14: } V_s = V_{s1} + V_{s2} = 279254.914$$

where:

$V_{s1} = 279254.914$ is calculated for jacket, with:

$$d = 320.00$$

$$A_v = 157079.633$$

$$f_y = 555.56$$

$$s = 100.00$$

V_{s1} is multiplied by $Col1 = 1.00$

$$s/d = 0.3125$$

$V_{s2} = 0.00$ is calculated for core, with:

$$d = 160.00$$

$$A_v = 100530.965$$

$$f_y = 444.44$$

$$s = 250.00$$

V_{s2} is multiplied by $Col2 = 0.00$

$$s/d = 1.5625$$

$$V_f \text{ ((11-3)-(11.4), ACI 440) } = 188111.148$$

$f = 0.95$, for fully-wrapped sections

$wf/sf = 1$ (FRP strips adjacent to one another).

In (11.3) $\sin \theta + \cos \theta$ is replaced with $(\cot \theta + \csc \theta) \sin \alpha$ which is more a generalised expression,

where θ is the angle of the crack direction (see KANEPE).

This later relation, considered as a function $V_f(\theta, \alpha)$, is implemented for every different fiber orientation α_i , as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.

orientation 1: $\theta = b1 + 90^\circ = 90.00$

$V_f = \text{Min}(|V_f(45, \alpha)|, |V_f(-45, \alpha)|)$, with:

total thickness per orientation, $tf1 = NL * t / NoDir = 1.016$

$dfv = d$ (figure 11.2, ACI 440) = 357.00

ffe ((11-5), ACI 440) = 259.312

$E_f = 64828.00$

$fe = 0.004$, from (11.6a), ACI 440

with $fu = 0.01$

From (11-11), ACI 440: $V_s + V_f \leq 463788.751$

$bw = 400.00$

Calculation of Shear Strength at edge 2, $V_{r2} = 633062.661$

$V_{r2} = V_{Col}$ ((10.3), ASCE 41-17) = $knl * V_{Col0}$

$V_{Col0} = 633062.661$

$knl = 1$ (zero step-static loading)

NOTE: In expression (10-3) ' $V_s = A_v * f_y * d / s$ ' is replaced by ' $V_s + f * V_f$ '

where V_f is the contribution of FRPs (11.3), ACI 440).

$\gamma = 1$ (normal-weight concrete)

Mean concrete strength: $fc' = (fc'_{jacket} * Area_{jacket} + fc'_{core} * Area_{core}) / Area_{section} = 29.75$, but $fc'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/d = 2.00$

$\mu_u = 4.3445556E-012$

$\nu_u = 2.8976040E-031$

$d = 0.8 * h = 320.00$

$N_u = 5926.932$

$A_g = 160000.00$

From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 279254.914$

where:

$V_{s1} = 279254.914$ is calculated for jacket, with:

$d = 320.00$

$A_v = 157079.633$

$f_y = 555.56$

$s = 100.00$

V_{s1} is multiplied by $Col1 = 1.00$

$s/d = 0.3125$

$V_{s2} = 0.00$ is calculated for core, with:

$d = 160.00$

$A_v = 100530.965$

$f_y = 444.44$

$s = 250.00$

V_{s2} is multiplied by $Col2 = 0.00$

$s/d = 1.5625$

V_f ((11-3)-(11.4), ACI 440) = 188111.148

$f = 0.95$, for fully-wrapped sections

$wf/sf = 1$ (FRP strips adjacent to one another).

In (11.3) $\sin \theta + \cos \theta$ is replaced with $(\cot \theta + \csc \theta) \sin \alpha$ which is more a generalised expression,

where θ is the angle of the crack direction (see KANEPE).

This later relation, considered as a function $V_f(\theta, \alpha)$, is implemented for every different fiber orientation α_i , as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.

orientation 1: $\theta = b1 + 90^\circ = 90.00$

$V_f = \text{Min}(|V_f(45, \alpha)|, |V_f(-45, \alpha)|)$, with:

total thickness per orientation, $tf1 = NL * t / NoDir = 1.016$

$dfv = d$ (figure 11.2, ACI 440) = 357.00

ffe ((11-5), ACI 440) = 259.312

$E_f = 64828.00$

$fe = 0.004$, from (11.6a), ACI 440

with $fu = 0.01$

From (11-11), ACI 440: $V_s + V_f \leq 463788.751$

bw = 400.00

End Of Calculation of Shear Capacity ratio for element: column JC1 of floor 1
At local axis: 3

Start Of Calculation of Shear Capacity ratio for element: column JC1 of floor 1
At Shear local axis: 2
(Bending local axis: 3)
Section Type: rcjrs

Constant Properties

Knowledge Factor, $\gamma = 0.80$

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

Existing material of Secondary Member: Concrete Strength, $f_c = f_{cm} = 20.00$

Existing material of Secondary Member: Steel Strength, $f_s = f_{sm} = 444.44$

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14

Jacket

New material: Steel Strength, $f_s = 1.25 \cdot f_{sm} = 694.45$

Existing Column

Existing material: Steel Strength, $f_s = 1.25 \cdot f_{sm} = 555.55$

#####

External Height, $H = 400.00$

External Width, $W = 400.00$

Internal Height, $H = 200.00$

Internal Width, $W = 200.00$

Cover Thickness, $c = 25.00$

Mean Confinement Factor overall section = 1.13212

Element Length, $L = 3000.00$

Secondary Member

Ribbed Bars

Ductile Steel

Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)

Longitudinal Bars With Ends Lapped Starting at the End Sections

Lap Length $l_o = 300.00$

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $e_{fu} = 0.01$

Number of directions, $NoDir = 1$

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, $V_a = -6.6805695E-033$

EDGE -B-

Shear Force, $V_b = 6.6805695E-033$

BOTH EDGES

Axial Force, $F = -5926.932$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: $As_{lt} = 0.00$

-Compression: $As_{lc} = 2060.885$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension: $As_{l,ten} = 829.3805$

-Compression: $As_{l,com} = 829.3805$

-Middle: $As_{l,mid} = 402.1239$

Calculation of Shear Capacity ratio, $V_e/V_r = 0.19159777$

Member Controlled by Flexure ($V_e/V_r < 1$)

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 121293.391$

with

$M_{pr1} = \text{Max}(Mu_{1+}, Mu_{1-}) = 1.8194E+008$

$Mu_{1+} = 1.8194E+008$, is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination

$Mu_{1-} = 1.8194E+008$, is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination

$M_{pr2} = \text{Max}(Mu_{2+}, Mu_{2-}) = 1.8194E+008$

$Mu_{2+} = 1.8194E+008$, is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the static loading combination

$Mu_{2-} = 1.8194E+008$, is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the static loading combination

Calculation of Mu_{1+}

Calculation of ultimate curvature ϕ_u according to 4.1, Biskinis/Fardis 2013:

$\phi_u = 3.6747033E-005$

$M_u = 1.8194E+008$

with full section properties:

$b = 400.00$

$d = 357.00$

$d' = 43.00$

$v = 0.00125773$

$N = 5926.932$

$f_c = 33.00$

$\alpha_{co} (5A.5, TBDY) = 0.002$

Final value of ϕ_u : $\phi_u^* = \text{shear_factor} * \text{Max}(\phi_u, \phi_c) = 0.01505571$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $\phi_u = 0.01505571$

$\phi_{we} ((5.4c), TBDY) = \alpha_{se} * \phi_{sh,min} * f_{ywe}/f_{ce} + \text{Min}(\phi_x, \phi_y) = 0.08345896$

where $\phi = \alpha_{pf} * \phi_{fe}/f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$\phi_x = 0.07683125$

$\alpha_{pf} = 0.57333333$

$b = 400.00$

$h = 400.00$

From EC8 A.4.4.3(6), $\phi_{pf} = 2t_f/b_w = 0.00508$

$b_w = 400.00$

effective stress from (A.35), $f_{fe} = 870.5244$

$\phi_y = 0.07683125$

$\alpha_{pf} = 0.57333333$

$b = 400.00$

$h = 400.00$

From EC8 A.4.4.3(6), $\phi_{pf} = 2t_f/b_w = 0.00508$

bw = 400.00
effective stress from (A.35), $f_{f,e} = 870.5244$

R = 40.00
Effective FRP thickness, $t_f = NL * t * \cos(b_1) = 1.016$
 $f_{u,f} = 1055.00$
 $E_f = 64828.00$
 $u_{,f} = 0.015$
 $ase((5.4d), TBDY) = (ase_1 * A_{ext} + ase_2 * A_{int}) / A_{sec} = 0.24250288$
 $ase_1 = 0.24250288$
 $bo_1 = 340.00$
 $ho_1 = 340.00$
 $bi_{2,1} = 462400.00$
 $ase_2 = \text{Max}(ase_1, ase_2) = 0.24250288$
 $bo_2 = 192.00$
 $ho_2 = 192.00$
 $bi_{2,2} = 147456.00$

$p_{sh, \min} * F_{ywe} = \text{Min}(p_{sh,x} * F_{ywe}, p_{sh,y} * F_{ywe}) = 3.00635$
Expression ((5.4d), TBDY) for $p_{sh, \min} * F_{ywe}$ has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$p_{sh,x} * F_{ywe} = p_{sh1} * F_{ywe1} + ps_2 * F_{ywe2} = 3.00635$
 ps_1 (external) = $(A_{sh1} * h_1 / s_1) / A_{sec} = 0.00392699$
 $A_{sh1} = A_{stir,1} * ns_1 = 157.0796$
No stirrups, $ns_1 = 2.00$
 $h_1 = 400.00$
 ps_2 (internal) = $(A_{sh2} * h_2 / s_2) / A_{sec} = 0.00050265$
 $A_{sh2} = A_{stir,2} * ns_2 = 100.531$
No stirrups, $ns_2 = 2.00$
 $h_2 = 200.00$

$p_{sh,y} * F_{ywe} = p_{sh1} * F_{ywe1} + ps_2 * F_{ywe2} = 3.00635$
 ps_1 (external) = $(A_{sh1} * h_1 / s_1) / A_{sec} = 0.00392699$
 $A_{sh1} = A_{stir,1} * ns_1 = 157.0796$
No stirrups, $ns_1 = 2.00$
 $h_1 = 400.00$
 ps_2 (internal) = $(A_{sh2} * h_2 / s_2) / A_{sec} = 0.00050265$
 $A_{sh2} = A_{stir,2} * ns_2 = 100.531$
No stirrups, $ns_2 = 2.00$
 $h_2 = 200.00$

$A_{sec} = 160000.00$
 $s_1 = 100.00$
 $s_2 = 250.00$
 $f_{ywe1} = 694.45$
 $f_{ywe2} = 555.55$
 $f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY: $cc = 0.00332119$
 $c = \text{confinement factor} = 1.13212$

$y_1 = 0.00184318$
 $sh_1 = 0.00589816$
 $ft_1 = 580.8818$
 $fy_1 = 484.0682$
 $su_1 = 0.01099427$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$lo/lo_{u, \min} = lb/ld = 0.45297586$
 $su_1 = 0.4 * esu_{1, \text{nominal}}((5.5), TBDY) = 0.032$

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 $fs_1 = fs_1 / 1.2$, from table 5.1, TBDY.

y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE 41-17.

with $fs_1 = (f_{s, \text{jacket}} * A_{s1, \text{ten, jacket}} + f_{s, \text{core}} * A_{s1, \text{ten, core}}) / A_{s1, \text{ten}} = 484.0682$

with $Es_1 = (E_{s, \text{jacket}} * A_{s1, \text{ten, jacket}} + E_{s, \text{core}} * A_{s1, \text{ten, core}}) / A_{s1, \text{ten}} = 200000.00$

$y_2 = 0.00184318$
 $sh_2 = 0.00589816$

$ft_2 = 580.8818$
 $fy_2 = 484.0682$
 $su_2 = 0.01099427$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 $Shear_factor = 1.00$
 $lo/lo_{min} = lb/lb_{min} = 0.45297586$
 $su_2 = 0.4 * esu_{2_nominal} ((5.5), TBDY) = 0.032$
 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 $Min(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE 41-17.
 with $fs_2 = (fs_{jacket} * A_{sl,com,jacket} + fs_{core} * A_{sl,com,core}) / A_{sl,com} = 484.0682$
 with $Es_2 = (Es_{jacket} * A_{sl,com,jacket} + Es_{core} * A_{sl,com,core}) / A_{sl,com} = 200000.00$
 $yv = 0.00184318$
 $shv = 0.00589816$
 $ftv = 614.3968$
 $fyv = 511.9973$
 $suv = 0.01099427$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 $Shear_factor = 1.00$
 $lo/lo_{min} = lb/ld = 0.45297586$
 $suv = 0.4 * esuv_{nominal} ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $esuv_{nominal} = 0.08$,
 considering characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY
 For calculation of $esuv_{nominal}$ and yv, shv, ftv, fyv , it is considered
 characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $Min(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE 41-17.
 with $fsv = (fs_{jacket} * A_{sl,mid,jacket} + fs_{mid} * A_{sl,mid,core}) / A_{sl,mid} = 511.9973$
 with $Es_v = (Es_{jacket} * A_{sl,mid,jacket} + Es_{mid} * A_{sl,mid,core}) / A_{sl,mid} = 200000.00$
 $1 = A_{sl,ten} / (b * d) * (fs_1 / fc) = 0.0851958$
 $2 = A_{sl,com} / (b * d) * (fs_2 / fc) = 0.0851958$
 $v = A_{sl,mid} / (b * d) * (fsv / fc) = 0.04369034$

and confined core properties:

$b = 340.00$
 $d = 327.00$
 $d' = 13.00$
 $fcc (5A.2, TBDY) = 37.35991$
 $cc (5A.5, TBDY) = 0.00332119$
 $c = \text{confinement factor} = 1.13212$
 $1 = A_{sl,ten} / (b * d) * (fs_1 / fc) = 0.1094258$
 $2 = A_{sl,com} / (b * d) * (fs_2 / fc) = 0.1094258$
 $v = A_{sl,mid} / (b * d) * (fsv / fc) = 0.05611603$

Case/Assumption: Unconfined full section - Steel rupture
 ' satisfies Eq. (4.3)

---->
 $v < v_{s,y_2}$ - LHS eq.(4.5) is satisfied
 ---->

$su (4.9) = 0.16193824$
 $Mu = MRc (4.14) = 1.8194E+008$
 $u = su (4.1) = 3.6747033E-005$

 Calculation of ratio lb/ld

Lap Length: $lb/ld = 0.45297586$
 $lb = 300.00$
 $ld = 662.2869$

Calculation of lb_{min} according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

$= 1$
 $db = 14.66667$
 Mean strength value of all re-bars: $fy = 656.5682$
 Mean concrete strength: $fc' = (fc'_{jacket} * Area_{jacket} + fc'_{core} * Area_{core}) / Area_{section} = 29.75$, but $fc'^{0.5} \leq 8.3$
 MPa (22.5.3.1, ACI 318-14)
 $t = 1.00$
 $s = 0.80$

e = 1.00
cb = 25.00
Ktr = 3.43481
Atr = Min(Atr_x,Atr_y) = 257.6106
where Atr_x, Atr_y are the sum of the area of all stirrup legs along X and Y loxal axis
s = Max(s_external,s_internal) = 250.00
n = 12.00

Calculation of Mu1-

Calculation of ultimate curvature μ according to 4.1, Biskinis/Fardis 2013:
u = 3.6747033E-005
Mu = 1.8194E+008

with full section properties:

b = 400.00
d = 357.00
d' = 43.00
v = 0.00125773
N = 5926.932
fc = 33.00
co (5A.5, TBDY) = 0.002
Final value of μ : $\mu^* = \text{shear_factor} * \text{Max}(\mu_c, \mu_s) = 0.01505571$
The Shear_factor is considered equal to 1 (pure moment strength)
From (5.4b), TBDY: $\mu_c = 0.01505571$
 μ_s ((5.4c), TBDY) = $\text{ase} * \text{sh,min} * \text{fywe} / \text{fce} + \text{Min}(f_x, f_y) = 0.08345896$
where $f = \text{af} * \text{pf} * \text{ffe} / \text{fce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

f_x = 0.07683125
af = 0.57333333
b = 400.00
h = 400.00
From EC8 A.4.4.3(6), pf = $2t_f / b_w = 0.00508$
b_w = 400.00
effective stress from (A.35), ff,e = 870.5244

f_y = 0.07683125
af = 0.57333333
b = 400.00
h = 400.00
From EC8 A.4.4.3(6), pf = $2t_f / b_w = 0.00508$
b_w = 400.00
effective stress from (A.35), ff,e = 870.5244

R = 40.00
Effective FRP thickness, $t_f = \text{NL} * t * \text{Cos}(b_1) = 1.016$
f_u,f = 1055.00
E_f = 64828.00
u,f = 0.015
ase ((5.4d), TBDY) = $(\text{ase}_1 * A_{\text{ext}} + \text{ase}_2 * A_{\text{int}}) / A_{\text{sec}} = 0.24250288$
ase1 = 0.24250288
bo_1 = 340.00
ho_1 = 340.00
bi2_1 = 462400.00
ase2 = Max(ase1,ase2) = 0.24250288
bo_2 = 192.00
ho_2 = 192.00
bi2_2 = 147456.00

psh,min*Fywe = Min(psh,x*Fywe , psh,y*Fywe) = 3.00635
Expression ((5.4d), TBDY) for psh,min*Fywe has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

psh_x*Fywe = psh1*Fywe1+ps2*Fywe2 = 3.00635

ps1 (external) = $(Ash1 \cdot h1 / s1) / Asec = 0.00392699$
Ash1 = Astir_1 * ns_1 = 157.0796
No stirups, ns_1 = 2.00
h1 = 400.00
ps2 (internal) = $(Ash2 \cdot h2 / s2) / Asec = 0.00050265$
Ash2 = Astir_2 * ns_2 = 100.531
No stirups, ns_2 = 2.00
h2 = 200.00

psh_y * Fywe = psh1 * Fywe1 + ps2 * Fywe2 = 3.00635
ps1 (external) = $(Ash1 \cdot h1 / s1) / Asec = 0.00392699$
Ash1 = Astir_1 * ns_1 = 157.0796
No stirups, ns_1 = 2.00
h1 = 400.00
ps2 (internal) = $(Ash2 \cdot h2 / s2) / Asec = 0.00050265$
Ash2 = Astir_2 * ns_2 = 100.531
No stirups, ns_2 = 2.00
h2 = 200.00

Asec = 160000.00
s1 = 100.00
s2 = 250.00
fywe1 = 694.45
fywe2 = 555.55
fce = 33.00

From ((5.A5), TBDY), TBDY: cc = 0.00332119
c = confinement factor = 1.13212

y1 = 0.00184318
sh1 = 0.00589816
ft1 = 580.8818
fy1 = 484.0682
su1 = 0.01099427

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/lb = 0.45297586
su1 = $0.4 \cdot esu1_nominal$ ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu1_nominal = 0.08,
For calculation of esu1_nominal and y1, sh1, ft1, fy1, it is considered
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1, ft1, fy1, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/lb)^{2/3})$, from 10.3.5, ASCE 41-17.
with fs1 = $(fs_jacket \cdot Asl,ten,jacket + fs_core \cdot Asl,ten,core) / Asl,ten = 484.0682$
with Es1 = $(Es_jacket \cdot Asl,ten,jacket + Es_core \cdot Asl,ten,core) / Asl,ten = 200000.00$

y2 = 0.00184318
sh2 = 0.00589816
ft2 = 580.8818
fy2 = 484.0682
su2 = 0.01099427

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/lb,min = 0.45297586
su2 = $0.4 \cdot esu2_nominal$ ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu2_nominal = 0.08,
For calculation of esu2_nominal and y2, sh2, ft2, fy2, it is considered
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

y1, sh1, ft1, fy1, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/lb)^{2/3})$, from 10.3.5, ASCE 41-17.
with fs2 = $(fs_jacket \cdot Asl,com,jacket + fs_core \cdot Asl,com,core) / Asl,com = 484.0682$
with Es2 = $(Es_jacket \cdot Asl,com,jacket + Es_core \cdot Asl,com,core) / Asl,com = 200000.00$

yv = 0.00184318
shv = 0.00589816
ftv = 614.3968
fyv = 511.9973
suv = 0.01099427

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$l_0/l_{ou,min} = l_b/l_d = 0.45297586$$

$$s_{uv} = 0.4 * e_{suv_nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: $e_{suv_nominal} = 0.08$,

considering characteristic value $f_{sv} = f_{sv}/1.2$, from table 5.1, TBDY

For calculation of $e_{suv_nominal}$ and γ_v , sh_v, ft_v, fy_v , it is considered

characteristic value $f_{sv} = f_{sv}/1.2$, from table 5.1, TBDY.

$$\gamma_1, sh_1, ft_1, fy_1, \text{ are also multiplied by } \text{Min}(1, 1.25 * (l_b/l_d)^{2/3}), \text{ from 10.3.5, ASCE 41-17.}$$

$$\text{with } f_{sv} = (f_{s,jacket} * A_{s,mid,jacket} + f_{s,mid} * A_{s,mid,core}) / A_{s,mid} = 511.9973$$

$$\text{with } E_{sv} = (E_{s,jacket} * A_{s,mid,jacket} + E_{s,mid} * A_{s,mid,core}) / A_{s,mid} = 200000.00$$

$$1 = A_{s,ten} / (b * d) * (f_{s1} / f_c) = 0.0851958$$

$$2 = A_{s,com} / (b * d) * (f_{s2} / f_c) = 0.0851958$$

$$v = A_{s,mid} / (b * d) * (f_{sv} / f_c) = 0.04369034$$

and confined core properties:

$$b = 340.00$$

$$d = 327.00$$

$$d' = 13.00$$

$$f_{cc} (5A.2, TBDY) = 37.35991$$

$$c_c (5A.5, TBDY) = 0.00332119$$

$$c = \text{confinement factor} = 1.13212$$

$$1 = A_{s,ten} / (b * d) * (f_{s1} / f_c) = 0.1094258$$

$$2 = A_{s,com} / (b * d) * (f_{s2} / f_c) = 0.1094258$$

$$v = A_{s,mid} / (b * d) * (f_{sv} / f_c) = 0.05611603$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < v_{s,y2}$ - LHS eq.(4.5) is satisfied

--->

$$s_u (4.9) = 0.16193824$$

$$M_u = M_{Rc} (4.14) = 1.8194E+008$$

$$u = s_u (4.1) = 3.6747033E-005$$

Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.45297586$

$$l_b = 300.00$$

$$l_d = 662.2869$$

Calculation of l_b, min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

$$= 1$$

$$d_b = 14.66667$$

Mean strength value of all re-bars: $f_y = 656.5682$

Mean concrete strength: $f'_c = (f'_{c,jacket} * Area_{jacket} + f'_{c,core} * Area_{core}) / Area_{section} = 29.75$, but $f_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 25.00$$

$$K_{tr} = 3.43481$$

$$A_{tr} = \text{Min}(A_{tr,x}, A_{tr,y}) = 257.6106$$

where $A_{tr,x}$, $A_{tr,y}$ are the sum of the area of all stirrup legs along X and Y local axis

$$s = \text{Max}(s_{external}, s_{internal}) = 250.00$$

$$n = 12.00$$

Calculation of M_u2+

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

$$u = 3.6747033E-005$$

$$M_u = 1.8194E+008$$

with full section properties:

$$b = 400.00$$

$$d = 357.00$$

$$d' = 43.00$$

$$v = 0.00125773$$

$$N = 5926.932$$

$$f_c = 33.00$$

$$c_o \text{ (5A.5, TBDY)} = 0.002$$

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.01505571$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } c_u = 0.01505571$$

$$\text{we ((5.4c), TBDY)} = a_{se} * s_{h,\min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.08345896$$

where $f = a_f * p_f * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.07683125$$

$$a_f = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 870.5244$$

$$f_y = 0.07683125$$

$$a_f = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 870.5244$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L * t * \text{Cos}(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$a_{se} \text{ ((5.4d), TBDY)} = (a_{se1} * A_{ext} + a_{se2} * A_{int}) / A_{sec} = 0.24250288$$

$$a_{se1} = 0.24250288$$

$$b_{o,1} = 340.00$$

$$h_{o,1} = 340.00$$

$$b_{i,2,1} = 462400.00$$

$$a_{se2} = \text{Max}(a_{se1}, a_{se2}) = 0.24250288$$

$$b_{o,2} = 192.00$$

$$h_{o,2} = 192.00$$

$$b_{i,2,2} = 147456.00$$

$$p_{sh,\min} * F_{ywe} = \text{Min}(p_{sh,x} * F_{ywe}, p_{sh,y} * F_{ywe}) = 3.00635$$

Expression ((5.4d), TBDY) for $p_{sh,\min} * F_{ywe}$ has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$$p_{sh,x} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{sh2} * F_{ywe2} = 3.00635$$

$$p_{s1} \text{ (external)} = (A_{sh1} * h_1 / s_1) / A_{sec} = 0.00392699$$

$$A_{sh1} = A_{stir,1} * n_{s,1} = 157.0796$$

$$\text{No stirrups, } n_{s,1} = 2.00$$

$$h_1 = 400.00$$

$$p_{s2} \text{ (internal)} = (A_{sh2} * h_2 / s_2) / A_{sec} = 0.00050265$$

$$A_{sh2} = A_{stir,2} * n_{s,2} = 100.531$$

$$\text{No stirrups, } n_{s,2} = 2.00$$

$$h_2 = 200.00$$

$$p_{sh,y} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{sh2} * F_{ywe2} = 3.00635$$

$$p_{s1} \text{ (external)} = (A_{sh1} * h_1 / s_1) / A_{sec} = 0.00392699$$

$$A_{sh1} = A_{stir,1} * n_{s,1} = 157.0796$$

$$\text{No stirrups, } n_{s,1} = 2.00$$

$$h_1 = 400.00$$

$$p_{s2} \text{ (internal)} = (A_{sh2} * h_2 / s_2) / A_{sec} = 0.00050265$$

$$A_{sh2} = A_{stir,2} * n_{s,2} = 100.531$$

$$\text{No stirrups, } n_{s,2} = 2.00$$

$$h_2 = 200.00$$

$$A_{sec} = 160000.00$$

$$s_1 = 100.00$$

$$s_2 = 250.00$$

fywe1 = 694.45
fywe2 = 555.55
fce = 33.00

From ((5.A.5), TBDY), TBDY: cc = 0.00332119
c = confinement factor = 1.13212

y1 = 0.00184318
sh1 = 0.00589816
ft1 = 580.8818
fy1 = 484.0682
su1 = 0.01099427

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/lb = 0.45297586

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 = 484.0682

with Es1 = (Es,jacket*Asl,ten,jacket + Es,core*Asl,ten,core)/Asl,ten = 200000.00

y2 = 0.00184318
sh2 = 0.00589816
ft2 = 580.8818
fy2 = 484.0682
su2 = 0.01099427

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/lb,min = 0.45297586

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 = 484.0682

with Es2 = (Es,jacket*Asl,com,jacket + Es,core*Asl,com,core)/Asl,com = 200000.00

yv = 0.00184318
shv = 0.00589816
ftv = 614.3968
fyv = 511.9973
suv = 0.01099427

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/lb = 0.45297586

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 = 511.9973

with Esv = (Es,jacket*Asl,mid,jacket + Es,mid*Asl,mid,core)/Asl,mid = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.0851958

2 = Asl,com/(b*d)*(fs2/fc) = 0.0851958

v = Asl,mid/(b*d)*(fsv/fc) = 0.04369034

and confined core properties:

b = 340.00
d = 327.00
d' = 13.00

fcc (5A.2, TBDY) = 37.35991

cc (5A.5, TBDY) = 0.00332119

c = confinement factor = 1.13212

1 = Asl,ten/(b*d)*(fs1/fc) = 0.1094258

2 = Asl,com/(b*d)*(fs2/fc) = 0.1094258

v = Asl,mid/(b*d)*(fsv/fc) = 0.05611603

Case/Assumption: Unconfined full section - Steel rupture
' satisfies Eq. (4.3)

--->
v < vs,y2 - LHS eq.(4.5) is satisfied
--->
su (4.9) = 0.16193824
Mu = MRc (4.14) = 1.8194E+008
u = su (4.1) = 3.6747033E-005

Calculation of ratio lb/l_d

Lap Length: lb/l_d = 0.45297586
lb = 300.00
l_d = 662.2869
Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
= 1
db = 14.66667
Mean strength value of all re-bars: fy = 656.5682
Mean concrete strength: fc' = (fc'_jacket*Area_jacket + fc'_core*Area_core)/Area_section = 29.75, but fc'^0.5 <= 8.3
MPa (22.5.3.1, ACI 318-14)
t = 1.00
s = 0.80
e = 1.00
cb = 25.00
Ktr = 3.43481
Atr = Min(Atr_x,Atr_y) = 257.6106
where Atr_x, Atr_y are the sum of the area of all stirrup legs along X and Y local axis
s = Max(s_external,s_internal) = 250.00
n = 12.00

Calculation of Mu2-

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:
u = 3.6747033E-005
Mu = 1.8194E+008

with full section properties:

b = 400.00
d = 357.00
d' = 43.00
v = 0.00125773
N = 5926.932
fc = 33.00
co (5A.5, TBDY) = 0.002
Final value of cu: cu* = shear_factor * Max(cu, cc) = 0.01505571
The Shear_factor is considered equal to 1 (pure moment strength)
From (5.4b), TBDY: cu = 0.01505571
we ((5.4c), TBDY) = ase* sh,min*fywe/fce+ Min(fx, fy) = 0.08345896
where f = af*pf*ffe/fce is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

fx = 0.07683125
af = 0.57333333
b = 400.00
h = 400.00
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 = 0.07683125
af = 0.57333333
b = 400.00
h = 400.00

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, $tf = NL*t*\text{Cos}(b1) = 1.016$
 $f_{u,f} = 1055.00$
 $E_f = 64828.00$
 $u_{,f} = 0.015$
 $ase((5.4d), \text{TBDY}) = (ase1*A_{ext} + ase2*A_{int})/A_{sec} = 0.24250288$
 $ase1 = 0.24250288$
 $bo_1 = 340.00$
 $ho_1 = 340.00$
 $bi2_1 = 462400.00$
 $ase2 = \text{Max}(ase1, ase2) = 0.24250288$
 $bo_2 = 192.00$
 $ho_2 = 192.00$
 $bi2_2 = 147456.00$

$psh_{,min}*F_{ywe} = \text{Min}(psh_{,x}*F_{ywe}, psh_{,y}*F_{ywe}) = 3.00635$
Expression ((5.4d), TBDY) for $psh_{,min}*F_{ywe}$ has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$psh_{,x}*F_{ywe} = psh1*F_{ywe1} + ps2*F_{ywe2} = 3.00635$
 $ps1(\text{external}) = (Ash1*h1/s1)/A_{sec} = 0.00392699$
 $Ash1 = Astir_1*ns_1 = 157.0796$
No stirrups, $ns_1 = 2.00$
 $h1 = 400.00$
 $ps2(\text{internal}) = (Ash2*h2/s2)/A_{sec} = 0.00050265$
 $Ash2 = Astir_2*ns_2 = 100.531$
No stirrups, $ns_2 = 2.00$
 $h2 = 200.00$

$psh_{,y}*F_{ywe} = psh1*F_{ywe1} + ps2*F_{ywe2} = 3.00635$
 $ps1(\text{external}) = (Ash1*h1/s1)/A_{sec} = 0.00392699$
 $Ash1 = Astir_1*ns_1 = 157.0796$
No stirrups, $ns_1 = 2.00$
 $h1 = 400.00$
 $ps2(\text{internal}) = (Ash2*h2/s2)/A_{sec} = 0.00050265$
 $Ash2 = Astir_2*ns_2 = 100.531$
No stirrups, $ns_2 = 2.00$
 $h2 = 200.00$

$A_{sec} = 160000.00$
 $s1 = 100.00$
 $s2 = 250.00$
 $f_{ywe1} = 694.45$
 $f_{ywe2} = 555.55$
 $f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY: $cc = 0.00332119$
 $c = \text{confinement factor} = 1.13212$

$y1 = 0.00184318$
 $sh1 = 0.00589816$
 $ft1 = 580.8818$
 $fy1 = 484.0682$
 $su1 = 0.01099427$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
 $\text{Shear_factor} = 1.00$

$lo/lo_{u,min} = lb/d = 0.45297586$
 $su1 = 0.4*esu1_{nominal}((5.5), \text{TBDY}) = 0.032$

From table 5A.1, TBDY: $esu1_{nominal} = 0.08$,

For calculation of $esu1_{nominal}$ and $y1, sh1, ft1, fy1$, it is considered
characteristic value $fsy1 = fs1/1.2$, from table 5.1, TBDY.

$y1, sh1, ft1, fy1$, are also multiplied by $\text{Min}(1, 1.25*(lb/d)^{2/3})$, from 10.3.5, ASCE 41-17.

with $fs1 = (fs_{jacket}*A_{sl,ten,jacket} + fs_{core}*A_{sl,ten,core})/A_{sl,ten} = 484.0682$

with $Es1 = (Es_{jacket}*A_{sl,ten,jacket} + Es_{core}*A_{sl,ten,core})/A_{sl,ten} = 200000.00$

$y2 = 0.00184318$

$sh_2 = 0.00589816$
 $ft_2 = 580.8818$
 $fy_2 = 484.0682$
 $su_2 = 0.01099427$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $lo/lo_{min} = lb/lb_{min} = 0.45297586$
 $su_2 = 0.4 * esu_{2,nominal} ((5.5), TBDY) = 0.032$
 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 $Min(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE 41-17.
 with $fs_2 = (fs_{jacket} * Asl_{com,jacket} + fs_{core} * Asl_{com,core}) / Asl_{com} = 484.0682$
 with $Es_2 = (Es_{jacket} * Asl_{com,jacket} + Es_{core} * Asl_{com,core}) / Asl_{com} = 200000.00$
 $yv = 0.00184318$
 $shv = 0.00589816$
 $ftv = 614.3968$
 $fyv = 511.9973$
 $suv = 0.01099427$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $lo/lo_{min} = lb/ld = 0.45297586$
 $suv = 0.4 * esuv_{nominal} ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $esuv_{nominal} = 0.08$,
 considering characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY
 For calculation of $esuv_{nominal}$ and yv, shv, ftv, fyv , it is considered
 characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $Min(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE 41-17.
 with $fsv = (fs_{jacket} * Asl_{mid,jacket} + fs_{mid} * Asl_{mid,core}) / Asl_{mid} = 511.9973$
 with $Es_v = (Es_{jacket} * Asl_{mid,jacket} + Es_{mid} * Asl_{mid,core}) / Asl_{mid} = 200000.00$
 $1 = Asl_{ten} / (b * d) * (fs_1 / fc) = 0.0851958$
 $2 = Asl_{com} / (b * d) * (fs_2 / fc) = 0.0851958$
 $v = Asl_{mid} / (b * d) * (fsv / fc) = 0.04369034$

and confined core properties:

$b = 340.00$
 $d = 327.00$
 $d' = 13.00$
 $fcc (5A.2, TBDY) = 37.35991$
 $cc (5A.5, TBDY) = 0.00332119$
 $c = \text{confinement factor} = 1.13212$
 $1 = Asl_{ten} / (b * d) * (fs_1 / fc) = 0.1094258$
 $2 = Asl_{com} / (b * d) * (fs_2 / fc) = 0.1094258$
 $v = Asl_{mid} / (b * d) * (fsv / fc) = 0.05611603$

Case/Assumption: Unconfined full section - Steel rupture
 ' satisfies Eq. (4.3)

--->
 $v < v_{s,y_2}$ - LHS eq.(4.5) is satisfied
 --->
 $su (4.9) = 0.16193824$
 $Mu = MRc (4.14) = 1.8194E+008$
 $u = su (4.1) = 3.6747033E-005$

 Calculation of ratio lb/ld

 Lap Length: $lb/ld = 0.45297586$
 $lb = 300.00$
 $ld = 662.2869$
 Calculation of lb_{min} according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
 $= 1$
 $db = 14.66667$
 Mean strength value of all re-bars: $fy = 656.5682$
 Mean concrete strength: $fc' = (fc'_{jacket} * Area_{jacket} + fc'_{core} * Area_{core}) / Area_{section} = 29.75$, but $fc'^{0.5} \leq 8.3$
 MPa (22.5.3.1, ACI 318-14)
 $t = 1.00$

$s = 0.80$
 $e = 1.00$
 $cb = 25.00$
 $K_{tr} = 3.43481$
 $A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 257.6106$
 where A_{tr_x} , A_{tr_y} are the sum of the area of all stirrup legs along X and Y local axis
 $s = \text{Max}(s_{\text{external}}, s_{\text{internal}}) = 250.00$
 $n = 12.00$

 Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 633062.661$

Calculation of Shear Strength at edge 1, $V_{r1} = 633062.661$
 $V_{r1} = V_{Col} \text{ ((10.3), ASCE 41-17)} = k_{nl} * V_{Col0}$
 $V_{Col0} = 633062.661$
 $k_{nl} = 1$ (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: $f_c' = (f_c'_{\text{jacket}} * \text{Area}_{\text{jacket}} + f_c'_{\text{core}} * \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 29.75$, but $f_c'^{0.5} \leq 8.3$
 MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$
 $\mu_u = 4.6931004E-013$
 $\nu_u = 6.6805695E-033$
 $d = 0.8 * h = 320.00$
 $N_u = 5926.932$
 $A_g = 160000.00$
 From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 279254.914$
 where:

$V_{s1} = 279254.914$ is calculated for jacket, with:
 $d = 320.00$
 $A_v = 157079.633$
 $f_y = 555.56$
 $s = 100.00$

V_{s1} is multiplied by $\text{Col1} = 1.00$
 $s/d = 0.3125$

$V_{s2} = 0.00$ is calculated for core, with:
 $d = 160.00$
 $A_v = 100530.965$
 $f_y = 444.44$
 $s = 250.00$

V_{s2} is multiplied by $\text{Col2} = 0.00$
 $s/d = 1.5625$

$V_f \text{ ((11-3)-(11.4), ACI 440)} = 188111.148$
 $f = 0.95$, for fully-wrapped sections
 $w_f / s_f = 1$ (FRP strips adjacent to one another).

In (11.3) $\sin + \cos$ is replaced with $(\cot + \cot a) \sin a$ which is more a generalised expression,
 where θ is the angle of the crack direction (see KANEPE).

This later relation, considered as a function $V_f(\theta, a_i)$, is implemented for every different fiber orientation a_i ,
 as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.

orientation 1: $\theta = b1 + 90^\circ = 90.00$
 $V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, a1)|)$, with:
 total thickness per orientation, $t_{f1} = N_L * t / N_{oDir} = 1.016$

$d_{fv} = d$ (figure 11.2, ACI 440) = 357.00
 $f_{fe} \text{ ((11-5), ACI 440)} = 259.312$

$E_f = 64828.00$
 $f_e = 0.004$, from (11.6a), ACI 440
 with $f_u = 0.01$

From (11-11), ACI 440: $V_s + V_f \leq 463788.751$
 $b_w = 400.00$

 Calculation of Shear Strength at edge 2, $V_{r2} = 633062.661$

Vr2 = VCol ((10.3), ASCE 41-17) = knl*VCol0

VCol0 = 633062.661

kn1 = 1 (zero step-static loading)

NOTE: In expression (10-3) 'Vs = Av*fy*d/s' is replaced by 'Vs+ f*Vf'
where Vf is the contribution of FRPs (11.3), ACI 440).

= 1 (normal-weight concrete)

Mean concrete strength: fc' = (fc'_jacket*Area_jacket + fc'_core*Area_core)/Area_section = 29.75, but fc'^0.5 <= 8.3 MPa (22.5.3.1, ACI 318-14)

M/Vd = 2.00

Mu = 4.6931004E-013

Vu = 6.6805695E-033

d = 0.8*h = 320.00

Nu = 5926.932

Ag = 160000.00

From (11.5.4.8), ACI 318-14: Vs = Vs1 + Vs2 = 279254.914

where:

Vs1 = 279254.914 is calculated for jacket, with:

d = 320.00

Av = 157079.633

fy = 555.56

s = 100.00

Vs1 is multiplied by Col1 = 1.00

s/d = 0.3125

Vs2 = 0.00 is calculated for core, with:

d = 160.00

Av = 100530.965

fy = 444.44

s = 250.00

Vs2 is multiplied by Col2 = 0.00

s/d = 1.5625

Vf ((11-3)-(11.4), ACI 440) = 188111.148

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) = 357.00

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 <= 463788.751

bw = 400.00

End Of Calculation of Shear Capacity ratio for element: column JC1 of floor 1

At local axis: 2

Start Of Calculation of Chord Rotation Capacity for element: column JC1 of floor 1

At local axis: 3

Integration Section: (a)

Section Type: rcjrs

Constant Properties

Knowledge Factor, = 0.80

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

Existing material of Secondary Member: Concrete Strength, $f_c = f_{cm} = 20.00$

Existing material of Secondary Member: Steel Strength, $f_s = f_{sm} = 444.44$

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

External Height, $H = 400.00$

External Width, $W = 400.00$

Internal Height, $H = 200.00$

Internal Width, $W = 200.00$

Cover Thickness, $c = 25.00$

Element Length, $L = 3000.00$

Secondary Member

Ribbed Bars

Ductile Steel

Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)

Longitudinal Bars With Ends Lapped Starting at the End Sections

Lap Length $l_b = 300.00$

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $e_{fu} = 0.01$

Number of directions, $N_{oDir} = 1$

Fiber orientations, $b_i = 0.00^\circ$

Number of layers, $N_L = 1$

Radius of rounding corners, $R = 40.00$

Stepwise Properties

Bending Moment, $M = -2.3276E+007$

Shear Force, $V_2 = -7751.185$

Shear Force, $V_3 = 2.6948337E-014$

Axial Force, $F = -6084.055$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: $A_{sl} = 829.3805$

-Compression: $A_{slc} = 1231.504$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension: $A_{sl,ten} = 829.3805$

-Compression: $A_{sl,com} = 829.3805$

-Middle: $A_{sl,mid} = 402.1239$

Longitudinal External Reinforcement Area Distribution (in 3 divisions)

-Tension: $A_{sl,ten,jacket} = 603.1858$

-Compression: $A_{sl,com,jacket} = 603.1858$

-Middle: $A_{sl,mid,jacket} = 402.1239$

Longitudinal Internal Reinforcement Area Distribution (in 3 divisions)

-Tension: $A_{sl,ten,core} = 226.1947$

-Compression: $A_{sl,com,core} = 226.1947$

-Middle: $A_{sl,mid,core} = 0.00$

Mean Diameter of Tension Reinforcement, $DbL = 14.40$

Existing component: From table 7-7, ASCE 41_17: Final chord rotation Capacity $u_{,R} = * u = 0.04024993$

$u = y + p = 0.05031241$

- Calculation of y -

$y = (M_y * L_s / 3) / E_{eff} = 0.00831241$ ((4.29), Biskinis Phd)
 $M_y = 1.4151E+008$
 $L_s = M/V$ (with $L_s > 0.1 * L$ and $L_s < 2 * L$) = 3002.949
 From table 10.5, ASCE 41_17: $E_{eff} = factor * E_c * I_g = 1.7040E+013$
 $factor = 0.30$
 $A_g = 160000.00$
 Mean concrete strength: $f'_c = (f'_{c_jacket} * Area_{jacket} + f'_{c_core} * Area_{core}) / Area_{section} = 29.75$
 $N = 6084.055$
 $E_c * I_g = E_{c_jacket} * I_{g_jacket} + E_{c_core} * I_{g_core} = 5.6801E+013$

Calculation of Yielding Moment M_y

Calculation of y and M_y according to Annex 7 -

$y = \text{Min}(y_{ten}, y_{com})$
 $y_{ten} = 8.5630881E-006$
 with ((10.1), ASCE 41-17) $f_y = \text{Min}(f_y, 1.25 * f_y * (I_b / I_d)^{2/3}) = 454.4281$
 $d = 357.00$
 $y = 0.25674727$
 $A = 0.01452572$
 $B = 0.00817889$
 with $pt = 0.00680078$
 $pc = 0.00580799$
 $pv = 0.00281599$
 $N = 6084.055$
 $b = 400.00$
 $" = 0.12044818$
 $y_{comp} = 2.5299695E-005$
 with f'_c (12.3, (ACI 440)) = 34.65599
 $f_c = 33.00$
 $f_l = 0.93147527$
 $b = 400.00$
 $h = 400.00$
 $A_g = 160000.00$
 From (12.9), ACI 440: $k_a = 0.56708553$
 $g = pt + pc + pv = 0.01443197$
 $rc = 40.00$
 $A_e / A_c = 0.56708553$
 Effective FRP thickness, $t_f = N L * t * \text{Cos}(b_1) = 1.016$
 effective strain from (12.5) and (12.12), $\epsilon_{fe} = 0.004$
 $f_u = 0.01$
 $E_f = 64828.00$
 $E_c = 26999.444$
 $y = 0.25580703$
 $A = 0.01433976$
 $B = 0.00808514$
 with $E_s = 200000.00$

Calculation of ratio I_b / I_d

Lap Length: $I_d / I_{d,min} = 0.56621983$

$I_b = 300.00$

$I_d = 529.8296$

Calculation of I according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

= 1

$db = 14.66667$

Mean strength value of all re-bars: $f_y = 525.2545$

Mean concrete strength: $f'_c = (f'_{c_jacket} * Area_{jacket} + f'_{c_core} * Area_{core}) / Area_{section} = 29.75$, but $f'_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

cb = 25.00
Ktr = 3.43481
Atr = Min(Atr_x,Atr_y) = 257.6106
where Atr_x, Atr_y are the sum of the area of all stirrup legs along X and Y loxal axis
s = Max(s_external,s_internal) = 250.00
n = 12.00

- Calculation of p -

From table 10-8: p = 0.042

with:

- Columns controlled by inadequate development or splicing along the clear height because $l_b/l_d < 1$

shear control ratio $V_y E / V_{CoI} E = 0.19159777$

d = d_external = 357.00

s = s_external = 0.00

t = $s_1 + s_2 + 2*tf/bw*(ffe/fs) = 0.00680078$

jacket: $s_1 = Av_1*h_1/(s_1*Ag) = 0.00392699$

Av1 = 157.0796, is the total area of all stirrups parallel to loading (shear) direction

h1 = 400.00

s1 = 100.00

core: $s_2 = Av_2*h_2/(s_2*Ag) = 0.00050265$

Av2 = 100.531, is the total area of all stirrups parallel to loading (shear) direction

h2 = 200.00

s2 = 250.00

The term $2*tf/bw*(ffe/fs)$ is implemented to account for FRP contribution

where $f = 2*tf/bw$ is FRP ratio (EC8 - 3, A.4.4.3(6)) and ffe/fs normalises f to steel strength

All these variables have already been given in Shear control ratio calculation.

For the normalisation fs of jacket is used.

NUD = 6084.055

Ag = 160000.00

f_{cE} = $(f_{c_jacket}*Area_jacket + f_{c_core}*Area_core)/section_area = 29.75$

f_{yI}E = $(f_{y_ext_Long_Reinf}*Area_ext_Long_Reinf + f_{y_int_Long_Reinf}*Area_int_Long_Reinf)/Area_Tot_Long_Rein =$
531.1678

f_{yT}E = $(f_{y_ext_Trans_Reinf}*Area_ext_Trans_Reinf + f_{y_int_Trans_Reinf}*Area_int_Trans_Reinf)/Area_Tot_Trans_Rein =$
542.9506

pl = $Area_Tot_Long_Rein/(b*d) = 0.01443197$

b = 400.00

d = 357.00

f_{cE} = 29.75

End Of Calculation of Chord Rotation Capacity for element: column JC1 of floor 1

At local axis: 3

Integration Section: (a)

Calculation No. 13

column C1, Floor 1

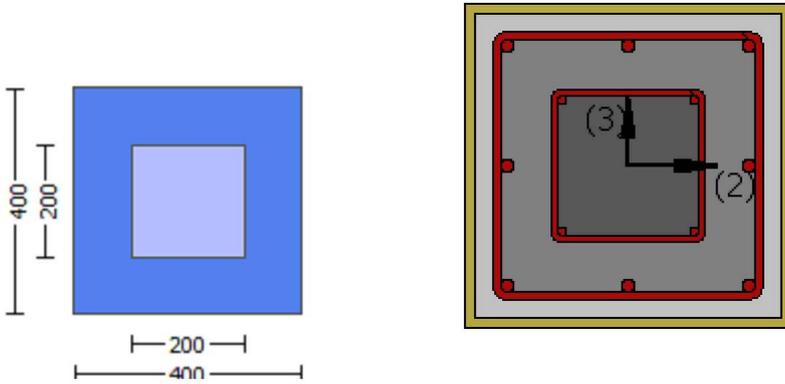
Limit State: Collapse Prevention (data interpolation between analysis steps 2 and 3)

Analysis: Uniform +X

Check: Shear capacity VRd

Edge: End

Local Axis: (2)



Start Of Calculation of Shear Capacity for element: column JC1 of floor 1

At local axis: 2

Integration Section: (b)

Section Type: rcjrs

Constant Properties

Knowledge Factor, $\gamma = 0.80$

Member Shear Force is generally considered as Force-Controlled Action according to Table C7-1, ASCE 41-17.

Lower-bound strengths are used for Force-Controlled Actions according to 7.5.1.3, ASCE 41-17

Consequently:

Jacket

New material of Secondary Member: Concrete Strength, $f_c = f_{c_lower_bound} = 25.00$

New material of Secondary Member: Steel Strength, $f_s = f_{s_lower_bound} = 500.00$

Concrete Elasticity, $E_c = 26999.444$

Steel Elasticity, $E_s = 200000.00$

Existing Column

Existing material of Secondary Member: Concrete Strength, $f_c = f_{c_lower_bound} = 16.00$

Existing material of Secondary Member: Steel Strength, $f_s = f_{s_lower_bound} = 400.00$

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of γ for displacement ductility demand, the expected (mean value) strengths are used (7.5.1.3, ASCE 41-17) because bending is considered as Deformation-Controlled Action (Table C7-1, ASCE 41-17).

Jacket

New material: Concrete Strength, $f_c = f_{cm} = 33.00$

New material: Steel Strength, $f_s = f_{sm} = 555.56$

Existing Column

Existing material: Concrete Strength, $f_c = f_{cm} = 20.00$

Existing material: Steel Strength, $f_s = f_{sm} = 444.44$

#####

External Height, $H = 400.00$

External Width, $W = 400.00$

Internal Height, $H = 200.00$

Internal Width, $W = 200.00$

Cover Thickness, $c = 25.00$

Element Length, $L = 3000.00$

Secondary Member

Ribbed Bars
Ductile Steel
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
Lap Length $l_o = l_b = 300.00$
FRP Wrapping Data
Type: Carbon
Cured laminate properties (design values)
Thickness, $t = 1.016$
Tensile Strength, $f_{fu} = 1055.00$
Tensile Modulus, $E_f = 64828.00$
Elongation, $e_{fu} = 0.01$
Number of directions, $N_{oDir} = 1$
Fiber orientations, $b_i: 0.00^\circ$
Number of layers, $N_L = 1$
Radius of rounding corners, $R = 40.00$

Stepwise Properties

EDGE -A-
Bending Moment, $M_a = -2.3276E+007$
Shear Force, $V_a = -7751.185$
EDGE -B-
Bending Moment, $M_b = 14604.754$
Shear Force, $V_b = 7751.185$
BOTH EDGES
Axial Force, $F = -6084.055$
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: $A_{sl,t} = 0.00$
-Compression: $A_{sl,c} = 2060.885$
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension: $A_{sl,ten} = 829.3805$
-Compression: $A_{sl,com} = 829.3805$
-Middle: $A_{sl,mid} = 402.1239$
Mean Diameter of Tension Reinforcement, $Db_{L,ten} = 14.40$

Existing component: From table 7-7, ASCE 41_17: Final Shear Capacity $V_R = \phi V_n = 447098.232$
 V_n ((10.3), ASCE 41-17) = $k_n \phi V_{CoI0} = 558872.791$
 $V_{CoI} = 558872.791$
 $k_n = 1.00$
displacement_ductility_demand = 0.24700515

NOTE: In expression (10-3) ' $V_s = A_v f_y d/s$ ' is replaced by ' $V_s + \phi V_f$ '
where V_f is the contribution of FRPs (11.3), ACI 440).

= 1 (normal-weight concrete)
Mean concrete strength: $f_c' = (f_c'_{jacket} \cdot Area_{jacket} + f_c'_{core} \cdot Area_{core}) / Area_{section} = 22.75$, but $f_c'^{0.5} \leq 8.3$
MPa (22.5.3.1, ACI 318-14)
 $M/Vd = 2.00$
 $M_u = 14604.754$
 $V_u = 7751.185$
 $d = 0.8 \cdot h = 320.00$
 $N_u = 6084.055$
 $A_g = 160000.00$
From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 251327.412$
where:
 $V_{s1} = 251327.412$ is calculated for jacket, with:
 $d = 320.00$
 $A_v = 157079.633$
 $f_y = 500.00$
 $s = 100.00$
 V_{s1} is multiplied by $CoI1 = 1.00$
 $s/d = 0.3125$

Vs2 = 0.00 is calculated for core, with:

$$d = 160.00$$

$$A_v = 100530.965$$

$$f_y = 400.00$$

$$s = 250.00$$

Vs2 is multiplied by Col2 = 0.00

$$s/d = 1.5625$$

Vf ((11-3)-(11.4), ACI 440) = 188111.148

$$f = 0.95, \text{ for fully-wrapped sections}$$

wf/sf = 1 (FRP strips adjacent to one another).

In (11.3) $\sin + \cos$ is replaced with $(\cot + \cot a) \sin a$ which is more a generalised expression,

where a is the angle of the crack direction (see KANEPE).

This later relation, considered as a function $V_f(\theta, a)$, is implemented for every different fiber orientation a_i , as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.

orientation 1: $\theta = b1 + 90^\circ = 90.00$

$V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, a1)|)$, with:

total thickness per orientation, $t_{f1} = NL * t / \text{NoDir} = 1.016$

$df_v = d$ (figure 11.2, ACI 440) = 357.00

ff_e ((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: $V_s + V_f \leq 405571.497$

$$bw = 400.00$$

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 $\theta = 0.00020512$

$$y = (M_y * L_s / 3) / E_{eff} = 0.00083042 \text{ ((4.29), Biskinis Phd)}$$

$$M_y = 1.4151E+008$$

$$L_s = M/V \text{ (with } L_s > 0.1 * L \text{ and } L_s < 2 * L) = 300.00$$

From table 10.5, ASCE 41_17: $E_{eff} = \text{factor} * E_c * I_g = 1.7040E+013$

$$\text{factor} = 0.30$$

$$A_g = 160000.00$$

$$\text{Mean concrete strength: } f_c' = (f_c'_{\text{jacket}} * A_{\text{jacket}} + f_c'_{\text{core}} * A_{\text{core}}) / A_{\text{section}} = 29.75$$

$$N = 6084.055$$

$$E_c * I_g = E_c * I_{g_{\text{jacket}}} + E_c * I_{g_{\text{core}}} = 5.6801E+013$$

Calculation of Yielding Moment M_y

Calculation of δ / y and M_y according to Annex 7 -

$$y = \text{Min}(y_{\text{ten}}, y_{\text{com}})$$

$$y_{\text{ten}} = 8.5630881E-006$$

$$\text{with ((10.1), ASCE 41-17) } f_y = \text{Min}(f_y, 1.25 * f_y * (I_b / I_d)^{2/3}) = 454.4281$$

$$d = 357.00$$

$$y = 0.25674727$$

$$A = 0.01452572$$

$$B = 0.00817889$$

$$\text{with } p_t = 0.00580799$$

$$p_c = 0.00580799$$

$$p_v = 0.00281599$$

$$N = 6084.055$$

$$b = 400.00$$

$$\theta = 0.12044818$$

$$y_{\text{comp}} = 2.5299695E-005$$

with f_c (12.3, (ACI 440)) = 34.65599

$$f_c = 33.00$$

$$f_l = 0.93147527$$

$$b = 400.00$$

h = 400.00
Ag = 160000.00
From (12.9), ACI 440: ka = 0.56708553
g = pt + pc + pv = 0.01443197
rc = 40.00
Ae/Ac = 0.56708553
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 = 0.25580703
A = 0.01433976
B = 0.00808514
with Es = 200000.00

Calculation of ratio lb/ld

Lap Length: ld/ld,min = 0.56621983

lb = 300.00

ld = 529.8296

Calculation of l according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

= 1

db = 14.66667

Mean strength value of all re-bars: fy = 525.2545

Mean concrete strength: fc' = (fc'_jacket*Area_jacket + fc'_core*Area_core)/Area_section = 29.75, but fc'^0.5 <= 8.3 MPa (22.5.3.1, ACI 318-14)

t = 1.00

s = 0.80

e = 1.00

cb = 25.00

Ktr = 3.43481

Atr = Min(Atr_x,Atr_y) = 257.6106

where Atr_x, Atr_y are the sum of the area of all stirrup legs along X and Y local axis

s = Max(s_external,s_internal) = 250.00

n = 12.00

End Of Calculation of Shear Capacity for element: column JC1 of floor 1

At local axis: 2

Integration Section: (b)

Calculation No. 14

column C1, Floor 1

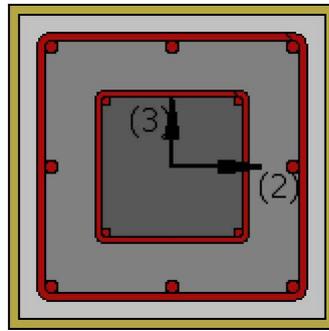
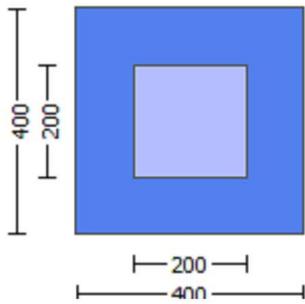
Limit State: Collapse Prevention (data interpolation between analysis steps 2 and 3)

Analysis: Uniform +X

Check: Chord rotation capacity (u)

Edge: End

Local Axis: (2)



Start Of Calculation of Shear Capacity ratio for element: column JC1 of floor 1

At Shear local axis: 3

(Bending local axis: 2)

Section Type: rcjrs

Constant Properties

Knowledge Factor, $\gamma = 0.80$

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

Existing material of Secondary Member: Concrete Strength, $f_c = f_{cm} = 20.00$

Existing material of Secondary Member: Steel Strength, $f_s = f_{sm} = 444.44$

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14

Jacket

New material: Steel Strength, $f_s = 1.25 \cdot f_{sm} = 694.45$

Existing Column

Existing material: Steel Strength, $f_s = 1.25 \cdot f_{sm} = 555.55$

#####

External Height, $H = 400.00$

External Width, $W = 400.00$

Internal Height, $H = 200.00$

Internal Width, $W = 200.00$

Cover Thickness, $c = 25.00$

Mean Confinement Factor overall section = 1.13212

Element Length, $L = 3000.00$

Secondary Member

Ribbed Bars

Ductile Steel

Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)

Longitudinal Bars With Ends Lapped Starting at the End Sections

Lap Length $l_o = 300.00$

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $e_{fu} = 0.01$

Number of directions, $NoDir = 1$

Fiber orientations, $b_i = 0.00^\circ$

Number of layers, $NL = 1$

Radius of rounding corners, $R = 40.00$

Stepwise Properties

At local axis: 3

EDGE -A-

Shear Force, $V_a = 2.8976040E-031$

EDGE -B-

Shear Force, $V_b = -2.8976040E-031$

BOTH EDGES

Axial Force, $F = -5926.932$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: $As_t = 0.00$

-Compression: $As_c = 2060.885$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension: $As_{t,ten} = 829.3805$

-Compression: $As_{l,com} = 829.3805$

-Middle: $As_{l,mid} = 402.1239$

Calculation of Shear Capacity ratio, $V_e/V_r = 0.19159777$

Member Controlled by Flexure ($V_e/V_r < 1$)

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 121293.391$

with

$M_{pr1} = \text{Max}(M_{u1+}, M_{u1-}) = 1.8194E+008$

$M_{u1+} = 1.8194E+008$, is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination

$M_{u1-} = 1.8194E+008$, is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination

$M_{pr2} = \text{Max}(M_{u2+}, M_{u2-}) = 1.8194E+008$

$M_{u2+} = 1.8194E+008$, is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the static loading combination

$M_{u2-} = 1.8194E+008$, is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the static loading combination

Calculation of M_{u1+}

Calculation of ultimate curvature ϕ_u according to 4.1, Biskinis/Fardis 2013:

$\phi_u = 3.6747033E-005$

$M_u = 1.8194E+008$

with full section properties:

$b = 400.00$

$d = 357.00$

$d' = 43.00$

$v = 0.00125773$

$N = 5926.932$

$f_c = 33.00$

α (5A.5, TBDY) = 0.002

Final value of ϕ_u : $\phi_u^* = \text{shear_factor} * \text{Max}(\phi_u, \phi_c) = 0.01505571$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $\phi_u = 0.01505571$

where ϕ_u ((5.4c), TBDY) = $\alpha s_e * \text{sh}_{\min} * f_{ywe} / f_{ce} + \text{Min}(\phi_x, \phi_y) = 0.08345896$

where $\phi = \alpha f * p_f * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$\phi_x = 0.07683125$

$\alpha f = 0.573333333$

$b = 400.00$

$h = 400.00$

From EC8 A.4.4.3(6), $p_f = 2t_f/bw = 0.00508$

$bw = 400.00$

effective stress from (A.35), $f_{fe} = 870.5244$

fy = 0.07683125
af = 0.57333333
b = 400.00
h = 400.00
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 = 0.24250288
ase1 = 0.24250288
bo_1 = 340.00
ho_1 = 340.00
bi2_1 = 462400.00
ase2 = Max(ase1,ase2) = 0.24250288
bo_2 = 192.00
ho_2 = 192.00
bi2_2 = 147456.00
psh,min*Fywe = Min(psh,x*Fywe , psh,y*Fywe) = 3.00635

Expression ((5.4d), TBDY) for psh,min*Fywe has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

psh_x*Fywe = psh1*Fywe1+ps2*Fywe2 = 3.00635
ps1 (external) = (Ash1*h1/s1)/Asec = 0.00392699
Ash1 = Astir_1*ns_1 = 157.0796
No stirrups, ns_1 = 2.00
h1 = 400.00
ps2 (internal) = (Ash2*h2/s2)/Asec = 0.00050265
Ash2 = Astir_2*ns_2 = 100.531
No stirrups, ns_2 = 2.00
h2 = 200.00

psh_y*Fywe = psh1*Fywe1+ps2*Fywe2 = 3.00635
ps1 (external) = (Ash1*h1/s1)/Asec = 0.00392699
Ash1 = Astir_1*ns_1 = 157.0796
No stirrups, ns_1 = 2.00
h1 = 400.00
ps2 (internal) = (Ash2*h2/s2)/Asec = 0.00050265
Ash2 = Astir_2*ns_2 = 100.531
No stirrups, ns_2 = 2.00
h2 = 200.00

Asec = 160000.00
s1 = 100.00
s2 = 250.00
fywe1 = 694.45
fywe2 = 555.55
fce = 33.00

From ((5.A5), TBDY), TBDY: cc = 0.00332119
c = confinement factor = 1.13212

y1 = 0.00184318
sh1 = 0.00589816
ft1 = 580.8818
fy1 = 484.0682
su1 = 0.01099427

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/d = 0.45297586

su1 = 0.4*esu1_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu1_nominal = 0.08,

For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered

characteristic value $f_{sy1} = f_{s1}/1.2$, from table 5.1, TBDY.

y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$, from 10.3.5, ASCE 41-17.

with $f_{s1} = (f_{s,jacket} \cdot A_{s,ten,jacket} + f_{s,core} \cdot A_{s,ten,core})/A_{s,ten} = 484.0682$

with $E_{s1} = (E_{s,jacket} \cdot A_{s,ten,jacket} + E_{s,core} \cdot A_{s,ten,core})/A_{s,ten} = 200000.00$

$y_2 = 0.00184318$

$sh_2 = 0.00589816$

$ft_2 = 580.8818$

$fy_2 = 484.0682$

$su_2 = 0.01099427$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor

and also multiplied by the shear_factor according to 15.7.1.4, with

Shear_factor = 1.00

$l_o/l_{o,min} = l_b/l_{b,min} = 0.45297586$

$su_2 = 0.4 \cdot esu_{2,nominal} ((5.5), TBDY) = 0.032$

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 $f_{s2} = (f_{s,jacket} \cdot A_{s,com,jacket} + f_{s,core} \cdot A_{s,com,core})/A_{s,com} = 484.0682$

with $E_{s2} = (E_{s,jacket} \cdot A_{s,com,jacket} + E_{s,core} \cdot A_{s,com,core})/A_{s,com} = 200000.00$

$y_v = 0.00184318$

$sh_v = 0.00589816$

$ft_v = 614.3968$

$fy_v = 511.9973$

$su_v = 0.01099427$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor

and also multiplied by the shear_factor according to 15.7.1.4, with

Shear_factor = 1.00

$l_o/l_{o,min} = l_b/l_d = 0.45297586$

$su_v = 0.4 \cdot esu_{v,nominal} ((5.5), TBDY) = 0.032$

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 $f_{sv} = (f_{s,jacket} \cdot A_{s,mid,jacket} + f_{s,mid} \cdot A_{s,mid,core})/A_{s,mid} = 511.9973$

with $E_{sv} = (E_{s,jacket} \cdot A_{s,mid,jacket} + E_{s,mid} \cdot A_{s,mid,core})/A_{s,mid} = 200000.00$

$1 = A_{s,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.0851958$

$2 = A_{s,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.0851958$

$v = A_{s,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.04369034$

and confined core properties:

$b = 340.00$

$d = 327.00$

$d' = 13.00$

$f_{cc} (5A.2, TBDY) = 37.35991$

$cc (5A.5, TBDY) = 0.00332119$

$c = \text{confinement factor} = 1.13212$

$1 = A_{s,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.1094258$

$2 = A_{s,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.1094258$

$v = A_{s,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.05611603$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < v_{s,y2}$ - LHS eq.(4.5) is satisfied

--->

$su (4.9) = 0.16193824$

$Mu = MRc (4.14) = 1.8194E+008$

$u = su (4.1) = 3.6747033E-005$

Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.45297586$

$l_b = 300.00$

$l_d = 662.2869$

Calculation of $l_{b,min}$ according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

= 1

$db = 14.66667$
 Mean strength value of all re-bars: $f_y = 656.5682$
 Mean concrete strength: $f_c' = (f_c'_{jacket} \cdot Area_{jacket} + f_c'_{core} \cdot Area_{core}) / Area_{section} = 29.75$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $t = 1.00$
 $s = 0.80$
 $e = 1.00$
 $cb = 25.00$
 $K_{tr} = 3.43481$
 $A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 257.6106$
 where A_{tr_x}, A_{tr_y} are the sum of the area of all stirrup legs along X and Y local axis
 $s = \text{Max}(s_{external}, s_{internal}) = 250.00$
 $n = 12.00$

 Calculation of μ_1 -

Calculation of ultimate curvature μ according to 4.1, Biskinis/Fardis 2013:
 $\mu = 3.6747033E-005$
 $\mu_u = 1.8194E+008$

 with full section properties:

$b = 400.00$
 $d = 357.00$
 $d' = 43.00$
 $v = 0.00125773$
 $N = 5926.932$
 $f_c = 33.00$
 α_1 (5A.5, TBDY) = 0.002

Final value of μ_u : $\mu_u^* = \text{shear_factor} \cdot \text{Max}(\mu_u, \mu_c) = 0.01505571$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $\mu_u = 0.01505571$

where μ_u ((5.4c), TBDY) = $\alpha_1 \cdot s \cdot \text{min}(f_y, f_c) / f_c = 0.08345896$

where $f = \alpha_1 \cdot p_f \cdot f_c / f_c$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

 $f_x = 0.07683125$
 $\alpha_f = 0.57333333$
 $b = 400.00$
 $h = 400.00$

From EC8 A.4.4.3(6), $p_f = 2t_f/b_w = 0.00508$
 $b_w = 400.00$
 effective stress from (A.35), $f_{f,e} = 870.5244$

 $f_y = 0.07683125$
 $\alpha_f = 0.57333333$
 $b = 400.00$
 $h = 400.00$

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, $t_f = NL \cdot t \cdot \text{Cos}(\beta_1) = 1.016$
 $f_{u,f} = 1055.00$
 $E_f = 64828.00$
 $u_{f,e} = 0.015$
 α_{se} ((5.4d), TBDY) = $(\alpha_{se1} \cdot A_{ext} + \alpha_{se2} \cdot A_{int}) / A_{sec} = 0.24250288$
 $\alpha_{se1} = 0.24250288$
 $b_{o,1} = 340.00$
 $h_{o,1} = 340.00$
 $b_{i,1} = 462400.00$
 $\alpha_{se2} = \text{Max}(\alpha_{se1}, \alpha_{se2}) = 0.24250288$
 $b_{o,2} = 192.00$
 $h_{o,2} = 192.00$

$$bi2_2 = 147456.00$$

$$psh,min*Fywe = \text{Min}(psh,x*Fywe, psh,y*Fywe) = 3.00635$$

Expression ((5.4d), TBDY) for $psh,min*Fywe$ has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$$psh_x*Fywe = psh1*Fywe1 + ps2*Fywe2 = 3.00635$$

$$ps1 \text{ (external)} = (Ash1*h1/s1)/Asec = 0.00392699$$

$$Ash1 = Astir_1*ns_1 = 157.0796$$

$$\text{No stirrups, } ns_1 = 2.00$$

$$h1 = 400.00$$

$$ps2 \text{ (internal)} = (Ash2*h2/s2)/Asec = 0.00050265$$

$$Ash2 = Astir_2*ns_2 = 100.531$$

$$\text{No stirrups, } ns_2 = 2.00$$

$$h2 = 200.00$$

$$psh_y*Fywe = psh1*Fywe1 + ps2*Fywe2 = 3.00635$$

$$ps1 \text{ (external)} = (Ash1*h1/s1)/Asec = 0.00392699$$

$$Ash1 = Astir_1*ns_1 = 157.0796$$

$$\text{No stirrups, } ns_1 = 2.00$$

$$h1 = 400.00$$

$$ps2 \text{ (internal)} = (Ash2*h2/s2)/Asec = 0.00050265$$

$$Ash2 = Astir_2*ns_2 = 100.531$$

$$\text{No stirrups, } ns_2 = 2.00$$

$$h2 = 200.00$$

$$Asec = 160000.00$$

$$s1 = 100.00$$

$$s2 = 250.00$$

$$fywe1 = 694.45$$

$$fywe2 = 555.55$$

$$fce = 33.00$$

$$\text{From ((5.A5), TBDY), TBDY: } cc = 0.00332119$$

$$c = \text{confinement factor} = 1.13212$$

$$y1 = 0.00184318$$

$$sh1 = 0.00589816$$

$$ft1 = 580.8818$$

$$fy1 = 484.0682$$

$$su1 = 0.01099427$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$$lo/lou,min = lb/l_d = 0.45297586$$

$$su1 = 0.4*esu1_nominal \text{ ((5.5), TBDY)} = 0.032$$

$$\text{From table 5A.1, TBDY: } esu1_nominal = 0.08,$$

For calculation of $esu1_nominal$ and $y1, sh1, ft1, fy1$, it is considered characteristic value $fsy1 = fs1/1.2$, from table 5.1, TBDY.

$y1, sh1, ft1, fy1$, are also multiplied by $\text{Min}(1, 1.25*(lb/l_d)^{2/3})$, from 10.3.5, ASCE 41-17.

$$\text{with } fs1 = (fs,jacket*Asl,ten,jacket + fs,core*Asl,ten,core)/Asl,ten = 484.0682$$

$$\text{with } Es1 = (Es,jacket*Asl,ten,jacket + Es,core*Asl,ten,core)/Asl,ten = 200000.00$$

$$y2 = 0.00184318$$

$$sh2 = 0.00589816$$

$$ft2 = 580.8818$$

$$fy2 = 484.0682$$

$$su2 = 0.01099427$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$$lo/lou,min = lb/l_b,min = 0.45297586$$

$$su2 = 0.4*esu2_nominal \text{ ((5.5), TBDY)} = 0.032$$

$$\text{From table 5A.1, TBDY: } esu2_nominal = 0.08,$$

For calculation of $esu2_nominal$ and $y2, sh2, ft2, fy2$, it is considered characteristic value $fsy2 = fs2/1.2$, from table 5.1, TBDY.

$y2, sh2, ft2, fy2$, are also multiplied by $\text{Min}(1, 1.25*(lb/l_d)^{2/3})$, from 10.3.5, ASCE 41-17.

$$\text{with } fs2 = (fs,jacket*Asl,com,jacket + fs,core*Asl,com,core)/Asl,com = 484.0682$$

$$\text{with } Es2 = (Es,jacket*Asl,com,jacket + Es,core*Asl,com,core)/Asl,com = 200000.00$$

$$yv = 0.00184318$$

$$shv = 0.00589816$$

$$f_{tv} = 614.3968$$

$$f_{yv} = 511.9973$$

$$s_{uv} = 0.01099427$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$l_o/l_{ou,min} = l_b/l_d = 0.45297586$$

$$s_{uv} = 0.4 * e_{suv,nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: $e_{suv,nominal} = 0.08$,

considering characteristic value $f_{sv} = f_{sv}/1.2$, from table 5.1, TBDY

For calculation of $e_{suv,nominal}$ and γ_v , sh_v, f_{tv}, f_{yv} , it is considered
characteristic value $f_{sv} = f_{sv}/1.2$, from table 5.1, TBDY.

γ_1 , sh_1, f_{t1}, f_{y1} , are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE 41-17.

with $f_{sv} = (f_{s,jacket} * A_{s,mid,jacket} + f_{s,mid} * A_{s,mid,core}) / A_{s,mid} = 511.9973$

with $E_{sv} = (E_{s,jacket} * A_{s,mid,jacket} + E_{s,mid} * A_{s,mid,core}) / A_{s,mid} = 200000.00$

$$1 = A_{s,ten} / (b * d) * (f_{s1} / f_c) = 0.0851958$$

$$2 = A_{s,com} / (b * d) * (f_{s2} / f_c) = 0.0851958$$

$$v = A_{s,mid} / (b * d) * (f_{sv} / f_c) = 0.04369034$$

and confined core properties:

$$b = 340.00$$

$$d = 327.00$$

$$d' = 13.00$$

$$f_{cc} (5A.2, TBDY) = 37.35991$$

$$c_c (5A.5, TBDY) = 0.00332119$$

c = confinement factor = 1.13212

$$1 = A_{s,ten} / (b * d) * (f_{s1} / f_c) = 0.1094258$$

$$2 = A_{s,com} / (b * d) * (f_{s2} / f_c) = 0.1094258$$

$$v = A_{s,mid} / (b * d) * (f_{sv} / f_c) = 0.05611603$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

$v < v_{s,y2}$ - LHS eq.(4.5) is satisfied

$$s_u (4.9) = 0.16193824$$

$$\mu_u = M_{Rc} (4.14) = 1.8194E+008$$

$$u = s_u (4.1) = 3.6747033E-005$$

Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.45297586$

$$l_b = 300.00$$

$$l_d = 662.2869$$

Calculation of l_b,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

$$= 1$$

$$d_b = 14.66667$$

Mean strength value of all re-bars: $f_y = 656.5682$

Mean concrete strength: $f_c' = (f_c',jacket * Area_{jacket} + f_c',core * Area_{core}) / Area_{section} = 29.75$, but $f_c'^{0.5} \leq 8.3$

MPa (22.5.3.1, ACI 318-14)

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 25.00$$

$$K_{tr} = 3.43481$$

$$A_{tr} = \text{Min}(A_{tr,x}, A_{tr,y}) = 257.6106$$

where $A_{tr,x}$, $A_{tr,y}$ are the sum of the area of all stirrup legs along X and Y local axis

$$s = \text{Max}(s_{external}, s_{internal}) = 250.00$$

$$n = 12.00$$

Calculation of μ_{u2+}

Calculation of ultimate curvature μ_u according to 4.1, Biskinis/Fardis 2013:

$$u = 3.6747033E-005$$

Mu = 1.8194E+008

with full section properties:

b = 400.00

d = 357.00

d' = 43.00

v = 0.00125773

N = 5926.932

fc = 33.00

co (5A.5, TBDY) = 0.002

Final value of cu: $cu^* = \text{shear_factor} * \text{Max}(cu, cc) = 0.01505571$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $cu = 0.01505571$

we ((5.4c), TBDY) = $ase * sh_{\min} * fy_{we} / f_{ce} + \text{Min}(fx, fy) = 0.08345896$

where $f = af * pf * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

fx = 0.07683125

af = 0.57333333

b = 400.00

h = 400.00

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 = 0.07683125

af = 0.57333333

b = 400.00

h = 400.00

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) = $(ase1 * A_{ext} + ase2 * A_{int}) / A_{sec} = 0.24250288$

ase1 = 0.24250288

bo_1 = 340.00

ho_1 = 340.00

bi2_1 = 462400.00

ase2 = $\text{Max}(ase1, ase2) = 0.24250288$

bo_2 = 192.00

ho_2 = 192.00

bi2_2 = 147456.00

$psh_{\min} * fy_{we} = \text{Min}(psh_x * fy_{we}, psh_y * fy_{we}) = 3.00635$

Expression ((5.4d), TBDY) for $psh_{\min} * fy_{we}$ has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$psh_x * fy_{we} = psh1 * fy_{we1} + ps2 * fy_{we2} = 3.00635$

ps1 (external) = $(Ash1 * h1 / s1) / A_{sec} = 0.00392699$

Ash1 = $A_{stir_1} * ns_1 = 157.0796$

No stirrups, $ns_1 = 2.00$

h1 = 400.00

ps2 (internal) = $(Ash2 * h2 / s2) / A_{sec} = 0.00050265$

Ash2 = $A_{stir_2} * ns_2 = 100.531$

No stirrups, $ns_2 = 2.00$

h2 = 200.00

$psh_y * fy_{we} = psh1 * fy_{we1} + ps2 * fy_{we2} = 3.00635$

ps1 (external) = $(Ash1 * h1 / s1) / A_{sec} = 0.00392699$

Ash1 = $A_{stir_1} * ns_1 = 157.0796$

No stirrups, $ns_1 = 2.00$

h1 = 400.00

ps2 (internal) = $(Ash2 * h2 / s2) / A_{sec} = 0.00050265$

Ash2 = $A_{stir_2} * ns_2 = 100.531$

No stirrups, ns_2 = 2.00
h2 = 200.00

Asec = 160000.00

s1 = 100.00

s2 = 250.00

fywe1 = 694.45

fywe2 = 555.55

fce = 33.00

From ((5.A.5), TBDY), TBDY: cc = 0.00332119

c = confinement factor = 1.13212

y1 = 0.00184318

sh1 = 0.00589816

ft1 = 580.8818

fy1 = 484.0682

su1 = 0.01099427

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/lb = 0.45297586

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 = 484.0682

with Es1 = (Es,jacket*Asl,ten,jacket + Es,core*Asl,ten,core)/Asl,ten = 200000.00

y2 = 0.00184318

sh2 = 0.00589816

ft2 = 580.8818

fy2 = 484.0682

su2 = 0.01099427

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/lb,min = 0.45297586

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 = 484.0682

with Es2 = (Es,jacket*Asl,com,jacket + Es,core*Asl,com,core)/Asl,com = 200000.00

yv = 0.00184318

shv = 0.00589816

ftv = 614.3968

fyv = 511.9973

suv = 0.01099427

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/lb = 0.45297586

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 = 511.9973

with Esv = (Es,jacket*Asl,mid,jacket + Es,mid*Asl,mid,core)/Asl,mid = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.0851958

2 = Asl,com/(b*d)*(fs2/fc) = 0.0851958

v = Asl,mid/(b*d)*(fsv/fc) = 0.04369034

and confined core properties:

b = 340.00

d = 327.00

d' = 13.00

fcc (5A.2, TBDY) = 37.35991
cc (5A.5, TBDY) = 0.00332119
c = confinement factor = 1.13212
1 = $Asl,ten/(b*d)*(fs1/fc)$ = 0.1094258
2 = $Asl,com/(b*d)*(fs2/fc)$ = 0.1094258
v = $Asl,mid/(b*d)*(fsv/fc)$ = 0.05611603
Case/Assumption: Unconfined full section - Steel rupture
' satisfies Eq. (4.3)

---->
v < vs,y2 - LHS eq.(4.5) is satisfied

---->
su (4.9) = 0.16193824
Mu = MRc (4.14) = 1.8194E+008
u = su (4.1) = 3.6747033E-005

Calculation of ratio lb/l_d

Lap Length: lb/l_d = 0.45297586

lb = 300.00

ld = 662.2869

Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
= 1

db = 14.66667

Mean strength value of all re-bars: fy = 656.5682

Mean concrete strength: fc' = $(fc'_jacket*Area_jacket + fc'_core*Area_core)/Area_section$ = 29.75, but $fc'^{0.5} \leq 8.3$
MPa (22.5.3.1, ACI 318-14)

t = 1.00

s = 0.80

e = 1.00

cb = 25.00

Ktr = 3.43481

Atr = $\text{Min}(Atr_x, Atr_y)$ = 257.6106

where Atr_x, Atr_y are the sum of the area of all stirrup legs along X and Y local axis

s = $\text{Max}(s_external, s_internal)$ = 250.00

n = 12.00

Calculation of Mu2-

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

u = 3.6747033E-005

Mu = 1.8194E+008

with full section properties:

b = 400.00

d = 357.00

d' = 43.00

v = 0.00125773

N = 5926.932

fc = 33.00

co (5A.5, TBDY) = 0.002

Final value of cu: $cu^* = \text{shear_factor} * \text{Max}(cu, cc)$ = 0.01505571

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: cu = 0.01505571

we ((5.4c), TBDY) = $ase * sh, \text{min} * fy_{we} / f_{ce} + \text{Min}(fx, fy)$ = 0.08345896

where f = $af * pf * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

fx = 0.07683125

af = 0.573333333

b = 400.00

h = 400.00

From EC8 A.4.4.3(6), pf = $2tf/bw$ = 0.00508

bw = 400.00

effective stress from (A.35), $f_{f,e} = 870.5244$

$f_y = 0.07683125$

$a_f = 0.57333333$

$b = 400.00$

$h = 400.00$

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, $t_f = NL*t*\cos(b_1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{,f} = 0.015$

$a_{se} ((5.4d), TBDY) = (a_{se1}*A_{ext} + a_{se2}*A_{int})/A_{sec} = 0.24250288$

$a_{se1} = 0.24250288$

$bo_{,1} = 340.00$

$ho_{,1} = 340.00$

$bi_{2,1} = 462400.00$

$a_{se2} = \text{Max}(a_{se1}, a_{se2}) = 0.24250288$

$bo_{,2} = 192.00$

$ho_{,2} = 192.00$

$bi_{2,2} = 147456.00$

$p_{sh,min}*F_{ywe} = \text{Min}(p_{sh,x}*F_{ywe}, p_{sh,y}*F_{ywe}) = 3.00635$

Expression ((5.4d), TBDY) for $p_{sh,min}*F_{ywe}$ has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$p_{sh,x}*F_{ywe} = p_{sh1}*F_{ywe1} + p_{s2}*F_{ywe2} = 3.00635$

p_{s1} (external) = $(A_{sh1}*h_1/s_1)/A_{sec} = 0.00392699$

$A_{sh1} = A_{stir,1}*n_{s,1} = 157.0796$

No stirrups, $n_{s,1} = 2.00$

$h_1 = 400.00$

p_{s2} (internal) = $(A_{sh2}*h_2/s_2)/A_{sec} = 0.00050265$

$A_{sh2} = A_{stir,2}*n_{s,2} = 100.531$

No stirrups, $n_{s,2} = 2.00$

$h_2 = 200.00$

$p_{sh,y}*F_{ywe} = p_{sh1}*F_{ywe1} + p_{s2}*F_{ywe2} = 3.00635$

p_{s1} (external) = $(A_{sh1}*h_1/s_1)/A_{sec} = 0.00392699$

$A_{sh1} = A_{stir,1}*n_{s,1} = 157.0796$

No stirrups, $n_{s,1} = 2.00$

$h_1 = 400.00$

p_{s2} (internal) = $(A_{sh2}*h_2/s_2)/A_{sec} = 0.00050265$

$A_{sh2} = A_{stir,2}*n_{s,2} = 100.531$

No stirrups, $n_{s,2} = 2.00$

$h_2 = 200.00$

$A_{sec} = 160000.00$

$s_1 = 100.00$

$s_2 = 250.00$

$f_{ywe1} = 694.45$

$f_{ywe2} = 555.55$

$f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY: $cc = 0.00332119$

c = confinement factor = 1.13212

$y_1 = 0.00184318$

$sh_1 = 0.00589816$

$ft_1 = 580.8818$

$f_{y1} = 484.0682$

$su_1 = 0.01099427$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$lo/lou,min = lb/d = 0.45297586$

$su_1 = 0.4*es_{u1,nominal} ((5.5), TBDY) = 0.032$

From table 5A.1, TBDY: $es_{u1,nominal} = 0.08$,

For calculation of $esu1_nominal$ 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 $Min(1, 1.25 \cdot (lb/ld)^{2/3})$, from 10.3.5, ASCE 41-17.

with $fs1 = (fs_{jacket} \cdot Asl_{ten,jacket} + fs_{core} \cdot Asl_{ten,core}) / Asl_{ten} = 484.0682$

with $Es1 = (Es_{jacket} \cdot Asl_{ten,jacket} + Es_{core} \cdot Asl_{ten,core}) / Asl_{ten} = 200000.00$

$y2 = 0.00184318$

$sh2 = 0.00589816$

$ft2 = 580.8818$

$fy2 = 484.0682$

$su2 = 0.01099427$

using (30) in Biskinis/Fardis (2013) multiplied with $shear_factor$ and also multiplied by the $shear_factor$ according to 15.7.1.4, with $Shear_factor = 1.00$

$lo/lou,min = lb/lb,min = 0.45297586$

$su2 = 0.4 \cdot esu2_nominal ((5.5), TBDY) = 0.032$

From table 5A.1, TBDY: $esu2_nominal = 0.08$,

For calculation of $esu2_nominal$ and $y2, sh2, ft2, fy2$, it is considered characteristic value $fsy2 = fs2/1.2$, from table 5.1, TBDY.

$y1, sh1, ft1, fy1$, are also multiplied by $Min(1, 1.25 \cdot (lb/ld)^{2/3})$, from 10.3.5, ASCE 41-17.

with $fs2 = (fs_{jacket} \cdot Asl_{com,jacket} + fs_{core} \cdot Asl_{com,core}) / Asl_{com} = 484.0682$

with $Es2 = (Es_{jacket} \cdot Asl_{com,jacket} + Es_{core} \cdot Asl_{com,core}) / Asl_{com} = 200000.00$

$yv = 0.00184318$

$shv = 0.00589816$

$ftv = 614.3968$

$fyv = 511.9973$

$suv = 0.01099427$

using (30) in Biskinis/Fardis (2013) multiplied with $shear_factor$ and also multiplied by the $shear_factor$ according to 15.7.1.4, with $Shear_factor = 1.00$

$lo/lou,min = lb/ld = 0.45297586$

$suv = 0.4 \cdot esuv_nominal ((5.5), TBDY) = 0.032$

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 $fsv = (fs_{jacket} \cdot Asl_{mid,jacket} + fs_{mid} \cdot Asl_{mid,core}) / Asl_{mid} = 511.9973$

with $Es_v = (Es_{jacket} \cdot Asl_{mid,jacket} + Es_{mid} \cdot Asl_{mid,core}) / Asl_{mid} = 200000.00$

1 = $Asl_{ten} / (b \cdot d) \cdot (fs1 / fc) = 0.0851958$

2 = $Asl_{com} / (b \cdot d) \cdot (fs2 / fc) = 0.0851958$

v = $Asl_{mid} / (b \cdot d) \cdot (fsv / fc) = 0.04369034$

and confined core properties:

$b = 340.00$

$d = 327.00$

$d' = 13.00$

$fcc (5A.2, TBDY) = 37.35991$

$cc (5A.5, TBDY) = 0.00332119$

$c = \text{confinement factor} = 1.13212$

1 = $Asl_{ten} / (b \cdot d) \cdot (fs1 / fc) = 0.1094258$

2 = $Asl_{com} / (b \cdot d) \cdot (fs2 / fc) = 0.1094258$

v = $Asl_{mid} / (b \cdot d) \cdot (fsv / fc) = 0.05611603$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < vs,y2$ - LHS eq.(4.5) is satisfied

--->

$su (4.9) = 0.16193824$

$Mu = MRc (4.14) = 1.8194E+008$

$u = su (4.1) = 3.6747033E-005$

Calculation of ratio lb/ld

Lap Length: $lb/ld = 0.45297586$

$lb = 300.00$

$ld = 662.2869$

Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

= 1

db = 14.66667

Mean strength value of all re-bars: $f_y = 656.5682$

Mean concrete strength: $f_c' = (f_c'_{\text{jacket}} \cdot \text{Area}_{\text{jacket}} + f_c'_{\text{core}} \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 29.75$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

t = 1.00

s = 0.80

e = 1.00

cb = 25.00

Ktr = 3.43481

$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 257.6106$

where A_{tr_x} , A_{tr_y} are the sum of the area of all stirrup legs along X and Y local axis

s = $\text{Max}(s_{\text{external}}, s_{\text{internal}}) = 250.00$

n = 12.00

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 633062.661$

Calculation of Shear Strength at edge 1, $V_{r1} = 633062.661$

$V_{r1} = V_{\text{Col}} ((10.3), \text{ASCE } 41-17) = k_{nl} \cdot V_{\text{Col}0}$

$V_{\text{Col}0} = 633062.661$

$k_{nl} = 1$ (zero step-static loading)

NOTE: In expression (10-3) ' $V_s = A_v \cdot f_y \cdot d / s$ ' is replaced by ' $V_s + f \cdot V_f$ '
where V_f is the contribution of FRPs (11.3), ACI 440).

= 1 (normal-weight concrete)

Mean concrete strength: $f_c' = (f_c'_{\text{jacket}} \cdot \text{Area}_{\text{jacket}} + f_c'_{\text{core}} \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 29.75$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

M/Vd = 2.00

$\mu_u = 4.3445556E-012$

$\nu_u = 2.8976040E-031$

d = $0.8 \cdot h = 320.00$

$N_u = 5926.932$

$A_g = 160000.00$

From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 279254.914$

where:

$V_{s1} = 279254.914$ is calculated for jacket, with:

d = 320.00

$A_v = 157079.633$

$f_y = 555.56$

s = 100.00

V_{s1} is multiplied by $\text{Col}1 = 1.00$

s/d = 0.3125

$V_{s2} = 0.00$ is calculated for core, with:

d = 160.00

$A_v = 100530.965$

$f_y = 444.44$

s = 250.00

V_{s2} is multiplied by $\text{Col}2 = 0.00$

s/d = 1.5625

$V_f ((11-3)-(11.4), \text{ACI } 440) = 188111.148$

f = 0.95, for fully-wrapped sections

wf/sf = 1 (FRP strips adjacent to one another).

In (11.3) $\sin + \cos$ is replaced with $(\cot + \cot a) \sin a$ which is more a generalised expression, where θ is the angle of the crack direction (see KANEPE).

This later relation, considered as a function $V_f(\theta, a_i)$, is implemented for every different fiber orientation a_i , as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.

orientation 1: $\theta = 90^\circ = 90.00$

$V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, \theta)|)$, with:

total thickness per orientation, $t_{f1} = N_L \cdot t / \text{NoDir} = 1.016$

$d_{fv} = d$ (figure 11.2, ACI 440) = 357.00

$f_{fe} ((11-5), \text{ACI } 440) = 259.312$

$E_f = 64828.00$

$f_e = 0.004$, from (11.6a), ACI 440

with $f_u = 0.01$

From (11-11), ACI 440: $V_s + V_f \leq 463788.751$
 $bw = 400.00$

Calculation of Shear Strength at edge 2, $V_{r2} = 633062.661$
 $V_{r2} = V_{Col} ((10.3), ASCE 41-17) = knl * V_{Col0}$
 $V_{Col0} = 633062.661$
 $knl = 1$ (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: $f_c' = (f_c'_{jacket} * Area_{jacket} + f_c'_{core} * Area_{core}) / Area_{section} = 29.75$, but $f_c'^{0.5} \leq 8.3$
MPa (22.5.3.1, ACI 318-14)

$M / Vd = 2.00$

$\mu_u = 4.3445556E-012$

$V_u = 2.8976040E-031$

$d = 0.8 * h = 320.00$

$N_u = 5926.932$

$A_g = 160000.00$

From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 279254.914$

where:

$V_{s1} = 279254.914$ is calculated for jacket, with:

$d = 320.00$

$A_v = 157079.633$

$f_y = 555.56$

$s = 100.00$

V_{s1} is multiplied by $Col1 = 1.00$

$s/d = 0.3125$

$V_{s2} = 0.00$ is calculated for core, with:

$d = 160.00$

$A_v = 100530.965$

$f_y = 444.44$

$s = 250.00$

V_{s2} is multiplied by $Col2 = 0.00$

$s/d = 1.5625$

$V_f ((11-3)-(11.4), ACI 440) = 188111.148$

$f = 0.95$, for fully-wrapped sections

$w_f / s_f = 1$ (FRP strips adjacent to one another).

In (11.3) $\sin + \cos$ is replaced with $(\cot + \cot_a) \sin a$ which is more a generalised expression,
where a is the angle of the crack direction (see KANEPE).

This later relation, considered as a function $V_f(a)$, is implemented for every different fiber orientation a_i ,
as well as for 2 crack directions, $a = 45^\circ$ and $a = -45^\circ$ to take into consideration the cyclic seismic loading.

orientation 1: $a_1 = b_1 + 90^\circ = 90.00$

$V_f = \text{Min}(|V_f(45, a_1)|, |V_f(-45, a_1)|)$, with:

total thickness per orientation, $t_{f1} = NL * t / \text{NoDir} = 1.016$

$d_{fv} = d$ (figure 11.2, ACI 440) = 357.00

$f_{fe} ((11-5), ACI 440) = 259.312$

$E_f = 64828.00$

$f_e = 0.004$, from (11.6a), ACI 440

with $f_u = 0.01$

From (11-11), ACI 440: $V_s + V_f \leq 463788.751$
 $bw = 400.00$

End Of Calculation of Shear Capacity ratio for element: column JC1 of floor 1
At local axis: 3

Start Of Calculation of Shear Capacity ratio for element: column JC1 of floor 1
At Shear local axis: 2
(Bending local axis: 3)
Section Type: rcjrs

Constant Properties

Knowledge Factor, $\gamma = 0.80$

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

Existing material of Secondary Member: Concrete Strength, $f_c = f_{cm} = 20.00$

Existing material of Secondary Member: Steel Strength, $f_s = f_{sm} = 444.44$

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14

Jacket

New material: Steel Strength, $f_s = 1.25 \cdot f_{sm} = 694.45$

Existing Column

Existing material: Steel Strength, $f_s = 1.25 \cdot f_{sm} = 555.55$

#####

External Height, $H = 400.00$

External Width, $W = 400.00$

Internal Height, $H = 200.00$

Internal Width, $W = 200.00$

Cover Thickness, $c = 25.00$

Mean Confinement Factor overall section = 1.13212

Element Length, $L = 3000.00$

Secondary Member

Ribbed Bars

Ductile Steel

Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)

Longitudinal Bars With Ends Lapped Starting at the End Sections

Lap Length $l_o = 300.00$

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $e_{fu} = 0.01$

Number of directions, $N_{oDir} = 1$

Fiber orientations, $b_i = 0.00^\circ$

Number of layers, $N_L = 1$

Radius of rounding corners, $R = 40.00$

Stepwise Properties

At local axis: 2

EDGE -A-

Shear Force, $V_a = -6.6805695E-033$

EDGE -B-

Shear Force, $V_b = 6.6805695E-033$

BOTH EDGES

Axial Force, $F = -5926.932$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: $A_{sl,t} = 0.00$

-Compression: $A_{sl,c} = 2060.885$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension: $A_{sl,ten} = 829.3805$

-Compression: $A_{sl,com} = 829.3805$

-Middle: $A_{sl,mid} = 402.1239$

Calculation of Shear Capacity ratio , $V_e/V_r = 0.19159777$

Member Controlled by Flexure ($V_e/V_r < 1$)

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 121293.391$

with
 $M_{pr1} = \text{Max}(M_{u1+} , M_{u1-}) = 1.8194E+008$
 $M_{u1+} = 1.8194E+008$, is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination
 $M_{u1-} = 1.8194E+008$, is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination
 $M_{pr2} = \text{Max}(M_{u2+} , M_{u2-}) = 1.8194E+008$
 $M_{u2+} = 1.8194E+008$, is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the the static loading combination
 $M_{u2-} = 1.8194E+008$, is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the the static loading combination

Calculation of M_{u1+}

Calculation of ultimate curvature ϕ_u according to 4.1, Biskinis/Fardis 2013:

$\phi_u = 3.6747033E-005$

$M_u = 1.8194E+008$

with full section properties:

$b = 400.00$

$d = 357.00$

$d' = 43.00$

$\nu = 0.00125773$

$N = 5926.932$

$f_c = 33.00$

$\alpha_{co} (5A.5, TBDY) = 0.002$

Final value of ϕ_{cu} : $\phi_{cu}^* = \text{shear_factor} * \text{Max}(\phi_{cu}, \phi_{cc}) = 0.01505571$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $\phi_{cu} = 0.01505571$

$\phi_{we} ((5.4c), TBDY) = \alpha_{se} * \phi_{h,min} * f_{ywe}/f_{ce} + \text{Min}(\phi_{fx}, \phi_{fy}) = 0.08345896$

where $\phi_{fx} = \alpha_{f} * \phi_{pf} * f_{fe}/f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$\phi_{fx} = 0.07683125$

$\alpha_f = 0.57333333$

$b = 400.00$

$h = 400.00$

From EC8 A.4.4.3(6), $\phi_{pf} = 2t_f/b_w = 0.00508$

$b_w = 400.00$

effective stress from (A.35), $f_{f,e} = 870.5244$

$\phi_{fy} = 0.07683125$

$\alpha_f = 0.57333333$

$b = 400.00$

$h = 400.00$

From EC8 A.4.4.3(6), $\phi_{pf} = 2t_f/b_w = 0.00508$

$b_w = 400.00$

effective stress from (A.35), $f_{f,e} = 870.5244$

$R = 40.00$

Effective FRP thickness, $t_f = N L * t * \text{Cos}(b_1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{,f} = 0.015$

ase ((5.4d), TBDY) = $(\alpha_{se1} * A_{ext} + \alpha_{se2} * A_{int}) / A_{sec} = 0.24250288$

$\alpha_{se1} = 0.24250288$

$b_{o,1} = 340.00$

$h_{o,1} = 340.00$

$b_{i,1} = 462400.00$

$$ase2 = \text{Max}(ase1, ase2) = 0.24250288$$

$$bo_2 = 192.00$$

$$ho_2 = 192.00$$

$$bi2_2 = 147456.00$$

$$psh, \text{min} * Fywe = \text{Min}(psh, x * Fywe, psh, y * Fywe) = 3.00635$$

Expression ((5.4d), TBDY) for psh, min * Fywe has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$$psh_x * Fywe = psh1 * Fywe1 + ps2 * Fywe2 = 3.00635$$

$$ps1 \text{ (external)} = (Ash1 * h1 / s1) / Asec = 0.00392699$$

$$Ash1 = Astir_1 * ns_1 = 157.0796$$

$$\text{No stirrups, } ns_1 = 2.00$$

$$h1 = 400.00$$

$$ps2 \text{ (internal)} = (Ash2 * h2 / s2) / Asec = 0.00050265$$

$$Ash2 = Astir_2 * ns_2 = 100.531$$

$$\text{No stirrups, } ns_2 = 2.00$$

$$h2 = 200.00$$

$$psh_y * Fywe = psh1 * Fywe1 + ps2 * Fywe2 = 3.00635$$

$$ps1 \text{ (external)} = (Ash1 * h1 / s1) / Asec = 0.00392699$$

$$Ash1 = Astir_1 * ns_1 = 157.0796$$

$$\text{No stirrups, } ns_1 = 2.00$$

$$h1 = 400.00$$

$$ps2 \text{ (internal)} = (Ash2 * h2 / s2) / Asec = 0.00050265$$

$$Ash2 = Astir_2 * ns_2 = 100.531$$

$$\text{No stirrups, } ns_2 = 2.00$$

$$h2 = 200.00$$

$$Asec = 160000.00$$

$$s1 = 100.00$$

$$s2 = 250.00$$

$$fywe1 = 694.45$$

$$fywe2 = 555.55$$

$$fce = 33.00$$

From ((5.A5), TBDY), TBDY: $cc = 0.00332119$

$$c = \text{confinement factor} = 1.13212$$

$$y1 = 0.00184318$$

$$sh1 = 0.00589816$$

$$ft1 = 580.8818$$

$$fy1 = 484.0682$$

$$su1 = 0.01099427$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$$lo/lou, \text{min} = lb/ld = 0.45297586$$

$$su1 = 0.4 * esu1_nominal \text{ ((5.5), TBDY)} = 0.032$$

From table 5A.1, TBDY: $esu1_nominal = 0.08$,

For calculation of $esu1_nominal$ and $y1, sh1, ft1, fy1$, it is considered characteristic value $fsy1 = fs1/1.2$, from table 5.1, TBDY.

$y1, sh1, ft1, fy1$, are also multiplied by $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE 41-17.

$$\text{with } fs1 = (fs, \text{jacket} * Asl, \text{ten, jacket} + fs, \text{core} * Asl, \text{ten, core}) / Asl, \text{ten} = 484.0682$$

$$\text{with } Es1 = (Es, \text{jacket} * Asl, \text{ten, jacket} + Es, \text{core} * Asl, \text{ten, core}) / Asl, \text{ten} = 200000.00$$

$$y2 = 0.00184318$$

$$sh2 = 0.00589816$$

$$ft2 = 580.8818$$

$$fy2 = 484.0682$$

$$su2 = 0.01099427$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$$lo/lou, \text{min} = lb/lb, \text{min} = 0.45297586$$

$$su2 = 0.4 * esu2_nominal \text{ ((5.5), TBDY)} = 0.032$$

From table 5A.1, TBDY: $esu2_nominal = 0.08$,

For calculation of $esu2_nominal$ and $y2, sh2, ft2, fy2$, it is considered characteristic value $fsy2 = fs2/1.2$, from table 5.1, TBDY.

$y1, sh1, ft1, fy1$, are also multiplied by $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE 41-17.

$$\text{with } fs2 = (fs, \text{jacket} * Asl, \text{com, jacket} + fs, \text{core} * Asl, \text{com, core}) / Asl, \text{com} = 484.0682$$

with $E_s2 = (E_{s,jacket} \cdot A_{s,com,jacket} + E_{s,core} \cdot A_{s,com,core}) / A_{s,com} = 200000.00$

$y_v = 0.00184318$
 $sh_v = 0.00589816$
 $ft_v = 614.3968$
 $fy_v = 511.9973$
 $su_v = 0.01099427$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$l_o/l_{o,min} = l_b/l_d = 0.45297586$
 $su_v = 0.4 \cdot esuv_nominal((5.5), TBDY) = 0.032$
From table 5A.1, TBDY: $esuv_nominal = 0.08$,
considering characteristic value $fs_yv = fsv/1.2$, from table 5.1, TBDY
For calculation of $esuv_nominal$ and y_v, sh_v, ft_v, fy_v , it is considered
characteristic value $fs_yv = fsv/1.2$, from table 5.1, TBDY.
 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 $fsv = (f_{s,jacket} \cdot A_{s,mid,jacket} + f_{s,mid} \cdot A_{s,mid,core}) / A_{s,mid} = 511.9973$
with $E_{sv} = (E_{s,jacket} \cdot A_{s,mid,jacket} + E_{s,mid} \cdot A_{s,mid,core}) / A_{s,mid} = 200000.00$

$1 = A_{s,ten} / (b \cdot d) \cdot (f_{s1} / f_c) = 0.0851958$
 $2 = A_{s,com} / (b \cdot d) \cdot (f_{s2} / f_c) = 0.0851958$
 $v = A_{s,mid} / (b \cdot d) \cdot (f_{sv} / f_c) = 0.04369034$

and confined core properties:

$b = 340.00$
 $d = 327.00$
 $d' = 13.00$
 $f_{cc}(5A.2, TBDY) = 37.35991$
 $cc(5A.5, TBDY) = 0.00332119$
 $c = \text{confinement factor} = 1.13212$
 $1 = A_{s,ten} / (b \cdot d) \cdot (f_{s1} / f_c) = 0.1094258$
 $2 = A_{s,com} / (b \cdot d) \cdot (f_{s2} / f_c) = 0.1094258$
 $v = A_{s,mid} / (b \cdot d) \cdot (f_{sv} / f_c) = 0.05611603$

Case/Assumption: Unconfined full section - Steel rupture
'satisfies Eq. (4.3)

--->
 $v < v_{s,y2}$ - LHS eq.(4.5) is satisfied
--->
 $su(4.9) = 0.16193824$
 $Mu = MRc(4.14) = 1.8194E+008$
 $u = su(4.1) = 3.6747033E-005$

Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.45297586$
 $l_b = 300.00$
 $l_d = 662.2869$

Calculation of l_b,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
= 1
 $db = 14.66667$
Mean strength value of all re-bars: $fy = 656.5682$
Mean concrete strength: $fc' = (fc'_{jacket} \cdot Area_{jacket} + fc'_{core} \cdot Area_{core}) / Area_{section} = 29.75$, but $fc'^{0.5} \leq 8.3$
MPa (22.5.3.1, ACI 318-14)

$t = 1.00$
 $s = 0.80$
 $e = 1.00$
 $cb = 25.00$
 $K_{tr} = 3.43481$
 $A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 257.6106$
where A_{tr_x}, A_{tr_y} are the sum of the area of all stirrup legs along X and Y loxal axis
 $s = \text{Max}(s_{external}, s_{internal}) = 250.00$
 $n = 12.00$

Calculation of $Mu1$ -

Calculation of ultimate curvature ϕ_u according to 4.1, Biskinis/Fardis 2013:

$$u = 3.6747033E-005$$

$$Mu = 1.8194E+008$$

with full section properties:

$$b = 400.00$$

$$d = 357.00$$

$$d' = 43.00$$

$$v = 0.00125773$$

$$N = 5926.932$$

$$f_c = 33.00$$

$$co(5A.5, TBDY) = 0.002$$

$$\text{Final value of } \phi_u: \phi_u^* = \text{shear_factor} * \text{Max}(\phi_{cu}, \phi_{cc}) = 0.01505571$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \phi_{cu} = 0.01505571$$

$$\phi_{we} \text{ ((5.4c), TBDY) } = a_{se} * \text{sh}_{,min} * f_{ywe} / f_{ce} + \text{Min}(\phi_{fx}, \phi_{fy}) = 0.08345896$$

where $\phi_f = a_f * p_f * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$\phi_{fx} = 0.07683125$$

$$a_f = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 870.5244$$

$$\phi_{fy} = 0.07683125$$

$$a_f = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 870.5244$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L * t * \text{Cos}(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$a_{se} \text{ ((5.4d), TBDY) } = (a_{se1} * A_{ext} + a_{se2} * A_{int}) / A_{sec} = 0.24250288$$

$$a_{se1} = 0.24250288$$

$$b_{o,1} = 340.00$$

$$h_{o,1} = 340.00$$

$$b_{i2,1} = 462400.00$$

$$a_{se2} = \text{Max}(a_{se1}, a_{se2}) = 0.24250288$$

$$b_{o,2} = 192.00$$

$$h_{o,2} = 192.00$$

$$b_{i2,2} = 147456.00$$

$$p_{sh,min} * F_{ywe} = \text{Min}(p_{sh,x} * F_{ywe}, p_{sh,y} * F_{ywe}) = 3.00635$$

Expression ((5.4d), TBDY) for $p_{sh,min} * F_{ywe}$ has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$$p_{sh,x} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{sh2} * F_{ywe2} = 3.00635$$

$$p_{sh1} \text{ (external) } = (A_{sh1} * h_1 / s_1) / A_{sec} = 0.00392699$$

$$A_{sh1} = A_{stir,1} * n_{s,1} = 157.0796$$

$$\text{No stirrups, } n_{s,1} = 2.00$$

$$h_1 = 400.00$$

$$p_{sh2} \text{ (internal) } = (A_{sh2} * h_2 / s_2) / A_{sec} = 0.00050265$$

$$A_{sh2} = A_{stir,2} * n_{s,2} = 100.531$$

$$\text{No stirrups, } n_{s,2} = 2.00$$

$$h_2 = 200.00$$

$$p_{sh,y} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{sh2} * F_{ywe2} = 3.00635$$

$$p_{sh1} \text{ (external) } = (A_{sh1} * h_1 / s_1) / A_{sec} = 0.00392699$$

$$A_{sh1} = A_{stir,1} * n_{s,1} = 157.0796$$

$$\text{No stirrups, } n_{s,1} = 2.00$$

h1 = 400.00
ps2 (internal) = (Ash2*h2/s2)/Asec = 0.00050265
Ash2 = Astir_2*ns_2 = 100.531
No stirups, ns_2 = 2.00
h2 = 200.00

Asec = 160000.00
s1 = 100.00
s2 = 250.00
fywe1 = 694.45
fywe2 = 555.55
fce = 33.00

From ((5.A5), TBDY), TBDY: cc = 0.00332119
c = confinement factor = 1.13212

y1 = 0.00184318
sh1 = 0.00589816
ft1 = 580.8818
fy1 = 484.0682
su1 = 0.01099427

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/d = 0.45297586
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 = 484.0682

with Es1 = (Es,jacket*Asl,ten,jacket + Es,core*Asl,ten,core)/Asl,ten = 200000.00

y2 = 0.00184318
sh2 = 0.00589816
ft2 = 580.8818
fy2 = 484.0682
su2 = 0.01099427

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/lb,min = 0.45297586
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 = 484.0682

with Es2 = (Es,jacket*Asl,com,jacket + Es,core*Asl,com,core)/Asl,com = 200000.00

yv = 0.00184318
shv = 0.00589816
ftv = 614.3968
fyv = 511.9973
suv = 0.01099427

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/d = 0.45297586
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 = 511.9973

with Esv = (Es,jacket*Asl,mid,jacket + Es,mid*Asl,mid,core)/Asl,mid = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.0851958

2 = Asl,com/(b*d)*(fs2/fc) = 0.0851958

v = Asl,mid/(b*d)*(fsv/fc) = 0.04369034

and confined core properties:

$b = 340.00$
 $d = 327.00$
 $d' = 13.00$
 $f_{cc} (5A.2, TBDY) = 37.35991$
 $cc (5A.5, TBDY) = 0.00332119$
 $c = \text{confinement factor} = 1.13212$
 $1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.1094258$
 $2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.1094258$
 $v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.05611603$
 Case/Assumption: Unconfined full section - Steel rupture
 ' satisfies Eq. (4.3)

--->
 $v < v_{s,y2}$ - LHS eq.(4.5) is satisfied
 --->
 $su (4.9) = 0.16193824$
 $Mu = MRc (4.14) = 1.8194E+008$
 $u = su (4.1) = 3.6747033E-005$

 Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.45297586$

$l_b = 300.00$

$l_d = 662.2869$

Calculation of l_b, \min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

= 1

$db = 14.66667$

Mean strength value of all re-bars: $f_y = 656.5682$

Mean concrete strength: $f_c' = (f_c'_{jacket} * Area_{jacket} + f_c'_{core} * Area_{core}) / Area_{section} = 29.75$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 3.43481$

$A_{tr} = \text{Min}(A_{tr,x}, A_{tr,y}) = 257.6106$

where $A_{tr,x}$, $A_{tr,y}$ are the sum of the area of all stirrup legs along X and Y loxal axis

$s = \text{Max}(s_{external}, s_{internal}) = 250.00$

$n = 12.00$

 Calculation of Mu_{2+}

 Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

$u = 3.6747033E-005$

$Mu = 1.8194E+008$

 with full section properties:

$b = 400.00$

$d = 357.00$

$d' = 43.00$

$v = 0.00125773$

$N = 5926.932$

$f_c = 33.00$

$co (5A.5, TBDY) = 0.002$

Final value of cu : $cu^* = \text{shear_factor} * \text{Max}(cu, cc) = 0.01505571$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $cu = 0.01505571$

we ((5.4c), TBDY) = $ase * sh, \min * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.08345896$

where $f = af * pf * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

 $f_x = 0.07683125$

$af = 0.57333333$

$b = 400.00$

h = 400.00
From EC8 A4.4.3(6), $pf = 2tf/bw = 0.00508$
bw = 400.00
effective stress from (A.35), $ff,e = 870.5244$

fy = 0.07683125
af = 0.57333333
b = 400.00
h = 400.00
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, $tf = NL*t*Cos(b1) = 1.016$
fu,f = 1055.00
Ef = 64828.00
u,f = 0.015
 $ase ((5.4d), TBDY) = (ase1*Aext+ase2*Aint)/Asec = 0.24250288$
ase1 = 0.24250288
bo_1 = 340.00
ho_1 = 340.00
bi2_1 = 462400.00
ase2 = Max(ase1,ase2) = 0.24250288
bo_2 = 192.00
ho_2 = 192.00
bi2_2 = 147456.00

$psh,min*Fywe = Min(psh,x*Fywe, psh,y*Fywe) = 3.00635$
Expression ((5.4d), TBDY) for $psh,min*Fywe$ has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$psh_x*Fywe = psh1*Fywe1+ps2*Fywe2 = 3.00635$
ps1 (external) = $(Ash1*h1/s1)/Asec = 0.00392699$
Ash1 = Astir_1*ns_1 = 157.0796
No stirrups, ns_1 = 2.00
h1 = 400.00
ps2 (internal) = $(Ash2*h2/s2)/Asec = 0.00050265$
Ash2 = Astir_2*ns_2 = 100.531
No stirrups, ns_2 = 2.00
h2 = 200.00

$psh_y*Fywe = psh1*Fywe1+ps2*Fywe2 = 3.00635$
ps1 (external) = $(Ash1*h1/s1)/Asec = 0.00392699$
Ash1 = Astir_1*ns_1 = 157.0796
No stirrups, ns_1 = 2.00
h1 = 400.00
ps2 (internal) = $(Ash2*h2/s2)/Asec = 0.00050265$
Ash2 = Astir_2*ns_2 = 100.531
No stirrups, ns_2 = 2.00
h2 = 200.00

Asec = 160000.00
s1 = 100.00
s2 = 250.00
fywe1 = 694.45
fywe2 = 555.55
fce = 33.00

From ((5.A5), TBDY), TBDY: $cc = 0.00332119$
c = confinement factor = 1.13212

y1 = 0.00184318
sh1 = 0.00589816
ft1 = 580.8818
fy1 = 484.0682
su1 = 0.01099427

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$l_0/l_{ou,min} = l_b/l_d = 0.45297586$$

$$s_u1 = 0.4 \cdot e_{su1_nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: $e_{su1_nominal} = 0.08$,

For calculation of $e_{su1_nominal}$ and y_1, sh_1, ft_1, fy_1 , it is considered characteristic value $f_{sy1} = f_{s1}/1.2$, from table 5.1, TBDY.

y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$, from 10.3.5, ASCE 41-17.

$$\text{with } f_{s1} = (f_{s,jacket} \cdot A_{s,ten,jacket} + f_{s,core} \cdot A_{s,ten,core}) / A_{s,ten} = 484.0682$$

$$\text{with } E_{s1} = (E_{s,jacket} \cdot A_{s,ten,jacket} + E_{s,core} \cdot A_{s,ten,core}) / A_{s,ten} = 200000.00$$

$$y_2 = 0.00184318$$

$$sh_2 = 0.00589816$$

$$ft_2 = 580.8818$$

$$fy_2 = 484.0682$$

$$s_u2 = 0.01099427$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$$l_0/l_{ou,min} = l_b/l_{b,min} = 0.45297586$$

$$s_u2 = 0.4 \cdot e_{su2_nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: $e_{su2_nominal} = 0.08$,

For calculation of $e_{su2_nominal}$ and y_2, sh_2, ft_2, fy_2 , it is considered characteristic value $f_{sy2} = f_{s2}/1.2$, from table 5.1, TBDY.

y_2, sh_2, ft_2, fy_2 , are also multiplied by $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$, from 10.3.5, ASCE 41-17.

$$\text{with } f_{s2} = (f_{s,jacket} \cdot A_{s,com,jacket} + f_{s,core} \cdot A_{s,com,core}) / A_{s,com} = 484.0682$$

$$\text{with } E_{s2} = (E_{s,jacket} \cdot A_{s,com,jacket} + E_{s,core} \cdot A_{s,com,core}) / A_{s,com} = 200000.00$$

$$y_v = 0.00184318$$

$$sh_v = 0.00589816$$

$$ft_v = 614.3968$$

$$fy_v = 511.9973$$

$$s_{uv} = 0.01099427$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$$l_0/l_{ou,min} = l_b/l_d = 0.45297586$$

$$s_{uv} = 0.4 \cdot e_{suv_nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: $e_{suv_nominal} = 0.08$,

considering characteristic value $f_{syv} = f_{sv}/1.2$, from table 5.1, TBDY

For calculation of $e_{suv_nominal}$ and y_v, sh_v, ft_v, fy_v , it is considered characteristic value $f_{syv} = f_{sv}/1.2$, from table 5.1, TBDY.

y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$, from 10.3.5, ASCE 41-17.

$$\text{with } f_{sv} = (f_{s,jacket} \cdot A_{s,mid,jacket} + f_{s,mid} \cdot A_{s,mid,core}) / A_{s,mid} = 511.9973$$

$$\text{with } E_{sv} = (E_{s,jacket} \cdot A_{s,mid,jacket} + E_{s,mid} \cdot A_{s,mid,core}) / A_{s,mid} = 200000.00$$

$$1 = A_{s,ten} / (b \cdot d) \cdot (f_{s1} / f_c) = 0.0851958$$

$$2 = A_{s,com} / (b \cdot d) \cdot (f_{s2} / f_c) = 0.0851958$$

$$v = A_{s,mid} / (b \cdot d) \cdot (f_{sv} / f_c) = 0.04369034$$

and confined core properties:

$$b = 340.00$$

$$d = 327.00$$

$$d' = 13.00$$

$$f_{cc} (5A.2, TBDY) = 37.35991$$

$$c_c (5A.5, TBDY) = 0.00332119$$

$$c = \text{confinement factor} = 1.13212$$

$$1 = A_{s,ten} / (b \cdot d) \cdot (f_{s1} / f_c) = 0.1094258$$

$$2 = A_{s,com} / (b \cdot d) \cdot (f_{s2} / f_c) = 0.1094258$$

$$v = A_{s,mid} / (b \cdot d) \cdot (f_{sv} / f_c) = 0.05611603$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < v_{s,y2}$ - LHS eq.(4.5) is satisfied

--->

$$s_u (4.9) = 0.16193824$$

$$\mu = MR_c (4.14) = 1.8194E+008$$

$$u = s_u (4.1) = 3.6747033E-005$$

Calculation of ratio l_b/l_d

$$\text{Lap Length: } l_b/l_d = 0.45297586$$

$$I_b = 300.00$$

$$I_d = 662.2869$$

Calculation of $I_{b,min}$ according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

$$= 1$$

$$d_b = 14.66667$$

$$\text{Mean strength value of all re-bars: } f_y = 656.5682$$

$$\text{Mean concrete strength: } f_c' = (f_c'_{\text{jacket}} \cdot \text{Area}_{\text{jacket}} + f_c'_{\text{core}} \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 29.75, \text{ but } f_c'^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 25.00$$

$$K_{tr} = 3.43481$$

$$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 257.6106$$

where A_{tr_x} , A_{tr_y} are the sum of the area of all stirrup legs along X and Y local axis

$$s = \text{Max}(s_{\text{external}}, s_{\text{internal}}) = 250.00$$

$$n = 12.00$$

Calculation of μ_2 -

Calculation of ultimate curvature μ according to 4.1, Biskinis/Fardis 2013:

$$\mu = 3.6747033E-005$$

$$\mu_2 = 1.8194E+008$$

with full section properties:

$$b = 400.00$$

$$d = 357.00$$

$$d' = 43.00$$

$$v = 0.00125773$$

$$N = 5926.932$$

$$f_c = 33.00$$

$$c_o \text{ (5A.5, TBDY)} = 0.002$$

$$\text{Final value of } \mu: \mu^* = \text{shear_factor} \cdot \text{Max}(\mu_c, \mu_{cc}) = 0.01505571$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } \mu_c = 0.01505571$$

$$\mu_{cc} \text{ ((5.4c), TBDY)} = a_{se} \cdot \text{sh}_{, \text{min}} \cdot f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.08345896$$

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)

$$f_x = 0.07683125$$

$$a_f = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{fe} = 870.5244$$

$$f_y = 0.07683125$$

$$a_f = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{fe} = 870.5244$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L^* t \cos(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$a_{se} \text{ ((5.4d), TBDY)} = (a_{se1} \cdot A_{ext} + a_{se2} \cdot A_{int}) / A_{sec} = 0.24250288$$

$$a_{se1} = 0.24250288$$

$$b_{o,1} = 340.00$$

$$h_{o,1} = 340.00$$

bi2_1 = 462400.00
ase2 = Max(ase1,ase2) = 0.24250288
bo_2 = 192.00
ho_2 = 192.00
bi2_2 = 147456.00

psh,min*Fywe = Min(psh,x*Fywe , psh,y*Fywe) = 3.00635

Expression ((5.4d), TBDY) for psh,min*Fywe has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

psh_x*Fywe = psh1*Fywe1+ps2*Fywe2 = 3.00635
ps1 (external) = (Ash1*h1/s1)/Asec = 0.00392699
Ash1 = Astir_1*ns_1 = 157.0796
No stirrups, ns_1 = 2.00
h1 = 400.00
ps2 (internal) = (Ash2*h2/s2)/Asec = 0.00050265
Ash2 = Astir_2*ns_2 = 100.531
No stirrups, ns_2 = 2.00
h2 = 200.00

psh_y*Fywe = psh1*Fywe1+ps2*Fywe2 = 3.00635
ps1 (external) = (Ash1*h1/s1)/Asec = 0.00392699
Ash1 = Astir_1*ns_1 = 157.0796
No stirrups, ns_1 = 2.00
h1 = 400.00
ps2 (internal) = (Ash2*h2/s2)/Asec = 0.00050265
Ash2 = Astir_2*ns_2 = 100.531
No stirrups, ns_2 = 2.00
h2 = 200.00

Asec = 160000.00
s1 = 100.00
s2 = 250.00
fywe1 = 694.45
fywe2 = 555.55
fce = 33.00

From ((5.A5), TBDY), TBDY: cc = 0.00332119
c = confinement factor = 1.13212

y1 = 0.00184318
sh1 = 0.00589816
ft1 = 580.8818
fy1 = 484.0682
su1 = 0.01099427

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/lb,min = 0.45297586

su1 = 0.4*esu1_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu1_nominal = 0.08,

For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/lb,min)^ 2/3), from 10.3.5, ASCE 41-17.

with fs1 = (fs,jacket*Asl,ten,jacket + fs,core*Asl,ten,core)/Asl,ten = 484.0682

with Es1 = (Es,jacket*Asl,ten,jacket + Es,core*Asl,ten,core)/Asl,ten = 200000.00

y2 = 0.00184318
sh2 = 0.00589816
ft2 = 580.8818
fy2 = 484.0682
su2 = 0.01099427

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/lb,min = 0.45297586

su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu2_nominal = 0.08,

For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/lb,min)^ 2/3), from 10.3.5, ASCE 41-17.

$with fs2 = (fs,jacket*Asl,com,jacket + fs,core*Asl,com,core)/Asl,com = 484.0682$
 $with Es2 = (Es,jacket*Asl,com,jacket + Es,core*Asl,com,core)/Asl,com = 200000.00$
 $yv = 0.00184318$
 $shv = 0.00589816$
 $ftv = 614.3968$
 $fyv = 511.9973$
 $suv = 0.01099427$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 $Shear_factor = 1.00$
 $lo/lou,min = lb/ld = 0.45297586$
 $suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032$
 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.
 $with fsv = (fs,jacket*Asl,mid,jacket + fs,mid*Asl,mid,core)/Asl,mid = 511.9973$
 $with Esv = (Es,jacket*Asl,mid,jacket + Es,mid*Asl,mid,core)/Asl,mid = 200000.00$
 $1 = Asl,ten/(b*d)*(fs1/fc) = 0.0851958$
 $2 = Asl,com/(b*d)*(fs2/fc) = 0.0851958$
 $v = Asl,mid/(b*d)*(fsv/fc) = 0.04369034$
 and confined core properties:
 $b = 340.00$
 $d = 327.00$
 $d' = 13.00$
 $fcc (5A.2, TBDY) = 37.35991$
 $cc (5A.5, TBDY) = 0.00332119$
 $c = confinement\ factor = 1.13212$
 $1 = Asl,ten/(b*d)*(fs1/fc) = 0.1094258$
 $2 = Asl,com/(b*d)*(fs2/fc) = 0.1094258$
 $v = Asl,mid/(b*d)*(fsv/fc) = 0.05611603$
 Case/Assumption: Unconfined full section - Steel rupture
 ' satisfies Eq. (4.3)
 --->
 $v < vs,y2$ - LHS eq.(4.5) is satisfied
 --->
 $su (4.9) = 0.16193824$
 $Mu = MRc (4.14) = 1.8194E+008$
 $u = su (4.1) = 3.6747033E-005$

 Calculation of ratio lb/ld

 Lap Length: $lb/ld = 0.45297586$
 $lb = 300.00$
 $ld = 662.2869$
 Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
 $= 1$
 $db = 14.66667$
 Mean strength value of all re-bars: $fy = 656.5682$
 Mean concrete strength: $fc' = (fc'_jacket*Area_jacket + fc'_core*Area_core)/Area_section = 29.75$, but $fc'^{0.5} <= 8.3$
 MPa (22.5.3.1, ACI 318-14)
 $t = 1.00$
 $s = 0.80$
 $e = 1.00$
 $cb = 25.00$
 $Ktr = 3.43481$
 $Atr = Min(Atr_x,Atr_y) = 257.6106$
 where Atr_x, Atr_y are the sum of the area of all stirrup legs along X and Y loxal axis
 $s = Max(s_external,s_internal) = 250.00$
 $n = 12.00$

 Calculation of Shear Strength $Vr = Min(Vr1,Vr2) = 633062.661$

Calculation of Shear Strength at edge 1, $V_{r1} = 633062.661$

$V_{r1} = V_{Col} ((10.3), ASCE 41-17) = knl * V_{ColO}$

$V_{ColO} = 633062.661$

$kn1 = 1$ (zero step-static loading)

NOTE: In expression (10-3) ' $V_s = A_v * f_y * d / s$ ' is replaced by ' $V_s + f * V_f$ '
where V_f is the contribution of FRPs (11.3), ACI 440).

 $= 1$ (normal-weight concrete)

Mean concrete strength: $f_c' = (f_c'_{jacket} * Area_{jacket} + f_c'_{core} * Area_{core}) / Area_{section} = 29.75$, but $f_c'^{0.5} \leq 8.3$
MPa (22.5.3.1, ACI 318-14)

$M / Vd = 2.00$

$M_u = 4.6931004E-013$

$V_u = 6.6805695E-033$

$d = 0.8 * h = 320.00$

$N_u = 5926.932$

$A_g = 160000.00$

From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 279254.914$

where:

$V_{s1} = 279254.914$ is calculated for jacket, with:

$d = 320.00$

$A_v = 157079.633$

$f_y = 555.56$

$s = 100.00$

V_{s1} is multiplied by $Col1 = 1.00$

$s/d = 0.3125$

$V_{s2} = 0.00$ is calculated for core, with:

$d = 160.00$

$A_v = 100530.965$

$f_y = 444.44$

$s = 250.00$

V_{s2} is multiplied by $Col2 = 0.00$

$s/d = 1.5625$

$V_f ((11-3)-(11.4), ACI 440) = 188111.148$

$f = 0.95$, for fully-wrapped sections

$w_f / s_f = 1$ (FRP strips adjacent to one another).

In (11.3) $\sin + \cos$ is replaced with $(\cot + \cot a) \sin a$ which is more a generalised expression,
where θ is the angle of the crack direction (see KANEPE).

This later relation, considered as a function $V_f(\theta, a)$, is implemented for every different fiber orientation a_i ,
as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.

orientation 1: $\theta = 45^\circ$ and $a = 90^\circ$

$V_f = \text{Min}(|V_f(45, 90)|, |V_f(-45, 90)|)$, with:

total thickness per orientation, $t_{f1} = NL * t / \text{NoDir} = 1.016$

$d_{fv} = d$ (figure 11.2, ACI 440) = 357.00

$f_{fe} ((11-5), ACI 440) = 259.312$

$E_f = 64828.00$

$f_e = 0.004$, from (11.6a), ACI 440

with $f_u = 0.01$

From (11-11), ACI 440: $V_s + V_f \leq 463788.751$

$b_w = 400.00$

Calculation of Shear Strength at edge 2, $V_{r2} = 633062.661$

$V_{r2} = V_{Col} ((10.3), ASCE 41-17) = knl * V_{ColO}$

$V_{ColO} = 633062.661$

$kn1 = 1$ (zero step-static loading)

NOTE: In expression (10-3) ' $V_s = A_v * f_y * d / s$ ' is replaced by ' $V_s + f * V_f$ '
where V_f is the contribution of FRPs (11.3), ACI 440).

 $= 1$ (normal-weight concrete)

Mean concrete strength: $f_c' = (f_c'_{jacket} * Area_{jacket} + f_c'_{core} * Area_{core}) / Area_{section} = 29.75$, but $f_c'^{0.5} \leq 8.3$
MPa (22.5.3.1, ACI 318-14)

$M / Vd = 2.00$

$M_u = 4.6931004E-013$

$V_u = 6.6805695E-033$

$d = 0.8 \cdot h = 320.00$
 $Nu = 5926.932$
 $Ag = 160000.00$
 From (11.5.4.8), ACI 318-14: $Vs = Vs1 + Vs2 = 279254.914$
 where:
 $Vs1 = 279254.914$ is calculated for jacket, with:
 $d = 320.00$
 $Av = 157079.633$
 $fy = 555.56$
 $s = 100.00$
 $Vs1$ is multiplied by $Col1 = 1.00$
 $s/d = 0.3125$
 $Vs2 = 0.00$ is calculated for core, with:
 $d = 160.00$
 $Av = 100530.965$
 $fy = 444.44$
 $s = 250.00$
 $Vs2$ is multiplied by $Col2 = 0.00$
 $s/d = 1.5625$
 Vf ((11-3)-(11.4), ACI 440) = 188111.148
 $f = 0.95$, for fully-wrapped sections
 $wf/sf = 1$ (FRP strips adjacent to one another).
 In (11.3) $\sin + \cos$ is replaced with $(\cot + \cot a) \sin a$ which is more a generalised expression,
 where a is the angle of the crack direction (see KANEPE).
 This later relation, considered as a function $Vf(,)$, is implemented for every different fiber orientation a_i ,
 as well as for 2 crack directions, $a = 45^\circ$ and $a = -45^\circ$ to take into consideration the cyclic seismic loading.
 orientation 1: $a = b1 + 90^\circ = 90.00$
 $Vf = \text{Min}(|Vf(45, 1)|, |Vf(-45, a1)|)$, with:
 total thickness per orientation, $tf1 = NL \cdot t / \text{NoDir} = 1.016$
 $dfv = d$ (figure 11.2, ACI 440) = 357.00
 ffe ((11-5), ACI 440) = 259.312
 $Ef = 64828.00$
 $fe = 0.004$, from (11.6a), ACI 440
 with $fu = 0.01$
 From (11-11), ACI 440: $Vs + Vf \leq 463788.751$
 $bw = 400.00$

 End Of Calculation of Shear Capacity ratio for element: column JC1 of floor 1
 At local axis: 2

 Start Of Calculation of Chord Rotation Capacity for element: column JC1 of floor 1
 At local axis: 2
 Integration Section: (b)
 Section Type: rcjrs

Constant Properties

 Knowledge Factor, $\lambda = 0.80$
 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
 Existing material of Secondary Member: Concrete Strength, $f_c = f_{cm} = 20.00$
 Existing material of Secondary Member: Steel Strength, $f_s = f_{sm} = 444.44$
 Concrete Elasticity, $E_c = 21019.039$
 Steel Elasticity, $E_s = 200000.00$
 External Height, $H = 400.00$
 External Width, $W = 400.00$

Internal Height, H = 200.00
Internal Width, W = 200.00
Cover Thickness, c = 25.00
Element Length, L = 3000.00
Secondary Member
Ribbed Bars
Ductile Steel
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
Lap Length l_b = 300.00
FRP Wrapping Data
Type: Carbon
Cured laminate properties (design values)
Thickness, t = 1.016
Tensile Strength, f_{fu} = 1055.00
Tensile Modulus, E_f = 64828.00
Elongation, e_{fu} = 0.01
Number of directions, NoDir = 1
Fiber orientations, b_i : 0.00°
Number of layers, NL = 1
Radius of rounding corners, R = 40.00

Stepwise Properties

Bending Moment, M = -3.0409439E-011
Shear Force, V2 = 7751.185
Shear Force, V3 = -2.6948337E-014
Axial Force, F = -6084.055
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: A_{st} = 0.00
-Compression: A_{sc} = 2060.885
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension: $A_{st,ten}$ = 829.3805
-Compression: $A_{sc,com}$ = 829.3805
-Middle: $A_{st,mid}$ = 402.1239
Longitudinal External Reinforcement Area Distribution (in 3 divisions)
-Tension: $A_{st,ten,jacket}$ = 603.1858
-Compression: $A_{sc,com,jacket}$ = 603.1858
-Middle: $A_{st,mid,jacket}$ = 402.1239
Longitudinal Internal Reinforcement Area Distribution (in 3 divisions)
-Tension: $A_{st,ten,core}$ = 226.1947
-Compression: $A_{sc,com,core}$ = 226.1947
-Middle: $A_{st,mid,core}$ = 0.00
Mean Diameter of Tension Reinforcement, D_bL = 14.40

Existing component: From table 7-7, ASCE 41_17: Final chord rotation Capacity $u_{,R} = * u = 0.0369217$
 $u = y + p = 0.04615212$

- Calculation of y -

$y = (M_y * L_s / 3) / E_{eff} = 0.00415212$ ((4.29), Biskinis Phd))
 $M_y = 1.4151E+008$
 $L_s = M/V$ (with $L_s > 0.1 * L$ and $L_s < 2 * L$) = 1500.00
From table 10.5, ASCE 41_17: $E_{eff} = factor * E_c * I_g = 1.7040E+013$
factor = 0.30
 $A_g = 160000.00$
Mean concrete strength: $f_c' = (f_c'_{jacket} * Area_{jacket} + f_c'_{core} * Area_{core}) / Area_{section} = 29.75$
N = 6084.055
 $E_c * I_g = E_c * I_{g,jacket} + E_c * I_{g,core} = 5.6801E+013$

Calculation of Yielding Moment M_y

Calculation of ρ_y and M_y according to Annex 7 -

$$y = \text{Min}(y_{\text{ten}}, y_{\text{com}})$$

$$y_{\text{ten}} = 8.5630881\text{E-}006$$

$$\text{with } ((10.1), \text{ASCE 41-17}) f_y = \text{Min}(f_y, 1.25 \cdot f_y \cdot (l_b/d)^{2/3}) = 454.4281$$

$$d = 357.00$$

$$y = 0.25674727$$

$$A = 0.01452572$$

$$B = 0.00817889$$

$$\text{with } p_t = 0.00680078$$

$$p_c = 0.00580799$$

$$p_v = 0.00281599$$

$$N = 6084.055$$

$$b = 400.00$$

$$" = 0.12044818$$

$$y_{\text{comp}} = 2.5299695\text{E-}005$$

$$\text{with } f_c^* (12.3, \text{ACI 440}) = 34.65599$$

$$f_c = 33.00$$

$$f_l = 0.93147527$$

$$b = 400.00$$

$$h = 400.00$$

$$A_g = 160000.00$$

$$\text{From } (12.9), \text{ACI 440: } k_a = 0.56708553$$

$$g = p_t + p_c + p_v = 0.01443197$$

$$r_c = 40.00$$

$$A_e/A_c = 0.56708553$$

$$\text{Effective FRP thickness, } t_f = N L^* t \cdot \text{Cos}(b_1) = 1.016$$

$$\text{effective strain from } (12.5) \text{ and } (12.12), e_{fe} = 0.004$$

$$f_u = 0.01$$

$$E_f = 64828.00$$

$$E_c = 26999.444$$

$$y = 0.25580703$$

$$A = 0.01433976$$

$$B = 0.00808514$$

$$\text{with } E_s = 200000.00$$

Calculation of ratio l_b/d

$$\text{Lap Length: } l_d/d, \text{min} = 0.56621983$$

$$l_b = 300.00$$

$$d = 529.8296$$

Calculation of l according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

$$= 1$$

$$d_b = 14.66667$$

$$\text{Mean strength value of all re-bars: } f_y = 525.2545$$

$$\text{Mean concrete strength: } f_c' = (f_c'_{\text{jacket}} \cdot \text{Area}_{\text{jacket}} + f_c'_{\text{core}} \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 29.75, \text{ but } f_c'^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 25.00$$

$$K_{tr} = 3.43481$$

$$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 257.6106$$

where A_{tr_x} , A_{tr_y} are the sum of the area of all stirrup legs along X and Y local axis

$$s = \text{Max}(s_{\text{external}}, s_{\text{internal}}) = 250.00$$

$$n = 12.00$$

- Calculation of ρ_p -

From table 10-8: $\rho_p = 0.042$

with:

- Columns controlled by inadequate development or splicing along the clear height because $l_b/d < 1$

shear control ratio $V_y E / V_{Co} I_{OE} = 0.19159777$

$d = d_{external} = 357.00$

$s = s_{external} = 0.00$

$t = s_1 + s_2 + 2 * t_f / b_w * (f_{fe} / f_s) = 0.00680078$

jacket: $s_1 = A_{v1} * h_1 / (s_1 * A_g) = 0.00392699$

$A_{v1} = 157.0796$, is the total area of all stirrups parallel to loading (shear) direction

$h_1 = 400.00$

$s_1 = 100.00$

core: $s_2 = A_{v2} * h_2 / (s_2 * A_g) = 0.00050265$

$A_{v2} = 100.531$, is the total area of all stirrups parallel to loading (shear) direction

$h_2 = 200.00$

$s_2 = 250.00$

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.

$NUD = 6084.055$

$A_g = 160000.00$

$f_{cE} = (f_{c_jacket} * Area_jacket + f_{c_core} * Area_core) / section_area = 29.75$

$f_{yE} = (f_{y_ext_Long_Reinf} * Area_ext_Long_Reinf + f_{y_int_Long_Reinf} * Area_int_Long_Reinf) / Area_Tot_Long_Rein = 531.1678$

$f_{yE} = (f_{y_ext_Trans_Reinf} * Area_ext_Trans_Reinf + f_{y_int_Trans_Reinf} * Area_int_Trans_Reinf) / Area_Tot_Trans_Rein = 542.9506$

$\rho_l = Area_Tot_Long_Rein / (b * d) = 0.01443197$

$b = 400.00$

$d = 357.00$

$f_{cE} = 29.75$

End Of Calculation of Chord Rotation Capacity for element: column JC1 of floor 1

At local axis: 2

Integration Section: (b)

Calculation No. 15

column C1, Floor 1

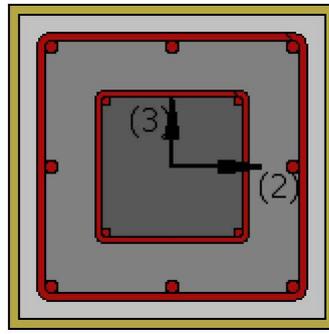
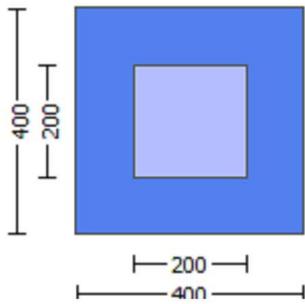
Limit State: Collapse Prevention (data interpolation between analysis steps 2 and 3)

Analysis: Uniform +X

Check: Shear capacity VRd

Edge: End

Local Axis: (3)



Start Of Calculation of Shear Capacity for element: column JC1 of floor 1

At local axis: 3

Integration Section: (b)

Section Type: rcjrs

Constant Properties

Knowledge Factor, $\gamma = 0.80$

Member Shear Force is generally considered as Force-Controlled Action according to Table C7-1, ASCE 41-17.

Lower-bound strengths are used for Force-Controlled Actions according to 7.5.1.3, ASCE 41-17

Consequently:

Jacket

New material of Secondary Member: Concrete Strength, $f_c = f_{c_lower_bound} = 25.00$

New material of Secondary Member: Steel Strength, $f_s = f_{s_lower_bound} = 500.00$

Concrete Elasticity, $E_c = 26999.444$

Steel Elasticity, $E_s = 200000.00$

Existing Column

Existing material of Secondary Member: Concrete Strength, $f_c = f_{c_lower_bound} = 16.00$

Existing material of Secondary Member: Steel Strength, $f_s = f_{s_lower_bound} = 400.00$

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of γ for displacement ductility demand, the expected (mean value) strengths are used (7.5.1.3, ASCE 41-17) because bending is considered as Deformation-Controlled Action (Table C7-1, ASCE 41-17).

Jacket

New material: Concrete Strength, $f_c = f_{cm} = 33.00$

New material: Steel Strength, $f_s = f_{sm} = 555.56$

Existing Column

Existing material: Concrete Strength, $f_c = f_{cm} = 20.00$

Existing material: Steel Strength, $f_s = f_{sm} = 444.44$

#####

External Height, $H = 400.00$

External Width, $W = 400.00$

Internal Height, $H = 200.00$

Internal Width, $W = 200.00$

Cover Thickness, $c = 25.00$

Element Length, $L = 3000.00$

Secondary Member

Ribbed Bars

Ductile Steel

Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)

Longitudinal Bars With Ends Lapped Starting at the End Sections

Lap Length $l_o = l_b = 300.00$

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $e_{fu} = 0.01$

Number of directions, $NoDir = 1$

Fiber orientations, θ_i : 0.00°
Number of layers, NL = 1
Radius of rounding corners, R = 40.00

Stepwise Properties

EDGE -A-
Bending Moment, M_a = -5.0458668E-011
Shear Force, V_a = 2.6948337E-014
EDGE -B-
Bending Moment, M_b = -3.0409439E-011
Shear Force, V_b = -2.6948337E-014
BOTH EDGES
Axial Force, F = -6084.055
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: A_{st} = 0.00
-Compression: A_{sc} = 2060.885
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension: $A_{st,ten}$ = 829.3805
-Compression: $A_{sc,com}$ = 829.3805
-Middle: $A_{st,mid}$ = 402.1239
Mean Diameter of Tension Reinforcement, $D_{bL,ten}$ = 14.40

Existing component: From table 7-7, ASCE 41_17: Final Shear Capacity $V_R = \phi V_n = 447098.232$
 V_n ((10.3), ASCE 41-17) = $k_n \phi V_{Co10} = 558872.791$
 $V_{Co10} = 558872.791$
 $k_n = 1.00$
displacement_ductility_demand = 0.00

NOTE: In expression (10-3) ' $V_s = A_v \cdot f_y \cdot d / s$ ' is replaced by ' $V_s + \phi V_f$ '
where V_f is the contribution of FRPs (11.3), ACI 440).

= 1 (normal-weight concrete)
Mean concrete strength: $f_c' = (f_c'_{jacket} \cdot Area_{jacket} + f_c'_{core} \cdot Area_{core}) / Area_{section} = 22.75$, but $f_c'^{0.5} \leq 8.3$
MPa (22.5.3.1, ACI 318-14)
 $M / Vd = 2.00$
 $M_u = 3.0409439E-011$
 $V_u = 2.6948337E-014$
 $d = 0.8 \cdot h = 320.00$
 $N_u = 6084.055$
 $A_g = 160000.00$
From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 251327.412$
where:
 $V_{s1} = 251327.412$ is calculated for jacket, with:
 $d = 320.00$
 $A_v = 157079.633$
 $f_y = 500.00$
 $s = 100.00$
 V_{s1} is multiplied by $Col1 = 1.00$
 $s/d = 0.3125$
 $V_{s2} = 0.00$ is calculated for core, with:
 $d = 160.00$
 $A_v = 100530.965$
 $f_y = 400.00$
 $s = 250.00$
 V_{s2} is multiplied by $Col2 = 0.00$
 $s/d = 1.5625$
 V_f ((11-3)-(11.4), ACI 440) = 188111.148
 $\phi = 0.95$, for fully-wrapped sections
 $w_f / s_f = 1$ (FRP strips adjacent to one another).
In (11.3) $\sin \theta + \cos \theta$ is replaced with $(\cot \theta + \csc \theta) \sin \alpha$ which is more a generalised expression,
where α 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 θ_i ,

as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.
orientation 1: $\theta = b1 + 90^\circ = 90.00$
 $V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, \theta)|)$, with:
total thickness per orientation, $t_{f1} = NL \cdot t / \text{NoDir} = 1.016$
 $d_{fv} = d$ (figure 11.2, ACI 440) = 357.00
 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: $V_s + V_f \leq 405571.497$
 $b_w = 400.00$

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 $\theta = 3.6096033E-023$
 $y = (M_y \cdot L_s / 3) / E_{eff} = 0.00415212$ ((4.29), Biskinis Phd)
 $M_y = 1.4151E+008$
 $L_s = M/V$ (with $L_s > 0.1 \cdot L$ and $L_s < 2 \cdot L$) = 1500.00
From table 10.5, ASCE 41_17: $E_{eff} = \text{factor} \cdot E_c \cdot I_g = 1.7040E+013$
factor = 0.30
 $A_g = 160000.00$
Mean concrete strength: $f_c' = (f_c'_{jacket} \cdot \text{Area}_{jacket} + f_c'_{core} \cdot \text{Area}_{core}) / \text{Area}_{section} = 29.75$
 $N = 6084.055$
 $E_c \cdot I_g = E_{c,jacket} \cdot I_{g,jacket} + E_{c,core} \cdot I_{g,core} = 5.6801E+013$

Calculation of Yielding Moment M_y

Calculation of δ / y and M_y according to Annex 7 -

$y = \text{Min}(y_{ten}, y_{com})$
 $y_{ten} = 8.5630881E-006$
with ((10.1), ASCE 41-17) $f_y = \text{Min}(f_y, 1.25 \cdot f_y \cdot (I_b / I_d)^{2/3}) = 454.4281$
 $d = 357.00$
 $y = 0.25674727$
 $A = 0.01452572$
 $B = 0.00817889$
with $p_t = 0.00580799$
 $p_c = 0.00580799$
 $p_v = 0.00281599$
 $N = 6084.055$
 $b = 400.00$
 $\theta = 0.12044818$
 $y_{comp} = 2.5299695E-005$
with f_c^* (12.3, (ACI 440)) = 34.65599
 $f_c = 33.00$
 $f_l = 0.93147527$
 $b = 400.00$
 $h = 400.00$
 $A_g = 160000.00$
From (12.9), ACI 440: $k_a = 0.56708553$
 $g = p_t + p_c + p_v = 0.01443197$
 $r_c = 40.00$
 $A_e / A_c = 0.56708553$
Effective FRP thickness, $t_f = NL \cdot t \cdot \text{Cos}(b1) = 1.016$
effective strain from (12.5) and (12.12), $e_{fe} = 0.004$
 $f_u = 0.01$
 $E_f = 64828.00$
 $E_c = 26999.444$
 $y = 0.25580703$
 $A = 0.01433976$

B = 0.00808514
with Es = 200000.00

Calculation of ratio lb/d

Lap Length: $l_d/l_{d,min} = 0.56621983$

lb = 300.00

ld = 529.8296

Calculation of I according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

= 1

db = 14.66667

Mean strength value of all re-bars: fy = 525.2545

Mean concrete strength: $f_c' = (f_c'_{jacket} \cdot Area_{jacket} + f_c'_{core} \cdot Area_{core}) / Area_{section} = 29.75$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

t = 1.00

s = 0.80

e = 1.00

cb = 25.00

Ktr = 3.43481

Atr = Min(Atr_x, Atr_y) = 257.6106

where Atr_x, Atr_y are the sum of the area of all stirrup legs along X and Y local axis

s = Max(s_external, s_internal) = 250.00

n = 12.00

End Of Calculation of Shear Capacity for element: column JC1 of floor 1

At local axis: 3

Integration Section: (b)

Calculation No. 16

column C1, Floor 1

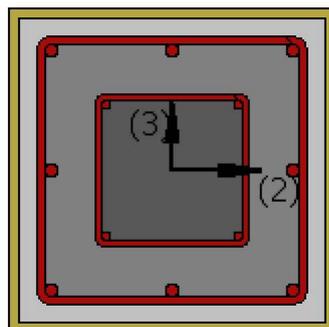
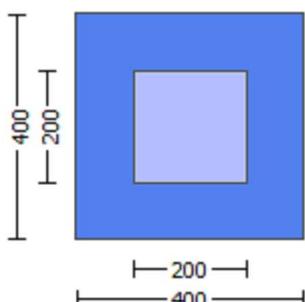
Limit State: Collapse Prevention (data interpolation between analysis steps 2 and 3)

Analysis: Uniform +X

Check: Chord rotation capacity (u)

Edge: End

Local Axis: (3)



Start Of Calculation of Shear Capacity ratio for element: column JC1 of floor 1

At Shear local axis: 3
(Bending local axis: 2)
Section Type: rcjrs

Constant Properties

Knowledge Factor, $\phi = 0.80$

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

Existing material of Secondary Member: Concrete Strength, $f_c = f_{cm} = 20.00$

Existing material of Secondary Member: Steel Strength, $f_s = f_{sm} = 444.44$

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14

Jacket

New material: Steel Strength, $f_s = 1.25 \cdot f_{sm} = 694.45$

Existing Column

Existing material: Steel Strength, $f_s = 1.25 \cdot f_{sm} = 555.55$

#####

External Height, $H = 400.00$

External Width, $W = 400.00$

Internal Height, $H = 200.00$

Internal Width, $W = 200.00$

Cover Thickness, $c = 25.00$

Mean Confinement Factor overall section = 1.13212

Element Length, $L = 3000.00$

Secondary Member

Ribbed Bars

Ductile Steel

Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)

Longitudinal Bars With Ends Lapped Starting at the End Sections

Lap Length $l_o = 300.00$

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $e_{fu} = 0.01$

Number of directions, $N_{oDir} = 1$

Fiber orientations, $b_i = 0.00^\circ$

Number of layers, $N_L = 1$

Radius of rounding corners, $R = 40.00$

Stepwise Properties

At local axis: 3

EDGE -A-

Shear Force, $V_a = 2.8976040E-031$

EDGE -B-

Shear Force, $V_b = -2.8976040E-031$

BOTH EDGES

Axial Force, $F = -5926.932$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: $A_{st} = 0.00$

-Compression: $A_{s,c} = 2060.885$

Longitudinal Reinforcement Area Distribution (in 3 divisions)

-Tension: $A_{s,t} = 829.3805$

-Compression: $A_{s,c} = 829.3805$

-Middle: $A_{s,m} = 402.1239$

Calculation of Shear Capacity ratio, $V_e/V_r = 0.19159777$

Member Controlled by Flexure ($V_e/V_r < 1$)

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 121293.391$

with

$M_{pr1} = \max(\mu_{1+}, \mu_{1-}) = 1.8194E+008$

$\mu_{1+} = 1.8194E+008$, is the ultimate moment strength at the edge 1 of the member in the actual moment direction which is defined for the static loading combination

$\mu_{1-} = 1.8194E+008$, is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination

$M_{pr2} = \max(\mu_{2+}, \mu_{2-}) = 1.8194E+008$

$\mu_{2+} = 1.8194E+008$, is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the static loading combination

$\mu_{2-} = 1.8194E+008$, is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the static loading combination

Calculation of μ_{1+}

Calculation of ultimate curvature μ according to 4.1, Biskinis/Fardis 2013:

$\mu = 3.6747033E-005$

$M_u = 1.8194E+008$

with full section properties:

$b = 400.00$

$d = 357.00$

$d' = 43.00$

$v = 0.00125773$

$N = 5926.932$

$f_c = 33.00$

$\alpha (5A.5, TBDY) = 0.002$

Final value of μ_c : $\mu_c^* = \text{shear_factor} * \max(\mu_c, \alpha) = 0.01505571$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $\mu_c = 0.01505571$

$\mu_{we} ((5.4c), TBDY) = \alpha * \min(f_y w_e / f_{ce} + \min(f_x, f_y)) = 0.08345896$

where $f = \alpha * p_f * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$f_x = 0.07683125$

$\alpha_f = 0.57333333$

$b = 400.00$

$h = 400.00$

From EC8 A.4.4.3(6), $p_f = 2t_f/b_w = 0.00508$

$b_w = 400.00$

effective stress from (A.35), $f_{fe} = 870.5244$

$f_y = 0.07683125$

$\alpha_f = 0.57333333$

$b = 400.00$

$h = 400.00$

From EC8 A.4.4.3(6), $p_f = 2t_f/b_w = 0.00508$

$b_w = 400.00$

effective stress from (A.35), $f_{fe} = 870.5244$

$R = 40.00$

Effective FRP thickness, $t_f = N L * t * \cos(b_1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

u,f = 0.015

ase ((5.4d), TBDY) = (ase1*Aext+ase2*Aint)/Asec = 0.24250288

ase1 = 0.24250288

bo_1 = 340.00

ho_1 = 340.00

bi2_1 = 462400.00

ase2 = Max(ase1,ase2) = 0.24250288

bo_2 = 192.00

ho_2 = 192.00

bi2_2 = 147456.00

psh,min*Fywe = Min(psh,x*Fywe , psh,y*Fywe) = 3.00635

Expression ((5.4d), TBDY) for psh,min*Fywe has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

psh_x*Fywe = psh1*Fywe1+ps2*Fywe2 = 3.00635

ps1 (external) = (Ash1*h1/s1)/Asec = 0.00392699

Ash1 = Astir_1*ns_1 = 157.0796

No stirrups, ns_1 = 2.00

h1 = 400.00

ps2 (internal) = (Ash2*h2/s2)/Asec = 0.00050265

Ash2 = Astir_2*ns_2 = 100.531

No stirrups, ns_2 = 2.00

h2 = 200.00

psh_y*Fywe = psh1*Fywe1+ps2*Fywe2 = 3.00635

ps1 (external) = (Ash1*h1/s1)/Asec = 0.00392699

Ash1 = Astir_1*ns_1 = 157.0796

No stirrups, ns_1 = 2.00

h1 = 400.00

ps2 (internal) = (Ash2*h2/s2)/Asec = 0.00050265

Ash2 = Astir_2*ns_2 = 100.531

No stirrups, ns_2 = 2.00

h2 = 200.00

Asec = 160000.00

s1 = 100.00

s2 = 250.00

fywe1 = 694.45

fywe2 = 555.55

fce = 33.00

From ((5.A5), TBDY), TBDY: cc = 0.00332119

c = confinement factor = 1.13212

y1 = 0.00184318

sh1 = 0.00589816

ft1 = 580.8818

fy1 = 484.0682

su1 = 0.01099427

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

lo/lou,min = lb/d = 0.45297586

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 = 484.0682

with Es1 = (Es,jacket*Asl,ten,jacket + Es,core*Asl,ten,core)/Asl,ten = 200000.00

y2 = 0.00184318

sh2 = 0.00589816

ft2 = 580.8818

fy2 = 484.0682

su2 = 0.01099427

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

lo/lou,min = lb/lb,min = 0.45297586

$su_2 = 0.4 * esu_2_nominal ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $esu_2_nominal = 0.08$,
 For calculation of $esu_2_nominal$ and y_2, sh_2, ft_2, fy_2 , it is considered
 characteristic value $fsy_2 = fs_2/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $Min(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE 41-17.
 with $fs_2 = (fs_jacket * Asl,com,jacket + fs_core * Asl,com,core) / Asl,com = 484.0682$
 with $Es_2 = (Es_jacket * Asl,com,jacket + Es_core * Asl,com,core) / Asl,com = 200000.00$
 $yv = 0.00184318$
 $shv = 0.00589816$
 $ftv = 614.3968$
 $fyv = 511.9973$
 $suv = 0.01099427$
 using (30) in Biskinis/Fardis (2013) multiplied with $shear_factor$
 and also multiplied by the $shear_factor$ according to 15.7.1.4, with
 $Shear_factor = 1.00$
 $lo/lo_{u,min} = lb/ld = 0.45297586$
 $suv = 0.4 * esuv_nominal ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $esuv_nominal = 0.08$,
 considering characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY
 For calculation of $esuv_nominal$ and yv, shv, ftv, fyv , it is considered
 characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $Min(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE 41-17.
 with $fsv = (fs_jacket * Asl,mid,jacket + fs_mid * Asl,mid,core) / Asl,mid = 511.9973$
 with $Es_v = (Es_jacket * Asl,mid,jacket + Es_mid * Asl,mid,core) / Asl,mid = 200000.00$
 $1 = Asl,ten / (b * d) * (fs_1 / fc) = 0.0851958$
 $2 = Asl,com / (b * d) * (fs_2 / fc) = 0.0851958$
 $v = Asl,mid / (b * d) * (fsv / fc) = 0.04369034$
 and confined core properties:
 $b = 340.00$
 $d = 327.00$
 $d' = 13.00$
 $fcc (5A.2, TBDY) = 37.35991$
 $cc (5A.5, TBDY) = 0.00332119$
 $c = confinement\ factor = 1.13212$
 $1 = Asl,ten / (b * d) * (fs_1 / fc) = 0.1094258$
 $2 = Asl,com / (b * d) * (fs_2 / fc) = 0.1094258$
 $v = Asl,mid / (b * d) * (fsv / fc) = 0.05611603$
 Case/Assumption: Unconfined full section - Steel rupture
 ' satisfies Eq. (4.3)
 --->
 $v < v_{s,y2}$ - LHS eq.(4.5) is satisfied
 --->
 $su (4.9) = 0.16193824$
 $Mu = MRc (4.14) = 1.8194E+008$
 $u = su (4.1) = 3.6747033E-005$

 Calculation of ratio lb/ld

 Lap Length: $lb/ld = 0.45297586$
 $lb = 300.00$
 $ld = 662.2869$
 Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
 $= 1$
 $db = 14.66667$
 Mean strength value of all re-bars: $fy = 656.5682$
 Mean concrete strength: $fc' = (fc'_jacket * Area_jacket + fc'_core * Area_core) / Area_section = 29.75$, but $fc'^{0.5} <= 8.3$
 MPa (22.5.3.1, ACI 318-14)
 $t = 1.00$
 $s = 0.80$
 $e = 1.00$
 $cb = 25.00$
 $Ktr = 3.43481$
 $Atr = Min(Atr_x, Atr_y) = 257.6106$
 where Atr_x, Atr_y are the sum of the area of all stirrup legs along X and Y loxal axis
 $s = Max(s_external, s_internal) = 250.00$
 $n = 12.00$

Calculation of Mu1-

Calculation of ultimate curvature μ according to 4.1, Biskinis/Fardis 2013:

$$\mu = 3.6747033E-005$$

$$Mu = 1.8194E+008$$

with full section properties:

$$b = 400.00$$

$$d = 357.00$$

$$d' = 43.00$$

$$v = 0.00125773$$

$$N = 5926.932$$

$$f_c = 33.00$$

$$c_o \text{ (5A.5, TBDY)} = 0.002$$

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_o) = 0.01505571$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } c_u = 0.01505571$$

$$w_e \text{ ((5.4c), TBDY)} = a_{se} * s_{h,min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.08345896$$

where $f = a_f * p_f * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.07683125$$

$$a_f = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 870.5244$$

$$f_y = 0.07683125$$

$$a_f = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 870.5244$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L * t * \text{Cos}(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$a_{se} \text{ ((5.4d), TBDY)} = (a_{se1} * A_{ext} + a_{se2} * A_{int}) / A_{sec} = 0.24250288$$

$$a_{se1} = 0.24250288$$

$$b_{o,1} = 340.00$$

$$h_{o,1} = 340.00$$

$$b_{i,2,1} = 462400.00$$

$$a_{se2} = \text{Max}(a_{se1}, a_{se2}) = 0.24250288$$

$$b_{o,2} = 192.00$$

$$h_{o,2} = 192.00$$

$$b_{i,2,2} = 147456.00$$

$$p_{sh,min} * F_{ywe} = \text{Min}(p_{sh,x} * F_{ywe}, p_{sh,y} * F_{ywe}) = 3.00635$$

Expression ((5.4d), TBDY) for $p_{sh,min} * F_{ywe}$ has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$$p_{sh,x} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{sh2} * F_{ywe2} = 3.00635$$

$$p_{s1} \text{ (external)} = (A_{sh1} * h_1 / s_1) / A_{sec} = 0.00392699$$

$$A_{sh1} = A_{stir,1} * n_{s,1} = 157.0796$$

$$\text{No stirrups, } n_{s,1} = 2.00$$

$$h_1 = 400.00$$

$$p_{s2} \text{ (internal)} = (A_{sh2} * h_2 / s_2) / A_{sec} = 0.00050265$$

$$A_{sh2} = A_{stir,2} * n_{s,2} = 100.531$$

$$\text{No stirrups, } n_{s,2} = 2.00$$

h2 = 200.00

psh_y*Fywe = psh1*Fywe1+ps2*Fywe2 = 3.00635
ps1 (external) = (Ash1*h1/s1)/Asec = 0.00392699
Ash1 = Astir_1*ns_1 = 157.0796
No stirups, ns_1 = 2.00
h1 = 400.00
ps2 (internal) = (Ash2*h2/s2)/Asec = 0.00050265
Ash2 = Astir_2*ns_2 = 100.531
No stirups, ns_2 = 2.00
h2 = 200.00

Asec = 160000.00

s1 = 100.00

s2 = 250.00

fywe1 = 694.45

fywe2 = 555.55

fce = 33.00

From ((5.A5), TBDY), TBDY: cc = 0.00332119

c = confinement factor = 1.13212

y1 = 0.00184318

sh1 = 0.00589816

ft1 = 580.8818

fy1 = 484.0682

su1 = 0.01099427

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/lb = 0.45297586

su1 = 0.4*esu1_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu1_nominal = 0.08,

For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/lb)^2/3), from 10.3.5, ASCE 41-17.

with fs1 = (fs,jacket*Asl,ten,jacket + fs,core*Asl,ten,core)/Asl,ten = 484.0682

with Es1 = (Es,jacket*Asl,ten,jacket + Es,core*Asl,ten,core)/Asl,ten = 200000.00

y2 = 0.00184318

sh2 = 0.00589816

ft2 = 580.8818

fy2 = 484.0682

su2 = 0.01099427

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/lb,min = 0.45297586

su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu2_nominal = 0.08,

For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/lb)^2/3), from 10.3.5, ASCE 41-17.

with fs2 = (fs,jacket*Asl,com,jacket + fs,core*Asl,com,core)/Asl,com = 484.0682

with Es2 = (Es,jacket*Asl,com,jacket + Es,core*Asl,com,core)/Asl,com = 200000.00

yv = 0.00184318

shv = 0.00589816

ftv = 614.3968

fyv = 511.9973

suv = 0.01099427

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/lb = 0.45297586

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/lb)^2/3), from 10.3.5, ASCE 41-17.

with $f_{sv} = (f_{s,jacket} \cdot A_{s,mid,jacket} + f_{s,mid} \cdot A_{s,mid,core}) / A_{s,mid} = 511.9973$
with $E_{sv} = (E_{s,jacket} \cdot A_{s,mid,jacket} + E_{s,mid} \cdot A_{s,mid,core}) / A_{s,mid} = 200000.00$
 $1 = A_{s,ten} / (b \cdot d) \cdot (f_{s1} / f_c) = 0.0851958$
 $2 = A_{s,com} / (b \cdot d) \cdot (f_{s2} / f_c) = 0.0851958$
 $v = A_{s,mid} / (b \cdot d) \cdot (f_{sv} / f_c) = 0.04369034$

and confined core properties:

$b = 340.00$
 $d = 327.00$
 $d' = 13.00$
 $f_{cc} (5A.2, TBDY) = 37.35991$
 $cc (5A.5, TBDY) = 0.00332119$
 $c = \text{confinement factor} = 1.13212$
 $1 = A_{s,ten} / (b \cdot d) \cdot (f_{s1} / f_c) = 0.1094258$
 $2 = A_{s,com} / (b \cdot d) \cdot (f_{s2} / f_c) = 0.1094258$
 $v = A_{s,mid} / (b \cdot d) \cdot (f_{sv} / f_c) = 0.05611603$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < v_{s,y2}$ - LHS eq.(4.5) is satisfied

--->

$\mu_u (4.9) = 0.16193824$
 $\mu_u = M_{Rc} (4.14) = 1.8194E+008$
 $u = \mu_u (4.1) = 3.6747033E-005$

Calculation of ratio l_b/d

Lap Length: $l_b/d = 0.45297586$

$l_b = 300.00$
 $l_d = 662.2869$

Calculation of $l_{b,min}$ according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

= 1

$d_b = 14.66667$
Mean strength value of all re-bars: $f_y = 656.5682$
Mean concrete strength: $f_c' = (f_c'_{jacket} \cdot Area_{jacket} + f_c'_{core} \cdot Area_{core}) / Area_{section} = 29.75$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $t = 1.00$
 $s = 0.80$
 $e = 1.00$
 $cb = 25.00$
 $K_{tr} = 3.43481$
 $A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 257.6106$
where A_{tr_x}, A_{tr_y} are the sum of the area of all stirrup legs along X and Y local axis
 $s = \text{Max}(s_{external}, s_{internal}) = 250.00$
 $n = 12.00$

Calculation of μ_{u2+}

Calculation of ultimate curvature μ_u according to 4.1, Biskinis/Fardis 2013:

$u = 3.6747033E-005$
 $\mu_u = 1.8194E+008$

with full section properties:

$b = 400.00$
 $d = 357.00$
 $d' = 43.00$
 $v = 0.00125773$
 $N = 5926.932$
 $f_c = 33.00$
 $co (5A.5, TBDY) = 0.002$
Final value of μ_u : $\mu_u^* = \text{shear_factor} \cdot \text{Max}(\mu_u, cc) = 0.01505571$
The Shear_factor is considered equal to 1 (pure moment strength)
From (5.4b), TBDY: $\mu_u = 0.01505571$

w_e ((5.4c), TBDY) = $a_{se} \cdot \min(f_{ywe}/f_{ce} + \min(f_x, f_y)) = 0.08345896$
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)

$f_x = 0.07683125$
 $a_f = 0.57333333$
 $b = 400.00$
 $h = 400.00$
From EC8 A.4.4.3(6), $p_f = 2t_f/bw = 0.00508$
 $bw = 400.00$
effective stress from (A.35), $f_{f,e} = 870.5244$

$f_y = 0.07683125$
 $a_f = 0.57333333$
 $b = 400.00$
 $h = 400.00$
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, $t_f = NL \cdot t \cdot \cos(b_1) = 1.016$
 $f_{u,f} = 1055.00$
 $E_f = 64828.00$
 $u_{,f} = 0.015$
 a_{se} ((5.4d), TBDY) = $(a_{se1} \cdot A_{ext} + a_{se2} \cdot A_{int})/A_{sec} = 0.24250288$
 $a_{se1} = 0.24250288$
 $bo_1 = 340.00$
 $ho_1 = 340.00$
 $bi2_1 = 462400.00$
 $a_{se2} = \max(a_{se1}, a_{se2}) = 0.24250288$
 $bo_2 = 192.00$
 $ho_2 = 192.00$
 $bi2_2 = 147456.00$

$p_{sh, \min} \cdot F_{ywe} = \min(p_{sh,x} \cdot F_{ywe}, p_{sh,y} \cdot F_{ywe}) = 3.00635$

Expression ((5.4d), TBDY) for $p_{sh, \min} \cdot F_{ywe}$ has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$p_{sh,x} \cdot F_{ywe} = p_{sh1} \cdot F_{ywe1} + p_{sh2} \cdot F_{ywe2} = 3.00635$
 $ps1$ (external) = $(A_{sh1} \cdot h_1/s_1)/A_{sec} = 0.00392699$
 $A_{sh1} = A_{stir_1} \cdot ns_1 = 157.0796$
No stirrups, $ns_1 = 2.00$
 $h_1 = 400.00$
 $ps2$ (internal) = $(A_{sh2} \cdot h_2/s_2)/A_{sec} = 0.00050265$
 $A_{sh2} = A_{stir_2} \cdot ns_2 = 100.531$
No stirrups, $ns_2 = 2.00$
 $h_2 = 200.00$

$p_{sh,y} \cdot F_{ywe} = p_{sh1} \cdot F_{ywe1} + p_{sh2} \cdot F_{ywe2} = 3.00635$
 $ps1$ (external) = $(A_{sh1} \cdot h_1/s_1)/A_{sec} = 0.00392699$
 $A_{sh1} = A_{stir_1} \cdot ns_1 = 157.0796$
No stirrups, $ns_1 = 2.00$
 $h_1 = 400.00$
 $ps2$ (internal) = $(A_{sh2} \cdot h_2/s_2)/A_{sec} = 0.00050265$
 $A_{sh2} = A_{stir_2} \cdot ns_2 = 100.531$
No stirrups, $ns_2 = 2.00$
 $h_2 = 200.00$

$A_{sec} = 160000.00$

$s_1 = 100.00$

$s_2 = 250.00$

$f_{ywe1} = 694.45$

$f_{ywe2} = 555.55$

$f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY: $cc = 0.00332119$

$c =$ confinement factor = 1.13212

$y_1 = 0.00184318$

$sh_1 = 0.00589816$

$$ft1 = 580.8818$$

$$fy1 = 484.0682$$

$$su1 = 0.01099427$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$lo/lou,min = lb/ld = 0.45297586$$

$$su1 = 0.4*esu1_nominal ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: esu1_nominal = 0.08,

For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25*(lb/ld)^{2/3})$, from 10.3.5, ASCE 41-17.

$$\text{with } fs1 = (fs,jacket*Asl,ten,jacket + fs,core*Asl,ten,core)/Asl,ten = 484.0682$$

$$\text{with } Es1 = (Es,jacket*Asl,ten,jacket + Es,core*Asl,ten,core)/Asl,ten = 200000.00$$

$$y2 = 0.00184318$$

$$sh2 = 0.00589816$$

$$ft2 = 580.8818$$

$$fy2 = 484.0682$$

$$su2 = 0.01099427$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$lo/lou,min = lb/lb,min = 0.45297586$$

$$su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: esu2_nominal = 0.08,

For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25*(lb/ld)^{2/3})$, from 10.3.5, ASCE 41-17.

$$\text{with } fs2 = (fs,jacket*Asl,com,jacket + fs,core*Asl,com,core)/Asl,com = 484.0682$$

$$\text{with } Es2 = (Es,jacket*Asl,com,jacket + Es,core*Asl,com,core)/Asl,com = 200000.00$$

$$yv = 0.00184318$$

$$shv = 0.00589816$$

$$ftv = 614.3968$$

$$fyv = 511.9973$$

$$suv = 0.01099427$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$lo/lou,min = lb/ld = 0.45297586$$

$$suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032$$

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.

$$\text{with } fsv = (fs,jacket*Asl,mid,jacket + fs,mid*Asl,mid,core)/Asl,mid = 511.9973$$

$$\text{with } Esv = (Es,jacket*Asl,mid,jacket + Es,mid*Asl,mid,core)/Asl,mid = 200000.00$$

$$1 = Asl,ten/(b*d)*(fs1/fc) = 0.0851958$$

$$2 = Asl,com/(b*d)*(fs2/fc) = 0.0851958$$

$$v = Asl,mid/(b*d)*(fsv/fc) = 0.04369034$$

and confined core properties:

$$b = 340.00$$

$$d = 327.00$$

$$d' = 13.00$$

$$fcc (5A.2, TBDY) = 37.35991$$

$$cc (5A.5, TBDY) = 0.00332119$$

$$c = \text{confinement factor} = 1.13212$$

$$1 = Asl,ten/(b*d)*(fs1/fc) = 0.1094258$$

$$2 = Asl,com/(b*d)*(fs2/fc) = 0.1094258$$

$$v = Asl,mid/(b*d)*(fsv/fc) = 0.05611603$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

v < vs,y2 - LHS eq.(4.5) is satisfied

--->

$$su (4.9) = 0.16193824$$

$$Mu = MRc (4.14) = 1.8194E+008$$

$$u = s_u(4.1) = 3.6747033E-005$$

Calculation of ratio l_b/d

$$\text{Lap Length: } l_b/d = 0.45297586$$

$$l_b = 300.00$$

$$d = 662.2869$$

Calculation of l_b, \min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

$$= 1$$

$$d_b = 14.66667$$

$$\text{Mean strength value of all re-bars: } f_y = 656.5682$$

$$\text{Mean concrete strength: } f_c' = (f_c'_{\text{jacket}} \cdot \text{Area}_{\text{jacket}} + f_c'_{\text{core}} \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 29.75, \text{ but } f_c'^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 25.00$$

$$K_{tr} = 3.43481$$

$$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 257.6106$$

where A_{tr_x} , A_{tr_y} are the sum of the area of all stirrup legs along X and Y local axis

$$s = \text{Max}(s_{\text{external}}, s_{\text{internal}}) = 250.00$$

$$n = 12.00$$

Calculation of μ_2

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:

$$u = 3.6747033E-005$$

$$\mu_u = 1.8194E+008$$

with full section properties:

$$b = 400.00$$

$$d = 357.00$$

$$d' = 43.00$$

$$v = 0.00125773$$

$$N = 5926.932$$

$$f_c = 33.00$$

$$c_o \text{ (5A.5, TBDY)} = 0.002$$

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.01505571$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } c_u = 0.01505571$$

$$w_e \text{ ((5.4c), TBDY)} = a_s c * s_{h, \min} * f_{y, w} / f_{c, e} + \text{Min}(f_x, f_y) = 0.08345896$$

where $f = a_f * p_f * f_{f, e} / f_{c, e}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.07683125$$

$$a_f = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{f, e} = 870.5244$$

$$f_y = 0.07683125$$

$$a_f = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{f, e} = 870.5244$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L * t * \text{Cos}(b_1) = 1.016$$

$$f_{u, f} = 1055.00$$

Ef = 64828.00

u,f = 0.015

ase ((5.4d), TBDY) = (ase1*Aext+ase2*Aint)/Asec = 0.24250288

ase1 = 0.24250288

bo_1 = 340.00

ho_1 = 340.00

bi2_1 = 462400.00

ase2 = Max(ase1,ase2) = 0.24250288

bo_2 = 192.00

ho_2 = 192.00

bi2_2 = 147456.00

psh,min*Fywe = Min(psh,x*Fywe , psh,y*Fywe) = 3.00635

Expression ((5.4d), TBDY) for psh,min*Fywe has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

psh_x*Fywe = psh1*Fywe1+ps2*Fywe2 = 3.00635

ps1 (external) = (Ash1*h1/s1)/Asec = 0.00392699

Ash1 = Astir_1*ns_1 = 157.0796

No stirrups, ns_1 = 2.00

h1 = 400.00

ps2 (internal) = (Ash2*h2/s2)/Asec = 0.00050265

Ash2 = Astir_2*ns_2 = 100.531

No stirrups, ns_2 = 2.00

h2 = 200.00

psh_y*Fywe = psh1*Fywe1+ps2*Fywe2 = 3.00635

ps1 (external) = (Ash1*h1/s1)/Asec = 0.00392699

Ash1 = Astir_1*ns_1 = 157.0796

No stirrups, ns_1 = 2.00

h1 = 400.00

ps2 (internal) = (Ash2*h2/s2)/Asec = 0.00050265

Ash2 = Astir_2*ns_2 = 100.531

No stirrups, ns_2 = 2.00

h2 = 200.00

Asec = 160000.00

s1 = 100.00

s2 = 250.00

fywe1 = 694.45

fywe2 = 555.55

fce = 33.00

From ((5.A5), TBDY), TBDY: cc = 0.00332119

c = confinement factor = 1.13212

y1 = 0.00184318

sh1 = 0.00589816

ft1 = 580.8818

fy1 = 484.0682

su1 = 0.01099427

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

lo/lou,min = lb/lb = 0.45297586

su1 = 0.4*esu1_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esu1_nominal = 0.08,

For calculation of esu1_nominal and y1, sh1,ft1,fy1, it is considered characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/lb)^2/3), from 10.3.5, ASCE 41-17.

with fs1 = (fs,jacket*Asl,ten,jacket + fs,core*Asl,ten,core)/Asl,ten = 484.0682

with Es1 = (Es,jacket*Asl,ten,jacket + Es,core*Asl,ten,core)/Asl,ten = 200000.00

y2 = 0.00184318

sh2 = 0.00589816

ft2 = 580.8818

fy2 = 484.0682

su2 = 0.01099427

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$$l_o/l_{o,min} = l_b/l_{b,min} = 0.45297586$$

$$s_u = 0.4 * e_{s_u,nominal} ((5.5), TBDY) = 0.032$$

$$\text{From table 5A.1, TBDY: } e_{s_u,nominal} = 0.08,$$

For calculation of $e_{s_u,nominal}$ and y_2, sh_2, ft_2, fy_2 , it is considered characteristic value $f_{s_y2} = f_{s2}/1.2$, from table 5.1, TBDY.

$$y_1, sh_1, ft_1, fy_1, \text{ are also multiplied by } \text{Min}(1, 1.25 * (l_b/l_d)^{2/3}), \text{ from 10.3.5, ASCE 41-17.}$$

$$\text{with } f_{s2} = (f_{s,jacket} * A_{s_l,com,jacket} + f_{s,core} * A_{s_l,com,core}) / A_{s_l,com} = 484.0682$$

$$\text{with } E_{s2} = (E_{s,jacket} * A_{s_l,com,jacket} + E_{s,core} * A_{s_l,com,core}) / A_{s_l,com} = 200000.00$$

$$y_v = 0.00184318$$

$$sh_v = 0.00589816$$

$$ft_v = 614.3968$$

$$fy_v = 511.9973$$

$$s_{u,v} = 0.01099427$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00

$$l_o/l_{o,min} = l_b/l_d = 0.45297586$$

$$s_{u,v} = 0.4 * e_{s_{u,v},nominal} ((5.5), TBDY) = 0.032$$

$$\text{From table 5A.1, TBDY: } e_{s_{u,v},nominal} = 0.08,$$

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, fy_v , it is considered characteristic value $f_{s_{u,v}} = f_{s_{u,v}}/1.2$, from table 5.1, TBDY.

$$y_1, sh_1, ft_1, fy_1, \text{ are also multiplied by } \text{Min}(1, 1.25 * (l_b/l_d)^{2/3}), \text{ from 10.3.5, ASCE 41-17.}$$

$$\text{with } f_{s_{u,v}} = (f_{s,jacket} * A_{s_l,mid,jacket} + f_{s,mid} * A_{s_l,mid,core}) / A_{s_l,mid} = 511.9973$$

$$\text{with } E_{s_{u,v}} = (E_{s,jacket} * A_{s_l,mid,jacket} + E_{s,mid} * A_{s_l,mid,core}) / A_{s_l,mid} = 200000.00$$

$$1 = A_{s_l,ten} / (b * d) * (f_{s1} / f_c) = 0.0851958$$

$$2 = A_{s_l,com} / (b * d) * (f_{s2} / f_c) = 0.0851958$$

$$v = A_{s_l,mid} / (b * d) * (f_{s_{u,v}} / f_c) = 0.04369034$$

and confined core properties:

$$b = 340.00$$

$$d = 327.00$$

$$d' = 13.00$$

$$f_{cc} (5A.2, TBDY) = 37.35991$$

$$c_c (5A.5, TBDY) = 0.00332119$$

$$c = \text{confinement factor} = 1.13212$$

$$1 = A_{s_l,ten} / (b * d) * (f_{s1} / f_c) = 0.1094258$$

$$2 = A_{s_l,com} / (b * d) * (f_{s2} / f_c) = 0.1094258$$

$$v = A_{s_l,mid} / (b * d) * (f_{s_{u,v}} / f_c) = 0.05611603$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

---->

$v < v_{s,y2}$ - LHS eq.(4.5) is satisfied

---->

$$s_u (4.9) = 0.16193824$$

$$\mu_u = M_{Rc} (4.14) = 1.8194E+008$$

$$u = s_u (4.1) = 3.6747033E-005$$

Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.45297586$

$$l_b = 300.00$$

$$l_d = 662.2869$$

Calculation of $l_{b,min}$ according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

$$= 1$$

$$d_b = 14.66667$$

Mean strength value of all re-bars: $f_y = 656.5682$

Mean concrete strength: $f'_c = (f'_c_{jacket} * Area_{jacket} + f'_c_{core} * Area_{core}) / Area_{section} = 29.75$, but $f'_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 25.00$$

$$K_{tr} = 3.43481$$

$$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 257.6106$$

where A_{tr_x}, A_{tr_y} are the sum of the area of all stirrup legs along X and Y local axis

$$s = \text{Max}(s_{external}, s_{internal}) = 250.00$$

n = 12.00

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 633062.661$

Calculation of Shear Strength at edge 1, $V_{r1} = 633062.661$

$V_{r1} = V_{Co1} \text{ ((10.3), ASCE 41-17)} = knl * V_{Co10}$

$V_{Co10} = 633062.661$

$knl = 1$ (zero step-static loading)

NOTE: In expression (10-3) ' $V_s = A_v * f_y * d / s$ ' is replaced by ' $V_s + f * V_f$ ' where V_f is the contribution of FRPs (11.3), ACI 440).

= 1 (normal-weight concrete)

Mean concrete strength: $f_c' = (f_c'_{\text{jacket}} * \text{Area}_{\text{jacket}} + f_c'_{\text{core}} * \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 29.75$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M / Vd = 2.00$

$\mu_u = 4.3445556E-012$

$V_u = 2.8976040E-031$

$d = 0.8 * h = 320.00$

$N_u = 5926.932$

$A_g = 160000.00$

From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 279254.914$

where:

$V_{s1} = 279254.914$ is calculated for jacket, with:

$d = 320.00$

$A_v = 157079.633$

$f_y = 555.56$

$s = 100.00$

V_{s1} is multiplied by $Col1 = 1.00$

$s/d = 0.3125$

$V_{s2} = 0.00$ is calculated for core, with:

$d = 160.00$

$A_v = 100530.965$

$f_y = 444.44$

$s = 250.00$

V_{s2} is multiplied by $Col2 = 0.00$

$s/d = 1.5625$

$V_f \text{ ((11-3)-(11.4), ACI 440)} = 188111.148$

$f = 0.95$, for fully-wrapped sections

$w_f / s_f = 1$ (FRP strips adjacent to one another).

In (11.3) $\sin \theta + \cos \theta$ is replaced with $(\cot \theta + \csc \theta) \sin \alpha$ which is more a generalised expression,

where θ is the angle of the crack direction (see KANEPE).

This later relation, considered as a function $V_f(\theta, \alpha)$, is implemented for every different fiber orientation α_i , as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.

orientation 1: $\theta = b1 + 90^\circ = 90.00$

$V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, \theta)|)$, with:

total thickness per orientation, $t_{f1} = NL * t / \text{NoDir} = 1.016$

$d_{fv} = d$ (figure 11.2, ACI 440) = 357.00

$f_{fe} \text{ ((11-5), ACI 440)} = 259.312$

$E_f = 64828.00$

$f_e = 0.004$, from (11.6a), ACI 440

with $f_u = 0.01$

From (11-11), ACI 440: $V_s + V_f \leq 463788.751$

$bw = 400.00$

Calculation of Shear Strength at edge 2, $V_{r2} = 633062.661$

$V_{r2} = V_{Co2} \text{ ((10.3), ASCE 41-17)} = knl * V_{Co20}$

$V_{Co20} = 633062.661$

$knl = 1$ (zero step-static loading)

NOTE: In expression (10-3) ' $V_s = A_v * f_y * d / s$ ' is replaced by ' $V_s + f * V_f$ ' where V_f is the contribution of FRPs (11.3), ACI 440).

= 1 (normal-weight concrete)
 Mean concrete strength: $f_c' = (f_c'_{\text{jacket}} \cdot \text{Area}_{\text{jacket}} + f_c'_{\text{core}} \cdot \text{Area}_{\text{core}}) / \text{Area}_{\text{section}} = 29.75$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $M/Vd = 2.00$
 $\mu_u = 4.3445556E-012$
 $V_u = 2.8976040E-031$
 $d = 0.8 \cdot h = 320.00$
 $N_u = 5926.932$
 $A_g = 160000.00$
 From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 279254.914$
 where:
 $V_{s1} = 279254.914$ is calculated for jacket, with:
 $d = 320.00$
 $A_v = 157079.633$
 $f_y = 555.56$
 $s = 100.00$
 V_{s1} is multiplied by $\text{Col1} = 1.00$
 $s/d = 0.3125$
 $V_{s2} = 0.00$ is calculated for core, with:
 $d = 160.00$
 $A_v = 100530.965$
 $f_y = 444.44$
 $s = 250.00$
 V_{s2} is multiplied by $\text{Col2} = 0.00$
 $s/d = 1.5625$
 V_f ((11-3)-(11.4), ACI 440) = 188111.148
 $f = 0.95$, for fully-wrapped sections
 $w_f/s_f = 1$ (FRP strips adjacent to one another).
 In (11.3) $\sin + \cos$ is replaced with $(\cot + \cot a) \sin a$ which is more a generalised expression, where a is the angle of the crack direction (see KANEPE).
 This later relation, considered as a function $V_f(\theta, a)$, is implemented for every different fiber orientation a_i , as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.
 orientation 1: $\theta = 45^\circ$
 $V_f = \text{Min}(|V_f(45, a_1)|, |V_f(-45, a_1)|)$, with:
 total thickness per orientation, $t_{f1} = NL \cdot t / \text{NoDir} = 1.016$
 $d_{fv} = d$ (figure 11.2, ACI 440) = 357.00
 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: $V_s + V_f \leq 463788.751$
 $b_w = 400.00$

 End Of Calculation of Shear Capacity ratio for element: column JC1 of floor 1
 At local axis: 3

 Start Of Calculation of Shear Capacity ratio for element: column JC1 of floor 1
 At Shear local axis: 2
 (Bending local axis: 3)
 Section Type: rcjrs

Constant Properties

 Knowledge Factor, $\phi = 0.80$
 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
 Existing material of Secondary Member: Concrete Strength, $f_c = f_{cm} = 20.00$

Existing material of Secondary Member: Steel Strength, $f_s = f_{sm} = 444.44$
Concrete Elasticity, $E_c = 21019.039$
Steel Elasticity, $E_s = 200000.00$

Note: Especially for the calculation of moment strengths,
the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14
Jacket
New material: Steel Strength, $f_s = 1.25 * f_{sm} = 694.45$
Existing Column
Existing material: Steel Strength, $f_s = 1.25 * f_{sm} = 555.55$

External Height, $H = 400.00$
External Width, $W = 400.00$
Internal Height, $H = 200.00$
Internal Width, $W = 200.00$
Cover Thickness, $c = 25.00$
Mean Confinement Factor overall section = 1.13212
Element Length, $L = 3000.00$
Secondary Member
Ribbed Bars
Ductile Steel
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
Lap Length $l_o = 300.00$
FRP Wrapping Data
Type: Carbon
Cured laminate properties (design values)
Thickness, $t = 1.016$
Tensile Strength, $f_{fu} = 1055.00$
Tensile Modulus, $E_f = 64828.00$
Elongation, $e_{fu} = 0.01$
Number of directions, $N_{oDir} = 1$
Fiber orientations, $b_i: 0.00^\circ$
Number of layers, $N_L = 1$
Radius of rounding corners, $R = 40.00$

Stepwise Properties

At local axis: 2
EDGE -A-
Shear Force, $V_a = -6.6805695E-033$
EDGE -B-
Shear Force, $V_b = 6.6805695E-033$
BOTH EDGES
Axial Force, $F = -5926.932$
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: $A_{sl,t} = 0.00$
-Compression: $A_{sl,c} = 2060.885$
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension: $A_{sl,ten} = 829.3805$
-Compression: $A_{sl,com} = 829.3805$
-Middle: $A_{sl,mid} = 402.1239$

Calculation of Shear Capacity ratio, $V_e/V_r = 0.19159777$
Member Controlled by Flexure ($V_e/V_r < 1$)
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 121293.391$
with
 $M_{pr1} = \text{Max}(M_{u1+}, M_{u1-}) = 1.8194E+008$
 $M_{u1+} = 1.8194E+008$, is the ultimate moment strength at the edge 1 of the member in the actual moment direction
which is defined for the static loading combination
 $M_{u1-} = 1.8194E+008$, is the ultimate moment strength at the edge 1 of the member in the opposite moment
direction which is defined for the static loading combination
 $M_{pr2} = \text{Max}(M_{u2+}, M_{u2-}) = 1.8194E+008$

Mu2+ = 1.8194E+008, is the ultimate moment strength at the edge 2 of the member in the actual moment direction which is defined for the the static loading combination

Mu2- = 1.8194E+008, is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the the static loading combination

Calculation of Mu1+

Calculation of ultimate curvature μ according to 4.1, Biskinis/Fardis 2013:

$$\mu = 3.6747033E-005$$

$$Mu = 1.8194E+008$$

with full section properties:

$$b = 400.00$$

$$d = 357.00$$

$$d' = 43.00$$

$$v = 0.00125773$$

$$N = 5926.932$$

$$f_c = 33.00$$

$$c_o \text{ (5A.5, TBDY)} = 0.002$$

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.01505571$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } c_u = 0.01505571$$

$$w_e \text{ ((5.4c), TBDY)} = a_{se} * s_{h,\min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.08345896$$

where $f = a_f * p_f * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.07683125$$

$$a_f = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 870.5244$$

$$f_y = 0.07683125$$

$$a_f = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 870.5244$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L * t * \text{Cos}(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$a_{se} \text{ ((5.4d), TBDY)} = (a_{se1} * A_{ext} + a_{se2} * A_{int}) / A_{sec} = 0.24250288$$

$$a_{se1} = 0.24250288$$

$$b_{o,1} = 340.00$$

$$h_{o,1} = 340.00$$

$$b_{i,1} = 462400.00$$

$$a_{se2} = \text{Max}(a_{se1}, a_{se2}) = 0.24250288$$

$$b_{o,2} = 192.00$$

$$h_{o,2} = 192.00$$

$$b_{i,2} = 147456.00$$

$$p_{sh,\min} * F_{ywe} = \text{Min}(p_{sh,x} * F_{ywe}, p_{sh,y} * F_{ywe}) = 3.00635$$

Expression ((5.4d), TBDY) for $p_{sh,\min} * F_{ywe}$ has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$$p_{sh,x} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{sh2} * F_{ywe2} = 3.00635$$

$$p_{s1} \text{ (external)} = (A_{sh1} * h_1 / s_1) / A_{sec} = 0.00392699$$

$$A_{sh1} = A_{stir,1} * n_{s,1} = 157.0796$$

$$\text{No stirrups, } n_{s,1} = 2.00$$

$$h_1 = 400.00$$

$$ps2 \text{ (internal)} = (Ash2 \cdot h2 / s2) / Asec = 0.00050265$$

$$Ash2 = Astir_2 \cdot ns_2 = 100.531$$

$$\text{No stirups, } ns_2 = 2.00$$

$$h2 = 200.00$$

$$psh_y \cdot Fywe = psh1 \cdot Fywe1 + ps2 \cdot Fywe2 = 3.00635$$

$$ps1 \text{ (external)} = (Ash1 \cdot h1 / s1) / Asec = 0.00392699$$

$$Ash1 = Astir_1 \cdot ns_1 = 157.0796$$

$$\text{No stirups, } ns_1 = 2.00$$

$$h1 = 400.00$$

$$ps2 \text{ (internal)} = (Ash2 \cdot h2 / s2) / Asec = 0.00050265$$

$$Ash2 = Astir_2 \cdot ns_2 = 100.531$$

$$\text{No stirups, } ns_2 = 2.00$$

$$h2 = 200.00$$

$$Asec = 160000.00$$

$$s1 = 100.00$$

$$s2 = 250.00$$

$$fywe1 = 694.45$$

$$fywe2 = 555.55$$

$$fce = 33.00$$

$$\text{From ((5.A.5), TBDY), TBDY: } cc = 0.00332119$$

$$c = \text{confinement factor} = 1.13212$$

$$y1 = 0.00184318$$

$$sh1 = 0.00589816$$

$$ft1 = 580.8818$$

$$fy1 = 484.0682$$

$$su1 = 0.01099427$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$lo/lou, \text{min} = lb/ld = 0.45297586$$

$$su1 = 0.4 \cdot esu1_nominal \text{ ((5.5), TBDY)} = 0.032$$

$$\text{From table 5A.1, TBDY: } esu1_nominal = 0.08,$$

For calculation of esu1_nominal and y1, sh1, ft1, fy1, it is considered
characteristic value fsy1 = fs1/1.2, from table 5.1, TBDY.

$$y1, sh1, ft1, fy1, \text{ are also multiplied by } \text{Min}(1, 1.25 \cdot (lb/ld)^{2/3}), \text{ from 10.3.5, ASCE 41-17.}$$

$$\text{with } fs1 = (fs_jacket \cdot Asl, \text{ten, jacket} + fs_core \cdot Asl, \text{ten, core}) / Asl, \text{ten} = 484.0682$$

$$\text{with } Es1 = (Es_jacket \cdot Asl, \text{ten, jacket} + Es_core \cdot Asl, \text{ten, core}) / Asl, \text{ten} = 200000.00$$

$$y2 = 0.00184318$$

$$sh2 = 0.00589816$$

$$ft2 = 580.8818$$

$$fy2 = 484.0682$$

$$su2 = 0.01099427$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$lo/lou, \text{min} = lb/lb, \text{min} = 0.45297586$$

$$su2 = 0.4 \cdot esu2_nominal \text{ ((5.5), TBDY)} = 0.032$$

$$\text{From table 5A.1, TBDY: } esu2_nominal = 0.08,$$

For calculation of esu2_nominal and y2, sh2, ft2, fy2, it is considered
characteristic value fsy2 = fs2/1.2, from table 5.1, TBDY.

$$y2, sh2, ft2, fy2, \text{ are also multiplied by } \text{Min}(1, 1.25 \cdot (lb/ld)^{2/3}), \text{ from 10.3.5, ASCE 41-17.}$$

$$\text{with } fs2 = (fs_jacket \cdot Asl, \text{com, jacket} + fs_core \cdot Asl, \text{com, core}) / Asl, \text{com} = 484.0682$$

$$\text{with } Es2 = (Es_jacket \cdot Asl, \text{com, jacket} + Es_core \cdot Asl, \text{com, core}) / Asl, \text{com} = 200000.00$$

$$yv = 0.00184318$$

$$shv = 0.00589816$$

$$ftv = 614.3968$$

$$fyv = 511.9973$$

$$suv = 0.01099427$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$lo/lou, \text{min} = lb/ld = 0.45297586$$

$$suv = 0.4 \cdot esuv_nominal \text{ ((5.5), TBDY)} = 0.032$$

$$\text{From table 5A.1, TBDY: } esuv_nominal = 0.08,$$

considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY

For calculation of $e_{suv_nominal}$ and y_v , sh_v , ft_v , fy_v , it is considered characteristic value $f_{sv} = f_{sv}/1.2$, from table 5.1, TBDY.

y_1 , sh_1 , ft_1 , fy_1 , are also multiplied by $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$, from 10.3.5, ASCE 41-17.

with $f_{sv} = (f_{s,jacket} \cdot A_{s,mid,jacket} + f_{s,mid} \cdot A_{s,mid,core})/A_{s,mid} = 511.9973$

with $E_{sv} = (E_{s,jacket} \cdot A_{s,mid,jacket} + E_{s,mid} \cdot A_{s,mid,core})/A_{s,mid} = 200000.00$

$1 = A_{s,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.0851958$

$2 = A_{s,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.0851958$

$v = A_{s,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.04369034$

and confined core properties:

$b = 340.00$

$d = 327.00$

$d' = 13.00$

f_{cc} (5A.2, TBDY) = 37.35991

cc (5A.5, TBDY) = 0.00332119

$c =$ confinement factor = 1.13212

$1 = A_{s,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.1094258$

$2 = A_{s,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.1094258$

$v = A_{s,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.05611603$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < v_{s,y2}$ - LHS eq.(4.5) is satisfied

--->

μ_u (4.9) = 0.16193824

$\mu_u = MR_c$ (4.14) = 1.8194E+008

$u = \mu_u$ (4.1) = 3.6747033E-005

Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.45297586$

$l_b = 300.00$

$l_d = 662.2869$

Calculation of $l_{b,min}$ according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

= 1

$d_b = 14.66667$

Mean strength value of all re-bars: $f_y = 656.5682$

Mean concrete strength: $f'_c = (f'_{c,jacket} \cdot Area_{jacket} + f'_{c,core} \cdot Area_{core})/Area_{section} = 29.75$, but $f_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 3.43481$

$A_{tr} = \text{Min}(A_{tr,x}, A_{tr,y}) = 257.6106$

where $A_{tr,x}$, $A_{tr,y}$ are the sum of the area of all stirrup legs along X and Y local axis

$s = \text{Max}(s_{external}, s_{internal}) = 250.00$

$n = 12.00$

Calculation of μ_{u1} -

Calculation of ultimate curvature μ_u according to 4.1, Biskinis/Fardis 2013:

$u = 3.6747033E-005$

$\mu_u = 1.8194E+008$

with full section properties:

$b = 400.00$

$d = 357.00$

$d' = 43.00$

$v = 0.00125773$

$N = 5926.932$

$f_c = 33.00$

cc (5A.5, TBDY) = 0.002

Final value of c_u : $c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.01505571$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $c_u = 0.01505571$

w_e ((5.4c), TBDY) = $ase^* sh_{\min} * fy_{we}/f_{ce} + \text{Min}(f_x, f_y) = 0.08345896$

where $f = af * pf * f_{fe}/f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

 $f_x = 0.07683125$

$af = 0.57333333$

$b = 400.00$

$h = 400.00$

From EC8 A.4.4.3(6), $pf = 2tf/bw = 0.00508$

$bw = 400.00$

effective stress from (A.35), $f_{f,e} = 870.5244$

 $f_y = 0.07683125$

$af = 0.57333333$

$b = 400.00$

$h = 400.00$

From EC8 A.4.4.3(6), $pf = 2tf/bw = 0.00508$

$bw = 400.00$

effective stress from (A.35), $f_{f,e} = 870.5244$

 $R = 40.00$

Effective FRP thickness, $tf = NL * t * \text{Cos}(b1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{f} = 0.015$

ase ((5.4d), TBDY) = $(ase1 * A_{ext} + ase2 * A_{int}) / A_{sec} = 0.24250288$

$ase1 = 0.24250288$

$bo_1 = 340.00$

$ho_1 = 340.00$

$bi2_1 = 462400.00$

$ase2 = \text{Max}(ase1, ase2) = 0.24250288$

$bo_2 = 192.00$

$ho_2 = 192.00$

$bi2_2 = 147456.00$

$psh_{\min} * fy_{we} = \text{Min}(psh_x * fy_{we}, psh_y * fy_{we}) = 3.00635$

Expression ((5.4d), TBDY) for $psh_{\min} * fy_{we}$ has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

 $psh_x * fy_{we} = psh1 * fy_{we1} + ps2 * fy_{we2} = 3.00635$

$ps1$ (external) = $(Ash1 * h1 / s1) / A_{sec} = 0.00392699$

$Ash1 = Astir_1 * ns_1 = 157.0796$

No stirrups, $ns_1 = 2.00$

$h1 = 400.00$

$ps2$ (internal) = $(Ash2 * h2 / s2) / A_{sec} = 0.00050265$

$Ash2 = Astir_2 * ns_2 = 100.531$

No stirrups, $ns_2 = 2.00$

$h2 = 200.00$

 $psh_y * fy_{we} = psh1 * fy_{we1} + ps2 * fy_{we2} = 3.00635$

$ps1$ (external) = $(Ash1 * h1 / s1) / A_{sec} = 0.00392699$

$Ash1 = Astir_1 * ns_1 = 157.0796$

No stirrups, $ns_1 = 2.00$

$h1 = 400.00$

$ps2$ (internal) = $(Ash2 * h2 / s2) / A_{sec} = 0.00050265$

$Ash2 = Astir_2 * ns_2 = 100.531$

No stirrups, $ns_2 = 2.00$

$h2 = 200.00$

 $A_{sec} = 160000.00$

$s1 = 100.00$

$s2 = 250.00$

$fy_{we1} = 694.45$

$fy_{we2} = 555.55$

$f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY: $cc = 0.00332119$

$c = \text{confinement factor} = 1.13212$
 $y1 = 0.00184318$
 $sh1 = 0.00589816$
 $ft1 = 580.8818$
 $fy1 = 484.0682$
 $su1 = 0.01099427$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 $\text{Shear_factor} = 1.00$
 $lo/lou,min = lb/ld = 0.45297586$
 $su1 = 0.4 * esu1_nominal ((5.5), \text{TBDY}) = 0.032$
 From table 5A.1, TBDY: $esu1_nominal = 0.08$,
 For calculation of $esu1_nominal$ and $y1, sh1, ft1, fy1$, it is considered
 characteristic value $fsy1 = fs1/1.2$, from table 5.1, TBDY.
 $y1, sh1, ft1, fy1$, are also multiplied by $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE 41-17.
 with $fs1 = (fs,jacket * Asl,ten,jacket + fs,core * Asl,ten,core) / Asl,ten = 484.0682$
 with $Es1 = (Es,jacket * Asl,ten,jacket + Es,core * Asl,ten,core) / Asl,ten = 200000.00$
 $y2 = 0.00184318$
 $sh2 = 0.00589816$
 $ft2 = 580.8818$
 $fy2 = 484.0682$
 $su2 = 0.01099427$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 $\text{Shear_factor} = 1.00$
 $lo/lou,min = lb/lb,min = 0.45297586$
 $su2 = 0.4 * esu2_nominal ((5.5), \text{TBDY}) = 0.032$
 From table 5A.1, TBDY: $esu2_nominal = 0.08$,
 For calculation of $esu2_nominal$ and $y2, sh2, ft2, fy2$, it is considered
 characteristic value $fsy2 = fs2/1.2$, from table 5.1, TBDY.
 $y1, sh1, ft1, fy1$, are also multiplied by $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE 41-17.
 with $fs2 = (fs,jacket * Asl,com,jacket + fs,core * Asl,com,core) / Asl,com = 484.0682$
 with $Es2 = (Es,jacket * Asl,com,jacket + Es,core * Asl,com,core) / Asl,com = 200000.00$
 $yv = 0.00184318$
 $shv = 0.00589816$
 $ftv = 614.3968$
 $fyv = 511.9973$
 $suv = 0.01099427$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 $\text{Shear_factor} = 1.00$
 $lo/lou,min = lb/ld = 0.45297586$
 $suv = 0.4 * esuv_nominal ((5.5), \text{TBDY}) = 0.032$
 From table 5A.1, TBDY: $esuv_nominal = 0.08$,
 considering characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY
 For calculation of $esuv_nominal$ and yv, shv, ftv, fyv , it is considered
 characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY.
 $y1, sh1, ft1, fy1$, are also multiplied by $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE 41-17.
 with $fsv = (fs,jacket * Asl,mid,jacket + fs,mid * Asl,mid,core) / Asl,mid = 511.9973$
 with $Es_v = (Es,jacket * Asl,mid,jacket + Es,mid * Asl,mid,core) / Asl,mid = 200000.00$
 $1 = Asl,ten / (b * d) * (fs1 / fc) = 0.0851958$
 $2 = Asl,com / (b * d) * (fs2 / fc) = 0.0851958$
 $v = Asl,mid / (b * d) * (fsv / fc) = 0.04369034$
 and confined core properties:
 $b = 340.00$
 $d = 327.00$
 $d' = 13.00$
 $fcc (5A.2, \text{TBDY}) = 37.35991$
 $cc (5A.5, \text{TBDY}) = 0.00332119$
 $c = \text{confinement factor} = 1.13212$
 $1 = Asl,ten / (b * d) * (fs1 / fc) = 0.1094258$
 $2 = Asl,com / (b * d) * (fs2 / fc) = 0.1094258$
 $v = Asl,mid / (b * d) * (fsv / fc) = 0.05611603$
 Case/Assumption: Unconfined full section - Steel rupture
 ' satisfies Eq. (4.3)
 --->
 $v < vs,y2$ - LHS eq.(4.5) is satisfied

--->

su (4.9) = 0.16193824
Mu = MRc (4.14) = 1.8194E+008
u = su (4.1) = 3.6747033E-005

Calculation of ratio lb/l_d

Lap Length: lb/l_d = 0.45297586

lb = 300.00

l_d = 662.2869

Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

= 1

db = 14.66667

Mean strength value of all re-bars: f_y = 656.5682

Mean concrete strength: f_c' = (f_c'_{jacket}*Area_{jacket} + f_c'_{core}*Area_{core})/Area_{section} = 29.75, but f_c'^{0.5} ≤ 8.3

MPa (22.5.3.1, ACI 318-14)

t = 1.00

s = 0.80

e = 1.00

cb = 25.00

K_{tr} = 3.43481

A_{tr} = Min(A_{tr_x}, A_{tr_y}) = 257.6106

where A_{tr_x}, A_{tr_y} are the sum of the area of all stirrup legs along X and Y local axis

s = Max(s_{external}, s_{internal}) = 250.00

n = 12.00

Calculation of Mu₂₊

Calculation of ultimate curvature κ_u according to 4.1, Biskinis/Fardis 2013:

u = 3.6747033E-005

Mu = 1.8194E+008

with full section properties:

b = 400.00

d = 357.00

d' = 43.00

v = 0.00125773

N = 5926.932

f_c = 33.00

co (5A.5, TBDY) = 0.002

Final value of κ_u : $\kappa_u^* = \text{shear_factor} * \text{Max}(\kappa_u, \kappa_c) = 0.01505571$

The Shear_factor is considered equal to 1 (pure moment strength)

From (5.4b), TBDY: $\kappa_u = 0.01505571$

we ((5.4c), TBDY) = $a_s e * \text{sh}_{\min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.08345896$

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 = 0.07683125

a_f = 0.57333333

b = 400.00

h = 400.00

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 = 0.07683125

a_f = 0.57333333

b = 400.00

h = 400.00

From EC8 A.4.4.3(6), p_f = 2t_f/b_w = 0.00508

b_w = 400.00

effective stress from (A.35), f_{f,e} = 870.5244

$R = 40.00$
 Effective FRP thickness, $t_f = NL * t * \cos(b_1) = 1.016$
 $f_{u,f} = 1055.00$
 $E_f = 64828.00$
 $u_{,f} = 0.015$
 $ase((5.4d), TBDY) = (ase_1 * A_{ext} + ase_2 * A_{int}) / A_{sec} = 0.24250288$
 $ase_1 = 0.24250288$
 $bo_1 = 340.00$
 $ho_1 = 340.00$
 $bi_2_1 = 462400.00$
 $ase_2 = \text{Max}(ase_1, ase_2) = 0.24250288$
 $bo_2 = 192.00$
 $ho_2 = 192.00$
 $bi_2_2 = 147456.00$

$psh_{,min} * F_{ywe} = \text{Min}(psh_{,x} * F_{ywe}, psh_{,y} * F_{ywe}) = 3.00635$
 Expression ((5.4d), TBDY) for $psh_{,min} * F_{ywe}$ has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$psh_{,x} * F_{ywe} = psh_1 * F_{ywe1} + ps_2 * F_{ywe2} = 3.00635$
 $ps_1 \text{ (external)} = (A_{sh1} * h_1 / s_1) / A_{sec} = 0.00392699$
 $A_{sh1} = A_{stir_1} * ns_1 = 157.0796$
 No stirrups, $ns_1 = 2.00$
 $h_1 = 400.00$
 $ps_2 \text{ (internal)} = (A_{sh2} * h_2 / s_2) / A_{sec} = 0.00050265$
 $A_{sh2} = A_{stir_2} * ns_2 = 100.531$
 No stirrups, $ns_2 = 2.00$
 $h_2 = 200.00$

$psh_{,y} * F_{ywe} = psh_1 * F_{ywe1} + ps_2 * F_{ywe2} = 3.00635$
 $ps_1 \text{ (external)} = (A_{sh1} * h_1 / s_1) / A_{sec} = 0.00392699$
 $A_{sh1} = A_{stir_1} * ns_1 = 157.0796$
 No stirrups, $ns_1 = 2.00$
 $h_1 = 400.00$
 $ps_2 \text{ (internal)} = (A_{sh2} * h_2 / s_2) / A_{sec} = 0.00050265$
 $A_{sh2} = A_{stir_2} * ns_2 = 100.531$
 No stirrups, $ns_2 = 2.00$
 $h_2 = 200.00$

$A_{sec} = 160000.00$
 $s_1 = 100.00$
 $s_2 = 250.00$
 $f_{ywe1} = 694.45$
 $f_{ywe2} = 555.55$
 $f_{ce} = 33.00$

From ((5.A5), TBDY), TBDY: $cc = 0.00332119$
 $c = \text{confinement factor} = 1.13212$

$y_1 = 0.00184318$
 $sh_1 = 0.00589816$
 $ft_1 = 580.8818$
 $fy_1 = 484.0682$
 $su_1 = 0.01099427$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 $\text{Shear_factor} = 1.00$

$lo/lo_{,min} = lb/ld = 0.45297586$
 $su_1 = 0.4 * esu_1_{,nominal} \text{ ((5.5), TBDY)} = 0.032$

From table 5A.1, TBDY: $esu_1_{,nominal} = 0.08$,

For calculation of $esu_1_{,nominal}$ and y_1, sh_1, ft_1, fy_1 , it is considered
 characteristic value $fsy_1 = fs_1 / 1.2$, from table 5.1, TBDY.

y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE 41-17.

with $fs_1 = (fs_{,jacket} * A_{sl,ten,jacket} + fs_{,core} * A_{sl,ten,core}) / A_{sl,ten} = 484.0682$

with $Es_1 = (Es_{,jacket} * A_{sl,ten,jacket} + Es_{,core} * A_{sl,ten,core}) / A_{sl,ten} = 200000.00$

$y_2 = 0.00184318$
 $sh_2 = 0.00589816$
 $ft_2 = 580.8818$
 $fy_2 = 484.0682$
 $su_2 = 0.01099427$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$l_o/l_{o,u,min} = l_b/l_{b,min} = 0.45297586$$

$$s_u2 = 0.4 * e_{s_u2,nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: $e_{s_u2,nominal} = 0.08$,

For calculation of $e_{s_u2,nominal}$ and y_2, sh_2, ft_2, fy_2 , it is considered
characteristic value $f_{s_y2} = f_{s_2}/1.2$, from table 5.1, TBDY.

y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE 41-17.

$$\text{with } f_{s_2} = (f_{s,jacket} * A_{s_l,com,jacket} + f_{s,core} * A_{s_l,com,core}) / A_{s_l,com} = 484.0682$$

$$\text{with } E_{s_2} = (E_{s,jacket} * A_{s_l,com,jacket} + E_{s,core} * A_{s_l,com,core}) / A_{s_l,com} = 200000.00$$

$$y_v = 0.00184318$$

$$sh_v = 0.00589816$$

$$ft_v = 614.3968$$

$$fy_v = 511.9973$$

$$s_{u_v} = 0.01099427$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$$l_o/l_{o,u,min} = l_b/l_d = 0.45297586$$

$$s_{u_v} = 0.4 * e_{s_{u_v},nominal} ((5.5), TBDY) = 0.032$$

From table 5A.1, TBDY: $e_{s_{u_v},nominal} = 0.08$,

considering characteristic value $f_{s_{y_v}} = f_{s_v}/1.2$, from table 5.1, TBDY

For calculation of $e_{s_{u_v},nominal}$ and y_v, sh_v, ft_v, fy_v , it is considered
characteristic value $f_{s_{y_v}} = f_{s_v}/1.2$, from table 5.1, TBDY.

y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE 41-17.

$$\text{with } f_{s_v} = (f_{s,jacket} * A_{s_l,mid,jacket} + f_{s,mid} * A_{s_l,mid,core}) / A_{s_l,mid} = 511.9973$$

$$\text{with } E_{s_v} = (E_{s,jacket} * A_{s_l,mid,jacket} + E_{s,mid} * A_{s_l,mid,core}) / A_{s_l,mid} = 200000.00$$

$$1 = A_{s_l,ten} / (b * d) * (f_{s_1} / f_c) = 0.0851958$$

$$2 = A_{s_l,com} / (b * d) * (f_{s_2} / f_c) = 0.0851958$$

$$v = A_{s_l,mid} / (b * d) * (f_{s_v} / f_c) = 0.04369034$$

and confined core properties:

$$b = 340.00$$

$$d = 327.00$$

$$d' = 13.00$$

$$f_{cc} (5A.2, TBDY) = 37.35991$$

$$cc (5A.5, TBDY) = 0.00332119$$

$$c = \text{confinement factor} = 1.13212$$

$$1 = A_{s_l,ten} / (b * d) * (f_{s_1} / f_c) = 0.1094258$$

$$2 = A_{s_l,com} / (b * d) * (f_{s_2} / f_c) = 0.1094258$$

$$v = A_{s_l,mid} / (b * d) * (f_{s_v} / f_c) = 0.05611603$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < v_{s,y_2}$ - LHS eq.(4.5) is satisfied

--->

$$s_u (4.9) = 0.16193824$$

$$\mu = MR_c (4.14) = 1.8194E+008$$

$$u = s_u (4.1) = 3.6747033E-005$$

Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.45297586$

$$l_b = 300.00$$

$$l_d = 662.2869$$

Calculation of $l_{b,min}$ according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

$$= 1$$

$$d_b = 14.66667$$

Mean strength value of all re-bars: $f_y = 656.5682$

Mean concrete strength: $f'_c = (f'_c_{jacket} * Area_{jacket} + f'_c_{core} * Area_{core}) / Area_{section} = 29.75$, but $f'_c^{0.5} \leq 8.3$
MPa (22.5.3.1, ACI 318-14)

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 25.00$$

$$K_{tr} = 3.43481$$

$$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 257.6106$$

where A_{tr_x} , A_{tr_y} are the sum of the area of all stirrup legs along X and Y local axis

$$s = \text{Max}(s_{\text{external}}, s_{\text{internal}}) = 250.00$$

$$n = 12.00$$

Calculation of μ_2 -

Calculation of ultimate curvature μ according to 4.1, Biskinis/Fardis 2013:

$$u = 3.6747033E-005$$

$$\mu = 1.8194E+008$$

with full section properties:

$$b = 400.00$$

$$d = 357.00$$

$$d' = 43.00$$

$$v = 0.00125773$$

$$N = 5926.932$$

$$f_c = 33.00$$

$$c_o \text{ (5A.5, TBDY)} = 0.002$$

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.01505571$$

The Shear_factor is considered equal to 1 (pure moment strength)

$$\text{From (5.4b), TBDY: } c_u = 0.01505571$$

$$w_e \text{ ((5.4c), TBDY)} = a_{se} * s_{h,\text{min}} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.08345896$$

where $f = a_f * p_f * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$f_x = 0.07683125$$

$$a_f = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 870.5244$$

$$f_y = 0.07683125$$

$$a_f = 0.57333333$$

$$b = 400.00$$

$$h = 400.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f / b_w = 0.00508$$

$$b_w = 400.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 870.5244$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L * t * \text{Cos}(b_1) = 1.016$$

$$f_{u,f} = 1055.00$$

$$E_f = 64828.00$$

$$u_{f} = 0.015$$

$$a_{se} \text{ ((5.4d), TBDY)} = (a_{se1} * A_{ext} + a_{se2} * A_{int}) / A_{sec} = 0.24250288$$

$$a_{se1} = 0.24250288$$

$$b_{o,1} = 340.00$$

$$h_{o,1} = 340.00$$

$$b_{i,1} = 462400.00$$

$$a_{se2} = \text{Max}(a_{se1}, a_{se2}) = 0.24250288$$

$$b_{o,2} = 192.00$$

$$h_{o,2} = 192.00$$

$$b_{i,2} = 147456.00$$

$$p_{sh,\text{min}} * F_{ywe} = \text{Min}(p_{sh,x} * F_{ywe}, p_{sh,y} * F_{ywe}) = 3.00635$$

Expression ((5.4d), TBDY) for $p_{sh,\text{min}} * F_{ywe}$ has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$$p_{sh,x} * F_{ywe} = p_{sh1} * F_{ywe1} + p_{sh2} * F_{ywe2} = 3.00635$$

$$p_{s1} \text{ (external)} = (A_{sh1} * h_1 / s_1) / A_{sec} = 0.00392699$$

$$A_{sh1} = A_{stir,1} * n_{s,1} = 157.0796$$

$$\text{No stirrups, } n_{s,1} = 2.00$$

h1 = 400.00
ps2 (internal) = (Ash2*h2/s2)/Asec = 0.00050265
Ash2 = Astir_2*ns_2 = 100.531
No stirups, ns_2 = 2.00
h2 = 200.00

psh_y*Fywe = psh1*Fywe1+ps2*Fywe2 = 3.00635
ps1 (external) = (Ash1*h1/s1)/Asec = 0.00392699
Ash1 = Astir_1*ns_1 = 157.0796
No stirups, ns_1 = 2.00
h1 = 400.00
ps2 (internal) = (Ash2*h2/s2)/Asec = 0.00050265
Ash2 = Astir_2*ns_2 = 100.531
No stirups, ns_2 = 2.00
h2 = 200.00

Asec = 160000.00
s1 = 100.00
s2 = 250.00
fywe1 = 694.45
fywe2 = 555.55
fce = 33.00

From ((5.A5), TBDY), TBDY: cc = 0.00332119
c = confinement factor = 1.13212

y1 = 0.00184318
sh1 = 0.00589816
ft1 = 580.8818
fy1 = 484.0682
su1 = 0.01099427

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/d = 0.45297586

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 = 484.0682

with Es1 = (Es,jacket*Asl,ten,jacket + Es,core*Asl,ten,core)/Asl,ten = 200000.00

y2 = 0.00184318
sh2 = 0.00589816
ft2 = 580.8818
fy2 = 484.0682
su2 = 0.01099427

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/lb,min = 0.45297586

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 = 484.0682

with Es2 = (Es,jacket*Asl,com,jacket + Es,core*Asl,com,core)/Asl,com = 200000.00

yv = 0.00184318
shv = 0.00589816
ftv = 614.3968
fyv = 511.9973
suv = 0.01099427

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

lo/lou,min = lb/d = 0.45297586

suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: esuv_nominal = 0.08,

considering characteristic value $f_{sv} = f_{sv}/1.2$, from table 5.1, TBDY

For calculation of $e_{suv_nominal}$ and y_v , sh_v , ft_v , fy_v , it is considered characteristic value $f_{sv} = f_{sv}/1.2$, from table 5.1, TBDY.

y_1 , sh_1 , ft_1 , fy_1 , are also multiplied by $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$, from 10.3.5, ASCE 41-17.

with $f_{sv} = (f_{s,jacket} \cdot A_{s,mid,jacket} + f_{s,mid} \cdot A_{s,mid,core}) / A_{s,mid} = 511.9973$

with $E_{sv} = (E_{s,jacket} \cdot A_{s,mid,jacket} + E_{s,mid} \cdot A_{s,mid,core}) / A_{s,mid} = 200000.00$

$1 = A_{s,ten} / (b \cdot d) \cdot (f_{s1} / f_c) = 0.0851958$

$2 = A_{s,com} / (b \cdot d) \cdot (f_{s2} / f_c) = 0.0851958$

$v = A_{s,mid} / (b \cdot d) \cdot (f_{sv} / f_c) = 0.04369034$

and confined core properties:

$b = 340.00$

$d = 327.00$

$d' = 13.00$

f_{cc} (5A.2, TBDY) = 37.35991

cc (5A.5, TBDY) = 0.00332119

c = confinement factor = 1.13212

$1 = A_{s,ten} / (b \cdot d) \cdot (f_{s1} / f_c) = 0.1094258$

$2 = A_{s,com} / (b \cdot d) \cdot (f_{s2} / f_c) = 0.1094258$

$v = A_{s,mid} / (b \cdot d) \cdot (f_{sv} / f_c) = 0.05611603$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

$v < v_{s,y2}$ - LHS eq.(4.5) is satisfied

--->

su (4.9) = 0.16193824

μ = M_{Rc} (4.14) = 1.8194E+008

u = su (4.1) = 3.6747033E-005

Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.45297586$

$l_b = 300.00$

$l_d = 662.2869$

Calculation of $l_{b,min}$ according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

= 1

$db = 14.66667$

Mean strength value of all re-bars: $f_y = 656.5682$

Mean concrete strength: $f'_c = (f'_{c,jacket} \cdot Area_{jacket} + f'_{c,core} \cdot Area_{core}) / Area_{section} = 29.75$, but $f_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 3.43481$

$A_{tr} = \text{Min}(A_{tr,x}, A_{tr,y}) = 257.6106$

where $A_{tr,x}$, $A_{tr,y}$ are the sum of the area of all stirrup legs along X and Y local axis

$s = \text{Max}(s_{external}, s_{internal}) = 250.00$

$n = 12.00$

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 633062.661$

Calculation of Shear Strength at edge 1, $V_{r1} = 633062.661$

$V_{r1} = V_{Col}$ ((10.3), ASCE 41-17) = $k_{nl} \cdot V_{Col0}$

$V_{Col0} = 633062.661$

$k_{nl} = 1$ (zero step-static loading)

NOTE: In expression (10-3) ' $V_s = A_v \cdot f_y \cdot d / s$ ' is replaced by ' $V_s + f \cdot V_f$ '

where V_f is the contribution of FRPs (11.3), ACI 440).

= 1 (normal-weight concrete)

Mean concrete strength: $f'_c = (f'_{c,jacket} \cdot Area_{jacket} + f'_{c,core} \cdot Area_{core}) / Area_{section} = 29.75$, but $f_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$\mu_u = 4.6931004E-013$
 $V_u = 6.6805695E-033$
 $d = 0.8 \cdot h = 320.00$
 $N_u = 5926.932$
 $A_g = 160000.00$
 From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 279254.914$
 where:
 $V_{s1} = 279254.914$ is calculated for jacket, with:
 $d = 320.00$
 $A_v = 157079.633$
 $f_y = 555.56$
 $s = 100.00$
 V_{s1} is multiplied by $Col1 = 1.00$
 $s/d = 0.3125$
 $V_{s2} = 0.00$ is calculated for core, with:
 $d = 160.00$
 $A_v = 100530.965$
 $f_y = 444.44$
 $s = 250.00$
 V_{s2} is multiplied by $Col2 = 0.00$
 $s/d = 1.5625$
 V_f ((11-3)-(11.4), ACI 440) = 188111.148
 $f = 0.95$, for fully-wrapped sections
 $w_f/s_f = 1$ (FRP strips adjacent to one another).
 In (11.3) $\sin \theta + \cos \theta$ is replaced with $(\cot \theta + \cot \alpha) \sin \alpha$ which is more a generalised expression,
 where θ is the angle of the crack direction (see KANEPE).
 This later relation, considered as a function $V_f(\theta, \alpha)$, is implemented for every different fiber orientation α_i ,
 as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.
 orientation 1: $\theta = b_1 + 90^\circ = 90.00$
 $V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, \theta)|)$, with:
 total thickness per orientation, $t_{f1} = N_L \cdot t / N_{oDir} = 1.016$
 $d_{fv} = d$ (figure 11.2, ACI 440) = 357.00
 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: $V_s + V_f \leq 463788.751$
 $b_w = 400.00$

Calculation of Shear Strength at edge 2, $V_{r2} = 633062.661$
 $V_{r2} = V_{Col}$ ((10.3), ASCE 41-17) = $k_{nl} \cdot V_{Col0}$
 $V_{Col0} = 633062.661$
 $k_{nl} = 1$ (zero step-static loading)

NOTE: In expression (10-3) ' $V_s = A_v \cdot f_y \cdot d / s$ ' is replaced by ' $V_s + f \cdot V_f$ '
 where V_f is the contribution of FRPs (11.3), ACI 440).

$\mu = 1$ (normal-weight concrete)
 Mean concrete strength: $f_c' = (f_c'_{jacket} \cdot Area_{jacket} + f_c'_{core} \cdot Area_{core}) / Area_{section} = 29.75$, but $f_c'^{0.5} \leq 8.3$
 MPa (22.5.3.1, ACI 318-14)
 $M/d = 2.00$
 $\mu_u = 4.6931004E-013$
 $V_u = 6.6805695E-033$
 $d = 0.8 \cdot h = 320.00$
 $N_u = 5926.932$
 $A_g = 160000.00$
 From (11.5.4.8), ACI 318-14: $V_s = V_{s1} + V_{s2} = 279254.914$
 where:
 $V_{s1} = 279254.914$ is calculated for jacket, with:
 $d = 320.00$
 $A_v = 157079.633$
 $f_y = 555.56$
 $s = 100.00$
 V_{s1} is multiplied by $Col1 = 1.00$
 $s/d = 0.3125$
 $V_{s2} = 0.00$ is calculated for core, with:

$d = 160.00$
 $A_v = 100530.965$
 $f_y = 444.44$
 $s = 250.00$
 Vs2 is multiplied by Col2 = 0.00
 $s/d = 1.5625$
 $V_f((11-3)-(11.4), \text{ACI 440}) = 188111.148$
 $f = 0.95$, 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: $\theta_1 = \theta_1 + 90^\circ = 90.00$
 $V_f = \text{Min}(|V_f(45, \theta_1)|, |V_f(-45, a_1)|)$, with:
 total thickness per orientation, $t_{f1} = N_L * t / \text{NoDir} = 1.016$
 $d_{fv} = d$ (figure 11.2, ACI 440) = 357.00
 $f_{fe}((11-5), \text{ACI 440}) = 259.312$
 $E_f = 64828.00$
 $f_e = 0.004$, from (11.6a), ACI 440
 with $f_u = 0.01$
 From (11-11), ACI 440: $V_s + V_f \leq 463788.751$
 $b_w = 400.00$

 End Of Calculation of Shear Capacity ratio for element: column JC1 of floor 1
 At local axis: 2

 Start Of Calculation of Chord Rotation Capacity for element: column JC1 of floor 1
 At local axis: 3

Integration Section: (b)
 Section Type: rcjrs

Constant Properties

 Knowledge Factor, $\gamma = 0.80$
 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
 Existing material of Secondary Member: Concrete Strength, $f_c = f_{cm} = 20.00$
 Existing material of Secondary Member: Steel Strength, $f_s = f_{sm} = 444.44$
 Concrete Elasticity, $E_c = 21019.039$
 Steel Elasticity, $E_s = 200000.00$
 External Height, $H = 400.00$
 External Width, $W = 400.00$
 Internal Height, $H = 200.00$
 Internal Width, $W = 200.00$
 Cover Thickness, $c = 25.00$
 Element Length, $L = 3000.00$
 Secondary Member
 Ribbed Bars
 Ductile Steel
 Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
 Longitudinal Bars With Ends Lapped Starting at the End Sections
 Lap Length $l_b = 300.00$
 FRP Wrapping Data
 Type: Carbon
 Cured laminate properties (design values)

Thickness, $t = 1.016$
Tensile Strength, $f_{fu} = 1055.00$
Tensile Modulus, $E_f = 64828.00$
Elongation, $e_{fu} = 0.01$
Number of directions, $NoDir = 1$
Fiber orientations, $bi = 0.00^\circ$
Number of layers, $NL = 1$
Radius of rounding corners, $R = 40.00$

Stepwise Properties

Bending Moment, $M = 14604.754$
Shear Force, $V_2 = 7751.185$
Shear Force, $V_3 = -2.6948337E-014$
Axial Force, $F = -6084.055$
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: $As_t = 0.00$
-Compression: $As_c = 2060.885$
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension: $As_{ten} = 829.3805$
-Compression: $As_{com} = 829.3805$
-Middle: $As_{mid} = 402.1239$
Longitudinal External Reinforcement Area Distribution (in 3 divisions)
-Tension: $As_{ten,jacket} = 603.1858$
-Compression: $As_{com,jacket} = 603.1858$
-Middle: $As_{mid,jacket} = 402.1239$
Longitudinal Internal Reinforcement Area Distribution (in 3 divisions)
-Tension: $As_{ten,core} = 226.1947$
-Compression: $As_{com,core} = 226.1947$
-Middle: $As_{mid,core} = 0.00$
Mean Diameter of Tension Reinforcement, $Db_L = 14.40$

Existing component: From table 7-7, ASCE 41_17: Final chord rotation Capacity $u_{R} = u = 0.03426434$
 $u = y + p = 0.04283042$

- Calculation of y -

$y = (M_y * L_s / 3) / E_{eff} = 0.00083042$ ((4.29), Biskinis Phd))
 $M_y = 1.4151E+008$
 $L_s = M/V$ (with $L_s > 0.1 * L$ and $L_s < 2 * L$) = 300.00
From table 10.5, ASCE 41_17: $E_{eff} = factor * E_c * I_g = 1.7040E+013$
factor = 0.30
 $A_g = 160000.00$
Mean concrete strength: $f'_c = (f'_{c,jacket} * Area_{jacket} + f'_{c,core} * Area_{core}) / Area_{section} = 29.75$
 $N = 6084.055$
 $E_c * I_g = E_{c,jacket} * I_{g,jacket} + E_{c,core} * I_{g,core} = 5.6801E+013$

Calculation of Yielding Moment M_y

Calculation of y and M_y according to Annex 7 -

$y = \text{Min}(y_{ten}, y_{com})$
 $y_{ten} = 8.5630881E-006$
with ((10.1), ASCE 41-17) $f_y = \text{Min}(f_y, 1.25 * f_y * ((l_b / d)^{2/3})) = 454.4281$
 $d = 357.00$
 $y = 0.25674727$
 $A = 0.01452572$
 $B = 0.00817889$
with $pt = 0.00680078$
 $pc = 0.00580799$

$p_v = 0.00281599$
 $N = 6084.055$
 $b = 400.00$
 $" = 0.12044818$
 $y_{comp} = 2.5299695E-005$
 with f_c^* (12.3, (ACI 440)) = 34.65599
 $f_c = 33.00$
 $f_l = 0.93147527$
 $b = 400.00$
 $h = 400.00$
 $A_g = 160000.00$
 From (12.9), ACI 440: $k_a = 0.56708553$
 $g = p_t + p_c + p_v = 0.01443197$
 $r_c = 40.00$
 $A_e/A_c = 0.56708553$
 Effective FRP thickness, $t_f = NL*t*\cos(b_1) = 1.016$
 effective strain from (12.5) and (12.12), $\epsilon_{fe} = 0.004$
 $f_u = 0.01$
 $E_f = 64828.00$
 $E_c = 26999.444$
 $y = 0.25580703$
 $A = 0.01433976$
 $B = 0.00808514$
 with $E_s = 200000.00$

 Calculation of ratio l_b/l_d

Lap Length: $l_d/l_{d,min} = 0.56621983$

$l_b = 300.00$

$l_d = 529.8296$

Calculation of l according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.

= 1

$d_b = 14.66667$

Mean strength value of all re-bars: $f_y = 525.2545$

Mean concrete strength: $f_c' = (f_c'_{jacket} * Area_{jacket} + f_c'_{core} * Area_{core}) / Area_{section} = 29.75$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 3.43481$

$A_{tr} = \min(A_{tr_x}, A_{tr_y}) = 257.6106$

where A_{tr_x} , A_{tr_y} are the sum of the area of all stirrup legs along X and Y local axis

$s = \max(s_{external}, s_{internal}) = 250.00$

$n = 12.00$

 - Calculation of ρ_p -

From table 10-8: $\rho_p = 0.042$

with:

- Columns controlled by inadequate development or splicing along the clear height because $l_b/l_d < 1$

shear control ratio $V_y E / V_{col} O E = 0.19159777$

$d = d_{external} = 357.00$

$s = s_{external} = 0.00$

$t = s_1 + s_2 + 2*t_f/bw*(f_{fe}/f_s) = 0.00680078$

jacket: $s_1 = A_{v1}*h_1/(s_1*A_g) = 0.00392699$

$A_{v1} = 157.0796$, is the total area of all stirrups parallel to loading (shear) direction

$h_1 = 400.00$

$s_1 = 100.00$

core: $s_2 = A_{v2}*h_2/(s_2*A_g) = 0.00050265$

$A_{v2} = 100.531$, is the total area of all stirrups parallel to loading (shear) direction

$h_2 = 200.00$

$s_2 = 250.00$

The term $2*t_f/bw*(f_{fe}/f_s)$ 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.

$$N_{UD} = 6084.055$$

$$A_g = 160000.00$$

$$f_{cE} = (f_{c_jacket} \cdot Area_jacket + f_{c_core} \cdot Area_core) / section_area = 29.75$$

$$f_{yIE} = (f_{y_ext_Long_Reinf} \cdot Area_ext_Long_Reinf + f_{y_int_Long_Reinf} \cdot Area_int_Long_Reinf) / Area_Tot_Long_Rein = 531.1678$$

$$f_{yTE} = (f_{y_ext_Trans_Reinf} \cdot Area_ext_Trans_Reinf + f_{y_int_Trans_Reinf} \cdot Area_int_Trans_Reinf) / Area_Tot_Trans_Rein = 542.9506$$

$$\rho_l = Area_Tot_Long_Rein / (b \cdot d) = 0.01443197$$

$$b = 400.00$$

$$d = 357.00$$

$$f_{cE} = 29.75$$

End Of Calculation of Chord Rotation Capacity for element: column JC1 of floor 1

At local axis: 3

Integration Section: (b)
