

Detailed Member Calculations

Units: N&mm

Regulation: ASCE 41-17

Calculation No. 1

column C1, Floor 1

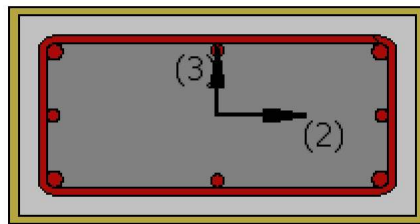
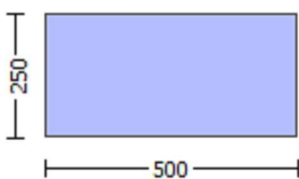
Limit State: Immediate Occupancy (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Shear capacity VR_d

Edge: Start

Local Axis: (2)



Start Of Calculation of Shear Capacity for element: column C1 of floor 1

At local axis: 2

Integration Section: (a)

Section Type: rcrs

Constant Properties

Knowledge Factor, $\gamma = 1.00$

Member Shear Force is generally considered as Force-Controlled Action according to Table C7-1, ASCE41-17.

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

Consequently:

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

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

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$
 #####
 Note: Especially for the calculation of γ for displacement ductility demand,
 the expected (mean value) strengths are used (7.5.1.3, ASCE41-17) because bending is considered as
 Deformation-Controlled Action (Table C7-1, ASCE41-17).
 Existing material: Concrete Strength, $f_c = f_{cm} = 20.00$
 Existing material: Steel Strength, $f_s = f_{sm} = 444.44$
 #####
 Section Height, $H = 250.00$
 Section Width, $W = 500.00$
 Cover Thickness, $c = 25.00$
 Element Length, $L = 3000.00$
 Primary Member
 Ribbed Bars
 Ductile Steel
 Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
 Longitudinal Bars With Ends Lapped Starting at the End Sections
 Lap Length $l_o = l_b = 300.00$
 FRP Wrapping Data
 Type: Carbon
 Cured laminate properties (design values)
 Thickness, $t = 1.016$
 Tensile Strength, $f_{fu} = 1055.00$
 Tensile Modulus, $E_f = 64828.00$
 Elongation, $e_{fu} = 0.01$
 Number of directions, $NoDir = 1$
 Fiber orientations, $bi: 0.00^\circ$
 Number of layers, $NL = 1$
 Radius of rounding corners, $R = 40.00$

Stepwise Properties

EDGE -A-
 Bending Moment, $M_a = -9.3362E+006$
 Shear Force, $V_a = -3085.676$
 EDGE -B-
 Bending Moment, $M_b = 76808.128$
 Shear Force, $V_b = 3085.676$
 BOTH EDGES
 Axial Force, $F = -4810.556$
 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: $As_{c,com} = 829.3805$
 -Middle: $As_{mid} = 402.1239$
 Mean Diameter of Tension Reinforcement, $Db_{L,ten} = 18.66667$

Existing component: From table 7-7, ASCE 41_17: Final Shear Capacity $V_R = V_n = 316023.074$
 $V_n ((10.3), ASCE 41-17) = k_n l * V_{CoI0} = 316023.074$
 $V_{CoI} = 316023.074$
 $k_n l = 1.00$
 $displacement_ductility_demand = 0.02290923$

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)
 $f'_c = 16.00$, but $f_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $M/Vd = 4.00$
 $M_u = 9.3362E+006$
 $V_u = 3085.676$

$d = 0.8 \cdot h = 400.00$
 $Nu = 4810.556$
 $Ag = 125000.00$
 From (11.5.4.8), ACI 318-14: $V_s = 147839.654$
 $Av = 157079.633$
 $f_y = 400.00$
 $s = 170.00$
 V_s is multiplied by $Col = 1.00$
 $s/d = 0.425$
 $V_f ((11-3)-(11.4), ACI 440) = 240803.347$
 $f = 0.95$, for fully-wrapped sections
 $wf/sf = 1$ (FRP strips adjacent to one another).
 In (11.3) $\sin + \cos$ is replaced with $(\cot + \cot a) \sin a$ which is more a generalised expression,
 where a is the angle of the crack direction (see KANEPE).
 This later relation, considered as a function $V_f(\theta)$, is implemented for every different fiber orientation a_i ,
 as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.
 orientation 1: $\theta_1 = b_1 + 90^\circ = 90.00$
 $V_f = \text{Min}(|V_f(45, \theta_1)|, |V_f(-45, a_1)|)$, with:
 total thickness per orientation, $tf_1 = NL \cdot t / NoDir = 1.016$
 $dfv = d$ (figure 11.2, ACI 440) = 457.00
 $ffe ((11-5), ACI 440) = 259.312$
 $E_f = 64828.00$
 $f_e = 0.004$, from (11.6a), ACI 440
 with $f_u = 0.01$
 From (11-11), ACI 440: $V_s + V_f \leq 265721.532$
 $bw = 250.00$

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 $\theta = 0.00016088$
 $y = (My \cdot L_s / 3) / Eleff = 0.00702237$ ((4.29), Biskinis Phd))
 $My = 1.1434E+008$
 $L_s = M/V$ (with $L_s > 0.1 \cdot L$ and $L_s < 2 \cdot L$) = 3025.674
 From table 10.5, ASCE 41-17: $Eleff = factor \cdot Ec \cdot I_g = 1.6421E+013$
 $factor = 0.30$
 $Ag = 125000.00$
 $fc' = 20.00$
 $N = 4810.556$
 $Ec \cdot I_g = 5.4737E+013$

Calculation of Yielding Moment My

Calculation of y and My according to Annex 7 -

$y = \text{Min}(y_{ten}, y_{com})$
 $y_{ten} = 4.5287315E-006$
 with ((10.1), ASCE 41-17) $f_y = \text{Min}(f_y, 1.25 \cdot f_y \cdot (I_b / I_d)^{2/3}) = 291.1836$
 $d = 457.00$
 $y = 0.29653227$
 $A = 0.01818298$
 $B = 0.01001242$
 with $pt = 0.00725935$
 $pc = 0.00725935$
 $pv = 0.00351968$
 $N = 4810.556$
 $b = 250.00$
 $\theta = 0.0940919$
 $y_{comp} = 1.2979423E-005$
 with $fc' (12.3, (ACI 440)) = 20.44585$
 $fc = 20.00$

$f_l = 0.9425867$
 $b = 250.00$
 $h = 500.00$
 $A_g = 125000.00$
 From (12.9), ACI 440: $k_a = 0.15087868$
 $g = p_t + p_c + p_v = 0.01803838$
 $rc = 40.00$
 $A_e/A_c = 0.60351471$
 Effective FRP thickness, $t_f = NL \cdot t \cdot \cos(\theta_1) = 1.016$
 effective strain from (12.5) and (12.12), $\epsilon_{fe} = 0.004$
 $f_u = 0.01$
 $E_f = 64828.00$
 $E_c = 21019.039$
 $y = 0.29518426$
 $A = 0.01791814$
 $B = 0.00986782$
 with $E_s = 200000.00$

Calculation of ratio I_b/I_d

Lap Length: $I_d/I_{d,min} = 0.37945973$

$I_b = 300.00$

$I_d = 790.5977$

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

$d_b = 18.00$

Mean strength value of all re-bars: $f_y = 444.44$

$f'_c = 20.00$, but $f_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$c_b = 25.00$

$K_{tr} = 4.61999$

$A_{tr} = \min(A_{tr_x}, A_{tr_y}) = 157.0796$

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

$s = 170.00$

$n = 8.00$

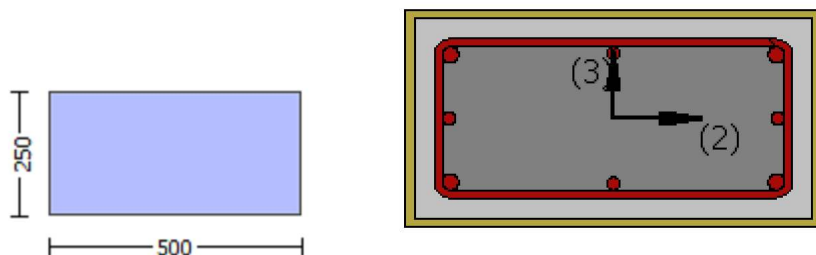
End Of Calculation of Shear Capacity for element: column C1 of floor 1

At local axis: 2

Integration Section: (a)

Calculation No. 2

column C1, Floor 1
 Limit State: Immediate Occupancy (data interpolation between analysis steps 1 and 2)
 Analysis: Uniform +X
 Check: Chord rotation capacity (ϕ)
 Edge: Start
 Local Axis: (2)



Start Of Calculation of Shear Capacity ratio for element: column C1 of floor 1
 At Shear local axis: 3
 (Bending local axis: 2)
 Section Type: rcrs

Constant Properties

 Knowledge Factor, $\gamma = 1.00$
 Mean strength values are used for both shear and moment calculations.
 Consequently:
 Existing material of Primary Member: Concrete Strength, $f_c = f_{cm} = 20.00$
 Existing material of Primary Member: Steel Strength, $f_s = f_{sm} = 444.44$
 Concrete Elasticity, $E_c = 21019.039$
 Steel Elasticity, $E_s = 200000.00$
 #####
 Note: Especially for the calculation of moment strengths,
 the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14
 Existing material: Steel Strength, $f_s = 1.25 \cdot f_{sm} = 555.55$
 #####
 Section Height, $H = 250.00$
 Section Width, $W = 500.00$
 Cover Thickness, $c = 25.00$
 Mean Confinement Factor overall section = 1.13916
 Element Length, $L = 3000.00$
 Primary Member
 Ribbed Bars
 Ductile Steel
 Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
 Longitudinal Bars With Ends Lapped Starting at the End Sections
 Lap Length $l_o = 300.00$
 FRP Wrapping Data
 Type: Carbon
 Cured laminate properties (design values)
 Thickness, $t = 1.016$
 Tensile Strength, $f_{fu} = 1055.00$
 Tensile Modulus, $E_f = 64828.00$
 Elongation, $\epsilon_{fu} = 0.01$
 Number of directions, $N_{oDir} = 1$
 Fiber orientations, $b_i: 0.00^\circ$

Number of layers, NL = 1
Radius of rounding corners, R = 40.00

Stepwise Properties

At local axis: 3
EDGE -A-
Shear Force, Va = 2.9007121E-031
EDGE -B-
Shear Force, Vb = -2.9007121E-031
BOTH EDGES
Axial Force, F = -4666.932
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: Aslt = 0.00
-Compression: Aslc = 2060.885
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension: Asl,ten = 829.3805
-Compression: Asl,com = 829.3805
-Middle: Asl,mid = 402.1239

Calculation of Shear Capacity ratio , $V_e/V_r = 0.15063296$
Member Controlled by Flexure ($V_e/V_r < 1$)
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 39953.171$
with
 $M_{pr1} = \text{Max}(\mu_{u1+}, \mu_{u1-}) = 5.9930\text{E}+007$
 $\mu_{u1+} = 5.9930\text{E}+007$, 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
 $\mu_{u1-} = 5.9930\text{E}+007$, 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
 $M_{pr2} = \text{Max}(\mu_{u2+}, \mu_{u2-}) = 5.9930\text{E}+007$
 $\mu_{u2+} = 5.9930\text{E}+007$, 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
 $\mu_{u2-} = 5.9930\text{E}+007$, is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the the static loading combination

Calculation of μ_{u1+}

Calculation of ultimate curvature μ_u according to 4.1, Biskinis/Fardis 2013:
 $\mu_u = 3.4011160\text{E}-005$
 $\mu_u = 5.9930\text{E}+007$

with full section properties:

b = 500.00
d = 207.00
d' = 43.00
 $\nu = 0.00225456$
N = 4666.932

$f_c = 20.00$

α_0 (5A.5, TBDY) = 0.002

Final value of μ_u : $\mu_u^* = \text{shear_factor} * \text{Max}(\mu_u, \alpha_0) = 0.01464474$

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

From (5.4b), TBDY: $\mu_u = 0.01464474$

ω_e ((5.4c), TBDY) = $\alpha_s * \text{sh}_{\min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.07762821$

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

$f_x = 0.07705054$

$\alpha_f = 0.45253333$

b = 500.00

h = 250.00

From EC8 A.4.4.3(6), $\rho_f = 2t_f/bw = 0.004064$

bw = 500.00
effective stress from (A.35), $f_{f,e} = 837.9178$

fy = 0.12936483
af = 0.45253333
b = 250.00
h = 500.00
From EC8 A.4.4.3(6), $p_f = 2t_f/bw = 0.008128$
bw = 250.00
effective stress from (A.35), $f_{f,e} = 703.4155$

R = 40.00
Effective FRP thickness, $t_f = NL \cdot t \cdot \cos(b_1) = 1.016$
 $f_{u,f} = 1055.00$
 $E_f = 64828.00$
 $u_f = 0.015$
 $a_{se}((5.4d), TBDY) = 0.03751166$
bo = 440.00
ho = 190.00
bi2 = 459400.00

$p_{sh,min} = \min(p_{sh,x}, p_{sh,y}) = 0.001848$

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

$p_{sh,x}((5.4d)) = 0.001848$
 $A_{sh} = A_{stir} \cdot n_s = 78.53982$
No stirrups, $n_s = 2.00$
bk = 500.00

$p_{sh,y}((5.4d)) = 0.00369599$
 $A_{sh} = A_{stir} \cdot n_s = 78.53982$
No stirrups, $n_s = 2.00$
bk = 250.00

s = 170.00
 $f_{ywe} = 555.55$
 $f_{ce} = 20.00$

From ((5.A5), TBDY), TBDY: $cc = 0.00339158$
c = confinement factor = 1.13916

$y_1 = 0.00130695$
 $sh_1 = 0.00451687$
 $ft_1 = 376.4017$
 $fy_1 = 313.6681$
 $su_1 = 0.005257$

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

$l_o/l_{ou,min} = l_b/l_d = 0.30356779$

$su_1 = 0.4 \cdot esu1_{nominal}((5.5), TBDY) = 0.032$

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

For calculation of $esu1_{nominal}$ and y_1, sh_1, ft_1, fy_1 , it is considered
characteristic value $fsy_1 = fs_1/1.2$, from table 5.1, TBDY.

y_1, sh_1, ft_1, fy_1 , are also multiplied by $\min(1, 1.25 \cdot (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

with $fs_1 = fs = 313.6681$

with $Es_1 = Es = 200000.00$

$y_2 = 0.00130695$
 $sh_2 = 0.00451687$
 $ft_2 = 376.4017$
 $fy_2 = 313.6681$
 $su_2 = 0.005257$

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

$l_o/l_{ou,min} = l_b/l_{b,min} = 0.30356779$

$su_2 = 0.4 \cdot esu2_{nominal}((5.5), TBDY) = 0.032$

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

For calculation of $esu2_{nominal}$ and y_2, sh_2, ft_2, fy_2 , it is considered

characteristic value $f_{sy2} = f_{s2}/1.2$, from table 5.1, TBDY.
 $y1, sh1, ft1, fy1$, are also multiplied by $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.
 with $f_{s2} = f_s = 313.6681$
 with $E_{s2} = E_s = 200000.00$
 $y_v = 0.00130695$
 $sh_v = 0.00451687$
 $ft_v = 376.4017$
 $fy_v = 313.6681$
 $suv = 0.005257$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $l_o/l_{ou,min} = l_b/l_d = 0.30356779$
 $suv = 0.4 \cdot esuv_{nominal} ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $esuv_{nominal} = 0.08$,
 considering characteristic value $f_{syv} = f_{sv}/1.2$, from table 5.1, TBDY
 For calculation of $esuv_{nominal}$ and y_v, sh_v, ft_v, fy_v , it is considered
 characteristic value $f_{syv} = f_{sv}/1.2$, from table 5.1, TBDY.
 $y1, sh1, ft1, fy1$, are also multiplied by $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.
 with $f_{sv} = f_s = 313.6681$
 with $E_{sv} = E_s = 200000.00$
 $1 = A_{sl,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.1256764$
 $2 = A_{sl,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.1256764$
 $v = A_{sl,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.06093401$
 and confined core properties:
 $b = 440.00$
 $d = 177.00$
 $d' = 13.00$
 $f_{cc} (5A.2, TBDY) = 22.78316$
 $cc (5A.5, TBDY) = 0.00339158$
 $c = \text{confinement factor} = 1.13916$
 $1 = A_{sl,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.16701987$
 $2 = A_{sl,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.16701987$
 $v = A_{sl,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.08097933$
 Case/Assumption: Unconfined full section - Steel rupture
 ' satisfies Eq. (4.3)
 --->
 $v < v_{s,y2}$ - LHS eq.(4.5) is satisfied
 --->
 $su (4.9) = 0.25329952$
 $Mu = MR_c (4.14) = 5.9930E+007$
 $u = su (4.1) = 3.4011160E-005$

Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.30356779$
 $l_b = 300.00$
 $l_d = 988.2471$
 Calculation of $l_{b,min}$ according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
 $= 1$
 $db = 18.00$
 Mean strength value of all re-bars: $f_y = 555.55$
 $f_c' = 20.00$, but $f_c'^{0.5} \leq 8.3 \text{ MPa}$ (22.5.3.1, ACI 318-14)
 $t = 1.00$
 $s = 0.80$
 $e = 1.00$
 $cb = 25.00$
 $K_{tr} = 4.61999$
 $A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$
 where A_{tr_x}, A_{tr_y} are the sum of the area of all stirrup legs along X and Y loxal axis
 $s = 170.00$
 $n = 8.00$

Calculation of $Mu1$ -

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

$$u = 3.4011160E-005$$

$$\mu = 5.9930E+007$$

with full section properties:

$$b = 500.00$$

$$d = 207.00$$

$$d' = 43.00$$

$$v = 0.00225456$$

$$N = 4666.932$$

$$f_c = 20.00$$

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

$$\text{Final value of } \phi_u: \phi_u^* = \text{shear_factor} * \text{Max}(\phi_u, \phi_c) = 0.01464474$$

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

$$\text{From (5.4b), TB DY: } \phi_u = 0.01464474$$

$$\phi_{we} ((5.4c), \text{TB DY}) = \alpha s_e * \phi_{sh, \min} * f_{ywe} / f_{ce} + \text{Min}(\phi_{fx}, \phi_{fy}) = 0.07762821$$

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

$$\phi_{fx} = 0.07705054$$

$$\alpha f = 0.45253333$$

$$b = 500.00$$

$$h = 250.00$$

$$\text{From EC8 A.4.4.3(6), } \phi_f = 2t_f / b_w = 0.004064$$

$$b_w = 500.00$$

$$\text{effective stress from (A.35), } f_{fe} = 837.9178$$

$$\phi_{fy} = 0.12936483$$

$$\alpha f = 0.45253333$$

$$b = 250.00$$

$$h = 500.00$$

$$\text{From EC8 A.4.4.3(6), } \phi_f = 2t_f / b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{fe} = 703.4155$$

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u_{f,f} = 0.015$$

$$\alpha s_e ((5.4d), \text{TB DY}) = 0.03751166$$

$$b_o = 440.00$$

$$h_o = 190.00$$

$$b_{i2} = 459400.00$$

$$\phi_{sh, \min} = \text{Min}(\phi_{sh,x}, \phi_{sh,y}) = 0.001848$$

Expression ((5.4d), TB DY) for $\phi_{sh, \min}$ has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$$\phi_{sh,x} (5.4d) = 0.001848$$

$$\alpha s_h = \alpha s_{tir} * n_s = 78.53982$$

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

$$b_k = 500.00$$

$$\phi_{sh,y} (5.4d) = 0.00369599$$

$$\alpha s_h = \alpha s_{tir} * n_s = 78.53982$$

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

$$b_k = 250.00$$

$$s = 170.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 20.00$$

$$\text{From ((5.A5), TB DY), TB DY: } \phi_c = 0.00339158$$

$$c = \text{confinement factor} = 1.13916$$

$$y_1 = 0.00130695$$

$$s_{h1} = 0.00451687$$

```

ft1 = 376.4017
fy1 = 313.6681
su1 = 0.005257
    using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779
    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, ASCE41-17.
    with fs1 = fs = 313.6681
    with Es1 = Es = 200000.00
y2 = 0.00130695
sh2 = 0.00451687
ft2 = 376.4017
fy2 = 313.6681
su2 = 0.005257
    using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779
    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, ASCE41-17.
    with fs2 = fs = 313.6681
    with Es2 = Es = 200000.00
yv = 0.00130695
shv = 0.00451687
ftv = 376.4017
fyv = 313.6681
suv = 0.005257
    using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779
    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,min)^ 2/3), from 10.3.5, ASCE41-17.
    with fsv = fs = 313.6681
    with Esv = Es = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.1256764
2 = Asl,com/(b*d)*(fs2/fc) = 0.1256764
v = Asl,mid/(b*d)*(fsv/fc) = 0.06093401
and confined core properties:
b = 440.00
d = 177.00
d' = 13.00
fcc (5A.2, TBDY) = 22.78316
cc (5A.5, TBDY) = 0.00339158
    c = confinement factor = 1.13916
    1 = Asl,ten/(b*d)*(fs1/fc) = 0.16701987
    2 = Asl,com/(b*d)*(fs2/fc) = 0.16701987
    v = Asl,mid/(b*d)*(fsv/fc) = 0.08097933
Case/Assumption: Unconfined full section - Steel rupture
' satisfies Eq. (4.3)
--->
v < vs,y2 - LHS eq.(4.5) is satisfied
--->
su (4.9) = 0.25329952
Mu = MRc (4.14) = 5.9930E+007

```

$$u = s_u(4.1) = 3.4011160E-005$$

Calculation of ratio l_b/d

Lap Length: $l_b/d = 0.30356779$

$$l_b = 300.00$$

$$d = 988.2471$$

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

$$= 1$$

$$d_b = 18.00$$

$$\text{Mean strength value of all re-bars: } f_y = 555.55$$

$$f'_c = 20.00, \text{ but } f_c^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 25.00$$

$$K_{tr} = 4.61999$$

$$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$$

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

$$s = 170.00$$

$$n = 8.00$$

Calculation of μ_{2+}

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

$$u = 3.4011160E-005$$

$$\mu = 5.9930E+007$$

with full section properties:

$$b = 500.00$$

$$d = 207.00$$

$$d' = 43.00$$

$$v = 0.00225456$$

$$N = 4666.932$$

$$f'_c = 20.00$$

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

$$\text{Final value of } \mu: \mu^* = \text{shear_factor} * \text{Max}(\mu, c_o) = 0.01464474$$

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

$$\text{From (5.4b), TB DY: } \mu = 0.01464474$$

$$\mu_e((5.4c), \text{TB DY}) = a_s e * s_{h, \min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.07762821$$

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

$$f_x = 0.07705054$$

$$a_f = 0.45253333$$

$$b = 500.00$$

$$h = 250.00$$

$$\text{From EC8 A4.4.3(6), } p_f = 2t_f/bw = 0.004064$$

$$bw = 500.00$$

$$\text{effective stress from (A.35), } f_{fe} = 837.9178$$

$$f_y = 0.12936483$$

$$a_f = 0.45253333$$

$$b = 250.00$$

$$h = 500.00$$

$$\text{From EC8 A4.4.3(6), } p_f = 2t_f/bw = 0.008128$$

$$bw = 250.00$$

$$\text{effective stress from (A.35), } f_{fe} = 703.4155$$

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$u, f = 0.015$
 $ase((5.4d), TBDY) = 0.03751166$
 $bo = 440.00$
 $ho = 190.00$
 $bi2 = 459400.00$
 $psh, min = \text{Min}(psh, x, psh, y) = 0.001848$
 Expression $((5.4d), TBDY)$ for psh, min has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$psh, x(5.4d) = 0.001848$
 $Ash = Astir * ns = 78.53982$
 No stirrups, $ns = 2.00$
 $bk = 500.00$

$psh, y(5.4d) = 0.00369599$
 $Ash = Astir * ns = 78.53982$
 No stirrups, $ns = 2.00$
 $bk = 250.00$

$s = 170.00$
 $fyw = 555.55$
 $fce = 20.00$
 From $((5.4d), TBDY)$, $TBDY$: $cc = 0.00339158$
 $c = \text{confinement factor} = 1.13916$
 $y1 = 0.00130695$
 $sh1 = 0.00451687$
 $ft1 = 376.4017$
 $fy1 = 313.6681$
 $su1 = 0.005257$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 $\text{Shear_factor} = 1.00$
 $lo/lou, min = lb/ld = 0.30356779$
 $su1 = 0.4 * esu1_nominal((5.5), TBDY) = 0.032$
 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, ASCE41-17.
 with $fs1 = fs = 313.6681$
 with $Es1 = Es = 200000.00$
 $y2 = 0.00130695$
 $sh2 = 0.00451687$
 $ft2 = 376.4017$
 $fy2 = 313.6681$
 $su2 = 0.005257$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 $\text{Shear_factor} = 1.00$
 $lo/lou, min = lb/lb, min = 0.30356779$
 $su2 = 0.4 * esu2_nominal((5.5), TBDY) = 0.032$
 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, ASCE41-17.
 with $fs2 = fs = 313.6681$
 with $Es2 = Es = 200000.00$
 $yv = 0.00130695$
 $shv = 0.00451687$
 $ftv = 376.4017$
 $fyv = 313.6681$
 $suv = 0.005257$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 $\text{Shear_factor} = 1.00$
 $lo/lou, min = lb/ld = 0.30356779$
 $suv = 0.4 * esuv_nominal((5.5), TBDY) = 0.032$
 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, ASCE41-17.

with $f_{sv} = f_s = 313.6681$

with $E_{sv} = E_s = 200000.00$

$1 = A_{sl,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.1256764$

$2 = A_{sl,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.1256764$

$v = A_{sl,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.06093401$

and confined core properties:

$b = 440.00$

$d = 177.00$

$d' = 13.00$

f_{cc} (5A.2, TBDY) = 22.78316

cc (5A.5, TBDY) = 0.00339158

c = confinement factor = 1.13916

$1 = A_{sl,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.16701987$

$2 = A_{sl,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.16701987$

$v = A_{sl,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.08097933$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

su (4.9) = 0.25329952

$Mu = MR_c$ (4.14) = 5.9930E+007

$u = su$ (4.1) = 3.4011160E-005

Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.30356779$

$l_b = 300.00$

$l_d = 988.2471$

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

= 1

$db = 18.00$

Mean strength value of all re-bars: $f_y = 555.55$

$f_c' = 20.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 4.61999$

$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$

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

$s = 170.00$

$n = 8.00$

Calculation of Mu_2 -

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

$u = 3.4011160E-005$

$Mu = 5.9930E+007$

with full section properties:

$b = 500.00$

$d = 207.00$

$d' = 43.00$

$v = 0.00225456$

$N = 4666.932$

$f_c = 20.00$

co (5A.5, TBDY) = 0.002

Final value of cu : $\text{cu}^* = \text{shear_factor} * \text{Max}(\text{cu}, \text{cc}) = 0.01464474$

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

From (5.4b), TBDY: $\text{cu} = 0.01464474$

we ((5.4c), TBDY) = $\text{ase} * \text{sh}_{\min} * \text{fy}_{\text{we}} / \text{f}_{\text{ce}} + \text{Min}(\text{fx}, \text{fy}) = 0.07762821$

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

 $\text{fx} = 0.07705054$

$\text{af} = 0.45253333$

$\text{b} = 500.00$

$\text{h} = 250.00$

From EC8 A4.4.3(6), $\text{pf} = 2\text{tf}/\text{bw} = 0.004064$

$\text{bw} = 500.00$

effective stress from (A.35), $\text{ff}_{\text{e}} = 837.9178$

 $\text{fy} = 0.12936483$

$\text{af} = 0.45253333$

$\text{b} = 250.00$

$\text{h} = 500.00$

From EC8 A4.4.3(6), $\text{pf} = 2\text{tf}/\text{bw} = 0.008128$

$\text{bw} = 250.00$

effective stress from (A.35), $\text{ff}_{\text{e}} = 703.4155$

 $\text{R} = 40.00$

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

$\text{fu}, \text{f} = 1055.00$

$\text{Ef} = 64828.00$

$\text{u}, \text{f} = 0.015$

$\text{ase} ((5.4d), \text{TBDY}) = 0.03751166$

$\text{bo} = 440.00$

$\text{ho} = 190.00$

$\text{bi2} = 459400.00$

$\text{psh}_{\min} = \text{Min}(\text{psh}, \text{x}, \text{psh}, \text{y}) = 0.001848$

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

 $\text{psh}, \text{x} ((5.4d)) = 0.001848$

$\text{Ash} = \text{Astir} * \text{ns} = 78.53982$

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

$\text{bk} = 500.00$

 $\text{psh}, \text{y} ((5.4d)) = 0.00369599$

$\text{Ash} = \text{Astir} * \text{ns} = 78.53982$

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

$\text{bk} = 250.00$

 $\text{s} = 170.00$

$\text{fy}_{\text{we}} = 555.55$

$\text{f}_{\text{ce}} = 20.00$

From ((5.A5), TBDY), TBDY: $\text{cc} = 0.00339158$

$\text{c} = \text{confinement factor} = 1.13916$

$\text{y1} = 0.00130695$

$\text{sh1} = 0.00451687$

$\text{ft1} = 376.4017$

$\text{fy1} = 313.6681$

$\text{su1} = 0.005257$

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

$\text{lo}/\text{lou}, \text{min} = \text{lb}/\text{ld} = 0.30356779$

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

From table 5A.1, TBDY: $\text{esu1_nominal} = 0.08$,

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

y1 , sh1 , ft1 , fy1 , are also multiplied by $\text{Min}(1, 1.25 * (\text{lb}/\text{ld})^{2/3})$, from 10.3.5, ASCE41-17.

with $\text{fs1} = \text{fs} = 313.6681$

with $\text{Es1} = \text{Es} = 200000.00$

$\text{y2} = 0.00130695$

```

sh2 = 0.00451687
ft2 = 376.4017
fy2 = 313.6681
su2 = 0.005257
    using (30) in Biskinis/Fardis (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 = 0.30356779
    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, ASCE41-17.
    with fs2 = fs = 313.6681
    with Es2 = Es = 200000.00
yv = 0.00130695
shv = 0.00451687
ftv = 376.4017
fyv = 313.6681
suv = 0.005257
    using (30) in Biskinis/Fardis (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 = 0.30356779
    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, ASCE41-17.
    with fsv = fs = 313.6681
    with Esv = Es = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.1256764
2 = Asl,com/(b*d)*(fs2/fc) = 0.1256764
v = Asl,mid/(b*d)*(fsv/fc) = 0.06093401
and confined core properties:
b = 440.00
d = 177.00
d' = 13.00
fcc (5A.2, TBDY) = 22.78316
cc (5A.5, TBDY) = 0.00339158
c = confinement factor = 1.13916
1 = Asl,ten/(b*d)*(fs1/fc) = 0.16701987
2 = Asl,com/(b*d)*(fs2/fc) = 0.16701987
v = Asl,mid/(b*d)*(fsv/fc) = 0.08097933
Case/Assumption: Unconfined full section - Steel rupture
' satisfies Eq. (4.3)
--->
v < vs,y2 - LHS eq.(4.5) is satisfied
--->
su (4.9) = 0.25329952
Mu = MRc (4.14) = 5.9930E+007
u = su (4.1) = 3.4011160E-005

```

Calculation of ratio lb/lb

```

Lap Length: lb/lb = 0.30356779
lb = 300.00
lb = 988.2471
Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
= 1
db = 18.00
Mean strength value of all re-bars: fy = 555.55
fc' = 20.00, but fc'^0.5 <= 8.3 MPa (22.5.3.1, ACI 318-14)
t = 1.00
s = 0.80

```

$e = 1.00$
 $cb = 25.00$
 $Ktr = 4.61999$
 $Atr = \text{Min}(Atr_x, Atr_y) = 157.0796$
 where Atr_x, Atr_y are the sum of the area of all stirrup legs along X and Y loxal axis
 $s = 170.00$
 $n = 8.00$

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 265235.248$

Calculation of Shear Strength at edge 1, $V_{r1} = 265235.248$

$V_{r1} = V_{Col} \text{ ((10.3), ASCE 41-17)} = knl * V_{Col0}$

$V_{Col0} = 265235.248$

$knl = 1$ (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)

$fc' = 20.00$, but $fc'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$\mu_u = 2.3992784E-012$

$\mu_v = 2.9007121E-031$

$d = 0.8 * h = 200.00$

$N_u = 4666.932$

$A_g = 125000.00$

From (11.5.4.8), ACI 318-14: $V_s = 49279.392$

$A_v = 157079.633$

$f_y = 444.44$

$s = 170.00$

V_s is multiplied by $Col = 0.60$

$s/d = 0.85$

$V_f \text{ ((11-3)-(11.4), ACI 440)} = 109072.851$

$f = 0.95$, for fully-wrapped sections

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

In (11.3) $\sin + \cos$ is replaced with $(\cot + \cot a) \sin a$ which is more a generalised expression,

where a is the angle of the crack direction (see KANEPE).

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

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

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

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

$d_{fv} = d$ (figure 11.2, ACI 440) = 207.00

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

$E_f = 64828.00$

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

with $f_u = 0.01$

From (11-11), ACI 440: $V_s + V_f \leq 297085.704$

$bw = 500.00$

Calculation of Shear Strength at edge 2, $V_{r2} = 265235.248$

$V_{r2} = V_{Col} \text{ ((10.3), ASCE 41-17)} = knl * V_{Col0}$

$V_{Col0} = 265235.248$

$knl = 1$ (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)

$fc' = 20.00$, but $fc'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$\mu_u = 2.3992784E-012$

$\mu_v = 2.9007121E-031$

$d = 0.8 \cdot h = 200.00$
 $N_u = 4666.932$
 $A_g = 125000.00$
 From (11.5.4.8), ACI 318-14: $V_s = 49279.392$
 $A_v = 157079.633$
 $f_y = 444.44$
 $s = 170.00$
 V_s is multiplied by $\text{Col} = 0.60$
 $s/d = 0.85$
 $V_f ((11-3)-(11.4), \text{ACI } 440) = 109072.851$
 $f = 0.95$, for fully-wrapped sections
 $w_f/s_f = 1$ (FRP strips adjacent to one another).
 In (11.3) $\sin + \cos$ is replaced with $(\cot + \cot a) \sin a$ which is more a generalised expression,
 where a is the angle of the crack direction (see KANEPE).
 This later relation, considered as a function $V_f(\theta, a)$, is implemented for every different fiber orientation a_i ,
 as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.
 orientation 1: $\theta = b1 + 90^\circ = 90.00$
 $V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, a1)|)$, with:
 total thickness per orientation, $t_{f1} = N_L \cdot t / \text{NoDir} = 1.016$
 $d_{fv} = d$ (figure 11.2, ACI 440) = 207.00
 $f_{fe} ((11-5), \text{ACI } 440) = 259.312$
 $E_f = 64828.00$
 $f_e = 0.004$, from (11.6a), ACI 440
 with $f_u = 0.01$
 From (11-11), ACI 440: $V_s + V_f \leq 297085.704$
 $b_w = 500.00$

 End Of Calculation of Shear Capacity ratio for element: column C1 of floor 1
 At local axis: 3

Start Of Calculation of Shear Capacity ratio for element: column C1 of floor 1
 At Shear local axis: 2
 (Bending local axis: 3)
 Section Type: rcrcs

Constant Properties

 Knowledge Factor, $\phi = 1.00$
 Mean strength values are used for both shear and moment calculations.
 Consequently:
 Existing material of Primary Member: Concrete Strength, $f_c = f_{cm} = 20.00$
 Existing material of Primary Member: Steel Strength, $f_s = f_{sm} = 444.44$
 Concrete Elasticity, $E_c = 21019.039$
 Steel Elasticity, $E_s = 200000.00$
 #####
 Note: Especially for the calculation of moment strengths,
 the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14
 Existing material: Steel Strength, $f_s = 1.25 \cdot f_{sm} = 555.55$
 #####
 Section Height, $H = 250.00$
 Section Width, $W = 500.00$
 Cover Thickness, $c = 25.00$
 Mean Confinement Factor overall section = 1.13916
 Element Length, $L = 3000.00$
 Primary Member
 Ribbed Bars
 Ductile Steel
 Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
 Longitudinal Bars With Ends Lapped Starting at the End Sections
 Lap Length $l_o = 300.00$
 FRP Wrapping Data
 Type: Carbon
 Cured laminate properties (design values)

Thickness, $t = 1.016$
Tensile Strength, $f_{fu} = 1055.00$
Tensile Modulus, $E_f = 64828.00$
Elongation, $\epsilon_{fu} = 0.01$
Number of directions, $N_{oDir} = 1$
Fiber orientations, $b_i = 0.00^\circ$
Number of layers, $N_L = 1$
Radius of rounding corners, $R = 40.00$

Stepwise Properties

At local axis: 2
EDGE -A-
Shear Force, $V_a = 1.3558547E-031$
EDGE -B-
Shear Force, $V_b = -1.3558547E-031$
BOTH EDGES
Axial Force, $F = -4666.932$
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: $A_{slt} = 0.00$
-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, $V_e/V_r = 0.23676754$
Member Controlled by Flexure ($V_e/V_r < 1$)
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 96937.922$
with
 $M_{pr1} = \max(\mu_{u1+}, \mu_{u1-}) = 1.4541E+008$
 $\mu_{u1+} = 1.4541E+008$, 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
 $\mu_{u1-} = 1.4541E+008$, 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
 $M_{pr2} = \max(\mu_{u2+}, \mu_{u2-}) = 1.4541E+008$
 $\mu_{u2+} = 1.4541E+008$, 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
 $\mu_{u2-} = 1.4541E+008$, 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_{u1+}

Calculation of ultimate curvature ϕ_u according to 4.1, Biskinis/Fardis 2013:
 $\phi_u = 1.4467178E-005$
 $\mu_u = 1.4541E+008$

with full section properties:

$b = 250.00$
 $d = 457.00$
 $d' = 43.00$
 $v = 0.00204242$
 $N = 4666.932$
 $f_c = 20.00$
 ϕ_o (5A.5, TBDY) = 0.002
Final value of ϕ_u : $\phi_u = \text{shear_factor} * \max(\phi_{cu}, \phi_{cc}) = 0.01464474$
The Shear_factor is considered equal to 1 (pure moment strength)
From (5.4b), TBDY: $\phi_{cu} = 0.01464474$
 ϕ_{we} ((5.4c), TBDY) = $a_s e * \phi_{sh,min} * f_{ywe} / f_{ce} + \min(\phi_{fx}, \phi_{fy}) = 0.07762821$
where $f = a_f * p_f * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

fx = 0.07705054
af = 0.45253333
b = 500.00
h = 250.00
From EC8 A.4.4.3(6), pf = 2tf/bw = 0.004064
bw = 500.00
effective stress from (A.35), ff,e = 837.9178

fy = 0.12936483
af = 0.45253333
b = 250.00
h = 500.00
From EC8 A.4.4.3(6), pf = 2tf/bw = 0.008128
bw = 250.00
effective stress from (A.35), ff,e = 703.4155

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) = 0.03751166
bo = 440.00
ho = 190.00
bi2 = 459400.00
psh,min = Min(psh,x , psh,y) = 0.001848
Expression ((5.4d), TBDY) for psh,min has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

psh,x (5.4d) = 0.001848
Ash = Astir*ns = 78.53982
No stirrups, ns = 2.00
bk = 500.00

psh,y (5.4d) = 0.00369599
Ash = Astir*ns = 78.53982
No stirrups, ns = 2.00
bk = 250.00

s = 170.00
fywe = 555.55
fce = 20.00
From ((5.A5), TBDY), cc = 0.00339158
c = confinement factor = 1.13916
y1 = 0.00130695
sh1 = 0.00451687
ft1 = 376.4017
fy1 = 313.6681
su1 = 0.005257
using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779
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, ASCE41-17.
with fs1 = fs = 313.6681
with Es1 = Es = 200000.00
y2 = 0.00130695
sh2 = 0.00451687
ft2 = 376.4017
fy2 = 313.6681
su2 = 0.005257
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor

and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $l_o/l_{o,min} = l_b/l_{b,min} = 0.30356779$
 $su_2 = 0.4 \cdot esu_{2,nominal} ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $esu_{2,nominal} = 0.08$,
 For calculation of $esu_{2,nominal}$ and y_2, sh_2, ft_2, fy_2 , it is considered
 characteristic value $fsy_2 = fs_2/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.
 with $fs_2 = fs = 313.6681$
 with $Es_2 = Es = 200000.00$
 $y_v = 0.00130695$
 $sh_v = 0.00451687$
 $ft_v = 376.4017$
 $fy_v = 313.6681$
 $suv = 0.005257$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $l_o/l_{o,min} = l_b/l_d = 0.30356779$
 $suv = 0.4 \cdot esuv_{nominal} ((5.5), TBDY) = 0.032$
 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 $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.
 with $fsv = fs = 313.6681$
 with $Es_v = Es = 200000.00$
 $1 = A_{sl,ten}/(b \cdot d) \cdot (fs_1/f_c) = 0.11385127$
 $2 = A_{sl,com}/(b \cdot d) \cdot (fs_2/f_c) = 0.11385127$
 $v = A_{sl,mid}/(b \cdot d) \cdot (fsv/f_c) = 0.05520062$
 and confined core properties:
 $b = 190.00$
 $d = 427.00$
 $d' = 13.00$
 $f_{cc} (5A.2, TBDY) = 22.78316$
 $cc (5A.5, TBDY) = 0.00339158$
 $c = \text{confinement factor} = 1.13916$
 $1 = A_{sl,ten}/(b \cdot d) \cdot (fs_1/f_c) = 0.1603292$
 $2 = A_{sl,com}/(b \cdot d) \cdot (fs_2/f_c) = 0.1603292$
 $v = A_{sl,mid}/(b \cdot d) \cdot (fsv/f_c) = 0.07773537$
 Case/Assumption: Unconfined full section - Steel rupture
 ' satisfies Eq. (4.3)
 --->
 $v < v_{s,y2}$ - LHS eq.(4.5) is satisfied
 --->
 $su (4.9) = 0.20486988$
 $Mu = MR_c (4.14) = 1.4541E+008$
 $u = su (4.1) = 1.4467178E-005$

Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.30356779$
 $l_b = 300.00$
 $l_d = 988.2471$
 Calculation of $l_{b,min}$ according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
 $= 1$
 $db = 18.00$
 Mean strength value of all re-bars: $fy = 555.55$
 $fc' = 20.00$, but $fc'^{0.5} \leq 8.3 \text{ MPa}$ (22.5.3.1, ACI 318-14)
 $t = 1.00$
 $s = 0.80$
 $e = 1.00$
 $cb = 25.00$
 $K_{tr} = 4.61999$
 $A_{tr} = \text{Min}(A_{tr,x}, A_{tr,y}) = 157.0796$
 where $A_{tr,x}, A_{tr,y}$ are the sum of the area of all stirrup legs along X and Y loxal axis

s = 170.00
n = 8.00

Calculation of Mu1-

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

$\phi_u = 1.4467178E-005$

$M_u = 1.4541E+008$

with full section properties:

b = 250.00

d = 457.00

d' = 43.00

$\nu = 0.00204242$

N = 4666.932

$f_{ck} = 20.00$

ϕ_{co} (5A.5, TBDY) = 0.002

Final value of ϕ_{cu} : $\phi_{cu} = \text{shear_factor} * \text{Max}(\phi_{cu}, \phi_{co}) = 0.01464474$

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

From (5.4b), TBDY: $\phi_{cu} = 0.01464474$

ϕ_{we} ((5.4c), TBDY) = $\text{ase} * \text{sh_min} * f_{ywe} / f_{ce} + \text{Min}(\phi_{fx}, \phi_{fy}) = 0.07762821$

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

$\phi_{fx} = 0.07705054$

$\text{af} = 0.45253333$

b = 500.00

h = 250.00

From EC8 A4.4.3(6), $\text{pf} = 2t_f/bw = 0.004064$

bw = 500.00

effective stress from (A.35), $f_{fe} = 837.9178$

$\phi_{fy} = 0.12936483$

$\text{af} = 0.45253333$

b = 250.00

h = 500.00

From EC8 A4.4.3(6), $\text{pf} = 2t_f/bw = 0.008128$

bw = 250.00

effective stress from (A.35), $f_{fe} = 703.4155$

R = 40.00

Effective FRP thickness, $t_f = \text{NL} * t * \text{Cos}(\theta_1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{f1} = 0.015$

ase ((5.4d), TBDY) = 0.03751166

$b_o = 440.00$

$h_o = 190.00$

$b_{i2} = 459400.00$

$\phi_{sh,min} = \text{Min}(\phi_{sh,x}, \phi_{sh,y}) = 0.001848$

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

$\phi_{sh,x}$ (5.4d) = 0.001848

$A_{sh} = A_{stir} * n_s = 78.53982$

No stirrups, $n_s = 2.00$

$b_k = 500.00$

$\phi_{sh,y}$ (5.4d) = 0.00369599

$A_{sh} = A_{stir} * n_s = 78.53982$

No stirrups, $n_s = 2.00$

$b_k = 250.00$

s = 170.00

```

fywe = 555.55
fce = 20.00
From ((5A.5), TBDY), TBDY: cc = 0.00339158
c = confinement factor = 1.13916
y1 = 0.00130695
sh1 = 0.00451687
ft1 = 376.4017
fy1 = 313.6681
su1 = 0.005257
using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779
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, ASCE41-17.
with fs1 = fs = 313.6681
with Es1 = Es = 200000.00
y2 = 0.00130695
sh2 = 0.00451687
ft2 = 376.4017
fy2 = 313.6681
su2 = 0.005257
using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779
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, ASCE41-17.
with fs2 = fs = 313.6681
with Es2 = Es = 200000.00
yv = 0.00130695
shv = 0.00451687
ftv = 376.4017
fyv = 313.6681
suv = 0.005257
using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779
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, ASCE41-17.
with fsv = fs = 313.6681
with Esv = Es = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.11385127
2 = Asl,com/(b*d)*(fs2/fc) = 0.11385127
v = Asl,mid/(b*d)*(fsv/fc) = 0.05520062
and confined core properties:
b = 190.00
d = 427.00
d' = 13.00
fcc (5A.2, TBDY) = 22.78316
cc (5A.5, TBDY) = 0.00339158
c = confinement factor = 1.13916
1 = Asl,ten/(b*d)*(fs1/fc) = 0.1603292
2 = Asl,com/(b*d)*(fs2/fc) = 0.1603292
v = Asl,mid/(b*d)*(fsv/fc) = 0.07773537
Case/Assumption: Unconfinedsd full section - Steel rupture

```

satisfies Eq. (4.3)

--->

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

--->

$\mu_u (4.9) = 0.20486988$

$\mu_u = M_{Rc} (4.14) = 1.4541E+008$

$u = \mu_u (4.1) = 1.4467178E-005$

Calculation of ratio I_b/I_d

Lap Length: $I_b/I_d = 0.30356779$

$I_b = 300.00$

$I_d = 988.2471$

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

= 1

$d_b = 18.00$

Mean strength value of all re-bars: $f_y = 555.55$

$f_c' = 20.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$c_b = 25.00$

$K_{tr} = 4.61999$

$A_{tr} = \text{Min}(A_{tr,x}, A_{tr,y}) = 157.0796$

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

$s = 170.00$

$n = 8.00$

Calculation of μ_{u2+}

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

$u = 1.4467178E-005$

$\mu_u = 1.4541E+008$

with full section properties:

$b = 250.00$

$d = 457.00$

$d' = 43.00$

$v = 0.00204242$

$N = 4666.932$

$f_c = 20.00$

ϕ_c (5A.5, TBDY) = 0.002

Final value of ϕ_c : $\phi_c^* = \text{shear_factor} * \text{Max}(\phi_c, \phi_{cc}) = 0.01464474$

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

From (5.4b), TBDY: $\phi_c = 0.01464474$

we ((5.4c), TBDY) = $\phi_c^* \cdot \phi_{sh,min} * f_{ywe}/f_{ce} + \text{Min}(\phi_{fx}, \phi_{fy}) = 0.07762821$

where $\phi_{fx} = \phi_{fy} = \phi_{sh,min} * f_{ywe}/f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$\phi_{fx} = 0.07705054$

$\phi_{fy} = 0.45253333$

$b = 500.00$

$h = 250.00$

From EC8 A.4.4.3(6), $\phi_{fx} = 2t_f/b_w = 0.004064$

$b_w = 500.00$

effective stress from (A.35), $f_{fe} = 837.9178$

$f_y = 0.12936483$

$\phi_{fy} = 0.45253333$

$b = 250.00$

$h = 500.00$

From EC8 A.4.4.3(6), $\phi_{fy} = 2t_f/b_w = 0.008128$

$b_w = 250.00$

effective stress from (A.35), $f_{f,e} = 703.4155$

$R = 40.00$

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

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{,f} = 0.015$

$a_{se}((5.4d), TBDY) = 0.03751166$

$b_o = 440.00$

$h_o = 190.00$

$b_{i2} = 459400.00$

$p_{sh,min} = \min(p_{sh,x}, p_{sh,y}) = 0.001848$

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

$p_{sh,x}(5.4d) = 0.001848$

$A_{sh} = A_{stir} \cdot n_s = 78.53982$

No stirrups, $n_s = 2.00$

$b_k = 500.00$

$p_{sh,y}(5.4d) = 0.00369599$

$A_{sh} = A_{stir} \cdot n_s = 78.53982$

No stirrups, $n_s = 2.00$

$b_k = 250.00$

$s = 170.00$

$f_{ywe} = 555.55$

$f_{ce} = 20.00$

From ((5.A5), TBDY), TBDY: $c_c = 0.00339158$

$c =$ confinement factor = 1.13916

$y_1 = 0.00130695$

$sh_1 = 0.00451687$

$ft_1 = 376.4017$

$fy_1 = 313.6681$

$su_1 = 0.005257$

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

$l_o/l_{ou,min} = l_b/l_d = 0.30356779$

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

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

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

y_1 , sh_1 , ft_1 , fy_1 , are also multiplied by $\min(1, 1.25 \cdot (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

with $fs_1 = fs = 313.6681$

with $Es_1 = Es = 200000.00$

$y_2 = 0.00130695$

$sh_2 = 0.00451687$

$ft_2 = 376.4017$

$fy_2 = 313.6681$

$su_2 = 0.005257$

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

$l_o/l_{ou,min} = l_b/l_{b,min} = 0.30356779$

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

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

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

y_1 , sh_1 , ft_1 , fy_1 , are also multiplied by $\min(1, 1.25 \cdot (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

with $fs_2 = fs = 313.6681$

with $Es_2 = Es = 200000.00$

$y_v = 0.00130695$

$sh_v = 0.00451687$

$ft_v = 376.4017$

$fy_v = 313.6681$

$su_v = 0.005257$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $l_o/l_{o,min} = l_b/l_d = 0.30356779$
 $suv = 0.4 * esuv_{nominal} ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $esuv_{nominal} = 0.08$,
 considering characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY
 For calculation of $esuv_{nominal}$ and y_v, shv, ftv, fyv , it is considered
 characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $Min(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.
 with $fsv = fs = 313.6681$
 with $Esv = Es = 200000.00$
 $1 = Asl_{ten}/(b*d) * (fs_1/fc) = 0.11385127$
 $2 = Asl_{com}/(b*d) * (fs_2/fc) = 0.11385127$
 $v = Asl_{mid}/(b*d) * (fsv/fc) = 0.05520062$

and confined core properties:

$b = 190.00$
 $d = 427.00$
 $d' = 13.00$
 $fcc (5A.2, TBDY) = 22.78316$
 $cc (5A.5, TBDY) = 0.00339158$
 $c = \text{confinement factor} = 1.13916$
 $1 = Asl_{ten}/(b*d) * (fs_1/fc) = 0.1603292$
 $2 = Asl_{com}/(b*d) * (fs_2/fc) = 0.1603292$
 $v = Asl_{mid}/(b*d) * (fsv/fc) = 0.07773537$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

$su (4.9) = 0.20486988$
 $Mu = MRc (4.14) = 1.4541E+008$
 $u = su (4.1) = 1.4467178E-005$

Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.30356779$

$l_b = 300.00$

$l_d = 988.2471$

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

= 1

$db = 18.00$

Mean strength value of all re-bars: $fy = 555.55$

$fc' = 20.00$, but $fc^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 4.61999$

$A_{tr} = Min(A_{tr_x}, A_{tr_y}) = 157.0796$

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

$s = 170.00$

$n = 8.00$

Calculation of Mu_2 -

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

$u = 1.4467178E-005$

$Mu = 1.4541E+008$

with full section properties:

$b = 250.00$

$d = 457.00$
 $d' = 43.00$
 $v = 0.00204242$
 $N = 4666.932$
 $f_c = 20.00$
 $\alpha (5A.5, TBDY) = 0.002$
 Final value of α : $\alpha^* = \text{shear_factor} * \text{Max}(\alpha, \alpha_c) = 0.01464474$
 The Shear_factor is considered equal to 1 (pure moment strength)
 From (5.4b), TBDY: $\alpha = 0.01464474$
 $\alpha_e ((5.4c), TBDY) = \alpha * \text{sh}_{\min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.07762821$
 where $f = \alpha * \rho_f * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$f_x = 0.07705054$
 $\alpha_f = 0.45253333$
 $b = 500.00$
 $h = 250.00$
 From EC8 A.4.4.3(6), $\rho_f = 2t_f/bw = 0.004064$
 $bw = 500.00$
 effective stress from (A.35), $f_{fe} = 837.9178$

$f_y = 0.12936483$
 $\alpha_f = 0.45253333$
 $b = 250.00$
 $h = 500.00$
 From EC8 A.4.4.3(6), $\rho_f = 2t_f/bw = 0.008128$
 $bw = 250.00$
 effective stress from (A.35), $f_{fe} = 703.4155$

$R = 40.00$
 Effective FRP thickness, $t_f = NL * t * \text{Cos}(b_1) = 1.016$
 $f_{u,f} = 1055.00$
 $E_f = 64828.00$
 $u_f = 0.015$
 $\alpha_e ((5.4d), TBDY) = 0.03751166$
 $b_o = 440.00$
 $h_o = 190.00$
 $b_{i2} = 459400.00$
 $\rho_{sh,\min} = \text{Min}(\rho_{sh,x}, \rho_{sh,y}) = 0.001848$
 Expression ((5.4d), TBDY) for $\rho_{sh,\min}$ has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$\rho_{sh,x} (5.4d) = 0.001848$
 $A_{sh} = A_{\text{stir}} * n_s = 78.53982$
 No stirrups, $n_s = 2.00$
 $b_k = 500.00$

$\rho_{sh,y} (5.4d) = 0.00369599$
 $A_{sh} = A_{\text{stir}} * n_s = 78.53982$
 No stirrups, $n_s = 2.00$
 $b_k = 250.00$

$s = 170.00$
 $f_{ywe} = 555.55$
 $f_{ce} = 20.00$
 From ((5A5), TBDY), TBDY: $\alpha_c = 0.00339158$
 $c = \text{confinement factor} = 1.13916$
 $y_1 = 0.00130695$
 $sh_1 = 0.00451687$
 $ft_1 = 376.4017$
 $fy_1 = 313.6681$
 $su_1 = 0.005257$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00
 $l_o/l_{o,\min} = l_b/d = 0.30356779$
 $su_1 = 0.4 * esu_1_{\text{nominal}} ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $esu_1_{\text{nominal}} = 0.08$

For calculation of $esu1_nominal$ 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, ASCE41-17.
 with $fs1 = fs = 313.6681$
 with $Es1 = Es = 200000.00$
 $y2 = 0.00130695$
 $sh2 = 0.00451687$
 $ft2 = 376.4017$
 $fy2 = 313.6681$
 $su2 = 0.005257$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $lo/lou, min = lb/lb, min = 0.30356779$
 $su2 = 0.4 \cdot esu2_nominal ((5.5), TBDY) = 0.032$
 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, ASCE41-17.
 with $fs2 = fs = 313.6681$
 with $Es2 = Es = 200000.00$
 $yv = 0.00130695$
 $shv = 0.00451687$
 $ftv = 376.4017$
 $fyv = 313.6681$
 $suv = 0.005257$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $lo/lou, min = lb/ld = 0.30356779$
 $suv = 0.4 \cdot esuv_nominal ((5.5), TBDY) = 0.032$
 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, ASCE41-17.
 with $fsv = fs = 313.6681$
 with $Esv = Es = 200000.00$
 $1 = Asl, ten / (b \cdot d) \cdot (fs1 / fc) = 0.11385127$
 $2 = Asl, com / (b \cdot d) \cdot (fs2 / fc) = 0.11385127$
 $v = Asl, mid / (b \cdot d) \cdot (fsv / fc) = 0.05520062$

and confined core properties:

$b = 190.00$
 $d = 427.00$
 $d' = 13.00$
 $fcc (5A.2, TBDY) = 22.78316$
 $cc (5A.5, TBDY) = 0.00339158$
 $c = \text{confinement factor} = 1.13916$
 $1 = Asl, ten / (b \cdot d) \cdot (fs1 / fc) = 0.1603292$
 $2 = Asl, com / (b \cdot d) \cdot (fs2 / fc) = 0.1603292$
 $v = Asl, mid / (b \cdot d) \cdot (fsv / fc) = 0.07773537$

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

--->
 $v < vs, y2$ - LHS eq.(4.5) is satisfied
 --->
 $su (4.9) = 0.20486988$
 $Mu = MRc (4.14) = 1.4541E+008$
 $u = su (4.1) = 1.4467178E-005$

Calculation of ratio lb/ld

Lap Length: $lb/ld = 0.30356779$
 $lb = 300.00$
 $ld = 988.2471$

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

$\lambda = 1$
 $d_b = 18.00$
Mean strength value of all re-bars: $f_y = 555.55$
 $f'_c = 20.00$, but $f'_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $t = 1.00$
 $s = 0.80$
 $e = 1.00$
 $c_b = 25.00$
 $K_{tr} = 4.61999$
 $A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$
where A_{tr_x} , A_{tr_y} are the sum of the area of all stirrup legs along X and Y local axis
 $s = 170.00$
 $n = 8.00$

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 409422.352$

Calculation of Shear Strength at edge 1, $V_{r1} = 409422.352$

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

$V_{Col0} = 409422.352$

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

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

$\lambda = 1$ (normal-weight concrete)
 $f'_c = 20.00$, but $f'_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $M/Vd = 2.00$
 $\mu_u = 2.8180236E-013$
 $\nu_u = 1.3558547E-031$
 $d = 0.8 \cdot h = 400.00$
 $N_u = 4666.932$
 $A_g = 125000.00$
From (11.5.4.8), ACI 318-14: $V_s = 164264.64$
 $A_v = 157079.633$
 $f_y = 444.44$
 $s = 170.00$
 V_s is multiplied by $\text{Col} = 1.00$
 $s/d = 0.425$
 V_f ((11-3)-(11.4), ACI 440) = 240803.347
 $f = 0.95$, 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: $\theta = \theta_1 + 90^\circ = 90.00$
 $V_f = \text{Min}(|V_f(45, \theta_1)|, |V_f(-45, \theta_1)|)$, with:
total thickness per orientation, $t_{f1} = N_L \cdot t / N_{oDir} = 1.016$
 $d_{fv} = d$ (figure 11.2, ACI 440) = 457.00
 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: $V_s + V_f \leq 297085.704$
 $b_w = 250.00$

Calculation of Shear Strength at edge 2, $V_{r2} = 409422.352$

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

$V_{Col0} = 409422.352$

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

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

= 1 (normal-weight concrete)
 $f_c' = 20.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $M/Vd = 2.00$
 $\mu_u = 2.8180236E-013$
 $\mu_v = 1.3558547E-031$
 $d = 0.8 \cdot h = 400.00$
 $N_u = 4666.932$
 $A_g = 125000.00$
 From (11.5.4.8), ACI 318-14: $V_s = 164264.64$
 $A_v = 157079.633$
 $f_y = 444.44$
 $s = 170.00$
 V_s is multiplied by $\text{Col} = 1.00$
 $s/d = 0.425$
 $V_f ((11-3)-(11.4), \text{ACI 440}) = 240803.347$
 $f = 0.95$, 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, $t_{f1} = N_L \cdot t / N_{\text{Dir}} = 1.016$
 $d_{fv} = d$ (figure 11.2, ACI 440) = 457.00
 $f_{fe} ((11-5), \text{ACI 440}) = 259.312$
 $E_f = 64828.00$
 $f_e = 0.004$, from (11.6a), ACI 440
 with $f_u = 0.01$
 From (11-11), ACI 440: $V_s + V_f \leq 297085.704$
 $b_w = 250.00$

End Of Calculation of Shear Capacity ratio for element: column C1 of floor 1
 At local axis: 2

Start Of Calculation of Chord Rotation Capacity for element: column C1 of floor 1
 At local axis: 2
 Integration Section: (a)
 Section Type: rcrs

Constant Properties

Knowledge Factor, $\phi = 1.00$
 Chord Rotation is generally considered as Deformation-Controlled Action according to Table C7-1, ASCE41-17.
 Mean strengths are used for Deformation-Controlled Actions according to 7.5.1.3, ASCE 41-17
 Consequently:
 Existing material of Primary Member: Concrete Strength, $f_c = f_{cm} = 20.00$
 Existing material of Primary Member: Steel Strength, $f_s = f_{sm} = 444.44$
 Concrete Elasticity, $E_c = 21019.039$
 Steel Elasticity, $E_s = 200000.00$
 Section Height, $H = 250.00$
 Section Width, $W = 500.00$
 Cover Thickness, $c = 25.00$
 Element Length, $L = 3000.00$
 Primary Member
 Ribbed Bars
 Ductile Steel
 Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
 Longitudinal Bars With Ends Lapped Starting at the End Sections
 Lap Length $l_b = 300.00$
 FRP Wrapping Data
 Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $\epsilon_{fu} = 0.01$

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

Bending Moment, $M = 6.5063436E-010$

Shear Force, $V_2 = -3085.676$

Shear Force, $V_3 = -2.2952864E-013$

Axial Force, $F = -4810.556$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: $A_{slt} = 0.00$

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

Mean Diameter of Tension Reinforcement, $D_bL = 18.66667$

Existing component: From table 7-7, ASCE 41_17: Final chord rotation Capacity $u_{,R} = u = 0.00620875$

$u = y + p = 0.00620875$

- Calculation of y -

$y = (M_y * L_s / 3) / E_{eff} = 0.00620875$ ((4.29), Biskinis Phd))

$M_y = 5.0977E+007$

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

From table 10.5, ASCE 41_17: $E_{eff} = factor * E_c * I_g = 4.1053E+012$

factor = 0.30

$A_g = 125000.00$

$f_c' = 20.00$

$N = 4810.556$

$E_c * I_g = 1.3684E+013$

Calculation of Yielding Moment M_y

Calculation of y and M_y according to Annex 7 -

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

$y_{ten} = 1.0451269E-005$

with ((10.1), ASCE 41-17) $f_y = \text{Min}(f_y, 1.25 * f_y * (I_b / I_d)^{2/3}) = 291.1836$

$d = 207.00$

$y = 0.32702707$

$A = 0.02007155$

$B = 0.01218373$

with $p_t = 0.00801334$

$p_c = 0.00801334$

$p_v = 0.00388525$

$N = 4810.556$

$b = 500.00$

" = 0.20772947

$y_{comp} = 2.5958133E-005$

with $f_c' (12.3, (ACI 440)) = 20.44529$

$f_c = 20.00$

$fl = 0.9425867$
 $b = 500.00$
 $h = 250.00$
 $Ag = 125000.00$
 From (12.9), ACI 440: $ka = 0.1506892$
 $g = pt + pc + pv = 0.01991193$
 $rc = 40.00$
 $Ae/Ac = 0.60275679$
 Effective FRP thickness, $tf = NL * t * \cos(b1) = 1.016$
 effective strain from (12.5) and (12.12), $efe = 0.004$
 $fu = 0.01$
 $Ef = 64828.00$
 $Ec = 21019.039$
 $y = 0.32584352$
 $A = 0.0197792$
 $B = 0.01202411$
 with $Es = 200000.00$

Calculation of ratio lb/ld

Lap Length: $ld/ld,min = 0.37945973$

$lb = 300.00$

$ld = 790.5977$

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

$= 1$

$db = 18.00$

Mean strength value of all re-bars: $fy = 444.44$

$fc' = 20.00$, but $fc'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$Ktr = 4.61999$

$Atr = \min(Atr_x, Atr_y) = 157.0796$

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

$s = 170.00$

$n = 8.00$

- Calculation of p -

From table 10-8: $p = 0.00$

with:

- Columns not controlled by inadequate development or splicing along the clear height because $lb/ld \geq 1$

shear control ratio $VyE/VCoIE = 0.15063296$

$d = 207.00$

$s = 0.00$

$t = Av/(bw*s) + 2*tf/bw*(ffe/fs) = 0.00$

$Av = 157.0796$, is the total area of all stirrups parallel to loading (shear) direction

$bw = 500.00$

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.

$NUD = 4810.556$

$Ag = 125000.00$

$fcE = 20.00$

$fytE = fyle = 0.00$

$pl = Area_Tot_Long_Rein/(b*d) = 0.01991193$

$b = 500.00$

$d = 207.00$

$fcE = 20.00$

End Of Calculation of Chord Rotation Capacity for element: column C1 of floor 1

At local axis: 2

Integration Section: (a)

Calculation No. 3

column C1, Floor 1

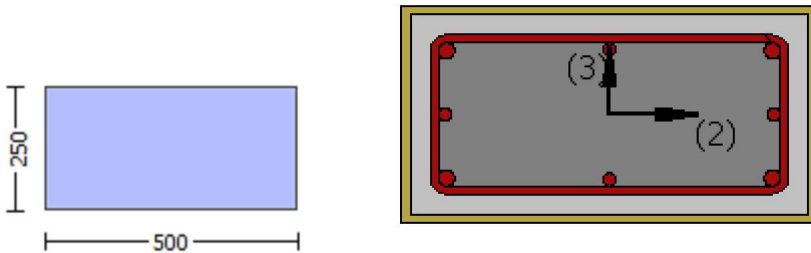
Limit State: Immediate Occupancy (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Shear capacity V_{Rd}

Edge: Start

Local Axis: (3)



Start Of Calculation of Shear Capacity for element: column C1 of floor 1

At local axis: 3

Integration Section: (a)

Section Type: rcrs

Constant Properties

Knowledge Factor, $\gamma = 1.00$

Member Shear Force is generally considered as Force-Controlled Action according to Table C7-1, ASCE41-17.

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

Consequently:

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

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

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of γ for displacement ductility demand, the expected (mean value) strengths are used (7.5.1.3, ASCE41-17) because bending is considered as Deformation-Controlled Action (Table C7-1, ASCE41-17).

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

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

#####

Section Height, $H = 250.00$

Section Width, $W = 500.00$

Cover Thickness, $c = 25.00$

Element Length, $L = 3000.00$
 Primary Member
 Ribbed Bars
 Ductile Steel
 Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
 Longitudinal Bars With Ends Lapped Starting at the End Sections
 Lap Length $l_o = l_b = 300.00$
 FRP Wrapping Data
 Type: Carbon
 Cured laminate properties (design values)
 Thickness, $t = 1.016$
 Tensile Strength, $f_{fu} = 1055.00$
 Tensile Modulus, $E_f = 64828.00$
 Elongation, $\epsilon_{fu} = 0.01$
 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

EDGE -A-
 Bending Moment, $M_a = 6.5063436E-010$
 Shear Force, $V_a = -2.2952864E-013$
 EDGE -B-
 Bending Moment, $M_b = 3.8606651E-011$
 Shear Force, $V_b = 2.2952864E-013$
 BOTH EDGES
 Axial Force, $F = -4810.556$
 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, $D_{bL,ten} = 18.66667$

Existing component: From table 7-7, ASCE 41_17: Final Shear Capacity $V_R = *V_n = 248574.19$
 V_n ((10.3), ASCE 41-17) = $k_n * V_{CoIO} = 248574.19$
 $V_{CoI} = 248574.19$
 $k_n = 1.00$
 displacement_ductility_demand = 0.00

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

= 1 (normal-weight concrete)
 $f'_c = 16.00$, but $f_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $M/Vd = 2.00$
 $M_u = 6.5063436E-010$
 $V_u = 2.2952864E-013$
 $d = 0.8 * h = 200.00$
 $N_u = 4810.556$
 $A_g = 125000.00$
 From (11.5.4.8), ACI 318-14: $V_s = 44351.896$
 $A_v = 157079.633$
 $f_y = 400.00$
 $s = 170.00$
 V_s is multiplied by $CoI = 0.60$
 $s/d = 0.85$
 V_f ((11-3)-(11.4), ACI 440) = 109072.851
 $f = 0.95$, for fully-wrapped sections

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

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

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

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

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

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

$dfv = d$ (figure 11.2, ACI 440) = 207.00

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: $Vs + Vf \leq 265721.532$

$bw = 500.00$

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 $\theta = 4.3510689E-020$

$y = (My * Ls / 3) / Eleff = 0.00620875$ ((4.29), Biskinis Phd))

$My = 5.0977E+007$

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

From table 10.5, ASCE 41_17: $Eleff = \text{factor} * Ec * Ig = 4.1053E+012$

factor = 0.30

$Ag = 125000.00$

$fc' = 20.00$

$N = 4810.556$

$Ec * Ig = 1.3684E+013$

Calculation of Yielding Moment My

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

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

$y_{ten} = 1.0451269E-005$

with ((10.1), ASCE 41-17) $f_y = \text{Min}(f_y, 1.25 * f_y * (lb/d)^{2/3}) = 291.1836$

$d = 207.00$

$y = 0.32702707$

$A = 0.02007155$

$B = 0.01218373$

with $pt = 0.00801334$

$pc = 0.00801334$

$pv = 0.00388525$

$N = 4810.556$

$b = 500.00$

$\alpha = 0.20772947$

$y_{comp} = 2.5958133E-005$

with $fc' = 20.00$ (12.3, (ACI 440)) = 20.44529

$fc = 20.00$

$fl = 0.9425867$

$b = 500.00$

$h = 250.00$

$Ag = 125000.00$

From (12.9), ACI 440: $ka = 0.1506892$

$g = pt + pc + pv = 0.01991193$

$rc = 40.00$

$Ae/Ac = 0.60275679$

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 = 21019.039
y = 0.32584352
A = 0.0197792
B = 0.01202411
with Es = 200000.00

Calculation of ratio lb/l_d

Lap Length: l_d/l_{d,min} = 0.37945973

l_b = 300.00

l_d = 790.5977

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

db = 18.00

Mean strength value of all re-bars: f_y = 444.44

f_c' = 20.00, 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} = 4.61999

A_{tr} = Min(A_{tr_x}, A_{tr_y}) = 157.0796

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

s = 170.00

n = 8.00

End Of Calculation of Shear Capacity for element: column C1 of floor 1

At local axis: 3

Integration Section: (a)

Calculation No. 4

column C1, Floor 1

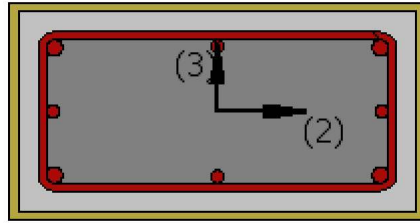
Limit State: Immediate Occupancy (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity (u)

Edge: Start

Local Axis: (3)



Start Of Calculation of Shear Capacity ratio for element: column C1 of floor 1

At Shear local axis: 3

(Bending local axis: 2)

Section Type: rcrs

Constant Properties

Knowledge Factor, $\gamma = 1.00$

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

Consequently:

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

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

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

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

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

#####

Section Height, $H = 250.00$

Section Width, $W = 500.00$

Cover Thickness, $c = 25.00$

Mean Confinement Factor overall section = 1.13916

Element Length, $L = 3000.00$

Primary Member

Ribbed Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

Lap Length $l_o = 300.00$

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $\epsilon_{fu} = 0.01$

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

Fiber orientations, $b_i: 0.00^\circ$

Number of layers, $N_L = 1$

Radius of rounding corners, $R = 40.00$

Stepwise Properties

At local axis: 3

EDGE -A-

Shear Force, $V_a = 2.9007121E-031$

EDGE -B-

Shear Force, $V_b = -2.9007121E-031$

BOTH EDGES

Axial Force, $F = -4666.932$

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: $A_{st,mid} = 402.1239$

Calculation of Shear Capacity ratio, $V_e/V_r = 0.15063296$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 39953.171$ with

$M_{pr1} = \text{Max}(M_{u1+}, M_{u1-}) = 5.9930E+007$

$M_{u1+} = 5.9930E+007$, 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

$M_{u1-} = 5.9930E+007$, 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

$M_{pr2} = \text{Max}(M_{u2+}, M_{u2-}) = 5.9930E+007$

$M_{u2+} = 5.9930E+007$, 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

$M_{u2-} = 5.9930E+007$, 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:

$\phi_u = 3.4011160E-005$

$M_u = 5.9930E+007$

with full section properties:

$b = 500.00$

$d = 207.00$

$d' = 43.00$

$v = 0.00225456$

$N = 4666.932$

$f_c = 20.00$

ϕ_c (5A.5, TBDY) = 0.002

Final value of ϕ_u : $\phi_u^* = \text{shear_factor} * \text{Max}(\phi_u, \phi_c) = 0.01464474$

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

From (5.4b), TBDY: $\phi_u = 0.01464474$

ϕ_{we} ((5.4c), TBDY) = $a_s e * \phi_{sh, min} * f_{ywe} / f_{ce} + \text{Min}(\phi_x, \phi_y) = 0.07762821$

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

$\phi_x = 0.07705054$

$a_f = 0.45253333$

$b = 500.00$

$h = 250.00$

From EC8 A4.4.3(6), $\phi_f = 2t_f/bw = 0.004064$

$bw = 500.00$

effective stress from (A.35), $f_{fe} = 837.9178$

$\phi_y = 0.12936483$

$a_f = 0.45253333$

$b = 250.00$

$h = 500.00$

From EC8 A4.4.3(6), $\phi_f = 2t_f/bw = 0.008128$

$bw = 250.00$

effective stress from (A.35), $f_{fe} = 703.4155$

$R = 40.00$

Effective FRP thickness, $t_f = NL * t * \cos(\theta_1) = 1.016$

$f_u, f = 1055.00$
 $E_f = 64828.00$
 $u, f = 0.015$
 $ase ((5.4d), TBDY) = 0.03751166$
 $bo = 440.00$
 $ho = 190.00$
 $bi2 = 459400.00$
 $psh, min = \text{Min}(psh, x, psh, y) = 0.001848$
 Expression ((5.4d), TBDY) for psh, min has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$psh, x (5.4d) = 0.001848$
 $A_{sh} = A_{stir} * n_s = 78.53982$
 No stirrups, $n_s = 2.00$
 $bk = 500.00$

$psh, y (5.4d) = 0.00369599$
 $A_{sh} = A_{stir} * n_s = 78.53982$
 No stirrups, $n_s = 2.00$
 $bk = 250.00$

$s = 170.00$
 $f_{ywe} = 555.55$
 $f_{ce} = 20.00$

From ((5.A5), TBDY), TBDY: $cc = 0.00339158$
 $c = \text{confinement factor} = 1.13916$

$y1 = 0.00130695$
 $sh1 = 0.00451687$
 $ft1 = 376.4017$
 $fy1 = 313.6681$
 $su1 = 0.005257$

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

$lo/lou, min = lb/ld = 0.30356779$

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

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, ASCE41-17.

with $fs1 = fs = 313.6681$

with $Es1 = Es = 200000.00$

$y2 = 0.00130695$
 $sh2 = 0.00451687$
 $ft2 = 376.4017$
 $fy2 = 313.6681$
 $su2 = 0.005257$

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

$lo/lou, min = lb/lb, min = 0.30356779$

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

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, ASCE41-17.

with $fs2 = fs = 313.6681$

with $Es2 = Es = 200000.00$

$yv = 0.00130695$
 $shv = 0.00451687$
 $ftv = 376.4017$
 $fyv = 313.6681$
 $suv = 0.005257$

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

$lo/lou, min = lb/ld = 0.30356779$

$suv = 0.4 * esuv_nominal ((5.5), TBDY) = 0.032$
 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, ASCE41-17.
 with $fsv = fs = 313.6681$
 with $Esv = Es = 200000.00$
 $1 = Asl,ten / (b * d) * (fs1 / fc) = 0.1256764$
 $2 = Asl,com / (b * d) * (fs2 / fc) = 0.1256764$
 $v = Asl,mid / (b * d) * (fsv / fc) = 0.06093401$

and confined core properties:

$b = 440.00$
 $d = 177.00$
 $d' = 13.00$
 $fcc (5A.2, TBDY) = 22.78316$
 $cc (5A.5, TBDY) = 0.00339158$
 $c = \text{confinement factor} = 1.13916$
 $1 = Asl,ten / (b * d) * (fs1 / fc) = 0.16701987$
 $2 = Asl,com / (b * d) * (fs2 / fc) = 0.16701987$
 $v = Asl,mid / (b * d) * (fsv / fc) = 0.08097933$

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

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

---->
 $su (4.9) = 0.25329952$
 $Mu = MRc (4.14) = 5.9930E+007$
 $u = su (4.1) = 3.4011160E-005$

Calculation of ratio lb/ld

Lap Length: $lb/ld = 0.30356779$
 $lb = 300.00$
 $ld = 988.2471$

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

$= 1$
 $db = 18.00$
 Mean strength value of all re-bars: $fy = 555.55$
 $fc' = 20.00$, but $fc'^{0.5} \leq 8.3 \text{ MPa}$ (22.5.3.1, ACI 318-14)
 $t = 1.00$
 $s = 0.80$
 $e = 1.00$
 $cb = 25.00$
 $Ktr = 4.61999$
 $Atr = Min(Atr_x, Atr_y) = 157.0796$
 where Atr_x , Atr_y are the sum of the area of all stirrup legs along X and Y loxal axis
 $s = 170.00$
 $n = 8.00$

Calculation of $Mu1$ -

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

$u = 3.4011160E-005$
 $Mu = 5.9930E+007$

with full section properties:

$b = 500.00$
 $d = 207.00$
 $d' = 43.00$
 $v = 0.00225456$
 $N = 4666.932$

```

fc = 20.00
co (5A.5, TBDY) = 0.002
Final value of cu: cu* = shear_factor * Max( cu, cc) = 0.01464474
The Shear_factor is considered equal to 1 (pure moment strength)
From (5.4b), TBDY: cu = 0.01464474
we ((5.4c), TBDY) = ase* sh,min*fywe/fce+Min( fx, fy) = 0.07762821
where f = af*pf*ffe/fce is accounting for FRP contribution like EC8-part3 A.4.4.3(6)
-----
fx = 0.07705054
af = 0.45253333
b = 500.00
h = 250.00
From EC8 A4.4.3(6), pf = 2tf/bw = 0.004064
bw = 500.00
effective stress from (A.35), ffe = 837.9178
-----
fy = 0.12936483
af = 0.45253333
b = 250.00
h = 500.00
From EC8 A4.4.3(6), pf = 2tf/bw = 0.008128
bw = 250.00
effective stress from (A.35), ffe = 703.4155
-----
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) = 0.03751166
bo = 440.00
ho = 190.00
bi2 = 459400.00
psh,min = Min(psh,x , psh,y) = 0.001848
Expression ((5.4d), TBDY) for psh,min has been multiplied by 0.3 according to 15.7.1.3 for members without
earthquake detailing (90° closed stirrups)
-----
psh,x (5.4d) = 0.001848
Ash = Astir*ns = 78.53982
No stirups, ns = 2.00
bk = 500.00
-----
psh,y (5.4d) = 0.00369599
Ash = Astir*ns = 78.53982
No stirups, ns = 2.00
bk = 250.00
-----
s = 170.00
fywe = 555.55
fce = 20.00
From ((5.A5), TBDY), TBDY: cc = 0.00339158
c = confinement factor = 1.13916
y1 = 0.00130695
sh1 = 0.00451687
ft1 = 376.4017
fy1 = 313.6681
su1 = 0.005257
using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779
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, ASCE41-17.
with fs1 = fs = 313.6681

```



```

with Es1 = Es = 200000.00
y2 = 0.00130695
sh2 = 0.00451687
ft2 = 376.4017
fy2 = 313.6681
su2 = 0.005257
using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779
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, ASCE41-17.
with fs2 = fs = 313.6681
with Es2 = Es = 200000.00
yv = 0.00130695
shv = 0.00451687
ftv = 376.4017
fyv = 313.6681
suv = 0.005257
using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779
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, ASCE41-17.
with fsv = fs = 313.6681
with Esv = Es = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.1256764
2 = Asl,com/(b*d)*(fs2/fc) = 0.1256764
v = Asl,mid/(b*d)*(fsv/fc) = 0.06093401
and confined core properties:
b = 440.00
d = 177.00
d' = 13.00
fcc (5A.2, TBDY) = 22.78316
cc (5A.5, TBDY) = 0.00339158
c = confinement factor = 1.13916
1 = Asl,ten/(b*d)*(fs1/fc) = 0.16701987
2 = Asl,com/(b*d)*(fs2/fc) = 0.16701987
v = Asl,mid/(b*d)*(fsv/fc) = 0.08097933
Case/Assumption: Unconfined full section - Steel rupture
'satisfies Eq. (4.3)
--->
v < vs,y2 - LHS eq.(4.5) is satisfied
--->
su (4.9) = 0.25329952
Mu = MRc (4.14) = 5.9930E+007
u = su (4.1) = 3.4011160E-005

```

Calculation of ratio lb/lb

```

Lap Length: lb/lb = 0.30356779
lb = 300.00
lb = 988.2471
Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
= 1
db = 18.00
Mean strength value of all re-bars: fy = 555.55
fc' = 20.00, but fc^0.5 <= 8.3 MPa (22.5.3.1, ACI 318-14)

```

$t = 1.00$
 $s = 0.80$
 $e = 1.00$
 $cb = 25.00$
 $K_{tr} = 4.61999$
 $A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$
 where A_{tr_x} , A_{tr_y} are the sum of the area of all stirrup legs along X and Y loxal axis
 $s = 170.00$
 $n = 8.00$

Calculation of μ_{2+}

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

$\mu = 3.4011160E-005$
 $\mu_u = 5.9930E+007$

with full section properties:

$b = 500.00$
 $d = 207.00$
 $d' = 43.00$
 $v = 0.00225456$
 $N = 4666.932$
 $f_c = 20.00$
 $\alpha_{co} (5A.5, \text{TBDY}) = 0.002$
 Final value of μ : $\mu^* = \text{shear_factor} * \text{Max}(\mu_c, \mu_{cc}) = 0.01464474$
 The Shear_factor is considered equal to 1 (pure moment strength)
 From (5.4b), TBDY: $\mu_c = 0.01464474$
 $\mu_{cc} ((5.4c), \text{TBDY}) = \alpha_{se} * \text{sh}_{\min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.07762821$
 where $f = \alpha_f * p_f * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$f_x = 0.07705054$
 $\alpha_f = 0.45253333$
 $b = 500.00$
 $h = 250.00$
 From EC8 A.4.4.3(6), $p_f = 2t_f/b_w = 0.004064$
 $b_w = 500.00$
 effective stress from (A.35), $f_{fe} = 837.9178$

$f_y = 0.12936483$
 $\alpha_f = 0.45253333$
 $b = 250.00$
 $h = 500.00$
 From EC8 A.4.4.3(6), $p_f = 2t_f/b_w = 0.008128$
 $b_w = 250.00$
 effective stress from (A.35), $f_{fe} = 703.4155$

$R = 40.00$
 Effective FRP thickness, $t_f = NL * t * \cos(b_1) = 1.016$
 $f_{u,f} = 1055.00$
 $E_f = 64828.00$
 $u_{,f} = 0.015$
 $\alpha_{se} ((5.4d), \text{TBDY}) = 0.03751166$
 $b_o = 440.00$
 $h_o = 190.00$
 $b_{i2} = 459400.00$
 $p_{sh,\min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.001848$

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

$p_{sh,x} (5.4d) = 0.001848$
 $A_{sh} = A_{stir} * n_s = 78.53982$
 No stirrups, $n_s = 2.00$
 $b_k = 500.00$

psh,y (5.4d) = 0.00369599
 Ash = Astir*ns = 78.53982
 No stirups, ns = 2.00
 bk = 250.00

s = 170.00
 fywe = 555.55
 fce = 20.00

From ((5.A5), TBDY), TBDY: cc = 0.00339158
 c = confinement factor = 1.13916

y1 = 0.00130695
 sh1 = 0.00451687

ft1 = 376.4017

fy1 = 313.6681

su1 = 0.005257

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779

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, ASCE41-17.

with fs1 = fs = 313.6681

with Es1 = Es = 200000.00

y2 = 0.00130695

sh2 = 0.00451687

ft2 = 376.4017

fy2 = 313.6681

su2 = 0.005257

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779

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, ASCE41-17.

with fs2 = fs = 313.6681

with Es2 = Es = 200000.00

yv = 0.00130695

shv = 0.00451687

ftv = 376.4017

fyv = 313.6681

suv = 0.005257

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779

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, ASCE41-17.

with fsv = fs = 313.6681

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.1256764

2 = Asl,com/(b*d)*(fs2/fc) = 0.1256764

v = Asl,mid/(b*d)*(fsv/fc) = 0.06093401

and confined core properties:

b = 440.00

d = 177.00

d' = 13.00

```

fcc (5A.2, TBDY) = 22.78316
cc (5A.5, TBDY) = 0.00339158
c = confinement factor = 1.13916
1 = Asl,ten/(b*d)*(fs1/fc) = 0.16701987
2 = Asl,com/(b*d)*(fs2/fc) = 0.16701987
v = Asl,mid/(b*d)*(fsv/fc) = 0.08097933
Case/Assumption: Unconfined full section - Steel rupture
'satisfies Eq. (4.3)
--->
v < vs,y2 - LHS eq.(4.5) is satisfied
--->
su (4.9) = 0.25329952
Mu = MRc (4.14) = 5.9930E+007
u = su (4.1) = 3.4011160E-005

```

Calculation of ratio lb/ld

```

Lap Length: lb/ld = 0.30356779
lb = 300.00
ld = 988.2471
Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars
= 1
db = 18.00
Mean strength value of all re-bars: fy = 555.55
fc' = 20.00, but fc^0.5 <= 8.3 MPa (22.5.3.1, ACI 318-14)
t = 1.00
s = 0.80
e = 1.00
cb = 25.00
Ktr = 4.61999
Atr = Min(Atr_x,Atr_y) = 157.0796
where Atr_x, Atr_y are the sum of the area of all stirrup legs along X and Y loxal axis
s = 170.00
n = 8.00

```

Calculation of Mu2-

```

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:
u = 3.4011160E-005
Mu = 5.9930E+007

```

with full section properties:

```

b = 500.00
d = 207.00
d' = 43.00
v = 0.00225456
N = 4666.932
fc = 20.00
co (5A.5, TBDY) = 0.002
Final value of cu: cu* = shear_factor * Max( cu, cc) = 0.01464474
The Shear_factor is considered equal to 1 (pure moment strength)
From (5.4b), TBDY: cu = 0.01464474
we ((5.4c), TBDY) = ase* sh,min*fywe/fce+Min( fx, fy) = 0.07762821
where f = af*pf*ffe/fce is accounting for FRP contribution like EC8-part3 A.4.4.3(6)
fx = 0.07705054
af = 0.45253333
b = 500.00
h = 250.00
From EC8 A.4.4.3(6), pf = 2tf/bw = 0.004064
bw = 500.00
effective stress from (A.35), ff,e = 837.9178

```

$$f_y = 0.12936483$$

$$a_f = 0.45253333$$

$$b = 250.00$$

$$h = 500.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 703.4155$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = NL \cdot t \cdot \cos(\beta_1) = 1.016$$

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

$$E_f = 64828.00$$

$$u_{f,f} = 0.015$$

$$a_{se}((5.4d), \text{TB DY}) = 0.03751166$$

$$b_o = 440.00$$

$$h_o = 190.00$$

$$b_{i2} = 459400.00$$

$$p_{sh,min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.001848$$

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

$$p_{sh,x} (5.4d) = 0.001848$$

$$A_{sh} = A_{stir} \cdot n_s = 78.53982$$

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

$$b_k = 500.00$$

$$p_{sh,y} (5.4d) = 0.00369599$$

$$A_{sh} = A_{stir} \cdot n_s = 78.53982$$

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

$$b_k = 250.00$$

$$s = 170.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 20.00$$

$$\text{From ((5.A5), TB DY), TB DY: } c_c = 0.00339158$$

$$c = \text{confinement factor} = 1.13916$$

$$y_1 = 0.00130695$$

$$sh_1 = 0.00451687$$

$$f_{t1} = 376.4017$$

$$f_{y1} = 313.6681$$

$$su_1 = 0.005257$$

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

$$l_o/l_{ou,min} = l_b/l_d = 0.30356779$$

$$su_1 = 0.4 \cdot esu1_{nominal} ((5.5), \text{TB DY}) = 0.032$$

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

For calculation of $esu1_{nominal}$ and $y_1, sh_1, f_{t1}, f_{y1}$, it is considered
characteristic value $fsy_1 = fs_1/1.2$, from table 5.1, TB DY.

$y_1, sh_1, f_{t1}, f_{y1}$, are also multiplied by $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

$$\text{with } fs_1 = fs = 313.6681$$

$$\text{with } Es_1 = Es = 200000.00$$

$$y_2 = 0.00130695$$

$$sh_2 = 0.00451687$$

$$f_{t2} = 376.4017$$

$$f_{y2} = 313.6681$$

$$su_2 = 0.005257$$

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

$$l_o/l_{ou,min} = l_b/l_{b,min} = 0.30356779$$

$$su_2 = 0.4 \cdot esu2_{nominal} ((5.5), \text{TB DY}) = 0.032$$

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

For calculation of $esu2_{nominal}$ and $y_2, sh_2, f_{t2}, f_{y2}$, it is considered
characteristic value $fsy_2 = fs_2/1.2$, from table 5.1, TB DY.

$y_1, sh_1, f_{t1}, f_{y1}$, are also multiplied by $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

```

with fs2 = fs = 313.6681
with Es2 = Es = 200000.00
yv = 0.00130695
shv = 0.00451687
ftv = 376.4017
fyv = 313.6681
suv = 0.005257
using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779
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, ASCE41-17.
with fsv = fs = 313.6681
with Esv = Es = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.1256764
2 = Asl,com/(b*d)*(fs2/fc) = 0.1256764
v = Asl,mid/(b*d)*(fsv/fc) = 0.06093401
and confined core properties:
b = 440.00
d = 177.00
d' = 13.00
fcc (5A.2, TBDY) = 22.78316
cc (5A.5, TBDY) = 0.00339158
c = confinement factor = 1.13916
1 = Asl,ten/(b*d)*(fs1/fc) = 0.16701987
2 = Asl,com/(b*d)*(fs2/fc) = 0.16701987
v = Asl,mid/(b*d)*(fsv/fc) = 0.08097933
Case/Assumption: Unconfined full section - Steel rupture
'satisfies Eq. (4.3)
--->
v < vs,y2 - LHS eq.(4.5) is satisfied
--->
su (4.9) = 0.25329952
Mu = MRc (4.14) = 5.9930E+007
u = su (4.1) = 3.4011160E-005

```

Calculation of ratio lb/ld

```

Lap Length: lb/ld = 0.30356779
lb = 300.00
ld = 988.2471
Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
= 1
db = 18.00
Mean strength value of all re-bars: fy = 555.55
fc' = 20.00, but fc^0.5 <= 8.3 MPa (22.5.3.1, ACI 318-14)
t = 1.00
s = 0.80
e = 1.00
cb = 25.00
Ktr = 4.61999
Atr = Min(Atr_x,Atr_y) = 157.0796
where Atr_x, Atr_y are the sum of the area of all stirrup legs along X and Y loxal axis
s = 170.00
n = 8.00

```

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 265235.248$

Calculation of Shear Strength at edge 1, $V_{r1} = 265235.248$

$V_{r1} = V_{Col} ((10.3), ASCE 41-17) = knl * V_{ColO}$

$V_{ColO} = 265235.248$

$knl = 1$ (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)

$f_c' = 20.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$\mu_u = 2.3992784E-012$

$V_u = 2.9007121E-031$

$d = 0.8 * h = 200.00$

$N_u = 4666.932$

$A_g = 125000.00$

From (11.5.4.8), ACI 318-14: $V_s = 49279.392$

$A_v = 157079.633$

$f_y = 444.44$

$s = 170.00$

V_s is multiplied by $Col = 0.60$

$s/d = 0.85$

$V_f ((11-3)-(11.4), ACI 440) = 109072.851$

$f = 0.95$, for fully-wrapped sections

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

In (11.3) $\sin + \cos$ is replaced with $(\cot + \cot a) \sin a$ which is more a generalised expression,

where a is the angle of the crack direction (see KANEPE).

This later relation, considered as a function $V_f(,)$, is implemented for every different fiber orientation a_i , as well as for 2 crack directions, $= 45^\circ$ and $= -45^\circ$ 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, $t_{f1} = NL * t / N_{oDir} = 1.016$

$d_{fv} = d$ (figure 11.2, ACI 440) = 207.00

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

$E_f = 64828.00$

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

with $f_u = 0.01$

From (11-11), ACI 440: $V_s + V_f \leq 297085.704$

$bw = 500.00$

Calculation of Shear Strength at edge 2, $V_{r2} = 265235.248$

$V_{r2} = V_{Col} ((10.3), ASCE 41-17) = knl * V_{ColO}$

$V_{ColO} = 265235.248$

$knl = 1$ (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)

$f_c' = 20.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$\mu_u = 2.3992784E-012$

$V_u = 2.9007121E-031$

$d = 0.8 * h = 200.00$

$N_u = 4666.932$

$A_g = 125000.00$

From (11.5.4.8), ACI 318-14: $V_s = 49279.392$

$A_v = 157079.633$

$f_y = 444.44$

$s = 170.00$

V_s is multiplied by $Col = 0.60$

$s/d = 0.85$

$V_f ((11-3)-(11.4), ACI 440) = 109072.851$

$f = 0.95$, 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: $\theta_1 = \theta_1 + 90^\circ = 90.00$

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

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

$d_{fv} = d$ (figure 11.2, ACI 440) = 207.00

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

$E_f = 64828.00$

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

with $f_u = 0.01$

From (11-11), ACI 440: $V_s + V_f \leq 297085.704$

$b_w = 500.00$

End Of Calculation of Shear Capacity ratio for element: column C1 of floor 1

At local axis: 3

Start Of Calculation of Shear Capacity ratio for element: column C1 of floor 1

At Shear local axis: 2

(Bending local axis: 3)

Section Type: rcrcs

Constant Properties

Knowledge Factor, $\phi = 1.00$

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

Consequently:

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

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

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

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

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

#####

Section Height, $H = 250.00$

Section Width, $W = 500.00$

Cover Thickness, $c = 25.00$

Mean Confinement Factor overall section = 1.13916

Element Length, $L = 3000.00$

Primary Member

Ribbed Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

Lap Length $l_o = 300.00$

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $e_{fu} = 0.01$

Number of directions, $\text{NoDir} = 1$

Fiber orientations, $b_i: 0.00^\circ$

Number of layers, $NL = 1$

Radius of rounding corners, $R = 40.00$

Stepwise Properties

At local axis: 2

EDGE -A-
 Shear Force, $V_a = 1.3558547E-031$
 EDGE -B-
 Shear Force, $V_b = -1.3558547E-031$
 BOTH EDGES
 Axial Force, $F = -4666.932$
 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 , $V_e/V_r = 0.23676754$
 Member Controlled by Flexure ($V_e/V_r < 1$)
 Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 96937.922$
 with
 $M_{pr1} = \text{Max}(Mu_{1+} , Mu_{1-}) = 1.4541E+008$
 $Mu_{1+} = 1.4541E+008$, 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
 $Mu_{1-} = 1.4541E+008$, 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
 $M_{pr2} = \text{Max}(Mu_{2+} , Mu_{2-}) = 1.4541E+008$
 $Mu_{2+} = 1.4541E+008$, 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
 $Mu_{2-} = 1.4541E+008$, 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:
 $\phi_u = 1.4467178E-005$
 $M_u = 1.4541E+008$

 with full section properties:

$b = 250.00$
 $d = 457.00$
 $d' = 43.00$
 $v = 0.00204242$
 $N = 4666.932$
 $f_c = 20.00$
 $\phi_c (5A.5, TBDY) = 0.002$
 Final value of ϕ_u : $\phi_u^* = \text{shear_factor} * \text{Max}(\phi_u, \phi_c) = 0.01464474$
 The Shear_factor is considered equal to 1 (pure moment strength)
 From (5.4b), TBDY: $\phi_u = 0.01464474$
 $\phi_{we} ((5.4c), TBDY) = a_s e^* \phi_{sh,min} * f_{ywe}/f_{ce} + \text{Min}(\phi_x, \phi_y) = 0.07762821$
 where $\phi = a_f * \phi_f * f_{fe}/f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

 $\phi_x = 0.07705054$
 $a_f = 0.45253333$
 $b = 500.00$
 $h = 250.00$
 From EC8 A.4.4.3(6), $\phi_f = 2t_f/bw = 0.004064$
 $bw = 500.00$
 effective stress from (A.35), $f_{fe} = 837.9178$

 $f_y = 0.12936483$
 $a_f = 0.45253333$
 $b = 250.00$
 $h = 500.00$

From EC8 A4.4.3(6), $pf = 2tf/bw = 0.008128$
 $bw = 250.00$
effective stress from (A.35), $ff,e = 703.4155$

$R = 40.00$
Effective FRP thickness, $tf = NL*t*\cos(b1) = 1.016$
 $f_{u,f} = 1055.00$
 $E_f = 64828.00$
 $u_{,f} = 0.015$
 $ase \text{ ((5.4d), TBDY)} = 0.03751166$
 $bo = 440.00$
 $ho = 190.00$
 $bi2 = 459400.00$
 $psh,min = \min(psh,x, psh,y) = 0.001848$

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

$psh,x \text{ (5.4d)} = 0.001848$
 $Ash = Astir*ns = 78.53982$
No stirrups, $ns = 2.00$
 $bk = 500.00$

$psh,y \text{ (5.4d)} = 0.00369599$
 $Ash = Astir*ns = 78.53982$
No stirrups, $ns = 2.00$
 $bk = 250.00$

$s = 170.00$
 $fywe = 555.55$
 $fce = 20.00$

From ((5.A5), TBDY), TBDY: $cc = 0.00339158$
 $c = \text{confinement factor} = 1.13916$

$y1 = 0.00130695$
 $sh1 = 0.00451687$

$ft1 = 376.4017$

$fy1 = 313.6681$

$su1 = 0.005257$

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

$lo/lou,min = lb/ld = 0.30356779$

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

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

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

$y1, sh1, ft1, fy1$, are also multiplied by $\min(1, 1.25*(lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

with $fs1 = fs = 313.6681$

with $Es1 = Es = 200000.00$

$y2 = 0.00130695$
 $sh2 = 0.00451687$

$ft2 = 376.4017$

$fy2 = 313.6681$

$su2 = 0.005257$

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

$lo/lou,min = lb/lb,min = 0.30356779$

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

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

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

$y1, sh1, ft1, fy1$, are also multiplied by $\min(1, 1.25*(lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

with $fs2 = fs = 313.6681$

with $Es2 = Es = 200000.00$

$yv = 0.00130695$
 $shv = 0.00451687$
 $ftv = 376.4017$

```

fyv = 313.6681
suv = 0.005257
using (30) in Biskinis/Fardis (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 = 0.30356779
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, ASCE41-17.
with fsv = fs = 313.6681
with Esv = Es = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.11385127
2 = Asl,com/(b*d)*(fs2/fc) = 0.11385127
v = Asl,mid/(b*d)*(fsv/fc) = 0.05520062
and confined core properties:
b = 190.00
d = 427.00
d' = 13.00
fcc (5A.2, TBDY) = 22.78316
cc (5A.5, TBDY) = 0.00339158
c = confinement factor = 1.13916
1 = Asl,ten/(b*d)*(fs1/fc) = 0.1603292
2 = Asl,com/(b*d)*(fs2/fc) = 0.1603292
v = Asl,mid/(b*d)*(fsv/fc) = 0.07773537
Case/Assumption: Unconfined full section - Steel rupture
'satisfies Eq. (4.3)
--->
v < vs,y2 - LHS eq.(4.5) is satisfied
--->
su (4.9) = 0.20486988
Mu = MRc (4.14) = 1.4541E+008
u = su (4.1) = 1.4467178E-005

```

Calculation of ratio lb/ld

```

Lap Length: lb/ld = 0.30356779
lb = 300.00
ld = 988.2471
Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
= 1
db = 18.00
Mean strength value of all re-bars: fy = 555.55
fc' = 20.00, but fc^0.5 <= 8.3 MPa (22.5.3.1, ACI 318-14)
t = 1.00
s = 0.80
e = 1.00
cb = 25.00
Ktr = 4.61999
Atr = Min(Atr_x,Atr_y) = 157.0796
where Atr_x, Atr_y are the sum of the area of all stirrup legs along X and Y loxal axis
s = 170.00
n = 8.00

```

Calculation of Mu1-

```

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:
u = 1.4467178E-005
Mu = 1.4541E+008

```

with full section properties:

$$b = 250.00$$

$$d = 457.00$$

$$d' = 43.00$$

$$v = 0.00204242$$

$$N = 4666.932$$

$$f_c = 20.00$$

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

$$\text{Final value of } \alpha: \alpha^* = \text{shear_factor} * \text{Max}(\alpha, \alpha_c) = 0.01464474$$

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

$$\text{From (5.4b), TB DY: } \alpha = 0.01464474$$

$$\alpha_e ((5.4c), \text{TB DY}) = \alpha * \text{sh}_{\min} * f_{ywe} / f_{ce} + \text{Min}(\alpha_x, \alpha_y) = 0.07762821$$

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

$$\alpha_x = 0.07705054$$

$$\alpha_f = 0.45253333$$

$$b = 500.00$$

$$h = 250.00$$

$$\text{From EC8 A.4.4.3(6), } \rho_f = 2t_f/bw = 0.004064$$

$$bw = 500.00$$

$$\text{effective stress from (A.35), } f_{fe} = 837.9178$$

$$\alpha_y = 0.12936483$$

$$\alpha_f = 0.45253333$$

$$b = 250.00$$

$$h = 500.00$$

$$\text{From EC8 A.4.4.3(6), } \rho_f = 2t_f/bw = 0.008128$$

$$bw = 250.00$$

$$\text{effective stress from (A.35), } f_{fe} = 703.4155$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = NL * t * \cos(\beta_1) = 1.016$$

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

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$\alpha_e ((5.4d), \text{TB DY}) = 0.03751166$$

$$b_o = 440.00$$

$$h_o = 190.00$$

$$b_i^2 = 459400.00$$

$$\rho_{sh,\min} = \text{Min}(\rho_{sh,x}, \rho_{sh,y}) = 0.001848$$

Expression ((5.4d), TB DY) for $\rho_{sh,\min}$ has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$$\rho_{sh,x} (5.4d) = 0.001848$$

$$A_{sh} = A_{stir} * n_s = 78.53982$$

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

$$b_k = 500.00$$

$$\rho_{sh,y} (5.4d) = 0.00369599$$

$$A_{sh} = A_{stir} * n_s = 78.53982$$

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

$$b_k = 250.00$$

$$s = 170.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 20.00$$

$$\text{From ((5A5), TB DY), TB DY: } \alpha_c = 0.00339158$$

$$c = \text{confinement factor} = 1.13916$$

$$y_1 = 0.00130695$$

$$sh_1 = 0.00451687$$

$$f_{t1} = 376.4017$$

$$f_{y1} = 313.6681$$

$$su_1 = 0.005257$$

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

and also multiplied by the shear_factor according to 15.7.1.4, with

$$\text{Shear_factor} = 1.00$$

$$l_o/l_{ou,\min} = l_b/d = 0.30356779$$

```

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, ASCE41-17.
with fs1 = fs = 313.6681
with Es1 = Es = 200000.00
y2 = 0.00130695
sh2 = 0.00451687
ft2 = 376.4017
fy2 = 313.6681
su2 = 0.005257
using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779
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, ASCE41-17.
with fs2 = fs = 313.6681
with Es2 = Es = 200000.00
yv = 0.00130695
shv = 0.00451687
ftv = 376.4017
fyv = 313.6681
suv = 0.005257
using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779
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, ASCE41-17.
with fsv = fs = 313.6681
with Esv = Es = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.11385127
2 = Asl,com/(b*d)*(fs2/fc) = 0.11385127
v = Asl,mid/(b*d)*(fsv/fc) = 0.05520062

```

and confined core properties:

```

b = 190.00
d = 427.00
d' = 13.00
fcc (5A.2, TBDY) = 22.78316
cc (5A.5, TBDY) = 0.00339158
c = confinement factor = 1.13916
1 = Asl,ten/(b*d)*(fs1/fc) = 0.1603292
2 = Asl,com/(b*d)*(fs2/fc) = 0.1603292
v = Asl,mid/(b*d)*(fsv/fc) = 0.07773537

```

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

```

--->
v < vs,y2 - LHS eq.(4.5) is satisfied
--->
su (4.9) = 0.20486988
Mu = MRc (4.14) = 1.4541E+008
u = su (4.1) = 1.4467178E-005

```

Calculation of ratio lb/ld

```

Lap Length: lb/ld = 0.30356779
lb = 300.00

```

Id = 988.2471

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

db = 18.00

Mean strength value of all re-bars: $f_y = 555.55$

$f_c' = 20.00$, but $f_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

t = 1.00

s = 0.80

e = 1.00

cb = 25.00

Ktr = 4.61999

$A_{tr} = \text{Min}(A_{tr,x}, A_{tr,y}) = 157.0796$

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

s = 170.00

n = 8.00

Calculation of μ_{2+}

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

$\mu = 1.4467178E-005$

$\mu_u = 1.4541E+008$

with full section properties:

b = 250.00

d = 457.00

d' = 43.00

v = 0.00204242

N = 4666.932

$f_c = 20.00$

ϕ (5A.5, TBDY) = 0.002

Final value of μ_u : $\mu_u^* = \text{shear_factor} * \text{Max}(\mu_u, \mu_c) = 0.01464474$

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

From (5.4b), TBDY: $\mu_u = 0.01464474$

we ((5.4c), TBDY) = $a_s * \frac{f_{y, \min} * f_{y, \text{we}}}{f_{c, \text{e}}} + \text{Min}(f_x, f_y) = 0.07762821$

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

$f_x = 0.07705054$

$a_f = 0.45253333$

b = 500.00

h = 250.00

From EC8 A.4.4.3(6), $p_f = 2t_f/bw = 0.004064$

bw = 500.00

effective stress from (A.35), $f_{f, \text{e}} = 837.9178$

$f_y = 0.12936483$

$a_f = 0.45253333$

b = 250.00

h = 500.00

From EC8 A.4.4.3(6), $p_f = 2t_f/bw = 0.008128$

bw = 250.00

effective stress from (A.35), $f_{f, \text{e}} = 703.4155$

R = 40.00

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

$f_{u, f} = 1055.00$

$E_f = 64828.00$

$u, f = 0.015$

a_s ((5.4d), TBDY) = 0.03751166

$b_o = 440.00$

$h_o = 190.00$

$b_{i2} = 459400.00$

$p_{sh, \min} = \text{Min}(p_{sh, x}, p_{sh, y}) = 0.001848$

Expression ((5.4d), TBDY) for $p_{sh, \min}$ has been multiplied by 0.3 according to 15.7.1.3 for members without

earthquake detailing (90° closed stirrups)

psh,x (5.4d) = 0.001848
Ash = Astir*ns = 78.53982
No stirups, ns = 2.00
bk = 500.00

psh,y (5.4d) = 0.00369599
Ash = Astir*ns = 78.53982
No stirups, ns = 2.00
bk = 250.00

s = 170.00
fywe = 555.55
fce = 20.00

From ((5.A5), TBDY), TBDY: cc = 0.00339158
c = confinement factor = 1.13916

y1 = 0.00130695
sh1 = 0.00451687
ft1 = 376.4017
fy1 = 313.6681
su1 = 0.005257

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779

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, ASCE41-17.

with fs1 = fs = 313.6681

with Es1 = Es = 200000.00

y2 = 0.00130695
sh2 = 0.00451687
ft2 = 376.4017
fy2 = 313.6681
su2 = 0.005257

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779

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, ASCE41-17.

with fs2 = fs = 313.6681

with Es2 = Es = 200000.00

yv = 0.00130695
shv = 0.00451687
ftv = 376.4017
fyv = 313.6681
suv = 0.005257

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779

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

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

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

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

y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/d)^ 2/3), from 10.3.5, ASCE41-17.

with fsv = fs = 313.6681

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.11385127

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.11385127$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.05520062$$

and confined core properties:

$$b = 190.00$$

$$d = 427.00$$

$$d' = 13.00$$

$$f_{cc} (5A.2, TBDY) = 22.78316$$

$$c_c (5A.5, TBDY) = 0.00339158$$

$$c = \text{confinement factor} = 1.13916$$

$$1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.1603292$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.1603292$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.07773537$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

$$s_u (4.9) = 0.20486988$$

$$M_u = M_{Rc} (4.14) = 1.4541E+008$$

$$u = s_u (4.1) = 1.4467178E-005$$

Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.30356779$

$$l_b = 300.00$$

$$l_d = 988.2471$$

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

$$= 1$$

$$d_b = 18.00$$

Mean strength value of all re-bars: $f_y = 555.55$

$$f_c' = 20.00, \text{ but } f_c'^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 25.00$$

$$K_{tr} = 4.61999$$

$$A_{tr} = \min(A_{tr,x}, A_{tr,y}) = 157.0796$$

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

$$s = 170.00$$

$$n = 8.00$$

Calculation of M_{u2} -

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

$$u = 1.4467178E-005$$

$$M_u = 1.4541E+008$$

with full section properties:

$$b = 250.00$$

$$d = 457.00$$

$$d' = 43.00$$

$$v = 0.00204242$$

$$N = 4666.932$$

$$f_c = 20.00$$

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

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \max(c_u, c_o) = 0.01464474$$

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

$$\text{From (5.4b), TBDY: } c_u = 0.01464474$$

$$\text{we ((5.4c), TBDY) } = a_s e^* s_{h,min} * f_{ywe}/f_{ce} + \min(f_x, f_y) = 0.07762821$$

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

$$f_x = 0.07705054$$

af = 0.45253333
b = 500.00
h = 250.00
From EC8 A4.4.3(6), pf = $2t_f/bw = 0.004064$
bw = 500.00
effective stress from (A.35), ff,e = 837.9178

fy = 0.12936483
af = 0.45253333
b = 250.00
h = 500.00
From EC8 A4.4.3(6), pf = $2t_f/bw = 0.008128$
bw = 250.00
effective stress from (A.35), ff,e = 703.4155

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) = 0.03751166
bo = 440.00
ho = 190.00
bi2 = 459400.00
psh,min = Min(psh,x , psh,y) = 0.001848
Expression ((5.4d), TBDY) for psh,min has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

psh,x (5.4d) = 0.001848
Ash = Astir*ns = 78.53982
No stirrups, ns = 2.00
bk = 500.00

psh,y (5.4d) = 0.00369599
Ash = Astir*ns = 78.53982
No stirrups, ns = 2.00
bk = 250.00

s = 170.00
fywe = 555.55
fce = 20.00
From ((5.A5), TBDY), TBDY: cc = 0.00339158
c = confinement factor = 1.13916
y1 = 0.00130695
sh1 = 0.00451687
ft1 = 376.4017
fy1 = 313.6681
su1 = 0.005257
using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779
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, ASCE41-17.
with fs1 = fs = 313.6681
with Es1 = Es = 200000.00
y2 = 0.00130695
sh2 = 0.00451687
ft2 = 376.4017
fy2 = 313.6681
su2 = 0.005257
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$l_o/l_{o,min} = l_b/l_{b,min} = 0.30356779$
 $su_2 = 0.4 \cdot esu_{2,nominal} ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $esu_{2,nominal} = 0.08$,
 For calculation of $esu_{2,nominal}$ and y_2, sh_2, ft_2, fy_2 , it is considered
 characteristic value $fsy_2 = fs_2/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.
 with $fs_2 = fs = 313.6681$
 with $Es_2 = Es = 200000.00$
 $y_v = 0.00130695$
 $sh_v = 0.00451687$
 $ft_v = 376.4017$
 $fy_v = 313.6681$
 $suv = 0.005257$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $l_o/l_{o,min} = l_b/l_d = 0.30356779$
 $suv = 0.4 \cdot esuv_{nominal} ((5.5), TBDY) = 0.032$
 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 $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.
 with $fsv = fs = 313.6681$
 with $Es_v = Es = 200000.00$
 $1 = A_{sl,ten}/(b \cdot d) \cdot (fs_1/f_c) = 0.11385127$
 $2 = A_{sl,com}/(b \cdot d) \cdot (fs_2/f_c) = 0.11385127$
 $v = A_{sl,mid}/(b \cdot d) \cdot (fsv/f_c) = 0.05520062$
 and confined core properties:
 $b = 190.00$
 $d = 427.00$
 $d' = 13.00$
 $f_{cc} (5A.2, TBDY) = 22.78316$
 $cc (5A.5, TBDY) = 0.00339158$
 $c = \text{confinement factor} = 1.13916$
 $1 = A_{sl,ten}/(b \cdot d) \cdot (fs_1/f_c) = 0.1603292$
 $2 = A_{sl,com}/(b \cdot d) \cdot (fs_2/f_c) = 0.1603292$
 $v = A_{sl,mid}/(b \cdot d) \cdot (fsv/f_c) = 0.07773537$
 Case/Assumption: Unconfined full section - Steel rupture
 ' satisfies Eq. (4.3)
 --->
 $v < v_{s,y2}$ - LHS eq.(4.5) is satisfied
 --->
 $su (4.9) = 0.20486988$
 $\mu_u = M_{Rc} (4.14) = 1.4541E+008$
 $u = su (4.1) = 1.4467178E-005$

Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.30356779$
 $l_b = 300.00$
 $l_d = 988.2471$
 Calculation of $l_{b,min}$ according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
 $= 1$
 $db = 18.00$
 Mean strength value of all re-bars: $f_y = 555.55$
 $f_c' = 20.00$, but $f_c'^{0.5} \leq 8.3 \text{ MPa}$ (22.5.3.1, ACI 318-14)
 $t = 1.00$
 $s = 0.80$
 $e = 1.00$
 $cb = 25.00$
 $K_{tr} = 4.61999$
 $A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$
 where A_{tr_x}, A_{tr_y} are the sum of the area of all stirrup legs along X and Y loxal axis
 $s = 170.00$
 $n = 8.00$

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 409422.352$

Calculation of Shear Strength at edge 1, $V_{r1} = 409422.352$

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

$V_{Col0} = 409422.352$

$k_{nl} = 1$ (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)

$f'_c = 20.00$, but $f'_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$\mu_u = 2.8180236E-013$

$V_u = 1.3558547E-031$

$d = 0.8 * h = 400.00$

$N_u = 4666.932$

$A_g = 125000.00$

From (11.5.4.8), ACI 318-14: $V_s = 164264.64$

$A_v = 157079.633$

$f_y = 444.44$

$s = 170.00$

V_s is multiplied by $Col = 1.00$

$s/d = 0.425$

$V_f \text{ ((11-3)-(11.4), ACI 440)} = 240803.347$

$f = 0.95$, 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: $\theta_1 = b_1 + 90^\circ = 90.00$

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

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

$d_{fv} = d$ (figure 11.2, ACI 440) = 457.00

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

$E_f = 64828.00$

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

with $f_u = 0.01$

From (11-11), ACI 440: $V_s + V_f \leq 297085.704$

$b_w = 250.00$

Calculation of Shear Strength at edge 2, $V_{r2} = 409422.352$

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

$V_{Col0} = 409422.352$

$k_{nl} = 1$ (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)

$f'_c = 20.00$, but $f'_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$\mu_u = 2.8180236E-013$

$V_u = 1.3558547E-031$

$d = 0.8 * h = 400.00$

$N_u = 4666.932$

$A_g = 125000.00$

From (11.5.4.8), ACI 318-14: $V_s = 164264.64$

$A_v = 157079.633$

$f_y = 444.44$

$s = 170.00$

V_s is multiplied by $\text{Col} = 1.00$
 $s/d = 0.425$
 $V_f ((11-3)-(11.4), \text{ACI } 440) = 240803.347$
 $f = 0.95$, 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 $V_f(,)$, 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: $a_1 = b_1 + 90^\circ = 90.00$
 $V_f = \text{Min}(|V_f(45, 1)|, |V_f(-45, a_1)|)$, with:
 total thickness per orientation, $tf_1 = NL * t / \text{NoDir} = 1.016$
 $df_v = d$ (figure 11.2, ACI 440) = 457.00
 $ffe ((11-5), \text{ACI } 440) = 259.312$
 $E_f = 64828.00$
 $fe = 0.004$, from (11.6a), ACI 440
 with $fu = 0.01$
 From (11-11), ACI 440: $V_s + V_f \leq 297085.704$
 $bw = 250.00$

 End Of Calculation of Shear Capacity ratio for element: column C1 of floor 1
 At local axis: 2

 Start Of Calculation of Chord Rotation Capacity for element: column C1 of floor 1
 At local axis: 3
 Integration Section: (a)
 Section Type: rcrs

Constant Properties

 Knowledge Factor, $\gamma = 1.00$
 Chord Rotation is generally considered as Deformation-Controlled Action according to Table C7-1, ASCE41-17.
 Mean strengths are used for Deformation-Controlled Actions according to 7.5.1.3, ASCE 41-17
 Consequently:
 Existing material of Primary Member: Concrete Strength, $f_c = f_{cm} = 20.00$
 Existing material of Primary Member: Steel Strength, $f_s = f_{sm} = 444.44$
 Concrete Elasticity, $E_c = 21019.039$
 Steel Elasticity, $E_s = 200000.00$
 Section Height, $H = 250.00$
 Section Width, $W = 500.00$
 Cover Thickness, $c = 25.00$
 Element Length, $L = 3000.00$
 Primary Member
 Ribbed Bars
 Ductile Steel
 Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
 Longitudinal Bars With Ends Lapped Starting at the End Sections
 Lap Length $l_b = 300.00$
 FRP Wrapping Data
 Type: Carbon
 Cured laminate properties (design values)
 Thickness, $t = 1.016$
 Tensile Strength, $ff_u = 1055.00$
 Tensile Modulus, $E_f = 64828.00$
 Elongation, $ef_u = 0.01$
 Number of directions, $\text{NoDir} = 1$
 Fiber orientations, $b_i: 0.00^\circ$
 Number of layers, $NL = 1$
 Radius of rounding corners, $R = 40.00$

Stepwise Properties

Bending Moment, $M = -9.3362\text{E}+006$
 Shear Force, $V2 = -3085.676$
 Shear Force, $V3 = -2.2952864\text{E}-013$
 Axial Force, $F = -4810.556$
 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: $As_{mid} = 402.1239$
 Mean Diameter of Tension Reinforcement, $Db_L = 18.66667$

Existing component: From table 7-7, ASCE 41_17: Final chord rotation Capacity $u_R = u = 0.00702237$
 $u = y + p = 0.00702237$

- Calculation of y -

$y = (M_y * L_s / 3) / E_{eff} = 0.00702237$ ((4.29), Biskinis Phd))
 $M_y = 1.1434\text{E}+008$
 $L_s = M/V$ (with $L_s > 0.1 * L$ and $L_s < 2 * L$) = 3025.674
 From table 10.5, ASCE 41_17: $E_{eff} = \text{factor} * E_c * I_g = 1.6421\text{E}+013$
 factor = 0.30
 $A_g = 125000.00$
 $f_c' = 20.00$
 $N = 4810.556$
 $E_c * I_g = 5.4737\text{E}+013$

Calculation of Yielding Moment M_y

Calculation of y and M_y according to Annex 7 -

$y = \text{Min}(y_{ten}, y_{com})$
 $y_{ten} = 4.5287315\text{E}-006$
 with ((10.1), ASCE 41-17) $f_y = \text{Min}(f_y, 1.25 * f_y * (I_b / I_d)^{2/3}) = 291.1836$
 $d = 457.00$
 $y = 0.29653227$
 $A = 0.01818298$
 $B = 0.01001242$
 with $p_t = 0.00725935$
 $p_c = 0.00725935$
 $p_v = 0.00351968$
 $N = 4810.556$
 $b = 250.00$
 $" = 0.0940919$
 $y_{comp} = 1.2979423\text{E}-005$
 with $f_c' (12.3, (ACI 440)) = 20.44585$
 $f_c = 20.00$
 $f_l = 0.9425867$
 $b = 250.00$
 $h = 500.00$
 $A_g = 125000.00$
 From (12.9), ACI 440: $k_a = 0.15087868$
 $g = p_t + p_c + p_v = 0.01803838$
 $rc = 40.00$
 $A_e / A_c = 0.60351471$
 Effective FRP thickness, $t_f = N L * t * \text{Cos}(b_1) = 1.016$
 effective strain from (12.5) and (12.12), $e_{fe} = 0.004$
 $f_u = 0.01$
 $E_f = 64828.00$
 $E_c = 21019.039$

y = 0.29518426
A = 0.01791814
B = 0.00986782
with Es = 200000.00

Calculation of ratio l_b/l_d

Lap Length: $l_d/l_{d,min} = 0.37945973$

$l_b = 300.00$

$l_d = 790.5977$

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

$d_b = 18.00$

Mean strength value of all re-bars: $f_y = 444.44$

$f_c' = 20.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$c_b = 25.00$

$K_{tr} = 4.61999$

$A_{tr} = \min(A_{tr_x}, A_{tr_y}) = 157.0796$

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

$s = 170.00$

$n = 8.00$

- Calculation of p -

From table 10-8: $p = 0.00$

with:

- Columns not controlled by inadequate development or splicing along the clear height because $l_b/l_d \geq 1$
shear control ratio $V_y E / V_{col} E = 0.23676754$

$d = 457.00$

$s = 0.00$

$t = A_v / (b_w \cdot s) + 2 \cdot t_f / b_w \cdot (f_{fe} / f_s) = 0.00$

$A_v = 157.0796$, is the total area of all stirrups parallel to loading (shear) direction

$b_w = 250.00$

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.

$NUD = 4810.556$

$A_g = 125000.00$

$f_{cE} = 20.00$

$f_{tE} = f_{yE} = 0.00$

$p_l = \text{Area_Tot_Long_Rein} / (b \cdot d) = 0.01803838$

$b = 250.00$

$d = 457.00$

$f_{cE} = 20.00$

End Of Calculation of Chord Rotation Capacity for element: column C1 of floor 1

At local axis: 3

Integration Section: (a)

Calculation No. 5

column C1, Floor 1

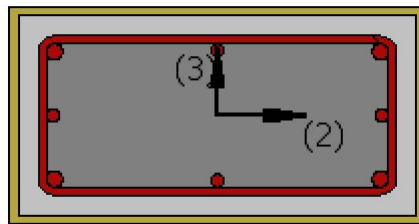
Limit State: Immediate Occupancy (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Shear capacity V_{Rd}

Edge: End

Local Axis: (2)



Start Of Calculation of Shear Capacity for element: column C1 of floor 1

At local axis: 2

Integration Section: (b)

Section Type: rcrs

Constant Properties

Knowledge Factor, $\gamma = 1.00$

Member Shear Force is generally considered as Force-Controlled Action according to Table C7-1, ASCE41-17.

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

Consequently:

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

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

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of γ for displacement ductility demand,

the expected (mean value) strengths are used (7.5.1.3, ASCE41-17) because bending is considered as

Deformation-Controlled Action (Table C7-1, ASCE41-17).

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

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

#####

Section Height, $H = 250.00$

Section Width, $W = 500.00$

Cover Thickness, $c = 25.00$

Element Length, $L = 3000.00$

Primary Member

Ribbed Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

Lap Length $l_o = l_b = 300.00$

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $\epsilon_{fu} = 0.01$

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

EDGE -A-

Bending Moment, $M_a = -9.3362E+006$

Shear Force, $V_a = -3085.676$

EDGE -B-

Bending Moment, $M_b = 76808.128$

Shear Force, $V_b = 3085.676$

BOTH EDGES

Axial Force, $F = -4810.556$

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, $Db_{L,ten} = 18.66667$

Existing component: From table 7-7, ASCE 41-17: Final Shear Capacity $V_R = V_n = 366324.617$

$V_n ((10.3), ASCE 41-17) = knl * V_{Col0} = 366324.617$

$V_{Col} = 366324.617$

$knl = 1.00$

$displacement_ductility_demand = 0.12428951$

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)

$f'_c = 16.00$, but $f'_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$M_u = 76808.128$

$V_u = 3085.676$

$d = 0.8 * h = 400.00$

$N_u = 4810.556$

$A_g = 125000.00$

From (11.5.4.8), ACI 318-14: $V_s = 147839.654$

$A_v = 157079.633$

$f_y = 400.00$

$s = 170.00$

V_s is multiplied by $Col = 1.00$

$s/d = 0.425$

$V_f ((11-3)-(11.4), ACI 440) = 240803.347$

$f = 0.95$, for fully-wrapped sections

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

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

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

orientation 1: $a_1 = b_1 + 90^\circ = 90.00$

$V_f = \text{Min}(|V_f(45, 1)|, |V_f(-45, a_1)|)$, with:

total thickness per orientation, $tf1 = NL*t/NoDir = 1.016$
 $dfv = d$ (figure 11.2, ACI 440) = 457.00
 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: $Vs + Vf \leq 265721.532$
 $bw = 250.00$

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 $\theta = 8.6540079E-005$
 $y = (My*Ls/3)/Eleff = 0.00069628$ ((4.29), Biskinis Phd))
 $My = 1.1434E+008$
 $Ls = M/V$ (with $Ls > 0.1*L$ and $Ls < 2*L$) = 300.00
 From table 10.5, ASCE 41_17: $Eleff = factor*Ec*lg = 1.6421E+013$
 $factor = 0.30$
 $Ag = 125000.00$
 $fc' = 20.00$
 $N = 4810.556$
 $Ec*lg = 5.4737E+013$

Calculation of Yielding Moment My

Calculation of δ and My according to Annex 7 -

$y = \text{Min}(y_{ten}, y_{com})$
 $y_{ten} = 4.5287315E-006$
 with ((10.1), ASCE 41-17) $fy = \text{Min}(fy, 1.25*fy*(lb/d)^{2/3}) = 291.1836$
 $d = 457.00$
 $y = 0.29653227$
 $A = 0.01818298$
 $B = 0.01001242$
 with $pt = 0.00725935$
 $pc = 0.00725935$
 $pv = 0.00351968$
 $N = 4810.556$
 $b = 250.00$
 $" = 0.0940919$
 $y_{comp} = 1.2979423E-005$
 with $fc' (12.3, (ACI 440)) = 20.44585$
 $fc = 20.00$
 $fl = 0.9425867$
 $b = 250.00$
 $h = 500.00$
 $Ag = 125000.00$
 From (12.9), ACI 440: $ka = 0.15087868$
 $g = pt + pc + pv = 0.01803838$
 $rc = 40.00$
 $Ae/Ac = 0.60351471$
 Effective FRP thickness, $tf = NL*t*\text{Cos}(b1) = 1.016$
 effective strain from (12.5) and (12.12), $efe = 0.004$
 $fu = 0.01$
 $Ef = 64828.00$
 $Ec = 21019.039$
 $y = 0.29518426$
 $A = 0.01791814$
 $B = 0.00986782$
 with $Es = 200000.00$

Calculation of ratio l_b/l_d

Lap Length: $l_d/l_{d,min} = 0.37945973$

$l_b = 300.00$

$l_d = 790.5977$

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

$= 1$

$d_b = 18.00$

Mean strength value of all re-bars: $f_y = 444.44$

$f'_c = 20.00$, but $f_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$c_b = 25.00$

$K_{tr} = 4.61999$

$A_{tr} = \min(A_{tr_x}, A_{tr_y}) = 157.0796$

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

$s = 170.00$

$n = 8.00$

End Of Calculation of Shear Capacity for element: column C1 of floor 1

At local axis: 2

Integration Section: (b)

Calculation No. 6

column C1, Floor 1

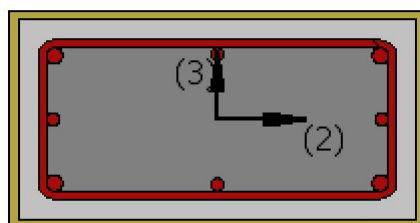
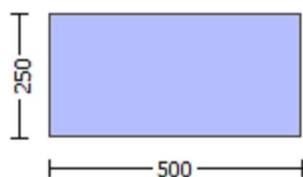
Limit State: Immediate Occupancy (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity (ϕ)

Edge: End

Local Axis: (2)



Start Of Calculation of Shear Capacity ratio for element: column C1 of floor 1

At Shear local axis: 3

(Bending local axis: 2)

Section Type: rcrs

Constant Properties

Knowledge Factor, $\gamma = 1.00$

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

Consequently:

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

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

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

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

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

#####

Section Height, $H = 250.00$

Section Width, $W = 500.00$

Cover Thickness, $c = 25.00$

Mean Confinement Factor overall section = 1.13916

Element Length, $L = 3000.00$

Primary Member

Ribbed Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

Lap Length $l_o = 300.00$

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $\epsilon_{fu} = 0.01$

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

Fiber orientations, $b_i: 0.00^\circ$

Number of layers, $N_L = 1$

Radius of rounding corners, $R = 40.00$

Stepwise Properties

At local axis: 3

EDGE -A-

Shear Force, $V_a = 2.9007121E-031$

EDGE -B-

Shear Force, $V_b = -2.9007121E-031$

BOTH EDGES

Axial Force, $F = -4666.932$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: $A_{slt} = 0.00$

-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, $V_e/V_r = 0.15063296$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 39953.171$

with

$M_{pr1} = \text{Max}(M_{u1+}, M_{u1-}) = 5.9930E+007$

$M_{u1+} = 5.9930E+007$, is the ultimate moment strength at the edge 1 of the member in the actual moment direction

which is defined for the static loading combination

$Mu1- = 5.9930E+007$, is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination

$Mpr2 = \text{Max}(Mu2+, Mu2-) = 5.9930E+007$

$Mu2+ = 5.9930E+007$, 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

$Mu2- = 5.9930E+007$, 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 $Mu1+$

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

$\phi_u = 3.4011160E-005$

$Mu = 5.9930E+007$

with full section properties:

$b = 500.00$

$d = 207.00$

$d' = 43.00$

$v = 0.00225456$

$N = 4666.932$

$f_c = 20.00$

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

Final value of ϕ_u : $\phi_u^* = \text{shear_factor} * \text{Max}(\phi_u, \phi_{co}) = 0.01464474$

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

From (5.4b), TBDY: $\phi_u = 0.01464474$

$\phi_{we} ((5.4c), TBDY) = a_{se} * \phi_{sh,min} * f_{ywe} / f_{ce} + \text{Min}(\phi_{fx}, \phi_{fy}) = 0.07762821$

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

$\phi_{fx} = 0.07705054$

$a_f = 0.45253333$

$b = 500.00$

$h = 250.00$

From EC8 A.4.4.3(6), $\phi_f = 2t_f/bw = 0.004064$

$bw = 500.00$

effective stress from (A.35), $f_{fe} = 837.9178$

$\phi_{fy} = 0.12936483$

$a_f = 0.45253333$

$b = 250.00$

$h = 500.00$

From EC8 A.4.4.3(6), $\phi_f = 2t_f/bw = 0.008128$

$bw = 250.00$

effective stress from (A.35), $f_{fe} = 703.4155$

$R = 40.00$

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

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{f} = 0.015$

$a_{se} ((5.4d), TBDY) = 0.03751166$

$b_o = 440.00$

$h_o = 190.00$

$b_{i2} = 459400.00$

$\phi_{sh,min} = \text{Min}(\phi_{sh,x}, \phi_{sh,y}) = 0.001848$

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

$\phi_{sh,x} (5.4d) = 0.001848$

$A_{sh} = A_{stir} * n_s = 78.53982$

No stirrups, $n_s = 2.00$

$b_k = 500.00$

$\phi_{sh,y} (5.4d) = 0.00369599$

Ash = Astir*ns = 78.53982
No stirrups, ns = 2.00
bk = 250.00

s = 170.00
fywe = 555.55
fce = 20.00

From ((5A.5), TBDY), TBDY: cc = 0.00339158
c = confinement factor = 1.13916

y1 = 0.00130695
sh1 = 0.00451687

ft1 = 376.4017

fy1 = 313.6681

su1 = 0.005257

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779

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, ASCE41-17.

with fs1 = fs = 313.6681

with Es1 = Es = 200000.00

y2 = 0.00130695

sh2 = 0.00451687

ft2 = 376.4017

fy2 = 313.6681

su2 = 0.005257

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779

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, ASCE41-17.

with fs2 = fs = 313.6681

with Es2 = Es = 200000.00

yv = 0.00130695

shv = 0.00451687

ftv = 376.4017

fyv = 313.6681

suv = 0.005257

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779

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, ASCE41-17.

with fsv = fs = 313.6681

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.1256764

2 = Asl,com/(b*d)*(fs2/fc) = 0.1256764

v = Asl,mid/(b*d)*(fsv/fc) = 0.06093401

and confined core properties:

b = 440.00

d = 177.00

d' = 13.00

fcc (5A.2, TBDY) = 22.78316

cc (5A.5, TBDY) = 0.00339158

$c = \text{confinement factor} = 1.13916$
 $1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.16701987$
 $2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.16701987$
 $v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.08097933$

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

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

$su(4.9) = 0.25329952$
 $Mu = MRc(4.14) = 5.9930E+007$
 $u = su(4.1) = 3.4011160E-005$

Calculation of ratio l_b/d

Lap Length: $l_b/d = 0.30356779$

$l_b = 300.00$

$l_d = 988.2471$

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

$db = 18.00$

Mean strength value of all re-bars: $f_y = 555.55$

$f'_c = 20.00$, but $f_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 4.61999$

$A_{tr} = \min(A_{tr,x}, A_{tr,y}) = 157.0796$

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

$s = 170.00$

$n = 8.00$

Calculation of $Mu1$ -

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

$u = 3.4011160E-005$

$Mu = 5.9930E+007$

with full section properties:

$b = 500.00$

$d = 207.00$

$d' = 43.00$

$v = 0.00225456$

$N = 4666.932$

$f_c = 20.00$

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

Final value of cu : $cu^* = \text{shear_factor} * \max(cu, cc) = 0.01464474$

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

From (5.4b), TBDY: $cu = 0.01464474$

we ((5.4c), TBDY) = $ase * sh_{\min} * f_{ywe}/f_{ce} + \min(f_x, f_y) = 0.07762821$

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

$f_x = 0.07705054$

$af = 0.45253333$

$b = 500.00$

$h = 250.00$

From EC8 A.4.4.3(6), $pf = 2tf/bw = 0.004064$

$bw = 500.00$

effective stress from (A.35), $f_{fe} = 837.9178$

$f_y = 0.12936483$

af = 0.45253333

b = 250.00

h = 500.00

From EC8 A.4.4.3(6), $pf = 2tf/bw = 0.008128$

bw = 250.00

effective stress from (A.35), $ff,e = 703.4155$

R = 40.00

Effective FRP thickness, $tf = NL*t*\cos(b1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{,f} = 0.015$

$ase((5.4d), TBDY) = 0.03751166$

bo = 440.00

ho = 190.00

bi2 = 459400.00

$psh,min = \min(psh,x, psh,y) = 0.001848$

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

$psh,x(5.4d) = 0.001848$

Ash = Astir*ns = 78.53982

No stirrups, ns = 2.00

bk = 500.00

$psh,y(5.4d) = 0.00369599$

Ash = Astir*ns = 78.53982

No stirrups, ns = 2.00

bk = 250.00

s = 170.00

$f_{ywe} = 555.55$

fce = 20.00

From ((5.A5), TBDY), TBDY: cc = 0.00339158

c = confinement factor = 1.13916

$y1 = 0.00130695$

sh1 = 0.00451687

ft1 = 376.4017

fy1 = 313.6681

su1 = 0.005257

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779

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

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, ASCE41-17.

with $fs1 = fs = 313.6681$

with $Es1 = Es = 200000.00$

$y2 = 0.00130695$

sh2 = 0.00451687

ft2 = 376.4017

fy2 = 313.6681

su2 = 0.005257

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779

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

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, ASCE41-17.

with $fs2 = fs = 313.6681$

with $Es2 = Es = 200000.00$

```

yv = 0.00130695
shv = 0.00451687
ftv = 376.4017
fyv = 313.6681
suv = 0.005257
using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779
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, ASCE41-17.
with fsv = fs = 313.6681
with Esv = Es = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.1256764
2 = Asl,com/(b*d)*(fs2/fc) = 0.1256764
v = Asl,mid/(b*d)*(fsv/fc) = 0.06093401
and confined core properties:
b = 440.00
d = 177.00
d' = 13.00
fcc (5A.2, TBDY) = 22.78316
cc (5A.5, TBDY) = 0.00339158
c = confinement factor = 1.13916
1 = Asl,ten/(b*d)*(fs1/fc) = 0.16701987
2 = Asl,com/(b*d)*(fs2/fc) = 0.16701987
v = Asl,mid/(b*d)*(fsv/fc) = 0.08097933
Case/Assumption: Unconfined full section - Steel rupture
' satisfies Eq. (4.3)
--->
v < vs,y2 - LHS eq.(4.5) is satisfied
--->
su (4.9) = 0.25329952
Mu = MRc (4.14) = 5.9930E+007
u = su (4.1) = 3.4011160E-005

```

Calculation of ratio lb/ld

```

Lap Length: lb/ld = 0.30356779
lb = 300.00
ld = 988.2471
Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
= 1
db = 18.00
Mean strength value of all re-bars: fy = 555.55
fc' = 20.00, but fc^0.5 <= 8.3 MPa (22.5.3.1, ACI 318-14)
t = 1.00
s = 0.80
e = 1.00
cb = 25.00
Ktr = 4.61999
Atr = Min(Atr_x,Atr_y) = 157.0796
where Atr_x, Atr_y are the sum of the area of all stirrup legs along X and Y loxal axis
s = 170.00
n = 8.00

```

Calculation of Mu2+

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

u = 3.4011160E-005
Mu = 5.9930E+007

with full section properties:

b = 500.00

d = 207.00

d' = 43.00

v = 0.00225456

N = 4666.932

fc = 20.00

co (5A.5, TBDY) = 0.002

Final value of cu: $cu^* = \text{shear_factor} * \text{Max}(cu, cc) = 0.01464474$

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

From (5.4b), TBDY: $cu = 0.01464474$

we ((5.4c), TBDY) = $ase * sh_{min} * fy_{we} / f_{ce} + \text{Min}(fx, fy) = 0.07762821$

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

fx = 0.07705054

af = 0.45253333

b = 500.00

h = 250.00

From EC8 A.4.4.3(6), $pf = 2tf/bw = 0.004064$

bw = 500.00

effective stress from (A.35), $ff_e = 837.9178$

fy = 0.12936483

af = 0.45253333

b = 250.00

h = 500.00

From EC8 A.4.4.3(6), $pf = 2tf/bw = 0.008128$

bw = 250.00

effective stress from (A.35), $ff_e = 703.4155$

R = 40.00

Effective FRP thickness, $tf = NL * t * \cos(b1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_f = 0.015$

ase ((5.4d), TBDY) = 0.03751166

bo = 440.00

ho = 190.00

bi2 = 459400.00

$psh_{min} = \text{Min}(psh_x, psh_y) = 0.001848$

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

psh_x (5.4d) = 0.001848

Ash = $A_{stir} * ns = 78.53982$

No stirrups, ns = 2.00

bk = 500.00

psh_y (5.4d) = 0.00369599

Ash = $A_{stir} * ns = 78.53982$

No stirrups, ns = 2.00

bk = 250.00

s = 170.00

$fy_{we} = 555.55$

$f_{ce} = 20.00$

From ((5.A5), TBDY), TBDY: $cc = 0.00339158$

c = confinement factor = 1.13916

y1 = 0.00130695

sh1 = 0.00451687

ft1 = 376.4017

fy1 = 313.6681

su1 = 0.005257

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

and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
 $l_o/l_{ou,min} = l_b/l_d = 0.30356779$
 $su_1 = 0.4 * esu_{1,nominal} ((5.5), TBDY) = 0.032$
From table 5A.1, TBDY: $esu_{1,nominal} = 0.08$,
For calculation of $esu_{1,nominal}$ and y_1, sh_1, ft_1, fy_1 , it is considered
characteristic value $fsy_1 = fs_1/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $Min(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.
with $fs_1 = fs = 313.6681$
with $Es_1 = Es = 200000.00$
 $y_2 = 0.00130695$
 $sh_2 = 0.00451687$
 $ft_2 = 376.4017$
 $fy_2 = 313.6681$
 $su_2 = 0.005257$
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
 $l_o/l_{ou,min} = l_b/l_{b,min} = 0.30356779$
 $su_2 = 0.4 * esu_{2,nominal} ((5.5), TBDY) = 0.032$
From table 5A.1, TBDY: $esu_{2,nominal} = 0.08$,
For calculation of $esu_{2,nominal}$ and y_2, sh_2, ft_2, fy_2 , it is considered
characteristic value $fsy_2 = fs_2/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $Min(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.
with $fs_2 = fs = 313.6681$
with $Es_2 = Es = 200000.00$
 $y_v = 0.00130695$
 $sh_v = 0.00451687$
 $ft_v = 376.4017$
 $fy_v = 313.6681$
 $suv = 0.005257$
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
 $l_o/l_{ou,min} = l_b/l_d = 0.30356779$
 $suv = 0.4 * esuv_{nominal} ((5.5), TBDY) = 0.032$
From table 5A.1, TBDY: $esuv_{nominal} = 0.08$,
considering characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY
For calculation of $esuv_{nominal}$ and y_v, sh_v, ft_v, fy_v , it is considered
characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $Min(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.
with $fsv = fs = 313.6681$
with $Esv = Es = 200000.00$
 $1 = Asl_{ten}/(b*d) * (fs_1/fc) = 0.1256764$
 $2 = Asl_{com}/(b*d) * (fs_2/fc) = 0.1256764$
 $v = Asl_{mid}/(b*d) * (fsv/fc) = 0.06093401$
and confined core properties:
 $b = 440.00$
 $d = 177.00$
 $d' = 13.00$
 $f_{cc} (5A.2, TBDY) = 22.78316$
 $cc (5A.5, TBDY) = 0.00339158$
 $c = \text{confinement factor} = 1.13916$
 $1 = Asl_{ten}/(b*d) * (fs_1/fc) = 0.16701987$
 $2 = Asl_{com}/(b*d) * (fs_2/fc) = 0.16701987$
 $v = Asl_{mid}/(b*d) * (fsv/fc) = 0.08097933$
Case/Assumption: Unconfined full section - Steel rupture
' satisfies Eq. (4.3)
--->
 $v < v_{s,y2}$ - LHS eq.(4.5) is satisfied
--->
 $su (4.9) = 0.25329952$
 $Mu = MRc (4.14) = 5.9930E+007$
 $u = su (4.1) = 3.4011160E-005$

Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.30356779$

$l_b = 300.00$

$l_d = 988.2471$

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

$= 1$

$d_b = 18.00$

Mean strength value of all re-bars: $f_y = 555.55$

$f_c' = 20.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$c_b = 25.00$

$K_{tr} = 4.61999$

$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$

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

$s = 170.00$

$n = 8.00$

Calculation of μ_2 -

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

$\mu = 3.4011160E-005$

$\mu_u = 5.9930E+007$

with full section properties:

$b = 500.00$

$d = 207.00$

$d' = 43.00$

$v = 0.00225456$

$N = 4666.932$

$f_c = 20.00$

α (5A.5, TBDY) = 0.002

Final value of μ : $\mu^* = \text{shear_factor} * \text{Max}(\mu, \alpha) = 0.01464474$

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

From (5.4b), TBDY: $\mu = 0.01464474$

we ((5.4c), TBDY) = $\alpha * \text{sh}_{\min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.07762821$

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

$f_x = 0.07705054$

$\alpha_f = 0.45253333$

$b = 500.00$

$h = 250.00$

From EC8 A.4.4.3(6), $p_f = 2t_f/bw = 0.004064$

$bw = 500.00$

effective stress from (A.35), $f_{fe} = 837.9178$

$f_y = 0.12936483$

$\alpha_f = 0.45253333$

$b = 250.00$

$h = 500.00$

From EC8 A.4.4.3(6), $p_f = 2t_f/bw = 0.008128$

$bw = 250.00$

effective stress from (A.35), $f_{fe} = 703.4155$

$R = 40.00$

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

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{,f} = 0.015$

α_{se} ((5.4d), TBDY) = 0.03751166

$b_o = 440.00$

$h_o = 190.00$

```

bi2 = 459400.00
psh,min = Min(psh,x , psh,y) = 0.001848
Expression ((5.4d), TBDY) for psh,min has been multiplied by 0.3 according to 15.7.1.3 for members without
earthquake detailing (90° closed stirrups)
-----
psh,x (5.4d) = 0.001848
Ash = Astir*ns = 78.53982
No stirups, ns = 2.00
bk = 500.00
-----
psh,y (5.4d) = 0.00369599
Ash = Astir*ns = 78.53982
No stirups, ns = 2.00
bk = 250.00
-----
s = 170.00
fywe = 555.55
fce = 20.00
From ((5.A5), TBDY), TBDY: cc = 0.00339158
c = confinement factor = 1.13916
y1 = 0.00130695
sh1 = 0.00451687
ft1 = 376.4017
fy1 = 313.6681
su1 = 0.005257
using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779
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, ASCE41-17.
with fs1 = fs = 313.6681
with Es1 = Es = 200000.00
y2 = 0.00130695
sh2 = 0.00451687
ft2 = 376.4017
fy2 = 313.6681
su2 = 0.005257
using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779
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, ASCE41-17.
with fs2 = fs = 313.6681
with Es2 = Es = 200000.00
yv = 0.00130695
shv = 0.00451687
ftv = 376.4017
fyv = 313.6681
suv = 0.005257
using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779
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,min)^ 2/3), from 10.3.5, ASCE41-17.

```

```

with fsv = fs = 313.6681
with Esv = Es = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.1256764
2 = Asl,com/(b*d)*(fs2/fc) = 0.1256764
v = Asl,mid/(b*d)*(fsv/fc) = 0.06093401
and confined core properties:
b = 440.00
d = 177.00
d' = 13.00
fcc (5A.2, TBDY) = 22.78316
cc (5A.5, TBDY) = 0.00339158
c = confinement factor = 1.13916
1 = Asl,ten/(b*d)*(fs1/fc) = 0.16701987
2 = Asl,com/(b*d)*(fs2/fc) = 0.16701987
v = Asl,mid/(b*d)*(fsv/fc) = 0.08097933
Case/Assumption: Unconfined full section - Steel rupture
'satisfies Eq. (4.3)

```

```

--->
v < vs,y2 - LHS eq.(4.5) is satisfied
--->
su (4.9) = 0.25329952
Mu = MRc (4.14) = 5.9930E+007
u = su (4.1) = 3.4011160E-005

```

Calculation of ratio lb/d

```

-----
Lap Length: lb/d = 0.30356779
lb = 300.00
ld = 988.2471
Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
= 1
db = 18.00
Mean strength value of all re-bars: fy = 555.55
fc' = 20.00, but fc^0.5 <= 8.3 MPa (22.5.3.1, ACI 318-14)
t = 1.00
s = 0.80
e = 1.00
cb = 25.00
Ktr = 4.61999
Atr = Min(Atr_x,Atr_y) = 157.0796
where Atr_x, Atr_y are the sum of the area of all stirrup legs along X and Y loxal axis
s = 170.00
n = 8.00

```

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 265235.248$

```

-----
Calculation of Shear Strength at edge 1, Vr1 = 265235.248
Vr1 = VCol ((10.3), ASCE 41-17) = knl*VColO
VColO = 265235.248
knl = 1 (zero step-static loading)

```

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

```

-----
= 1 (normal-weight concrete)
fc' = 20.00, but fc^0.5 <= 8.3 MPa (22.5.3.1, ACI 318-14)
M/Vd = 2.00
Mu = 2.3992784E-012
Vu = 2.9007121E-031
d = 0.8*h = 200.00
Nu = 4666.932
Ag = 125000.00
From (11.5.4.8), ACI 318-14: Vs = 49279.392

```

$A_v = 157079.633$
 $f_y = 444.44$
 $s = 170.00$
 V_s is multiplied by $\text{Col} = 0.60$
 $s/d = 0.85$
 $V_f ((11-3)-(11.4), \text{ACI } 440) = 109072.851$
 $f = 0.95$, for fully-wrapped sections
 $w_f/s_f = 1$ (FRP strips adjacent to one another).
 $\ln (11.3) \sin + \cos$ is replaced with $(\cot + \cot a) \sin a$ which is more a generalised expression,
 where θ is the angle of the crack direction (see KANEPE).
 This later relation, considered as a function $V_f(\theta)$, 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, $t_{f1} = N_L * t / \text{NoDir} = 1.016$
 $d_{fv} = d$ (figure 11.2, ACI 440) = 207.00
 $f_{fe} ((11-5), \text{ACI } 440) = 259.312$
 $E_f = 64828.00$
 $f_e = 0.004$, from (11.6a), ACI 440
 with $f_u = 0.01$
 From (11-11), ACI 440: $V_s + V_f \leq 297085.704$
 $b_w = 500.00$

Calculation of Shear Strength at edge 2, $V_{r2} = 265235.248$
 $V_{r2} = V_{\text{Col}} ((10.3), \text{ASCE } 41-17) = k_{nl} * V_{\text{ColO}}$
 $V_{\text{ColO}} = 265235.248$
 $k_{nl} = 1$ (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).

$\beta = 1$ (normal-weight concrete)
 $f'_c = 20.00$, but $f_c^{0.5} \leq 8.3 \text{ MPa}$ (22.5.3.1, ACI 318-14)
 $M/Vd = 2.00$
 $\mu_u = 2.3992784\text{E-}012$
 $\nu_u = 2.9007121\text{E-}031$
 $d = 0.8 * h = 200.00$
 $N_u = 4666.932$
 $A_g = 125000.00$
 From (11.5.4.8), ACI 318-14: $V_s = 49279.392$
 $A_v = 157079.633$
 $f_y = 444.44$
 $s = 170.00$
 V_s is multiplied by $\text{Col} = 0.60$
 $s/d = 0.85$
 $V_f ((11-3)-(11.4), \text{ACI } 440) = 109072.851$
 $f = 0.95$, for fully-wrapped sections
 $w_f/s_f = 1$ (FRP strips adjacent to one another).
 $\ln (11.3) \sin + \cos$ is replaced with $(\cot + \cot a) \sin a$ which is more a generalised expression,
 where θ is the angle of the crack direction (see KANEPE).
 This later relation, considered as a function $V_f(\theta)$, 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, $t_{f1} = N_L * t / \text{NoDir} = 1.016$
 $d_{fv} = d$ (figure 11.2, ACI 440) = 207.00
 $f_{fe} ((11-5), \text{ACI } 440) = 259.312$
 $E_f = 64828.00$
 $f_e = 0.004$, from (11.6a), ACI 440
 with $f_u = 0.01$
 From (11-11), ACI 440: $V_s + V_f \leq 297085.704$
 $b_w = 500.00$

End Of Calculation of Shear Capacity ratio for element: column C1 of floor 1
 At local axis: 3

Start Of Calculation of Shear Capacity ratio for element: column C1 of floor 1

At Shear local axis: 2

(Bending local axis: 3)

Section Type: rcrs

Constant Properties

Knowledge Factor, $\gamma = 1.00$

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

Consequently:

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

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

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

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

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

#####

Section Height, $H = 250.00$

Section Width, $W = 500.00$

Cover Thickness, $c = 25.00$

Mean Confinement Factor overall section = 1.13916

Element Length, $L = 3000.00$

Primary Member

Ribbed Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

Lap Length $l_o = 300.00$

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $\epsilon_{fu} = 0.01$

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

Fiber orientations, $b_i = 0.00^\circ$

Number of layers, $N_L = 1$

Radius of rounding corners, $R = 40.00$

Stepwise Properties

At local axis: 2

EDGE -A-

Shear Force, $V_a = 1.3558547E-031$

EDGE -B-

Shear Force, $V_b = -1.3558547E-031$

BOTH EDGES

Axial Force, $F = -4666.932$

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 , $V_e/V_r = 0.23676754$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 96937.922$

with

$M_{pr1} = \text{Max}(M_{u1+}, M_{u1-}) = 1.4541\text{E}+008$

$M_{u1+} = 1.4541\text{E}+008$, 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

$M_{u1-} = 1.4541\text{E}+008$, 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

$M_{pr2} = \text{Max}(M_{u2+}, M_{u2-}) = 1.4541\text{E}+008$

$M_{u2+} = 1.4541\text{E}+008$, 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

$M_{u2-} = 1.4541\text{E}+008$, 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:

$\phi_u = 1.4467178\text{E}-005$

$M_u = 1.4541\text{E}+008$

with full section properties:

$b = 250.00$

$d = 457.00$

$d' = 43.00$

$v = 0.00204242$

$N = 4666.932$

$f_c = 20.00$

ϕ_{co} (5A.5, TBDY) = 0.002

Final value of ϕ_u : $\phi_u^* = \text{shear_factor} * \text{Max}(\phi_{cu}, \phi_{cc}) = 0.01464474$

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

From (5.4b), TBDY: $\phi_{cu} = 0.01464474$

ϕ_{we} ((5.4c), TBDY) = $a_{se} * \phi_{sh, \min} * f_{ywe}/f_{ce} + \text{Min}(\phi_{fx}, \phi_{fy}) = 0.07762821$

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

 $\phi_{fx} = 0.07705054$

$a_f = 0.45253333$

$b = 500.00$

$h = 250.00$

From EC8 A4.4.3(6), $\phi_{pf} = 2t_f/bw = 0.004064$

$bw = 500.00$

effective stress from (A.35), $f_{fe} = 837.9178$

$\phi_{fy} = 0.12936483$

$a_f = 0.45253333$

$b = 250.00$

$h = 500.00$

From EC8 A4.4.3(6), $\phi_{pf} = 2t_f/bw = 0.008128$

$bw = 250.00$

effective stress from (A.35), $f_{fe} = 703.4155$

$R = 40.00$

Effective FRP thickness, $t_f = NL * t * \cos(\beta_1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{f, \min} = 0.015$

a_{se} ((5.4d), TBDY) = 0.03751166

$b_o = 440.00$

$h_o = 190.00$

$b_{i2} = 459400.00$

$\phi_{sh, \min} = \text{Min}(\phi_{sh,x}, \phi_{sh,y}) = 0.001848$

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

psh,x (5.4d) = 0.001848
Ash = Astir*ns = 78.53982
No stirups, ns = 2.00
bk = 500.00

psh,y (5.4d) = 0.00369599
Ash = Astir*ns = 78.53982
No stirups, ns = 2.00
bk = 250.00

s = 170.00
fywe = 555.55
fce = 20.00

From ((5.A5), TBDY), TBDY: cc = 0.00339158
c = confinement factor = 1.13916

y1 = 0.00130695
sh1 = 0.00451687

ft1 = 376.4017

fy1 = 313.6681

su1 = 0.005257

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779

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

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

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

y1, sh1,ft1,fy1, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

with fs1 = fs = 313.6681

with Es1 = Es = 200000.00

y2 = 0.00130695

sh2 = 0.00451687

ft2 = 376.4017

fy2 = 313.6681

su2 = 0.005257

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779

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, ASCE41-17.

with fs2 = fs = 313.6681

with Es2 = Es = 200000.00

yv = 0.00130695

shv = 0.00451687

ftv = 376.4017

fyv = 313.6681

suv = 0.005257

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779

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, ASCE41-17.

with fsv = fs = 313.6681

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.11385127

2 = Asl,com/(b*d)*(fs2/fc) = 0.11385127

v = Asl,mid/(b*d)*(fsv/fc) = 0.05520062

and confined core properties:

$$b = 190.00$$

$$d = 427.00$$

$$d' = 13.00$$

$$fcc(5A.2, TBDY) = 22.78316$$

$$cc(5A.5, TBDY) = 0.00339158$$

$$c = \text{confinement factor} = 1.13916$$

$$1 = A_{s1,ten}/(b*d)*(f_{s1}/f_c) = 0.1603292$$

$$2 = A_{s2,com}/(b*d)*(f_{s2}/f_c) = 0.1603292$$

$$v = A_{s,mid}/(b*d)*(f_{sv}/f_c) = 0.07773537$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

$$s_u(4.9) = 0.20486988$$

$$M_u = M_{Rc}(4.14) = 1.4541E+008$$

$$u = s_u(4.1) = 1.4467178E-005$$

Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.30356779$

$$l_b = 300.00$$

$$l_d = 988.2471$$

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

$$= 1$$

$$d_b = 18.00$$

Mean strength value of all re-bars: $f_y = 555.55$

$$f_c' = 20.00, \text{ but } f_c'^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 25.00$$

$$K_{tr} = 4.61999$$

$$A_{tr} = \text{Min}(A_{tr,x}, A_{tr,y}) = 157.0796$$

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

$$s = 170.00$$

$$n = 8.00$$

Calculation of M_{u1} -

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

$$u = 1.4467178E-005$$

$$M_u = 1.4541E+008$$

with full section properties:

$$b = 250.00$$

$$d = 457.00$$

$$d' = 43.00$$

$$v = 0.00204242$$

$$N = 4666.932$$

$$f_c = 20.00$$

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

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_o) = 0.01464474$$

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

$$\text{From (5.4b), TBDY: } c_u = 0.01464474$$

$$w_e((5.4c), TBDY) = a_s e^* s_{h,min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.07762821$$

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

$$f_x = 0.07705054$$

$$a_f = 0.45253333$$

$$b = 500.00$$

h = 250.00
From EC8 A4.4.3(6), $pf = 2tf/bw = 0.004064$
bw = 500.00
effective stress from (A.35), $ff,e = 837.9178$

fy = 0.12936483
af = 0.45253333
b = 250.00
h = 500.00
From EC8 A4.4.3(6), $pf = 2tf/bw = 0.008128$
bw = 250.00
effective stress from (A.35), $ff,e = 703.4155$

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) = 0.03751166
bo = 440.00
ho = 190.00
bi2 = 459400.00
psh,min = Min(psh,x , psh,y) = 0.001848
Expression ((5.4d), TBDY) for psh,min has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

psh,x (5.4d) = 0.001848
Ash = Astir*ns = 78.53982
No stirrups, ns = 2.00
bk = 500.00

psh,y (5.4d) = 0.00369599
Ash = Astir*ns = 78.53982
No stirrups, ns = 2.00
bk = 250.00

s = 170.00
fywe = 555.55
fce = 20.00
From ((5.A5), TBDY), TBDY: cc = 0.00339158
c = confinement factor = 1.13916
y1 = 0.00130695
sh1 = 0.00451687
ft1 = 376.4017
fy1 = 313.6681
su1 = 0.005257
using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779
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, ASCE41-17.
with fs1 = fs = 313.6681
with Es1 = Es = 200000.00
y2 = 0.00130695
sh2 = 0.00451687
ft2 = 376.4017
fy2 = 313.6681
su2 = 0.005257
using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779
su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: $es_{u2_nominal} = 0.08$,
For calculation of $es_{u2_nominal}$ and y_2 , sh_2, ft_2, fy_2 , it is considered
characteristic value $fs_{y2} = fs_2/1.2$, from table 5.1, TBDY.
 y_1 , sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.
with $fs_2 = fs = 313.6681$
with $Es_2 = Es = 200000.00$
 $y_v = 0.00130695$
 $sh_v = 0.00451687$
 $ft_v = 376.4017$
 $fy_v = 313.6681$
 $s_{uv} = 0.005257$
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
 $lo/lo_{u,min} = lb/ld = 0.30356779$
 $s_{uv} = 0.4 \cdot es_{uv_nominal} ((5.5), TBDY) = 0.032$
From table 5A.1, TBDY: $es_{uv_nominal} = 0.08$,
considering characteristic value $fs_{yv} = fs_v/1.2$, from table 5.1, TBDY
For calculation of $es_{uv_nominal}$ and y_v , sh_v, ft_v, fy_v , it is considered
characteristic value $fs_{yv} = fs_v/1.2$, from table 5.1, TBDY.
 y_1 , sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.
with $fs_v = fs = 313.6681$
with $Es_v = Es = 200000.00$
 $1 = As_{l,ten}/(b \cdot d) \cdot (fs_1/f_c) = 0.11385127$
 $2 = As_{l,com}/(b \cdot d) \cdot (fs_2/f_c) = 0.11385127$
 $v = As_{l,mid}/(b \cdot d) \cdot (fs_v/f_c) = 0.05520062$
and confined core properties:
 $b = 190.00$
 $d = 427.00$
 $d' = 13.00$
 $f_{cc} (5A.2, TBDY) = 22.78316$
 $cc (5A.5, TBDY) = 0.00339158$
 $c = \text{confinement factor} = 1.13916$
 $1 = As_{l,ten}/(b \cdot d) \cdot (fs_1/f_c) = 0.1603292$
 $2 = As_{l,com}/(b \cdot d) \cdot (fs_2/f_c) = 0.1603292$
 $v = As_{l,mid}/(b \cdot d) \cdot (fs_v/f_c) = 0.07773537$
Case/Assumption: Unconfined full section - Steel rupture
'satisfies Eq. (4.3)
--->
 $v < v_{s,y2}$ - LHS eq.(4.5) is satisfied
--->
 $su (4.9) = 0.20486988$
 $Mu = MR_c (4.14) = 1.4541E+008$
 $u = su (4.1) = 1.4467178E-005$

Calculation of ratio lb/ld

Lap Length: $lb/ld = 0.30356779$
 $lb = 300.00$
 $ld = 988.2471$
Calculation of lb_{min} according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
 $= 1$
 $db = 18.00$
Mean strength value of all re-bars: $fy = 555.55$
 $fc' = 20.00$, but $fc'^{0.5} \leq 8.3 \text{ MPa}$ (22.5.3.1, ACI 318-14)
 $t = 1.00$
 $s = 0.80$
 $e = 1.00$
 $cb = 25.00$
 $K_{tr} = 4.61999$
 $A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$
where A_{tr_x} , A_{tr_y} are the sum of the area of all stirrup legs along X and Y loxal axis
 $s = 170.00$
 $n = 8.00$

Calculation of μ_{2+}

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

$$\mu = 1.4467178E-005$$

$$\mu = 1.4541E+008$$

with full section properties:

$$b = 250.00$$

$$d = 457.00$$

$$d' = 43.00$$

$$v = 0.00204242$$

$$N = 4666.932$$

$$f_c = 20.00$$

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

$$\text{Final value of } \mu: \mu^* = \text{shear_factor} * \text{Max}(\mu, \alpha) = 0.01464474$$

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

$$\text{From (5.4b), TB DY: } \mu = 0.01464474$$

$$\mu_e ((5.4c), \text{TB DY}) = \alpha * \min(f_{ywe}/f_{ce} + \min(f_x, f_y)) = 0.07762821$$

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

$$f_x = 0.07705054$$

$$\alpha_f = 0.45253333$$

$$b = 500.00$$

$$h = 250.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/bw = 0.004064$$

$$bw = 500.00$$

$$\text{effective stress from (A.35), } f_{fe} = 837.9178$$

$$f_y = 0.12936483$$

$$\alpha_f = 0.45253333$$

$$b = 250.00$$

$$h = 500.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/bw = 0.008128$$

$$bw = 250.00$$

$$\text{effective stress from (A.35), } f_{fe} = 703.4155$$

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$\alpha_e ((5.4d), \text{TB DY}) = 0.03751166$$

$$b_o = 440.00$$

$$h_o = 190.00$$

$$b_{i2} = 459400.00$$

$$p_{sh,min} = \min(p_{sh,x}, p_{sh,y}) = 0.001848$$

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

$$p_{sh,x} (5.4d) = 0.001848$$

$$A_{sh} = A_{stir} * n_s = 78.53982$$

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

$$b_k = 500.00$$

$$p_{sh,y} (5.4d) = 0.00369599$$

$$A_{sh} = A_{stir} * n_s = 78.53982$$

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

$$b_k = 250.00$$

$$s = 170.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 20.00$$

$$\text{From ((5.A5), TB DY), TB DY: } \alpha_c = 0.00339158$$

$$\alpha_c = \text{confinement factor} = 1.13916$$

```

y1 = 0.00130695
sh1 = 0.00451687
ft1 = 376.4017
fy1 = 313.6681
su1 = 0.005257
    using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779
    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, ASCE41-17.
    with fs1 = fs = 313.6681
    with Es1 = Es = 200000.00
y2 = 0.00130695
sh2 = 0.00451687
ft2 = 376.4017
fy2 = 313.6681
su2 = 0.005257
    using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779
    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, ASCE41-17.
    with fs2 = fs = 313.6681
    with Es2 = Es = 200000.00
yv = 0.00130695
shv = 0.00451687
ftv = 376.4017
fyv = 313.6681
suv = 0.005257
    using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779
    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, ASCE41-17.
    with fsv = fs = 313.6681
    with Esv = Es = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.11385127
2 = Asl,com/(b*d)*(fs2/fc) = 0.11385127
v = Asl,mid/(b*d)*(fsv/fc) = 0.05520062
and confined core properties:
b = 190.00
d = 427.00
d' = 13.00
fcc (5A.2, TBDY) = 22.78316
cc (5A.5, TBDY) = 0.00339158
c = confinement factor = 1.13916
1 = Asl,ten/(b*d)*(fs1/fc) = 0.1603292
2 = Asl,com/(b*d)*(fs2/fc) = 0.1603292
v = Asl,mid/(b*d)*(fsv/fc) = 0.07773537
Case/Assumption: Unconfined full section - Steel rupture
' satisfies Eq. (4.3)
---->
v < vs,y2 - LHS eq.(4.5) is satisfied
---->

```

$s_u(4.9) = 0.20486988$
 $\mu = MRC(4.14) = 1.4541E+008$
 $u = s_u(4.1) = 1.4467178E-005$

Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.30356779$

$l_b = 300.00$

$l_d = 988.2471$

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

$= 1$

$db = 18.00$

Mean strength value of all re-bars: $f_y = 555.55$

$f_c' = 20.00$, but $f_c'^{0.5} \leq 8.3 \text{ MPa}$ (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 4.61999$

$A_{tr} = \min(A_{tr_x}, A_{tr_y}) = 157.0796$

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

$s = 170.00$

$n = 8.00$

Calculation of μ_2 -

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

$u = 1.4467178E-005$

$\mu = 1.4541E+008$

with full section properties:

$b = 250.00$

$d = 457.00$

$d' = 43.00$

$v = 0.00204242$

$N = 4666.932$

$f_c = 20.00$

$\phi(5A.5, \text{TB DY}) = 0.002$

Final value of ϕ : $\phi^* = \text{shear_factor} * \max(\phi, \phi_c) = 0.01464474$

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

From (5.4b), TB DY: $\phi = 0.01464474$

we ((5.4c), TB DY) = $\phi_{se} * \phi_{sh, \min} * f_{ywe}/f_{ce} + \min(\phi_x, \phi_y) = 0.07762821$

where $\phi = \phi_{se} * \phi_{sh, \min} * f_{ywe}/f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$\phi_x = 0.07705054$

$\phi_{se} = 0.45253333$

$b = 500.00$

$h = 250.00$

From EC8 A4.4.3(6), $\phi_{se} = 2t_f/bw = 0.004064$

$bw = 500.00$

effective stress from (A.35), $f_{fe} = 837.9178$

$f_y = 0.12936483$

$\phi_{se} = 0.45253333$

$b = 250.00$

$h = 500.00$

From EC8 A4.4.3(6), $\phi_{se} = 2t_f/bw = 0.008128$

$bw = 250.00$

effective stress from (A.35), $f_{fe} = 703.4155$

$R = 40.00$

Effective FRP thickness, $t_f = NL * t * \cos(\theta_1) = 1.016$

$f_{u,f} = 1055.00$
 $E_f = 64828.00$
 $u,f = 0.015$
 $ase((5.4d), TBDY) = 0.03751166$
 $bo = 440.00$
 $ho = 190.00$
 $bi2 = 459400.00$
 $psh,min = \text{Min}(psh,x, psh,y) = 0.001848$
 Expression ((5.4d), TBDY) for psh,min has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$psh,x(5.4d) = 0.001848$
 $A_{sh} = A_{stir} \cdot n_s = 78.53982$
 No stirrups, $n_s = 2.00$
 $bk = 500.00$

$psh,y(5.4d) = 0.00369599$
 $A_{sh} = A_{stir} \cdot n_s = 78.53982$
 No stirrups, $n_s = 2.00$
 $bk = 250.00$

$s = 170.00$
 $f_{ywe} = 555.55$
 $f_{ce} = 20.00$

From ((5.A5), TBDY), TBDY: $cc = 0.00339158$
 $c = \text{confinement factor} = 1.13916$

$y1 = 0.00130695$
 $sh1 = 0.00451687$
 $ft1 = 376.4017$
 $fy1 = 313.6681$
 $su1 = 0.005257$

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

$lo/lou,min = lb/ld = 0.30356779$

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

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 $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

with $fs1 = fs = 313.6681$

with $Es1 = Es = 200000.00$

$y2 = 0.00130695$
 $sh2 = 0.00451687$
 $ft2 = 376.4017$
 $fy2 = 313.6681$
 $su2 = 0.005257$

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

$lo/lou,min = lb/lb,min = 0.30356779$

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

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.

$y2, sh2, ft2, fy2$, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

with $fs2 = fs = 313.6681$

with $Es2 = Es = 200000.00$

$yv = 0.00130695$
 $shv = 0.00451687$
 $ftv = 376.4017$
 $fyv = 313.6681$
 $suv = 0.005257$

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

$lo/lou,min = lb/ld = 0.30356779$

$suv = 0.4 * esuv_nominal ((5.5), TBDY) = 0.032$
 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, ASCE41-17.
 with $fsv = fs = 313.6681$
 with $Esv = Es = 200000.00$
 $1 = Asl,ten / (b * d) * (fs1 / fc) = 0.11385127$
 $2 = Asl,com / (b * d) * (fs2 / fc) = 0.11385127$
 $v = Asl,mid / (b * d) * (fsv / fc) = 0.05520062$

and confined core properties:

$b = 190.00$
 $d = 427.00$
 $d' = 13.00$
 $fcc (5A.2, TBDY) = 22.78316$
 $cc (5A.5, TBDY) = 0.00339158$
 $c = \text{confinement factor} = 1.13916$
 $1 = Asl,ten / (b * d) * (fs1 / fc) = 0.1603292$
 $2 = Asl,com / (b * d) * (fs2 / fc) = 0.1603292$
 $v = Asl,mid / (b * d) * (fsv / fc) = 0.07773537$

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

--->
 $v < vs,y2$ - LHS eq.(4.5) is satisfied
 ---->
 $su (4.9) = 0.20486988$
 $Mu = MRc (4.14) = 1.4541E+008$
 $u = su (4.1) = 1.4467178E-005$

Calculation of ratio lb/ld

Lap Length: $lb/ld = 0.30356779$
 $lb = 300.00$
 $ld = 988.2471$
 Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
 $= 1$
 $db = 18.00$
 Mean strength value of all re-bars: $fy = 555.55$
 $fc' = 20.00$, but $fc'^{0.5} \leq 8.3 \text{ MPa}$ (22.5.3.1, ACI 318-14)
 $t = 1.00$
 $s = 0.80$
 $e = 1.00$
 $cb = 25.00$
 $Ktr = 4.61999$
 $Atr = Min(Atr_x, Atr_y) = 157.0796$
 where Atr_x , Atr_y are the sum of the area of all stirrup legs along X and Y loxal axis
 $s = 170.00$
 $n = 8.00$

Calculation of Shear Strength $Vr = Min(Vr1, Vr2) = 409422.352$

Calculation of Shear Strength at edge 1, $Vr1 = 409422.352$
 $Vr1 = VCol ((10.3), ASCE 41-17) = knl * VCol0$
 $VCol0 = 409422.352$
 $knl = 1$ (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)
 $fc' = 20.00$, but $fc'^{0.5} \leq 8.3 \text{ MPa}$ (22.5.3.1, ACI 318-14)
 $M/Vd = 2.00$

$\mu_u = 2.8180236E-013$
 $\mu_v = 1.3558547E-031$
 $d = 0.8 \cdot h = 400.00$
 $N_u = 4666.932$
 $A_g = 125000.00$
 From (11.5.4.8), ACI 318-14: $V_s = 164264.64$
 $A_v = 157079.633$
 $f_y = 444.44$
 $s = 170.00$
 V_s is multiplied by $\text{Col} = 1.00$
 $s/d = 0.425$
 $V_f ((11-3)-(11.4), \text{ACI } 440) = 240803.347$
 $f = 0.95$, for fully-wrapped sections
 $w_f/s_f = 1$ (FRP strips adjacent to one another).
 In (11.3) $\sin + \cos$ is replaced with $(\cot + \cot a) \sin a$ which is more a generalised expression,
 where a is the angle of the crack direction (see KANEPE).
 This later relation, considered as a function $V_f(\theta, a)$, is implemented for every different fiber orientation a_i ,
 as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.
 orientation 1: $\theta = b_1 + 90^\circ = 90.00$
 $V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, a_1)|)$, with:
 total thickness per orientation, $t_{f1} = N_L \cdot t / \text{NoDir} = 1.016$
 $d_{fv} = d$ (figure 11.2, ACI 440) = 457.00
 $f_{fe} ((11-5), \text{ACI } 440) = 259.312$
 $E_f = 64828.00$
 $f_e = 0.004$, from (11.6a), ACI 440
 with $f_u = 0.01$
 From (11-11), ACI 440: $V_s + V_f \leq 297085.704$
 $b_w = 250.00$

Calculation of Shear Strength at edge 2, $V_{r2} = 409422.352$
 $V_{r2} = V_{\text{Col}} ((10.3), \text{ASCE } 41-17) = k_{nl} \cdot V_{\text{Col}0}$
 $V_{\text{Col}0} = 409422.352$
 $k_{nl} = 1$ (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)
 $f'_c = 20.00$, but $f'_c^{0.5} \leq 8.3 \text{ MPa}$ (22.5.3.1, ACI 318-14)
 $M/Vd = 2.00$
 $\mu_u = 2.8180236E-013$
 $\mu_v = 1.3558547E-031$
 $d = 0.8 \cdot h = 400.00$
 $N_u = 4666.932$
 $A_g = 125000.00$
 From (11.5.4.8), ACI 318-14: $V_s = 164264.64$
 $A_v = 157079.633$
 $f_y = 444.44$
 $s = 170.00$
 V_s is multiplied by $\text{Col} = 1.00$
 $s/d = 0.425$
 $V_f ((11-3)-(11.4), \text{ACI } 440) = 240803.347$
 $f = 0.95$, for fully-wrapped sections
 $w_f/s_f = 1$ (FRP strips adjacent to one another).
 In (11.3) $\sin + \cos$ is replaced with $(\cot + \cot a) \sin a$ which is more a generalised expression,
 where a is the angle of the crack direction (see KANEPE).
 This later relation, considered as a function $V_f(\theta, a)$, is implemented for every different fiber orientation a_i ,
 as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.
 orientation 1: $\theta = b_1 + 90^\circ = 90.00$
 $V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, a_1)|)$, with:
 total thickness per orientation, $t_{f1} = N_L \cdot t / \text{NoDir} = 1.016$
 $d_{fv} = d$ (figure 11.2, ACI 440) = 457.00
 $f_{fe} ((11-5), \text{ACI } 440) = 259.312$
 $E_f = 64828.00$
 $f_e = 0.004$, from (11.6a), ACI 440
 with $f_u = 0.01$

From (11-11), ACI 440: $V_s + V_f \leq 297085.704$
 $bw = 250.00$

End Of Calculation of Shear Capacity ratio for element: column C1 of floor 1
At local axis: 2

Start Of Calculation of Chord Rotation Capacity for element: column C1 of floor 1
At local axis: 2
Integration Section: (b)
Section Type: rcrs

Constant Properties

Knowledge Factor, $\phi = 1.00$
Chord Rotation is generally considered as Deformation-Controlled Action according to Table C7-1, ASCE41-17.
Mean strengths are used for Deformation-Controlled Actions according to 7.5.1.3, ASCE 41-17
Consequently:
Existing material of Primary Member: Concrete Strength, $f_c = f_{cm} = 20.00$
Existing material of Primary Member: Steel Strength, $f_s = f_{sm} = 444.44$
Concrete Elasticity, $E_c = 21019.039$
Steel Elasticity, $E_s = 200000.00$
Section Height, $H = 250.00$
Section Width, $W = 500.00$
Cover Thickness, $c = 25.00$
Element Length, $L = 3000.00$
Primary Member
Ribbed Bars
Ductile Steel
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
Lap Length $l_b = 300.00$
FRP Wrapping Data
Type: Carbon
Cured laminate properties (design values)
Thickness, $t = 1.016$
Tensile Strength, $f_{fu} = 1055.00$
Tensile Modulus, $E_f = 64828.00$
Elongation, $\epsilon_{fu} = 0.01$
Number of directions, $N_{dir} = 1$
Fiber orientations, $\theta_i = 0.00^\circ$
Number of layers, $N_L = 1$
Radius of rounding corners, $R = 40.00$

Stepwise Properties

Bending Moment, $M = 3.8606651E-011$
Shear Force, $V_2 = 3085.676$
Shear Force, $V_3 = 2.2952864E-013$
Axial Force, $F = -4810.556$
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: $A_{st,com} = 829.3805$
-Middle: $A_{st,mid} = 402.1239$
Mean Diameter of Tension Reinforcement, $D_{bL} = 18.66667$

Existing component: From table 7-7, ASCE 41_17: Final chord rotation Capacity $\phi_{u,R} = \phi_u = 0.00620875$

$$u = y + p = 0.00620875$$

- Calculation of y -

$$y = (M_y * L_s / 3) / E_{eff} = 0.00620875 \text{ ((4.29), Biskinis Phd)}$$

$$M_y = 5.0977E+007$$

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

$$\text{From table 10.5, ASCE 41_17: } E_{eff} = \text{factor} * E_c * I_g = 4.1053E+012$$

$$\text{factor} = 0.30$$

$$A_g = 125000.00$$

$$f_c' = 20.00$$

$$N = 4810.556$$

$$E_c * I_g = 1.3684E+013$$

Calculation of Yielding Moment M_y

Calculation of y and M_y according to Annex 7 -

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

$$y_{ten} = 1.0451269E-005$$

$$\text{with ((10.1), ASCE 41-17) } f_y = \text{Min}(f_y, 1.25 * f_y * (I_b / I_d)^{2/3}) = 291.1836$$

$$d = 207.00$$

$$y = 0.32702707$$

$$A = 0.02007155$$

$$B = 0.01218373$$

$$\text{with } p_t = 0.00801334$$

$$p_c = 0.00801334$$

$$p_v = 0.00388525$$

$$N = 4810.556$$

$$b = 500.00$$

$$" = 0.20772947$$

$$y_{comp} = 2.5958133E-005$$

$$\text{with } f_c' (12.3, \text{ACI 440}) = 20.44529$$

$$f_c = 20.00$$

$$f_l = 0.9425867$$

$$b = 500.00$$

$$h = 250.00$$

$$A_g = 125000.00$$

$$\text{From (12.9), ACI 440: } k_a = 0.1506892$$

$$g = p_t + p_c + p_v = 0.01991193$$

$$r_c = 40.00$$

$$A_e / A_c = 0.60275679$$

$$\text{Effective FRP thickness, } t_f = N L * t * \cos(\theta_1) = 1.016$$

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

$$f_u = 0.01$$

$$E_f = 64828.00$$

$$E_c = 21019.039$$

$$y = 0.32584352$$

$$A = 0.0197792$$

$$B = 0.01202411$$

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

Calculation of ratio I_b / I_d

$$\text{Lap Length: } I_d / I_{d,min} = 0.37945973$$

$$I_b = 300.00$$

$$I_d = 790.5977$$

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

$$= 1$$

$$d_b = 18.00$$

$$\text{Mean strength value of all re-bars: } f_y = 444.44$$

$$f_c' = 20.00, \text{ but } f_c'^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

$t = 1.00$
 $s = 0.80$
 $e = 1.00$
 $cb = 25.00$
 $K_{tr} = 4.61999$
 $A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$
 where A_{tr_x} , A_{tr_y} are the sum of the area of all stirrup legs along X and Y local axis
 $s = 170.00$
 $n = 8.00$

- Calculation of p -

From table 10-8: $p = 0.00$

with:

- Columns not controlled by inadequate development or splicing along the clear height because $l_b/d \geq 1$
 shear control ratio $V_y E / V_{col} E = 0.15063296$

$d = 207.00$

$s = 0.00$

$t = A_v / (b_w \cdot s) + 2 \cdot t_f / b_w \cdot (f_{fe} / f_s) = 0.00$

$A_v = 157.0796$, is the total area of all stirrups parallel to loading (shear) direction

$b_w = 500.00$

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.

$NUD = 4810.556$

$A_g = 125000.00$

$f_{cE} = 20.00$

$f_{ytE} = f_{ylE} = 0.00$

$p_l = \text{Area_Tot_Long_Rein} / (b \cdot d) = 0.01991193$

$b = 500.00$

$d = 207.00$

$f_{cE} = 20.00$

End Of Calculation of Chord Rotation Capacity for element: column C1 of floor 1

At local axis: 2

Integration Section: (b)

Calculation No. 7

column C1, Floor 1

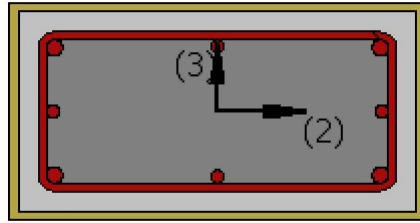
Limit State: Immediate Occupancy (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Shear capacity V_{Rd}

Edge: End

Local Axis: (3)



Start Of Calculation of Shear Capacity for element: column C1 of floor 1

At local axis: 3

Integration Section: (b)

Section Type: rcrs

Constant Properties

Knowledge Factor, $\gamma = 1.00$

Member Shear Force is generally considered as Force-Controlled Action according to Table C7-1, ASCE41-17.

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

Consequently:

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

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

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of γ for displacement ductility demand, the expected (mean value) strengths are used (7.5.1.3, ASCE41-17) because bending is considered as Deformation-Controlled Action (Table C7-1, ASCE41-17).

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

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

#####

Section Height, $H = 250.00$

Section Width, $W = 500.00$

Cover Thickness, $c = 25.00$

Element Length, $L = 3000.00$

Primary Member

Ribbed Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

Lap Length $l_o = l_b = 300.00$

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $\epsilon_{fu} = 0.01$

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, $M_a = 6.5063436E-010$

Shear Force, $V_a = -2.2952864E-013$

EDGE -B-

Bending Moment, $M_b = 3.8606651E-011$

Shear Force, $V_b = 2.2952864E-013$
 BOTH EDGES
 Axial Force, $F = -4810.556$
 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: $As_{mid} = 402.1239$
 Mean Diameter of Tension Reinforcement, $Db_{L,ten} = 18.66667$

Existing component: From table 7-7, ASCE 41_17: Final Shear Capacity $VR = V_n = 248574.19$
 V_n ((10.3), ASCE 41-17) = $k_n \cdot V_{Col0} = 248574.19$
 $V_{Col} = 248574.19$
 $k_n = 1.00$
 $displacement_ductility_demand = 0.00$

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).

$f' = 16.00$, but $f_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $M/V_d = 2.00$
 $\mu_u = 3.8606651E-011$
 $V_u = 2.2952864E-013$
 $d = 0.8 \cdot h = 200.00$
 $N_u = 4810.556$
 $A_g = 125000.00$
 From (11.5.4.8), ACI 318-14: $V_s = 44351.896$
 $A_v = 157079.633$
 $f_y = 400.00$
 $s = 170.00$
 V_s is multiplied by $Col = 0.60$
 $s/d = 0.85$
 V_f ((11-3)-(11.4), ACI 440) = 109072.851
 $f = 0.95$, for fully-wrapped sections
 $w_f/s_f = 1$ (FRP strips adjacent to one another).
 In (11.3) $\sin^2 + \cos^2$ is replaced with $(\cot^2 + \cot a) \sin a$ 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: $\theta_1 = b_1 + 90^\circ = 90.00$
 $V_f = \text{Min}(|V_f(45, \theta_1)|, |V_f(-45, a_1)|)$, with:
 total thickness per orientation, $t_{f1} = N_L \cdot t / N_{oDir} = 1.016$
 $d_{fv} = d$ (figure 11.2, ACI 440) = 207.00
 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: $V_s + V_f \leq 265721.532$
 $b_w = 500.00$

$displacement_ductility_demand$ is calculated as Δ / y

- Calculation of Δ / y for END B -
 for rotation axis 2 and integ. section (b)

From analysis, chord rotation $\theta = 2.1039935E-020$
 $y = (M_y \cdot L_s / 3) / E_{eff} = 0.00620875$ ((4.29), Biskinis Phd))
 $M_y = 5.0977E+007$
 $L_s = M/V$ (with $L_s > 0.1 \cdot L$ and $L_s < 2 \cdot L$) = 1500.00

From table 10.5, ASCE 41_17: $E_{eff} = factor * E_c * I_g = 4.1053E+012$

factor = 0.30

$A_g = 125000.00$

$f_c' = 20.00$

$N = 4810.556$

$E_c * I_g = 1.3684E+013$

Calculation of Yielding Moment M_y

Calculation of y and M_y according to Annex 7 -

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

$y_{ten} = 1.0451269E-005$

with ((10.1), ASCE 41-17) $f_y = \text{Min}(f_y, 1.25 * f_y * (I_b / I_d)^{2/3}) = 291.1836$

$d = 207.00$

$y = 0.32702707$

$A = 0.02007155$

$B = 0.01218373$

with $p_t = 0.00801334$

$p_c = 0.00801334$

$p_v = 0.00388525$

$N = 4810.556$

$b = 500.00$

$" = 0.20772947$

$y_{comp} = 2.5958133E-005$

with $f_c' (12.3, (ACI 440)) = 20.44529$

$f_c = 20.00$

$f_l = 0.9425867$

$b = 500.00$

$h = 250.00$

$A_g = 125000.00$

From (12.9), ACI 440: $k_a = 0.1506892$

$g = p_t + p_c + p_v = 0.01991193$

$r_c = 40.00$

$A_e / A_c = 0.60275679$

Effective FRP thickness, $t_f = N L * t * \cos(b_1) = 1.016$

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

$f_u = 0.01$

$E_f = 64828.00$

$E_c = 21019.039$

$y = 0.32584352$

$A = 0.0197792$

$B = 0.01202411$

with $E_s = 200000.00$

Calculation of ratio I_b / I_d

Lap Length: $I_d / I_{d,min} = 0.37945973$

$I_b = 300.00$

$I_d = 790.5977$

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

$= 1$

$d_b = 18.00$

Mean strength value of all re-bars: $f_y = 444.44$

$f_c' = 20.00$, but $f_c'^{0.5} \leq 8.3 \text{ MPa}$ (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$c_b = 25.00$

$K_{tr} = 4.61999$

$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$

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

$s = 170.00$

n = 8.00

End Of Calculation of Shear Capacity for element: column C1 of floor 1

At local axis: 3

Integration Section: (b)

Calculation No. 8

column C1, Floor 1

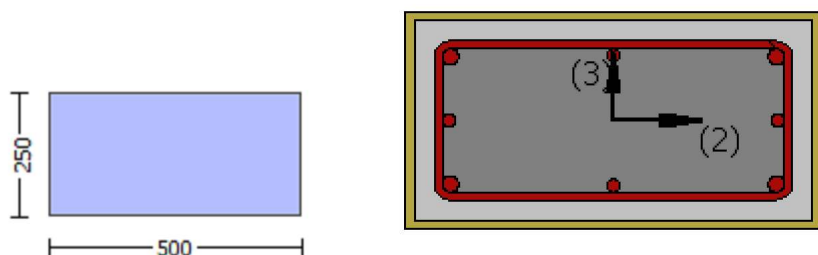
Limit State: Immediate Occupancy (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity (ϕ)

Edge: End

Local Axis: (3)



Start Of Calculation of Shear Capacity ratio for element: column C1 of floor 1

At Shear local axis: 3

(Bending local axis: 2)

Section Type: rcrs

Constant Properties

Knowledge Factor, $\gamma = 1.00$

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

Consequently:

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

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

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

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

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

#####

Section Height, $H = 250.00$

Section Width, $W = 500.00$

Cover Thickness, $c = 25.00$

Mean Confinement Factor overall section = 1.13916
 Element Length, L = 3000.00
 Primary Member
 Ribbed Bars
 Ductile Steel
 Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
 Longitudinal Bars With Ends Lapped Starting at the End Sections
 Lap Length l_o = 300.00
 FRP Wrapping Data
 Type: Carbon
 Cured laminate properties (design values)
 Thickness, t = 1.016
 Tensile Strength, f_{fu} = 1055.00
 Tensile Modulus, E_f = 64828.00
 Elongation, $ε_{fu}$ = 0.01
 Number of directions, 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 = 2.9007121E-031
 EDGE -B-
 Shear Force, V_b = -2.9007121E-031
 BOTH EDGES
 Axial Force, F = -4666.932
 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 = 0.15063296
 Member Controlled by Flexure ($V_e/V_r < 1$)
 Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 39953.171$
 with
 $M_{pr1} = \text{Max}(\mu_{u1+}, \mu_{u1-}) = 5.9930E+007$
 $\mu_{u1+} = 5.9930E+007$, 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
 $\mu_{u1-} = 5.9930E+007$, 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
 $M_{pr2} = \text{Max}(\mu_{u2+}, \mu_{u2-}) = 5.9930E+007$
 $\mu_{u2+} = 5.9930E+007$, 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
 $\mu_{u2-} = 5.9930E+007$, is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the the static loading combination

Calculation of μ_{u1+}

Calculation of ultimate curvature ϕ_u according to 4.1, Biskinis/Fardis 2013:
 $\phi_u = 3.4011160E-005$
 $\mu_u = 5.9930E+007$

with full section properties:
 $b = 500.00$

$d = 207.00$
 $d' = 43.00$
 $v = 0.00225456$
 $N = 4666.932$
 $f_c = 20.00$
 $\alpha (5A.5, TBDY) = 0.002$
 Final value of α : $\alpha^* = \text{shear_factor} * \text{Max}(\alpha, \alpha_c) = 0.01464474$
 The Shear_factor is considered equal to 1 (pure moment strength)
 From (5.4b), TBDY: $\alpha = 0.01464474$
 $\alpha_{we} ((5.4c), TBDY) = \alpha * \text{sh}_{\min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.07762821$
 where $f = \alpha * \rho_f * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$f_x = 0.07705054$
 $\alpha_f = 0.45253333$
 $b = 500.00$
 $h = 250.00$
 From EC8 A.4.4.3(6), $\rho_f = 2t_f/bw = 0.004064$
 $bw = 500.00$
 effective stress from (A.35), $f_{fe} = 837.9178$

$f_y = 0.12936483$
 $\alpha_f = 0.45253333$
 $b = 250.00$
 $h = 500.00$
 From EC8 A.4.4.3(6), $\rho_f = 2t_f/bw = 0.008128$
 $bw = 250.00$
 effective stress from (A.35), $f_{fe} = 703.4155$

$R = 40.00$
 Effective FRP thickness, $t_f = NL * t * \cos(b_1) = 1.016$
 $f_{u,f} = 1055.00$
 $E_f = 64828.00$
 $u_f = 0.015$
 $\alpha_{se} ((5.4d), TBDY) = 0.03751166$
 $b_o = 440.00$
 $h_o = 190.00$
 $b_{i2} = 459400.00$
 $\rho_{sh,\min} = \text{Min}(\rho_{sh,x}, \rho_{sh,y}) = 0.001848$
 Expression ((5.4d), TBDY) for $\rho_{sh,\min}$ has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$\rho_{sh,x} (5.4d) = 0.001848$
 $A_{sh} = A_{stir} * n_s = 78.53982$
 No stirrups, $n_s = 2.00$
 $b_k = 500.00$

$\rho_{sh,y} (5.4d) = 0.00369599$
 $A_{sh} = A_{stir} * n_s = 78.53982$
 No stirrups, $n_s = 2.00$
 $b_k = 250.00$

$s = 170.00$
 $f_{ywe} = 555.55$
 $f_{ce} = 20.00$
 From ((5A5), TBDY), TBDY: $\alpha_c = 0.00339158$
 $c = \text{confinement factor} = 1.13916$
 $y_1 = 0.00130695$
 $sh_1 = 0.00451687$
 $ft_1 = 376.4017$
 $fy_1 = 313.6681$
 $su_1 = 0.005257$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00
 $l_o/l_{ou,\min} = l_b/d = 0.30356779$
 $su_1 = 0.4 * esu_{1_nominal} ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $esu_{1_nominal} = 0.08$

For calculation of $esu1_nominal$ 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, ASCE41-17.
 with $fs1 = fs = 313.6681$
 with $Es1 = Es = 200000.00$
 $y2 = 0.00130695$
 $sh2 = 0.00451687$
 $ft2 = 376.4017$
 $fy2 = 313.6681$
 $su2 = 0.005257$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $lo/lou, min = lb/lb, min = 0.30356779$
 $su2 = 0.4 \cdot esu2_nominal \cdot ((5.5), TBDY) = 0.032$
 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, ASCE41-17.
 with $fs2 = fs = 313.6681$
 with $Es2 = Es = 200000.00$
 $yv = 0.00130695$
 $shv = 0.00451687$
 $ftv = 376.4017$
 $fyv = 313.6681$
 $suv = 0.005257$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $lo/lou, min = lb/ld = 0.30356779$
 $suv = 0.4 \cdot esuv_nominal \cdot ((5.5), TBDY) = 0.032$
 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, ASCE41-17.
 with $fsv = fs = 313.6681$
 with $Esv = Es = 200000.00$
 $1 = Asl, ten / (b \cdot d) \cdot (fs1 / fc) = 0.1256764$
 $2 = Asl, com / (b \cdot d) \cdot (fs2 / fc) = 0.1256764$
 $v = Asl, mid / (b \cdot d) \cdot (fsv / fc) = 0.06093401$

and confined core properties:

$b = 440.00$
 $d = 177.00$
 $d' = 13.00$
 $fcc (5A.2, TBDY) = 22.78316$
 $cc (5A.5, TBDY) = 0.00339158$
 $c = \text{confinement factor} = 1.13916$
 $1 = Asl, ten / (b \cdot d) \cdot (fs1 / fc) = 0.16701987$
 $2 = Asl, com / (b \cdot d) \cdot (fs2 / fc) = 0.16701987$
 $v = Asl, mid / (b \cdot d) \cdot (fsv / fc) = 0.08097933$

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

--->
 $v < vs, y2$ - LHS eq.(4.5) is satisfied
 --->
 $su (4.9) = 0.25329952$
 $Mu = MRc (4.14) = 5.9930E+007$
 $u = su (4.1) = 3.4011160E-005$

Calculation of ratio lb/ld

Lap Length: $lb/ld = 0.30356779$
 $lb = 300.00$
 $ld = 988.2471$

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

$\gamma = 1$
 $d_b = 18.00$
Mean strength value of all re-bars: $f_y = 555.55$
 $f'_c = 20.00$, but $f_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $t = 1.00$
 $s = 0.80$
 $e = 1.00$
 $c_b = 25.00$
 $K_{tr} = 4.61999$
 $A_{tr} = \text{Min}(A_{tr,x}, A_{tr,y}) = 157.0796$
where $A_{tr,x}$, $A_{tr,y}$ are the sum of the area of all stirrup legs along X and Y loxal axis
 $s = 170.00$
 $n = 8.00$

Calculation of μ_1 -

Calculation of ultimate curvature μ according to 4.1, Biskinis/Fardis 2013:
 $\mu = 3.4011160E-005$
 $\mu_u = 5.9930E+007$

with full section properties:

$b = 500.00$
 $d = 207.00$
 $d' = 43.00$
 $v = 0.00225456$
 $N = 4666.932$
 $f_c = 20.00$
 α_1 (5A.5, TBDY) = 0.002
Final value of μ_u : $\mu_u^* = \text{shear_factor} * \text{Max}(\mu_u, \mu_c) = 0.01464474$
The Shear_factor is considered equal to 1 (pure moment strength)
From (5.4b), TBDY: $\mu_u = 0.01464474$
 μ_{ue} ((5.4c), TBDY) = $\alpha_1 * \mu_u * \min(f_{yue}/f_{ce} + \text{Min}(f_x, f_y)) = 0.07762821$
where $f = \alpha_1 * \mu_u * f_{fe}/f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$f_x = 0.07705054$
 $\alpha_1 = 0.45253333$
 $b = 500.00$
 $h = 250.00$
From EC8 A.4.4.3(6), $\mu_u = 2t_f/bw = 0.004064$
 $bw = 500.00$
effective stress from (A.35), $f_{fe} = 837.9178$

$f_y = 0.12936483$
 $\alpha_1 = 0.45253333$
 $b = 250.00$
 $h = 500.00$
From EC8 A.4.4.3(6), $\mu_u = 2t_f/bw = 0.008128$
 $bw = 250.00$
effective stress from (A.35), $f_{fe} = 703.4155$

$R = 40.00$
Effective FRP thickness, $t_f = N L^* t \cos(\beta_1) = 1.016$
 $f_{u,f} = 1055.00$
 $E_f = 64828.00$
 $\mu_{u,f} = 0.015$
 α_1 ((5.4d), TBDY) = 0.03751166
 $b_o = 440.00$
 $h_o = 190.00$
 $b_{i2} = 459400.00$
 $\mu_{sh,min} = \text{Min}(\mu_{sh,x}, \mu_{sh,y}) = 0.001848$
Expression ((5.4d), TBDY) for $\mu_{sh,min}$ has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

psh,x (5.4d) = 0.001848
Ash = Astir*ns = 78.53982
No stirups, ns = 2.00
bk = 500.00

psh,y (5.4d) = 0.00369599
Ash = Astir*ns = 78.53982
No stirups, ns = 2.00
bk = 250.00

s = 170.00
fywe = 555.55
fce = 20.00

From ((5.A5), TBDY), TBDY: cc = 0.00339158
c = confinement factor = 1.13916

y1 = 0.00130695
sh1 = 0.00451687

ft1 = 376.4017

fy1 = 313.6681

su1 = 0.005257

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779

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, ASCE41-17.

with fs1 = fs = 313.6681

with Es1 = Es = 200000.00

y2 = 0.00130695

sh2 = 0.00451687

ft2 = 376.4017

fy2 = 313.6681

su2 = 0.005257

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779

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, ASCE41-17.

with fs2 = fs = 313.6681

with Es2 = Es = 200000.00

yv = 0.00130695

shv = 0.00451687

ftv = 376.4017

fyv = 313.6681

suv = 0.005257

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779

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, ASCE41-17.

with fsv = fs = 313.6681

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.1256764

2 = Asl,com/(b*d)*(fs2/fc) = 0.1256764

v = Asl,mid/(b*d)*(fsv/fc) = 0.06093401

and confined core properties:

$$b = 440.00$$

$$d = 177.00$$

$$d' = 13.00$$

$$fcc(5A.2, TBDY) = 22.78316$$

$$cc(5A.5, TBDY) = 0.00339158$$

$$c = \text{confinement factor} = 1.13916$$

$$1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.16701987$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.16701987$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.08097933$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

$$s_u(4.9) = 0.25329952$$

$$M_u = M_{Rc}(4.14) = 5.9930E+007$$

$$u = s_u(4.1) = 3.4011160E-005$$

Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.30356779$

$$l_b = 300.00$$

$$l_d = 988.2471$$

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

$$= 1$$

$$d_b = 18.00$$

Mean strength value of all re-bars: $f_y = 555.55$

$$f_c' = 20.00, \text{ but } f_c'^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 25.00$$

$$K_{tr} = 4.61999$$

$$A_{tr} = \text{Min}(A_{tr,x}, A_{tr,y}) = 157.0796$$

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

$$s = 170.00$$

$$n = 8.00$$

Calculation of M_{u2+}

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

$$u = 3.4011160E-005$$

$$M_u = 5.9930E+007$$

with full section properties:

$$b = 500.00$$

$$d = 207.00$$

$$d' = 43.00$$

$$v = 0.00225456$$

$$N = 4666.932$$

$$f_c = 20.00$$

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

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_c) = 0.01464474$$

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

$$\text{From (5.4b), TBDY: } c_u = 0.01464474$$

$$w_e((5.4c), TBDY) = a_s e^* s_{h,min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.07762821$$

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

$$f_x = 0.07705054$$

$$a_f = 0.45253333$$

$$b = 500.00$$

h = 250.00
From EC8 A4.4.3(6), $pf = 2tf/bw = 0.004064$
bw = 500.00
effective stress from (A.35), $ff,e = 837.9178$

fy = 0.12936483
af = 0.45253333
b = 250.00
h = 500.00
From EC8 A4.4.3(6), $pf = 2tf/bw = 0.008128$
bw = 250.00
effective stress from (A.35), $ff,e = 703.4155$

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) = 0.03751166
bo = 440.00
ho = 190.00
bi2 = 459400.00
psh,min = Min(psh,x , psh,y) = 0.001848
Expression ((5.4d), TBDY) for psh,min has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

psh,x (5.4d) = 0.001848
Ash = Astir*ns = 78.53982
No stirrups, ns = 2.00
bk = 500.00

psh,y (5.4d) = 0.00369599
Ash = Astir*ns = 78.53982
No stirrups, ns = 2.00
bk = 250.00

s = 170.00
fywe = 555.55
fce = 20.00
From ((5.A5), TBDY), TBDY: cc = 0.00339158
c = confinement factor = 1.13916
y1 = 0.00130695
sh1 = 0.00451687
ft1 = 376.4017
fy1 = 313.6681
su1 = 0.005257
using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779
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, ASCE41-17.
with fs1 = fs = 313.6681
with Es1 = Es = 200000.00
y2 = 0.00130695
sh2 = 0.00451687
ft2 = 376.4017
fy2 = 313.6681
su2 = 0.005257
using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779
su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: $es_{u2_nominal} = 0.08$,
For calculation of $es_{u2_nominal}$ and y_2 , sh_2, ft_2, fy_2 , it is considered
characteristic value $fs_{y2} = fs_2/1.2$, from table 5.1, TBDY.
 y_1 , sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.
with $fs_2 = fs = 313.6681$
with $Es_2 = Es = 200000.00$
 $y_v = 0.00130695$
 $sh_v = 0.00451687$
 $ft_v = 376.4017$
 $fy_v = 313.6681$
 $s_{uv} = 0.005257$
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
 $lo/lo_{u,min} = lb/ld = 0.30356779$
 $s_{uv} = 0.4 \cdot es_{uv_nominal} ((5.5), TBDY) = 0.032$
From table 5A.1, TBDY: $es_{uv_nominal} = 0.08$,
considering characteristic value $fs_{yv} = fs_v/1.2$, from table 5.1, TBDY
For calculation of $es_{uv_nominal}$ and y_v , sh_v, ft_v, fy_v , it is considered
characteristic value $fs_{yv} = fs_v/1.2$, from table 5.1, TBDY.
 y_1 , sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.
with $fs_v = fs = 313.6681$
with $Es_v = Es = 200000.00$
 $1 = As_{l,ten}/(b \cdot d) \cdot (fs_1/f_c) = 0.1256764$
 $2 = As_{l,com}/(b \cdot d) \cdot (fs_2/f_c) = 0.1256764$
 $v = As_{l,mid}/(b \cdot d) \cdot (fs_v/f_c) = 0.06093401$
and confined core properties:
 $b = 440.00$
 $d = 177.00$
 $d' = 13.00$
 $f_{cc} (5A.2, TBDY) = 22.78316$
 $cc (5A.5, TBDY) = 0.00339158$
 $c = \text{confinement factor} = 1.13916$
 $1 = As_{l,ten}/(b \cdot d) \cdot (fs_1/f_c) = 0.16701987$
 $2 = As_{l,com}/(b \cdot d) \cdot (fs_2/f_c) = 0.16701987$
 $v = As_{l,mid}/(b \cdot d) \cdot (fs_v/f_c) = 0.08097933$
Case/Assumption: Unconfined full section - Steel rupture
'satisfies Eq. (4.3)
--->
 $v < v_{s,y2}$ - LHS eq.(4.5) is satisfied
--->
 $su (4.9) = 0.25329952$
 $Mu = MR_c (4.14) = 5.9930E+007$
 $u = su (4.1) = 3.4011160E-005$

Calculation of ratio lb/ld

Lap Length: $lb/ld = 0.30356779$
 $lb = 300.00$
 $ld = 988.2471$
Calculation of lb_{min} according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
= 1
 $db = 18.00$
Mean strength value of all re-bars: $fy = 555.55$
 $fc' = 20.00$, but $fc'^{0.5} \leq 8.3 \text{ MPa}$ (22.5.3.1, ACI 318-14)
 $t = 1.00$
 $s = 0.80$
 $e = 1.00$
 $cb = 25.00$
 $K_{tr} = 4.61999$
 $A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$
where A_{tr_x} , A_{tr_y} are the sum of the area of all stirrup legs along X and Y loxal axis
 $s = 170.00$
 $n = 8.00$

Calculation of Mu2-

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

$$\mu = 3.4011160E-005$$

$$Mu = 5.9930E+007$$

with full section properties:

$$b = 500.00$$

$$d = 207.00$$

$$d' = 43.00$$

$$v = 0.00225456$$

$$N = 4666.932$$

$$f_c = 20.00$$

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

$$\text{Final value of } \mu: \mu^* = \text{shear_factor} * \text{Max}(\mu, c_o) = 0.01464474$$

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

$$\text{From (5.4b), TBDY: } \mu = 0.01464474$$

$$w_e \text{ ((5.4c), TBDY)} = a_s * \min(f_{ywe}/f_{ce} + \min(f_x, f_y)) = 0.07762821$$

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

$$f_x = 0.07705054$$

$$a_f = 0.45253333$$

$$b = 500.00$$

$$h = 250.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/bw = 0.004064$$

$$bw = 500.00$$

$$\text{effective stress from (A.35), } f_{fe} = 837.9178$$

$$f_y = 0.12936483$$

$$a_f = 0.45253333$$

$$b = 250.00$$

$$h = 500.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/bw = 0.008128$$

$$bw = 250.00$$

$$\text{effective stress from (A.35), } f_{fe} = 703.4155$$

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$a_s \text{ ((5.4d), TBDY)} = 0.03751166$$

$$b_o = 440.00$$

$$h_o = 190.00$$

$$b_{i2} = 459400.00$$

$$p_{sh,min} = \min(p_{sh,x}, p_{sh,y}) = 0.001848$$

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

$$p_{sh,x} \text{ (5.4d)} = 0.001848$$

$$A_{sh} = A_{stir} * n_s = 78.53982$$

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

$$b_k = 500.00$$

$$p_{sh,y} \text{ (5.4d)} = 0.00369599$$

$$A_{sh} = A_{stir} * n_s = 78.53982$$

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

$$b_k = 250.00$$

$$s = 170.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 20.00$$

$$\text{From ((5.A5), TBDY), TBDY: } c_c = 0.00339158$$

$$c = \text{confinement factor} = 1.13916$$

```

y1 = 0.00130695
sh1 = 0.00451687
ft1 = 376.4017
fy1 = 313.6681
su1 = 0.005257
    using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779
    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, ASCE41-17.
    with fs1 = fs = 313.6681
    with Es1 = Es = 200000.00
y2 = 0.00130695
sh2 = 0.00451687
ft2 = 376.4017
fy2 = 313.6681
su2 = 0.005257
    using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779
    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, ASCE41-17.
    with fs2 = fs = 313.6681
    with Es2 = Es = 200000.00
yv = 0.00130695
shv = 0.00451687
ftv = 376.4017
fyv = 313.6681
suv = 0.005257
    using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779
    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, ASCE41-17.
    with fsv = fs = 313.6681
    with Esv = Es = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.1256764
2 = Asl,com/(b*d)*(fs2/fc) = 0.1256764
v = Asl,mid/(b*d)*(fsv/fc) = 0.06093401
and confined core properties:
b = 440.00
d = 177.00
d' = 13.00
fcc (5A.2, TBDY) = 22.78316
cc (5A.5, TBDY) = 0.00339158
c = confinement factor = 1.13916
1 = Asl,ten/(b*d)*(fs1/fc) = 0.16701987
2 = Asl,com/(b*d)*(fs2/fc) = 0.16701987
v = Asl,mid/(b*d)*(fsv/fc) = 0.08097933
Case/Assumption: Unconfined full section - Steel rupture
'satisfies Eq. (4.3)
---->
v < vs,y2 - LHS eq.(4.5) is satisfied
---->

```

$\mu_u(4.9) = 0.25329952$
 $\mu_u = M_{Rc}(4.14) = 5.9930E+007$
 $u = \mu_u(4.1) = 3.4011160E-005$

Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.30356779$

$l_b = 300.00$

$l_d = 988.2471$

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

$= 1$

$d_b = 18.00$

Mean strength value of all re-bars: $f_y = 555.55$

$f'_c = 20.00$, but $f_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$c_b = 25.00$

$K_{tr} = 4.61999$

$A_{tr} = \min(A_{tr_x}, A_{tr_y}) = 157.0796$

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

$s = 170.00$

$n = 8.00$

Calculation of Shear Strength $V_r = \min(V_{r1}, V_{r2}) = 265235.248$

Calculation of Shear Strength at edge 1, $V_{r1} = 265235.248$

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

$V_{Col0} = 265235.248$

$k_{nl} = 1$ (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)

$f'_c = 20.00$, but $f_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$\mu_u = 2.3992784E-012$

$V_u = 2.9007121E-031$

$d = 0.8 * h = 200.00$

$N_u = 4666.932$

$A_g = 125000.00$

From (11.5.4.8), ACI 318-14: $V_s = 49279.392$

$A_v = 157079.633$

$f_y = 444.44$

$s = 170.00$

V_s is multiplied by $\phi_{Col} = 0.60$

$s/d = 0.85$

$V_f((11-3)-(11.4), ACI 440) = 109072.851$

$f = 0.95$, 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: $\theta = b_1 + 90^\circ = 90.00$

$V_f = \min(|V_f(45, \theta)|, |V_f(-45, a_1)|)$, with:

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

$d_{fv} = d$ (figure 11.2, ACI 440) = 207.00

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

$E_f = 64828.00$

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

with $f_u = 0.01$

From (11-11), ACI 440: $V_s + V_f \leq 297085.704$
 $bw = 500.00$

Calculation of Shear Strength at edge 2, $V_{r2} = 265235.248$
 $V_{r2} = V_{Col} ((10.3), ASCE 41-17) = knl * V_{Col0}$
 $V_{Col0} = 265235.248$
 $knl = 1$ (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)
 $f'_c = 20.00$, but $f_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $M/Vd = 2.00$
 $M_u = 2.3992784E-012$
 $V_u = 2.9007121E-031$
 $d = 0.8 * h = 200.00$
 $N_u = 4666.932$
 $A_g = 125000.00$
From (11.5.4.8), ACI 318-14: $V_s = 49279.392$
 $A_v = 157079.633$
 $f_y = 444.44$
 $s = 170.00$
 V_s is multiplied by $Col = 0.60$
 $s/d = 0.85$
 $V_f ((11-3)-(11.4), ACI 440) = 109072.851$
 $f = 0.95$, for fully-wrapped sections
 $w_f/s_f = 1$ (FRP strips adjacent to one another).
In (11.3) $\sin + \cos$ is replaced with $(\cot + \cot a) \sin a$ which is more a generalised expression,
where a is the angle of the crack direction (see KANEPE).
This later relation, considered as a function $V_f(,)$, is implemented for every different fiber orientation a_i ,
as well as for 2 crack directions, $= 45^\circ$ and $= -45^\circ$ to take into consideration the cyclic seismic loading.
orientation 1: $\theta_1 = b_1 + 90^\circ = 90.00$
 $V_f = \text{Min}(|V_f(45, 1)|, |V_f(-45, a_1)|)$, with:
total thickness per orientation, $t_{f1} = NL * t / NoDir = 1.016$
 $d_{fv} = d$ (figure 11.2, ACI 440) = 207.00
 $f_{fe} ((11-5), ACI 440) = 259.312$
 $E_f = 64828.00$
 $f_e = 0.004$, from (11.6a), ACI 440
with $f_u = 0.01$
From (11-11), ACI 440: $V_s + V_f \leq 297085.704$
 $bw = 500.00$

End Of Calculation of Shear Capacity ratio for element: column C1 of floor 1
At local axis: 3

Start Of Calculation of Shear Capacity ratio for element: column C1 of floor 1
At Shear local axis: 2
(Bending local axis: 3)
Section Type: rcrcs

Constant Properties

Knowledge Factor, $= 1.00$
Mean strength values are used for both shear and moment calculations.
Consequently:
Existing material of Primary Member: Concrete Strength, $f_c = f_{cm} = 20.00$
Existing material of Primary Member: Steel Strength, $f_s = f_{sm} = 444.44$
Concrete Elasticity, $E_c = 21019.039$
Steel Elasticity, $E_s = 200000.00$

Note: Especially for the calculation of moment strengths,

```

the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14
Existing material: Steel Strength,  $f_s = 1.25 \cdot f_{sm} = 555.55$ 
#####
Section Height,  $H = 250.00$ 
Section Width,  $W = 500.00$ 
Cover Thickness,  $c = 25.00$ 
Mean Confinement Factor overall section = 1.13916
Element Length,  $L = 3000.00$ 
Primary Member
Ribbed Bars
Ductile Steel
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
Lap Length  $l_o = 300.00$ 
FRP Wrapping Data
Type: Carbon
Cured laminate properties (design values)
Thickness,  $t = 1.016$ 
Tensile Strength,  $f_{fu} = 1055.00$ 
Tensile Modulus,  $E_f = 64828.00$ 
Elongation,  $e_{fu} = 0.01$ 
Number of directions,  $N_{oDir} = 1$ 
Fiber orientations,  $b_i = 0.00^\circ$ 
Number of layers,  $N_L = 1$ 
Radius of rounding corners,  $R = 40.00$ 
-----

Stepwise Properties
-----
At local axis: 2
EDGE -A-
Shear Force,  $V_a = 1.3558547E-031$ 
EDGE -B-
Shear Force,  $V_b = -1.3558547E-031$ 
BOTH EDGES
Axial Force,  $F = -4666.932$ 
Longitudinal Reinforcement Area Distribution (in 2 divisions)
  -Tension:  $A_{slt} = 0.00$ 
  -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 ,  $V_e/V_r = 0.23676754$ 
Member Controlled by Flexure ( $V_e/V_r < 1$ )
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14  $V_e = (M_{pr1} + M_{pr2})/l_n = 96937.922$ 
with
 $M_{pr1} = \text{Max}(\mu_{u1+} , \mu_{u1-}) = 1.4541E+008$ 
 $\mu_{u1+} = 1.4541E+008$ , 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
 $\mu_{u1-} = 1.4541E+008$ , 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
 $M_{pr2} = \text{Max}(\mu_{u2+} , \mu_{u2-}) = 1.4541E+008$ 
 $\mu_{u2+} = 1.4541E+008$ , 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
 $\mu_{u2-} = 1.4541E+008$ , 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  $\mu_{u1+}$ 
-----
-----

```

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

$$u = 1.4467178E-005$$

$$\mu = 1.4541E+008$$

with full section properties:

$$b = 250.00$$

$$d = 457.00$$

$$d' = 43.00$$

$$v = 0.00204242$$

$$N = 4666.932$$

$$f_c = 20.00$$

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

$$\text{Final value of } \phi_u: \phi_u^* = \text{shear_factor} * \text{Max}(\phi_u, \phi_c) = 0.01464474$$

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

$$\text{From (5.4b), TB DY: } \phi_u = 0.01464474$$

$$\omega_e ((5.4c), \text{TB DY}) = a_s e * \frac{\min(f_{ywe}/f_{ce}, \min(f_x, f_y))}{f_c} = 0.07762821$$

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

$$f_x = 0.07705054$$

$$a_f = 0.45253333$$

$$b = 500.00$$

$$h = 250.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/bw = 0.004064$$

$$bw = 500.00$$

$$\text{effective stress from (A.35), } f_{fe} = 837.9178$$

$$f_y = 0.12936483$$

$$a_f = 0.45253333$$

$$b = 250.00$$

$$h = 500.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/bw = 0.008128$$

$$bw = 250.00$$

$$\text{effective stress from (A.35), } f_{fe} = 703.4155$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = NL * t * \cos(\beta_1) = 1.016$$

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

$$E_f = 64828.00$$

$$u_{f,f} = 0.015$$

$$a_s e ((5.4d), \text{TB DY}) = 0.03751166$$

$$b_o = 440.00$$

$$h_o = 190.00$$

$$b_{i2} = 459400.00$$

$$p_{sh,min} = \min(p_{sh,x}, p_{sh,y}) = 0.001848$$

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

$$p_{sh,x} (5.4d) = 0.001848$$

$$A_{sh} = A_{stir} * n_s = 78.53982$$

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

$$b_k = 500.00$$

$$p_{sh,y} (5.4d) = 0.00369599$$

$$A_{sh} = A_{stir} * n_s = 78.53982$$

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

$$b_k = 250.00$$

$$s = 170.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 20.00$$

$$\text{From ((5.A5), TB DY), TB DY: } \phi_c = 0.00339158$$

$$c = \text{confinement factor} = 1.13916$$

$$y_1 = 0.00130695$$

$$sh_1 = 0.00451687$$

$$ft_1 = 376.4017$$

$$fy_1 = 313.6681$$

$$su_1 = 0.005257$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
 $l_o/l_{ou,min} = l_b/l_d = 0.30356779$
 $su_1 = 0.4 * esu_{1,nominal} ((5.5), TBDY) = 0.032$
From table 5A.1, TBDY: $esu_{1,nominal} = 0.08$,
For calculation of $esu_{1,nominal}$ and y_1, sh_1, ft_1, fy_1 , it is considered
characteristic value $fsy_1 = fs_1/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $Min(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.
with $fs_1 = fs = 313.6681$
with $Es_1 = Es = 200000.00$
 $y_2 = 0.00130695$
 $sh_2 = 0.00451687$
 $ft_2 = 376.4017$
 $fy_2 = 313.6681$
 $su_2 = 0.005257$
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
 $l_o/l_{ou,min} = l_b/l_{b,min} = 0.30356779$
 $su_2 = 0.4 * esu_{2,nominal} ((5.5), TBDY) = 0.032$
From table 5A.1, TBDY: $esu_{2,nominal} = 0.08$,
For calculation of $esu_{2,nominal}$ and y_2, sh_2, ft_2, fy_2 , it is considered
characteristic value $fsy_2 = fs_2/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $Min(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.
with $fs_2 = fs = 313.6681$
with $Es_2 = Es = 200000.00$
 $y_v = 0.00130695$
 $sh_v = 0.00451687$
 $ft_v = 376.4017$
 $fy_v = 313.6681$
 $suv = 0.005257$
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
 $l_o/l_{ou,min} = l_b/l_d = 0.30356779$
 $suv = 0.4 * esuv_{nominal} ((5.5), TBDY) = 0.032$
From table 5A.1, TBDY: $esuv_{nominal} = 0.08$,
considering characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY
For calculation of $esuv_{nominal}$ and y_v, sh_v, ft_v, fy_v , it is considered
characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $Min(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.
with $fsv = fs = 313.6681$
with $Es_v = Es = 200000.00$
 $1 = Asl_{ten}/(b*d) * (fs_1/f_c) = 0.11385127$
 $2 = Asl_{com}/(b*d) * (fs_2/f_c) = 0.11385127$
 $v = Asl_{mid}/(b*d) * (fsv/f_c) = 0.05520062$
and confined core properties:
 $b = 190.00$
 $d = 427.00$
 $d' = 13.00$
 $f_{cc} (5A.2, TBDY) = 22.78316$
 $cc (5A.5, TBDY) = 0.00339158$
 $c = \text{confinement factor} = 1.13916$
 $1 = Asl_{ten}/(b*d) * (fs_1/f_c) = 0.1603292$
 $2 = Asl_{com}/(b*d) * (fs_2/f_c) = 0.1603292$
 $v = Asl_{mid}/(b*d) * (fsv/f_c) = 0.07773537$
Case/Assumption: Unconfined full section - Steel rupture
'satisfies Eq. (4.3)
--->
 $v < v_{s,y2}$ - LHS eq.(4.5) is satisfied
--->
 $su (4.9) = 0.20486988$
 $Mu = MRc (4.14) = 1.4541E+008$
 $u = su (4.1) = 1.4467178E-005$

Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.30356779$

$l_b = 300.00$

$l_d = 988.2471$

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

$= 1$

$d_b = 18.00$

Mean strength value of all re-bars: $f_y = 555.55$

$f_c' = 20.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$c_b = 25.00$

$K_{tr} = 4.61999$

$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$

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

$s = 170.00$

$n = 8.00$

Calculation of μ_1 -

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

$\mu = 1.4467178E-005$

$\mu_u = 1.4541E+008$

with full section properties:

$b = 250.00$

$d = 457.00$

$d' = 43.00$

$v = 0.00204242$

$N = 4666.932$

$f_c = 20.00$

α_1 (5A.5, TBDY) = 0.002

Final value of μ_u : $\mu_u^* = \text{shear_factor} * \text{Max}(\mu_u, \mu_c) = 0.01464474$

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

From (5.4b), TBDY: $\mu_u = 0.01464474$

we ((5.4c), TBDY) = $\alpha_1 * \text{sh}_{\min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.07762821$

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

$f_x = 0.07705054$

$\alpha_1 = 0.45253333$

$b = 500.00$

$h = 250.00$

From EC8 A.4.4.3(6), $p_f = 2t_f/bw = 0.004064$

$bw = 500.00$

effective stress from (A.35), $f_{fe} = 837.9178$

$f_y = 0.12936483$

$\alpha_1 = 0.45253333$

$b = 250.00$

$h = 500.00$

From EC8 A.4.4.3(6), $p_f = 2t_f/bw = 0.008128$

$bw = 250.00$

effective stress from (A.35), $f_{fe} = 703.4155$

$R = 40.00$

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

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{,f} = 0.015$

α_1 ((5.4d), TBDY) = 0.03751166

$b_o = 440.00$

$h_o = 190.00$
 $bi2 = 459400.00$
 $psh,min = \text{Min}(psh,x, psh,y) = 0.001848$
 Expression ((5.4d), TBDY) for psh,min has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$psh,x (5.4d) = 0.001848$
 $Ash = Astir*ns = 78.53982$
 No stirrups, $ns = 2.00$
 $bk = 500.00$

$psh,y (5.4d) = 0.00369599$
 $Ash = Astir*ns = 78.53982$
 No stirrups, $ns = 2.00$
 $bk = 250.00$

$s = 170.00$
 $fywe = 555.55$
 $fce = 20.00$
 From ((5.A5), TBDY), TBDY: $cc = 0.00339158$
 $c = \text{confinement factor} = 1.13916$
 $y1 = 0.00130695$
 $sh1 = 0.00451687$
 $ft1 = 376.4017$
 $fy1 = 313.6681$
 $su1 = 0.005257$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00
 $lo/lou,min = lb/ld = 0.30356779$
 $su1 = 0.4*esu1_nominal ((5.5), TBDY) = 0.032$
 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, ASCE41-17.
 with $fs1 = fs = 313.6681$
 with $Es1 = Es = 200000.00$
 $y2 = 0.00130695$
 $sh2 = 0.00451687$
 $ft2 = 376.4017$
 $fy2 = 313.6681$
 $su2 = 0.005257$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00
 $lo/lou,min = lb/lb,min = 0.30356779$
 $su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032$
 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, ASCE41-17.
 with $fs2 = fs = 313.6681$
 with $Es2 = Es = 200000.00$
 $yv = 0.00130695$
 $shv = 0.00451687$
 $ftv = 376.4017$
 $fyv = 313.6681$
 $suv = 0.005257$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00
 $lo/lou,min = lb/ld = 0.30356779$
 $suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032$
 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, ASCE41-17.
 with $fsv = fs = 313.6681$
 with $Esv = Es = 200000.00$
 $1 = Asl,ten/(b \cdot d) \cdot (fs1/fc) = 0.11385127$
 $2 = Asl,com/(b \cdot d) \cdot (fs2/fc) = 0.11385127$
 $v = Asl,mid/(b \cdot d) \cdot (fsv/fc) = 0.05520062$
 and confined core properties:
 $b = 190.00$
 $d = 427.00$
 $d' = 13.00$
 $fcc (5A.2, TBDY) = 22.78316$
 $cc (5A.5, TBDY) = 0.00339158$
 $c = \text{confinement factor} = 1.13916$
 $1 = Asl,ten/(b \cdot d) \cdot (fs1/fc) = 0.1603292$
 $2 = Asl,com/(b \cdot d) \cdot (fs2/fc) = 0.1603292$
 $v = Asl,mid/(b \cdot d) \cdot (fsv/fc) = 0.07773537$
 Case/Assumption: Unconfined full section - Steel rupture
 ' satisfies Eq. (4.3)
 --->
 $v < vs,y2$ - LHS eq.(4.5) is satisfied
 --->
 $su (4.9) = 0.20486988$
 $Mu = MRc (4.14) = 1.4541E+008$
 $u = su (4.1) = 1.4467178E-005$

 Calculation of ratio lb/ld

 Lap Length: $lb/ld = 0.30356779$
 $lb = 300.00$
 $ld = 988.2471$
 Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
 $= 1$
 $db = 18.00$
 Mean strength value of all re-bars: $fy = 555.55$
 $fc' = 20.00$, but $fc^{0.5} \leq 8.3 \text{ MPa}$ (22.5.3.1, ACI 318-14)
 $t = 1.00$
 $s = 0.80$
 $e = 1.00$
 $cb = 25.00$
 $Ktr = 4.61999$
 $Atr = \text{Min}(Atr_x, Atr_y) = 157.0796$
 where Atr_x, Atr_y are the sum of the area of all stirrup legs along X and Y loxal axis
 $s = 170.00$
 $n = 8.00$

 Calculation of $Mu2+$

 Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:
 $u = 1.4467178E-005$
 $Mu = 1.4541E+008$

 with full section properties:
 $b = 250.00$
 $d = 457.00$
 $d' = 43.00$
 $v = 0.00204242$
 $N = 4666.932$
 $fc = 20.00$
 $co (5A.5, TBDY) = 0.002$
 Final value of cu : $cu^* = \text{shear_factor} \cdot \text{Max}(cu, cc) = 0.01464474$
 The Shear_factor is considered equal to 1 (pure moment strength)
 From (5.4b), TBDY: $cu = 0.01464474$

$w_e ((5.4c), TBDY) = a_{se} \cdot \frac{f_{ywe}}{f_{ce}} + \min(f_x, f_y) = 0.07762821$
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)

$f_x = 0.07705054$
 $a_f = 0.45253333$
 $b = 500.00$
 $h = 250.00$
From EC8 A.4.4.3(6), $p_f = 2t_f/bw = 0.004064$
 $bw = 500.00$
effective stress from (A.35), $f_{fe} = 837.9178$

$f_y = 0.12936483$
 $a_f = 0.45253333$
 $b = 250.00$
 $h = 500.00$
From EC8 A.4.4.3(6), $p_f = 2t_f/bw = 0.008128$
 $bw = 250.00$
effective stress from (A.35), $f_{fe} = 703.4155$

$R = 40.00$
Effective FRP thickness, $t_f = N_L \cdot t \cdot \cos(b_1) = 1.016$
 $f_{u,f} = 1055.00$
 $E_f = 64828.00$
 $u_f = 0.015$
 $a_{se} ((5.4d), TBDY) = 0.03751166$
 $b_o = 440.00$
 $h_o = 190.00$
 $b_{i2} = 459400.00$
 $p_{sh,min} = \min(p_{sh,x}, p_{sh,y}) = 0.001848$
Expression ((5.4d), TBDY) for $p_{sh,min}$ has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$p_{sh,x} (5.4d) = 0.001848$
 $A_{sh} = A_{stir} \cdot n_s = 78.53982$
No stirrups, $n_s = 2.00$
 $b_k = 500.00$

$p_{sh,y} (5.4d) = 0.00369599$
 $A_{sh} = A_{stir} \cdot n_s = 78.53982$
No stirrups, $n_s = 2.00$
 $b_k = 250.00$

$s = 170.00$
 $f_{ywe} = 555.55$
 $f_{ce} = 20.00$
From ((5.A5), TBDY), TBDY: $c_c = 0.00339158$
 $c = \text{confinement factor} = 1.13916$
 $y_1 = 0.00130695$
 $sh_1 = 0.00451687$
 $ft_1 = 376.4017$
 $fy_1 = 313.6681$
 $su_1 = 0.005257$
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
 $l_o/l_{ou,min} = l_b/l_d = 0.30356779$
 $su_1 = 0.4 \cdot esu_{1,nominal} ((5.5), TBDY) = 0.032$
From table 5A.1, TBDY: $esu_{1,nominal} = 0.08$
For calculation of $esu_{1,nominal}$ and y_1, sh_1, ft_1, fy_1 , it is considered
characteristic value $fsy_1 = fs_1/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $\min(1, 1.25 \cdot (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.
with $fs_1 = fs = 313.6681$
with $Es_1 = Es = 200000.00$
 $y_2 = 0.00130695$
 $sh_2 = 0.00451687$
 $ft_2 = 376.4017$
 $fy_2 = 313.6681$

```

su2 = 0.005257
using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779
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, ASCE41-17.
with fs2 = fs = 313.6681
with Es2 = Es = 200000.00
yv = 0.00130695
shv = 0.00451687
ftv = 376.4017
fyv = 313.6681
suv = 0.005257
using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779
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, ASCE41-17.
with fsv = fs = 313.6681
with Esv = Es = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.11385127
2 = Asl,com/(b*d)*(fs2/fc) = 0.11385127
v = Asl,mid/(b*d)*(fsv/fc) = 0.05520062
and confined core properties:
b = 190.00
d = 427.00
d' = 13.00
fcc (5A.2, TBDY) = 22.78316
cc (5A.5, TBDY) = 0.00339158
c = confinement factor = 1.13916
1 = Asl,ten/(b*d)*(fs1/fc) = 0.1603292
2 = Asl,com/(b*d)*(fs2/fc) = 0.1603292
v = Asl,mid/(b*d)*(fsv/fc) = 0.07773537
Case/Assumption: Unconfined full section - Steel rupture
'satisfies Eq. (4.3)
---->
v < vs,y2 - LHS eq.(4.5) is satisfied
---->
su (4.9) = 0.20486988
Mu = MRc (4.14) = 1.4541E+008
u = su (4.1) = 1.4467178E-005

```

Calculation of ratio lb/ld

```

Lap Length: lb/ld = 0.30356779
lb = 300.00
ld = 988.2471
Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
= 1
db = 18.00
Mean strength value of all re-bars: fy = 555.55
fc' = 20.00, but fc'^0.5 <= 8.3 MPa (22.5.3.1, ACI 318-14)
t = 1.00
s = 0.80
e = 1.00
cb = 25.00
Ktr = 4.61999

```

$$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$$

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

$$s = 170.00$$

$$n = 8.00$$

Calculation of μ_2 -

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

$$\mu = 1.4467178E-005$$

$$\mu = 1.4541E+008$$

with full section properties:

$$b = 250.00$$

$$d = 457.00$$

$$d' = 43.00$$

$$v = 0.00204242$$

$$N = 4666.932$$

$$f_c = 20.00$$

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

$$\text{Final value of } \mu: \mu^* = \text{shear_factor} * \text{Max}(\mu, \alpha) = 0.01464474$$

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

$$\text{From (5.4b), TBDY: } \mu = 0.01464474$$

$$\mu \text{ ((5.4c), TBDY)} = \alpha * \mu_{\min} * f_{ywe} / f_{ce} + \text{Min}(\mu_x, \mu_y) = 0.07762821$$

where $\mu = \alpha * \mu_{\min} * f_{ywe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$\mu_x = 0.07705054$$

$$\alpha = 0.45253333$$

$$b = 500.00$$

$$h = 250.00$$

$$\text{From EC8 A.4.4.3(6), } \mu_f = 2t_f/bw = 0.004064$$

$$bw = 500.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 837.9178$$

$$\mu_y = 0.12936483$$

$$\alpha = 0.45253333$$

$$b = 250.00$$

$$h = 500.00$$

$$\text{From EC8 A.4.4.3(6), } \mu_f = 2t_f/bw = 0.008128$$

$$bw = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 703.4155$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = NL * t * \cos(\theta_1) = 1.016$$

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

$$E_f = 64828.00$$

$$\mu_{f} = 0.015$$

$$\alpha \text{ ((5.4d), TBDY)} = 0.03751166$$

$$b_o = 440.00$$

$$h_o = 190.00$$

$$b_{i2} = 459400.00$$

$$\mu_{\min} = \text{Min}(\mu_x, \mu_y) = 0.001848$$

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

$$\mu_x \text{ (5.4d)} = 0.001848$$

$$A_{sh} = A_{stir} * n_s = 78.53982$$

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

$$b_k = 500.00$$

$$\mu_y \text{ (5.4d)} = 0.00369599$$

$$A_{sh} = A_{stir} * n_s = 78.53982$$

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

$$b_k = 250.00$$

```

s = 170.00
fywe = 555.55
fce = 20.00
From ((5A5), TBDY), TBDY: cc = 0.00339158
c = confinement factor = 1.13916
y1 = 0.00130695
sh1 = 0.00451687
ft1 = 376.4017
fy1 = 313.6681
su1 = 0.005257
using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779
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, ASCE41-17.
with fs1 = fs = 313.6681
with Es1 = Es = 200000.00
y2 = 0.00130695
sh2 = 0.00451687
ft2 = 376.4017
fy2 = 313.6681
su2 = 0.005257
using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779
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, ASCE41-17.
with fs2 = fs = 313.6681
with Es2 = Es = 200000.00
yv = 0.00130695
shv = 0.00451687
ftv = 376.4017
fyv = 313.6681
suv = 0.005257
using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779
suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032
From table 5A.1, TBDY: esuv_nominal = 0.08,
considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY
For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered
characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.
y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/d)^ 2/3), from 10.3.5, ASCE41-17.
with fsv = fs = 313.6681
with Esv = Es = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.11385127
2 = Asl,com/(b*d)*(fs2/fc) = 0.11385127
v = Asl,mid/(b*d)*(fsv/fc) = 0.05520062
and confined core properties:
b = 190.00
d = 427.00
d' = 13.00
fcc (5A.2, TBDY) = 22.78316
cc (5A.5, TBDY) = 0.00339158
c = confinement factor = 1.13916
1 = Asl,ten/(b*d)*(fs1/fc) = 0.1603292
2 = Asl,com/(b*d)*(fs2/fc) = 0.1603292

```

$$v = A_{sl, mid} / (b \cdot d) \cdot (f_{sv} / f_c) = 0.07773537$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

$$\mu_u (4.9) = 0.20486988$$

$$\mu_u = M_{Rc} (4.14) = 1.4541E+008$$

$$u = \mu_u (4.1) = 1.4467178E-005$$

Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.30356779$

$$l_b = 300.00$$

$$l_d = 988.2471$$

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

$$= 1$$

$$d_b = 18.00$$

Mean strength value of all re-bars: $f_y = 555.55$

$f'_c = 20.00$, but $f'_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 25.00$$

$$K_{tr} = 4.61999$$

$$A_{tr} = \min(A_{tr_x}, A_{tr_y}) = 157.0796$$

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

$$s = 170.00$$

$$n = 8.00$$

Calculation of Shear Strength $V_r = \min(V_{r1}, V_{r2}) = 409422.352$

Calculation of Shear Strength at edge 1, $V_{r1} = 409422.352$

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

$$V_{CoI0} = 409422.352$$

$k_{nl} = 1$ (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)

$f'_c = 20.00$, but $f'_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$$M/Vd = 2.00$$

$$\mu_u = 2.8180236E-013$$

$$\mu_v = 1.3558547E-031$$

$$d = 0.8 \cdot h = 400.00$$

$$N_u = 4666.932$$

$$A_g = 125000.00$$

From (11.5.4.8), ACI 318-14: $V_s = 164264.64$

$$A_v = 157079.633$$

$$f_y = 444.44$$

$$s = 170.00$$

V_s is multiplied by $Col = 1.00$

$$s/d = 0.425$$

$$V_f ((11-3)-(11.4), ACI 440) = 240803.347$$

$f = 0.95$, for fully-wrapped sections

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

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

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

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

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

total thickness per orientation, $tf1 = NL \cdot t / NoDir = 1.016$
 $dfv = d$ (figure 11.2, ACI 440) = 457.00
 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: $Vs + Vf \leq 297085.704$
 $bw = 250.00$

Calculation of Shear Strength at edge 2, $Vr2 = 409422.352$
 $Vr2 = VCol$ ((10.3), ASCE 41-17) = $knl \cdot VColO$
 $VColO = 409422.352$
 $knl = 1$ (zero step-static loading)

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

$= 1$ (normal-weight concrete)
 $fc' = 20.00$, but $fc^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $M/Vd = 2.00$
 $Mu = 2.8180236E-013$
 $Vu = 1.3558547E-031$
 $d = 0.8 \cdot h = 400.00$
 $Nu = 4666.932$
 $Ag = 125000.00$
 From (11.5.4.8), ACI 318-14: $Vs = 164264.64$
 $Av = 157079.633$
 $fy = 444.44$
 $s = 170.00$
 Vs is multiplied by $Col = 1.00$
 $s/d = 0.425$
 Vf ((11-3)-(11.4), ACI 440) = 240803.347
 $f = 0.95$, for fully-wrapped sections
 $wf/sf = 1$ (FRP strips adjacent to one another).
 In (11.3) $\sin + \cos$ is replaced with $(\cot + \cot a) \sin a$ which is more a generalised expression,
 where a is the angle of the crack direction (see KANEPE).
 This later relation, considered as a function $Vf(,)$, is implemented for every different fiber orientation ai ,
 as well as for 2 crack directions, $= 45^\circ$ and $= -45^\circ$ to take into consideration the cyclic seismic loading.
 orientation 1: $1 = b1 + 90^\circ = 90.00$
 $Vf = \text{Min}(|Vf(45, 1)|, |Vf(-45, a1)|)$, with:
 total thickness per orientation, $tf1 = NL \cdot t / NoDir = 1.016$
 $dfv = d$ (figure 11.2, ACI 440) = 457.00
 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: $Vs + Vf \leq 297085.704$
 $bw = 250.00$

End Of Calculation of Shear Capacity ratio for element: column C1 of floor 1
 At local axis: 2

Start Of Calculation of Chord Rotation Capacity for element: column C1 of floor 1
 At local axis: 3
 Integration Section: (b)
 Section Type: rcrs

Constant Properties

Knowledge Factor, $= 1.00$
 Chord Rotation is generally considered as Deformation-Controlled Action according to Table C7-1, ASCE41-17.
 Mean strengths are used for Deformation-Controlled Actions according to 7.5.1.3, ASCE 41-17

Consequently:

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

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

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

Section Height, $H = 250.00$

Section Width, $W = 500.00$

Cover Thickness, $c = 25.00$

Element Length, $L = 3000.00$

Primary Member

Ribbed Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

Lap Length $l_b = 300.00$

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $ε_{fu} = 0.01$

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

Fiber orientations, $bi = 0.00^\circ$

Number of layers, $N_L = 1$

Radius of rounding corners, $R = 40.00$

Stepwise Properties

Bending Moment, $M = 76808.128$

Shear Force, $V_2 = 3085.676$

Shear Force, $V_3 = 2.2952864E-013$

Axial Force, $F = -4810.556$

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: $As_{c,com} = 829.3805$

-Middle: $As_{mid} = 402.1239$

Mean Diameter of Tension Reinforcement, $Db_L = 18.66667$

Existing component: From table 7-7, ASCE 41_17: Final chord rotation Capacity $u_{R} = u = 0.00069628$

$u = y + p = 0.00069628$

- Calculation of y -

$y = (M_y * L_s / 3) / E_{eff} = 0.00069628$ ((4.29), Biskinis Phd))

$M_y = 1.1434E+008$

$L_s = M/V$ (with $L_s > 0.1 * L$ and $L_s < 2 * L$) = 300.00

From table 10.5, ASCE 41_17: $E_{eff} = factor * E_c * I_g = 1.6421E+013$

factor = 0.30

$A_g = 125000.00$

$f_c' = 20.00$

$N = 4810.556$

$E_c * I_g = 5.4737E+013$

Calculation of Yielding Moment M_y

Calculation of y and M_y according to Annex 7 -

```

y = Min( y_ten, y_com)
y_ten = 4.5287315E-006
with ((10.1), ASCE 41-17) fy = Min(fy, 1.25*fy*(lb/d)^ 2/3) = 291.1836
d = 457.00
y = 0.29653227
A = 0.01818298
B = 0.01001242
with pt = 0.00725935
pc = 0.00725935
pv = 0.00351968
N = 4810.556
b = 250.00
" = 0.0940919
y_comp = 1.2979423E-005
with fc* (12.3, (ACI 440)) = 20.44585
fc = 20.00
fl = 0.9425867
b = 250.00
h = 500.00
Ag = 125000.00
From (12.9), ACI 440: ka = 0.15087868
g = pt + pc + pv = 0.01803838
rc = 40.00
Ae/Ac = 0.60351471
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 = 21019.039
y = 0.29518426
A = 0.01791814
B = 0.00986782
with Es = 200000.00

```

Calculation of ratio lb/d

```

Lap Length: ld/d,min = 0.37945973
lb = 300.00
ld = 790.5977
Calculation of l according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
= 1
db = 18.00
Mean strength value of all re-bars: fy = 444.44
fc' = 20.00, but fc^0.5 <= 8.3 MPa (22.5.3.1, ACI 318-14)
t = 1.00
s = 0.80
e = 1.00
cb = 25.00
Ktr = 4.61999
Atr = Min(Atr_x,Atr_y) = 157.0796
where Atr_x, Atr_y are the sum of the area of all stirrup legs along X and Y loxal axis
s = 170.00
n = 8.00

```

- Calculation of p -

```

From table 10-8: p = 0.00
with:
- Columns not controlled by inadequate development or splicing along the clear height because lb/d >= 1
shear control ratio VyE/VColOE = 0.23676754
d = 457.00
s = 0.00
t = Av/(bw*s) + 2*tf/bw*(ffe/fs) = 0.00

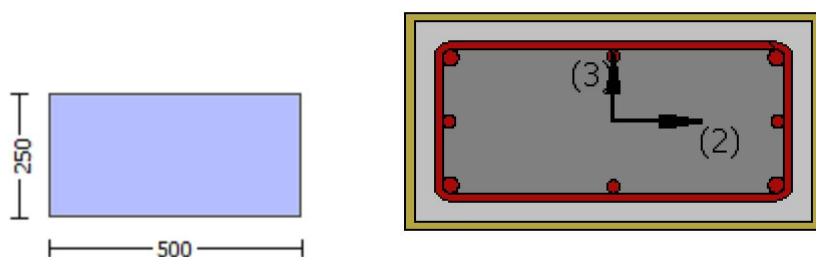
```

$A_v = 157.0796$, is the total area of all stirrups parallel to loading (shear) direction
 $b_w = 250.00$
 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.
 $N_{UD} = 4810.556$
 $A_g = 125000.00$
 $f_{cE} = 20.00$
 $f_{ytE} = f_{ylE} = 0.00$
 $\rho_l = \text{Area_Tot_Long_Rein} / (b \cdot d) = 0.01803838$
 $b = 250.00$
 $d = 457.00$
 $f_{cE} = 20.00$

 End Of Calculation of Chord Rotation Capacity for element: column C1 of floor 1
 At local axis: 3
 Integration Section: (b)

Calculation No. 9

column C1, Floor 1
 Limit State: Collapse Prevention (data interpolation between analysis steps 1 and 2)
 Analysis: Uniform +X
 Check: Shear capacity V_{Rd}
 Edge: Start
 Local Axis: (2)



Start Of Calculation of Shear Capacity for element: column C1 of floor 1
 At local axis: 2
 Integration Section: (a)
 Section Type: rcrs

Constant Properties

 Knowledge Factor, $= 1.00$

Member Shear Force is generally considered as Force-Controlled Action according to Table C7-1, ASCE41-17.
 Lower-bound strengths are used for Force-Controlled Actions according to 7.5.1.3, ASCE 41-17
 Consequently:
 Existing material of Primary Member: Concrete Strength, $f_c = f_{c_lower_bound} = 16.00$
 Existing material of Primary Member: Steel Strength, $f_s = f_{s_lower_bound} = 400.00$
 Concrete Elasticity, $E_c = 21019.039$
 Steel Elasticity, $E_s = 200000.00$
 #####
 Note: Especially for the calculation of μ_y for displacement ductility demand,
 the expected (mean value) strengths are used (7.5.1.3, ASCE41-17) because bending is considered as
 Deformation-Controlled Action (Table C7-1, ASCE41-17).
 Existing material: Concrete Strength, $f_c = f_{cm} = 20.00$
 Existing material: Steel Strength, $f_s = f_{sm} = 444.44$
 #####
 Section Height, $H = 250.00$
 Section Width, $W = 500.00$
 Cover Thickness, $c = 25.00$
 Element Length, $L = 3000.00$
 Primary Member
 Ribbed Bars
 Ductile Steel
 Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
 Longitudinal Bars With Ends Lapped Starting at the End Sections
 Lap Length $l_o = l_b = 300.00$
 FRP Wrapping Data
 Type: Carbon
 Cured laminate properties (design values)
 Thickness, $t = 1.016$
 Tensile Strength, $f_{fu} = 1055.00$
 Tensile Modulus, $E_f = 64828.00$
 Elongation, $\epsilon_{fu} = 0.01$
 Number of directions, $NoDir = 1$
 Fiber orientations, $b_i: 0.00^\circ$
 Number of layers, $NL = 1$
 Radius of rounding corners, $R = 40.00$

Stepwise Properties

EDGE -A-
 Bending Moment, $M_a = -1.4246E+007$
 Shear Force, $V_a = -4708.27$
 EDGE -B-
 Bending Moment, $M_b = 117197.472$
 Shear Force, $V_b = 4708.27$
 BOTH EDGES
 Axial Force, $F = -4886.081$
 Longitudinal Reinforcement Area Distribution (in 2 divisions)
 -Tension: $As_{lt} = 1231.504$
 -Compression: $As_{lc} = 829.3805$
 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, $Db_{L,ten} = 18.66667$

Existing component: From table 7-7, ASCE 41_17: Final Shear Capacity $V_R = \phi V_n = 316030.554$
 $V_n ((10.3), ASCE 41-17) = knl * V_{CoI} = 316030.554$
 $V_{CoI} = 316030.554$
 $knl = 1.00$
 $displacement_ductility_demand = 0.03495173$

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).

$\lambda = 1$ (normal-weight concrete)
 $f'_c = 16.00$, but $f'_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $M/Vd = 4.00$
 $\mu_u = 1.4246E+007$
 $V_u = 4708.27$
 $d = 0.8 \cdot h = 400.00$
 $N_u = 4886.081$
 $A_g = 125000.00$
 From (11.5.4.8), ACI 318-14: $V_s = 147839.654$
 $A_v = 157079.633$
 $f_y = 400.00$
 $s = 170.00$
 V_s is multiplied by $\text{Col} = 1.00$
 $s/d = 0.425$
 $V_f ((11-3)-(11.4), \text{ACI 440}) = 240803.347$
 $f = 0.95$, for fully-wrapped sections
 $w_f/s_f = 1$ (FRP strips adjacent to one another).
 In (11.3) $\sin + \cos$ is replaced with $(\cot + \cot a) \sin a$ which is more a generalised expression,
 where a is the angle of the crack direction (see KANEPE).
 This later relation, considered as a function $V_f(\theta)$, is implemented for every different fiber orientation a_i ,
 as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.
 orientation 1: $\theta = b_1 + 90^\circ = 90.00$
 $V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, a_1)|)$, with:
 total thickness per orientation, $t_{f1} = N_L \cdot t / N_{\text{Dir}} = 1.016$
 $d_{fv} = d$ (figure 11.2, ACI 440) = 457.00
 $f_{fe} ((11-5), \text{ACI 440}) = 259.312$
 $E_f = 64828.00$
 $f_e = 0.004$, from (11.6a), ACI 440
 with $f_u = 0.01$
 From (11-11), ACI 440: $V_s + V_f \leq 265721.532$
 $b_w = 250.00$

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 $\theta = 0.00024547$
 $y = (M_y \cdot L_s / 3) / E_{\text{eff}} = 0.00702323$ ((4.29), Biskinis Phd))
 $M_y = 1.1435E+008$
 $L_s = M/V$ (with $L_s > 0.1 \cdot L$ and $L_s < 2 \cdot L$) = 3025.674
 From table 10.5, ASCE 41_17: $E_{\text{eff}} = \text{factor} \cdot E_c \cdot I_g = 1.6421E+013$
 factor = 0.30
 $A_g = 125000.00$
 $f'_c = 20.00$
 $N = 4886.081$
 $E_c \cdot I_g = 5.4737E+013$

Calculation of Yielding Moment M_y

Calculation of δ and M_y according to Annex 7 -

$y = \text{Min}(y_{\text{ten}}, y_{\text{com}})$
 $y_{\text{ten}} = 4.5289398E-006$
 with ((10.1), ASCE 41-17) $f_y = \text{Min}(f_y, 1.25 \cdot f_y \cdot (I_b / I_d)^{2/3}) = 291.1836$
 $d = 457.00$
 $y = 0.29656463$
 $A = 0.01818525$
 $B = 0.01001469$
 with $p_t = 0.00725935$
 $p_c = 0.00725935$
 $p_v = 0.00351968$

$N = 4886.081$
 $b = 250.00$
 $" = 0.0940919$
 $y_{comp} = 1.2978922E-005$
 with $f_c^* (12.3, (ACI 440)) = 20.44585$
 $f_c = 20.00$
 $f_l = 0.9425867$
 $b = 250.00$
 $h = 500.00$
 $A_g = 125000.00$
 From (12.9), ACI 440: $k_a = 0.15087868$
 $g = p_t + p_c + p_v = 0.01803838$
 $r_c = 40.00$
 $A_e/A_c = 0.60351471$
 Effective FRP thickness, $t_f = NL * t * \cos(b_1) = 1.016$
 effective strain from (12.5) and (12.12), $\epsilon_{fe} = 0.004$
 $f_u = 0.01$
 $E_f = 64828.00$
 $E_c = 21019.039$
 $y = 0.29519565$
 $A = 0.01791625$
 $B = 0.00986782$
 with $E_s = 200000.00$

Calculation of ratio l_b/l_d

Lap Length: $l_d/l_{d,min} = 0.37945973$

$l_b = 300.00$

$l_d = 790.5977$

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

$d_b = 18.00$

Mean strength value of all re-bars: $f_y = 444.44$

$f_c' = 20.00$, but $f_c^{0.5} \leq 8.3 \text{ MPa}$ (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$c_b = 25.00$

$K_{tr} = 4.61999$

$A_{tr} = \min(A_{tr_x}, A_{tr_y}) = 157.0796$

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

$s = 170.00$

$n = 8.00$

End Of Calculation of Shear Capacity for element: column C1 of floor 1

At local axis: 2

Integration Section: (a)

Calculation No. 10

column C1, Floor 1

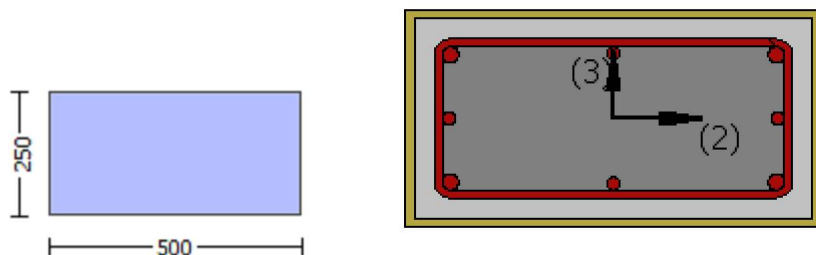
Limit State: Collapse Prevention (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity (ϕ)

Edge: Start

Local Axis: (2)



Start Of Calculation of Shear Capacity ratio for element: column C1 of floor 1

At Shear local axis: 3

(Bending local axis: 2)

Section Type: rcrs

Constant Properties

Knowledge Factor, $\gamma = 1.00$

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

Consequently:

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

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

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

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

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

#####

Section Height, $H = 250.00$

Section Width, $W = 500.00$

Cover Thickness, $c = 25.00$

Mean Confinement Factor overall section = 1.13916

Element Length, $L = 3000.00$

Primary Member

Ribbed Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

Lap Length $l_o = 300.00$

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $\epsilon_{fu} = 0.01$

Number of directions, $NoDir = 1$

Fiber orientations, $bi: 0.00^\circ$

Number of layers, NL = 1
Radius of rounding corners, R = 40.00

Stepwise Properties

At local axis: 3
EDGE -A-
Shear Force, Va = 2.9007121E-031
EDGE -B-
Shear Force, Vb = -2.9007121E-031
BOTH EDGES
Axial Force, F = -4666.932
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: Aslt = 0.00
-Compression: Aslc = 2060.885
Longitudinal Reinforcement Area Distribution (in 3 divisions)
-Tension: Asl,ten = 829.3805
-Compression: Asl,com = 829.3805
-Middle: Asl,mid = 402.1239

Calculation of Shear Capacity ratio , $V_e/V_r = 0.15063296$
Member Controlled by Flexure ($V_e/V_r < 1$)
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 39953.171$
with
 $M_{pr1} = \text{Max}(\mu_{1+}, \mu_{1-}) = 5.9930\text{E}+007$
 $\mu_{1+} = 5.9930\text{E}+007$, 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
 $\mu_{1-} = 5.9930\text{E}+007$, 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
 $M_{pr2} = \text{Max}(\mu_{2+}, \mu_{2-}) = 5.9930\text{E}+007$
 $\mu_{2+} = 5.9930\text{E}+007$, 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
 $\mu_{2-} = 5.9930\text{E}+007$, 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:
 $\mu = 3.4011160\text{E}-005$
 $\mu_u = 5.9930\text{E}+007$

with full section properties:

b = 500.00
d = 207.00
d' = 43.00
 $\nu = 0.00225456$
N = 4666.932

$f_c = 20.00$

α_0 (5A.5, TBDY) = 0.002

Final value of μ_u : $\mu_u^* = \text{shear_factor} * \text{Max}(\mu_u, \mu_c) = 0.01464474$

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

From (5.4b), TBDY: $\mu_u = 0.01464474$

μ_{we} ((5.4c), TBDY) = $\alpha_{se} * \text{sh}_{\min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.07762821$

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

$f_x = 0.07705054$

$\alpha_f = 0.45253333$

b = 500.00

h = 250.00

From EC8 A.4.4.3(6), $\rho_f = 2t_f/bw = 0.004064$

bw = 500.00
effective stress from (A.35), $f_{f,e} = 837.9178$

fy = 0.12936483
af = 0.45253333
b = 250.00
h = 500.00
From EC8 A.4.4.3(6), $p_f = 2t_f/bw = 0.008128$
bw = 250.00
effective stress from (A.35), $f_{f,e} = 703.4155$

R = 40.00
Effective FRP thickness, $t_f = NL \cdot t \cdot \cos(b_1) = 1.016$
 $f_{u,f} = 1055.00$
 $E_f = 64828.00$
 $u_f = 0.015$
 $a_{se}((5.4d), TBDY) = 0.03751166$
bo = 440.00
ho = 190.00
bi2 = 459400.00

psh,min = Min(psh,x , psh,y) = 0.001848

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

psh,x (5.4d) = 0.001848
Ash = Astir*ns = 78.53982
No stirrups, ns = 2.00
bk = 500.00

psh,y (5.4d) = 0.00369599
Ash = Astir*ns = 78.53982
No stirrups, ns = 2.00
bk = 250.00

s = 170.00
fywe = 555.55
fce = 20.00

From ((5.A5), TBDY), TBDY: cc = 0.00339158
c = confinement factor = 1.13916

y1 = 0.00130695
sh1 = 0.00451687
ft1 = 376.4017
fy1 = 313.6681
su1 = 0.005257

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779

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 $fs_1 = f_s/1.2$, 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, ASCE41-17.

with $fs_1 = f_s = 313.6681$

with $Es_1 = E_s = 200000.00$

y2 = 0.00130695
sh2 = 0.00451687
ft2 = 376.4017
fy2 = 313.6681
su2 = 0.005257

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779

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

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

For calculation of esu2_nominal and y2, sh2,ft2,fy2, it is considered

characteristic value $f_{sy2} = f_{s2}/1.2$, from table 5.1, TBDY.
 $y1, sh1, ft1, fy1$, are also multiplied by $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.
 with $f_{s2} = f_s = 313.6681$
 with $E_{s2} = E_s = 200000.00$
 $y_v = 0.00130695$
 $sh_v = 0.00451687$
 $ft_v = 376.4017$
 $fy_v = 313.6681$
 $suv = 0.005257$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $l_o/l_{ou,min} = l_b/l_d = 0.30356779$
 $suv = 0.4 \cdot esuv_{nominal} ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $esuv_{nominal} = 0.08$,
 considering characteristic value $f_{syv} = f_{sv}/1.2$, from table 5.1, TBDY
 For calculation of $esuv_{nominal}$ and y_v, sh_v, ft_v, fy_v , it is considered
 characteristic value $f_{syv} = f_{sv}/1.2$, from table 5.1, TBDY.
 $y1, sh1, ft1, fy1$, are also multiplied by $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.
 with $f_{sv} = f_s = 313.6681$
 with $E_{sv} = E_s = 200000.00$
 $1 = A_{sl,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.1256764$
 $2 = A_{sl,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.1256764$
 $v = A_{sl,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.06093401$
 and confined core properties:
 $b = 440.00$
 $d = 177.00$
 $d' = 13.00$
 $f_{cc} (5A.2, TBDY) = 22.78316$
 $cc (5A.5, TBDY) = 0.00339158$
 $c = \text{confinement factor} = 1.13916$
 $1 = A_{sl,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.16701987$
 $2 = A_{sl,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.16701987$
 $v = A_{sl,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.08097933$
 Case/Assumption: Unconfined full section - Steel rupture
 ' satisfies Eq. (4.3)
 --->
 $v < v_{s,y2}$ - LHS eq.(4.5) is satisfied
 --->
 $su (4.9) = 0.25329952$
 $Mu = MR_c (4.14) = 5.9930E+007$
 $u = su (4.1) = 3.4011160E-005$

Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.30356779$
 $l_b = 300.00$
 $l_d = 988.2471$
 Calculation of $l_{b,min}$ according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
 $= 1$
 $db = 18.00$
 Mean strength value of all re-bars: $f_y = 555.55$
 $f_c' = 20.00$, but $f_c'^{0.5} \leq 8.3 \text{ MPa}$ (22.5.3.1, ACI 318-14)
 $t = 1.00$
 $s = 0.80$
 $e = 1.00$
 $cb = 25.00$
 $K_{tr} = 4.61999$
 $A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$
 where A_{tr_x}, A_{tr_y} are the sum of the area of all stirrup legs along X and Y loxal axis
 $s = 170.00$
 $n = 8.00$

Calculation of $Mu1$ -

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

$$\phi_u = 3.4011160E-005$$

$$M_u = 5.9930E+007$$

with full section properties:

$$b = 500.00$$

$$d = 207.00$$

$$d' = 43.00$$

$$v = 0.00225456$$

$$N = 4666.932$$

$$f_c = 20.00$$

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

$$\text{Final value of } \phi_{cu}: \phi_{cu}^* = \text{shear_factor} * \text{Max}(\phi_{cu}, \phi_{cc}) = 0.01464474$$

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

$$\text{From (5.4b), TBDY: } \phi_{cu} = 0.01464474$$

$$\phi_{we} ((5.4c), TBDY) = a_{se} * \phi_{sh, \min} * f_{ywe} / f_{ce} + \text{Min}(\phi_{fx}, \phi_{fy}) = 0.07762821$$

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

$$\phi_{fx} = 0.07705054$$

$$a_f = 0.45253333$$

$$b = 500.00$$

$$h = 250.00$$

$$\text{From EC8 A.4.4.3(6), } \phi_f = 2t_f/bw = 0.004064$$

$$bw = 500.00$$

$$\text{effective stress from (A.35), } f_{fe} = 837.9178$$

$$\phi_{fy} = 0.12936483$$

$$a_f = 0.45253333$$

$$b = 250.00$$

$$h = 500.00$$

$$\text{From EC8 A.4.4.3(6), } \phi_f = 2t_f/bw = 0.008128$$

$$bw = 250.00$$

$$\text{effective stress from (A.35), } f_{fe} = 703.4155$$

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u_{f,f} = 0.015$$

$$a_{se} ((5.4d), TBDY) = 0.03751166$$

$$b_o = 440.00$$

$$h_o = 190.00$$

$$b_{i2} = 459400.00$$

$$\phi_{sh, \min} = \text{Min}(\phi_{sh,x}, \phi_{sh,y}) = 0.001848$$

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

$$\phi_{sh,x} (5.4d) = 0.001848$$

$$A_{sh} = A_{stir} * n_s = 78.53982$$

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

$$b_k = 500.00$$

$$\phi_{sh,y} (5.4d) = 0.00369599$$

$$A_{sh} = A_{stir} * n_s = 78.53982$$

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

$$b_k = 250.00$$

$$s = 170.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 20.00$$

$$\text{From ((5.A5), TBDY), TBDY: } \phi_{cc} = 0.00339158$$

$$c = \text{confinement factor} = 1.13916$$

$$y_1 = 0.00130695$$

$$sh_1 = 0.00451687$$

```

ft1 = 376.4017
fy1 = 313.6681
su1 = 0.005257
    using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779
    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, ASCE41-17.
    with fs1 = fs = 313.6681
    with Es1 = Es = 200000.00
y2 = 0.00130695
sh2 = 0.00451687
ft2 = 376.4017
fy2 = 313.6681
su2 = 0.005257
    using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779
    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, ASCE41-17.
    with fs2 = fs = 313.6681
    with Es2 = Es = 200000.00
yv = 0.00130695
shv = 0.00451687
ftv = 376.4017
fyv = 313.6681
suv = 0.005257
    using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779
    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,min)^ 2/3), from 10.3.5, ASCE41-17.
    with fsv = fs = 313.6681
    with Esv = Es = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.1256764
2 = Asl,com/(b*d)*(fs2/fc) = 0.1256764
v = Asl,mid/(b*d)*(fsv/fc) = 0.06093401
and confined core properties:
b = 440.00
d = 177.00
d' = 13.00
fcc (5A.2, TBDY) = 22.78316
cc (5A.5, TBDY) = 0.00339158
    c = confinement factor = 1.13916
    1 = Asl,ten/(b*d)*(fs1/fc) = 0.16701987
    2 = Asl,com/(b*d)*(fs2/fc) = 0.16701987
    v = Asl,mid/(b*d)*(fsv/fc) = 0.08097933
Case/Assumption: Unconfined full section - Steel rupture
' satisfies Eq. (4.3)
--->
v < vs,y2 - LHS eq.(4.5) is satisfied
--->
su (4.9) = 0.25329952
Mu = MRc (4.14) = 5.9930E+007

```

$$u = s_u(4.1) = 3.4011160E-005$$

Calculation of ratio l_b/d

Lap Length: $l_b/d = 0.30356779$

$$l_b = 300.00$$

$$d = 988.2471$$

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

$$= 1$$

$$d_b = 18.00$$

$$\text{Mean strength value of all re-bars: } f_y = 555.55$$

$$f'_c = 20.00, \text{ but } f_c^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 25.00$$

$$K_{tr} = 4.61999$$

$$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$$

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

$$s = 170.00$$

$$n = 8.00$$

Calculation of μ_{2+}

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

$$u = 3.4011160E-005$$

$$\mu = 5.9930E+007$$

with full section properties:

$$b = 500.00$$

$$d = 207.00$$

$$d' = 43.00$$

$$v = 0.00225456$$

$$N = 4666.932$$

$$f'_c = 20.00$$

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

$$\text{Final value of } \mu: \mu^* = \text{shear_factor} * \text{Max}(\mu, c_o) = 0.01464474$$

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

$$\text{From (5.4b), TB DY: } \mu = 0.01464474$$

$$\mu_e((5.4c), \text{TB DY}) = a_s e * s_{h, \min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.07762821$$

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

$$f_x = 0.07705054$$

$$a_f = 0.45253333$$

$$b = 500.00$$

$$h = 250.00$$

$$\text{From EC8 A4.4.3(6), } p_f = 2t_f/bw = 0.004064$$

$$bw = 500.00$$

$$\text{effective stress from (A.35), } f_{fe} = 837.9178$$

$$f_y = 0.12936483$$

$$a_f = 0.45253333$$

$$b = 250.00$$

$$h = 500.00$$

$$\text{From EC8 A4.4.3(6), } p_f = 2t_f/bw = 0.008128$$

$$bw = 250.00$$

$$\text{effective stress from (A.35), } f_{fe} = 703.4155$$

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$u, f = 0.015$
 $ase((5.4d), TBDY) = 0.03751166$
 $bo = 440.00$
 $ho = 190.00$
 $bi2 = 459400.00$
 $psh, min = \text{Min}(psh, x, psh, y) = 0.001848$
 Expression $((5.4d), TBDY)$ for psh, min has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$psh, x(5.4d) = 0.001848$
 $Ash = Astir * ns = 78.53982$
 No stirrups, $ns = 2.00$
 $bk = 500.00$

$psh, y(5.4d) = 0.00369599$
 $Ash = Astir * ns = 78.53982$
 No stirrups, $ns = 2.00$
 $bk = 250.00$

$s = 170.00$
 $fyw = 555.55$
 $fce = 20.00$
 From $((5.4d), TBDY)$, $TBDY$: $cc = 0.00339158$
 $c = \text{confinement factor} = 1.13916$
 $y1 = 0.00130695$
 $sh1 = 0.00451687$
 $ft1 = 376.4017$
 $fy1 = 313.6681$
 $su1 = 0.005257$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00
 $lo/lou, min = lb/ld = 0.30356779$
 $su1 = 0.4 * esu1_{nominal}((5.5), TBDY) = 0.032$
 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, ASCE41-17.
 with $fs1 = fs = 313.6681$
 with $Es1 = Es = 200000.00$
 $y2 = 0.00130695$
 $sh2 = 0.00451687$
 $ft2 = 376.4017$
 $fy2 = 313.6681$
 $su2 = 0.005257$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00
 $lo/lou, min = lb/lb, min = 0.30356779$
 $su2 = 0.4 * esu2_{nominal}((5.5), TBDY) = 0.032$
 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, ASCE41-17.
 with $fs2 = fs = 313.6681$
 with $Es2 = Es = 200000.00$
 $yv = 0.00130695$
 $shv = 0.00451687$
 $ftv = 376.4017$
 $fyv = 313.6681$
 $suv = 0.005257$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00
 $lo/lou, min = lb/ld = 0.30356779$
 $suv = 0.4 * esuv_{nominal}((5.5), TBDY) = 0.032$
 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, ASCE41-17.

with $f_{sv} = f_s = 313.6681$

with $E_{sv} = E_s = 200000.00$

$1 = A_{sl,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.1256764$

$2 = A_{sl,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.1256764$

$v = A_{sl,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.06093401$

and confined core properties:

$b = 440.00$

$d = 177.00$

$d' = 13.00$

f_{cc} (5A.2, TBDY) = 22.78316

cc (5A.5, TBDY) = 0.00339158

c = confinement factor = 1.13916

$1 = A_{sl,ten}/(b \cdot d) \cdot (f_{s1}/f_c) = 0.16701987$

$2 = A_{sl,com}/(b \cdot d) \cdot (f_{s2}/f_c) = 0.16701987$

$v = A_{sl,mid}/(b \cdot d) \cdot (f_{sv}/f_c) = 0.08097933$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

su (4.9) = 0.25329952

$Mu = MR_c$ (4.14) = 5.9930E+007

$u = su$ (4.1) = 3.4011160E-005

Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.30356779$

$l_b = 300.00$

$l_d = 988.2471$

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

= 1

$db = 18.00$

Mean strength value of all re-bars: $f_y = 555.55$

$f_c' = 20.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 4.61999$

$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$

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

$s = 170.00$

$n = 8.00$

Calculation of Mu_2 -

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

$u = 3.4011160E-005$

$Mu = 5.9930E+007$

with full section properties:

$b = 500.00$

$d = 207.00$

$d' = 43.00$

$v = 0.00225456$

$N = 4666.932$

$f_c = 20.00$

co (5A.5, TBDY) = 0.002

Final value of cu : $\text{cu}^* = \text{shear_factor} * \text{Max}(\text{cu}, \text{cc}) = 0.01464474$
The Shear_factor is considered equal to 1 (pure moment strength)
From (5.4b), TBDY: $\text{cu} = 0.01464474$
we ((5.4c), TBDY) $= \text{ase} * \text{sh}_{\min} * \text{fy}_{\text{we}} / \text{f}_{\text{ce}} + \text{Min}(\text{fx}, \text{fy}) = 0.07762821$
where $\text{f} = \text{af} * \text{pf} * \text{ffe} / \text{f}_{\text{ce}}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$\text{fx} = 0.07705054$
 $\text{af} = 0.45253333$
 $\text{b} = 500.00$
 $\text{h} = 250.00$
From EC8 A4.4.3(6), $\text{pf} = 2\text{tf}/\text{bw} = 0.004064$
 $\text{bw} = 500.00$
effective stress from (A.35), $\text{ff}_{\text{e}} = 837.9178$

$\text{fy} = 0.12936483$
 $\text{af} = 0.45253333$
 $\text{b} = 250.00$
 $\text{h} = 500.00$
From EC8 A4.4.3(6), $\text{pf} = 2\text{tf}/\text{bw} = 0.008128$
 $\text{bw} = 250.00$
effective stress from (A.35), $\text{ff}_{\text{e}} = 703.4155$

$\text{R} = 40.00$
Effective FRP thickness, $\text{tf} = \text{NL} * \text{t} * \text{Cos}(\text{b1}) = 1.016$
 $\text{fu}, \text{f} = 1055.00$
 $\text{Ef} = 64828.00$
 $\text{u}, \text{f} = 0.015$
 $\text{ase} ((5.4\text{d}), \text{TBDY}) = 0.03751166$
 $\text{bo} = 440.00$
 $\text{ho} = 190.00$
 $\text{bi2} = 459400.00$
 $\text{psh}_{\min} = \text{Min}(\text{psh}, \text{x}, \text{psh}, \text{y}) = 0.001848$
Expression ((5.4d), TBDY) for psh_{\min} has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$\text{psh}, \text{x} ((5.4\text{d})) = 0.001848$
 $\text{Ash} = \text{Astir} * \text{ns} = 78.53982$
No stirrups, $\text{ns} = 2.00$
 $\text{bk} = 500.00$

$\text{psh}, \text{y} ((5.4\text{d})) = 0.00369599$
 $\text{Ash} = \text{Astir} * \text{ns} = 78.53982$
No stirrups, $\text{ns} = 2.00$
 $\text{bk} = 250.00$

$\text{s} = 170.00$
 $\text{fy}_{\text{we}} = 555.55$
 $\text{f}_{\text{ce}} = 20.00$
From ((5.A5), TBDY), TBDY: $\text{cc} = 0.00339158$
 $\text{c} = \text{confinement factor} = 1.13916$
 $\text{y1} = 0.00130695$
 $\text{sh1} = 0.00451687$
 $\text{ft1} = 376.4017$
 $\text{fy1} = 313.6681$
 $\text{su1} = 0.005257$
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
 $\text{lo}/\text{lou}, \text{min} = \text{lb}/\text{ld} = 0.30356779$
 $\text{su1} = 0.4 * \text{esu1}_{\text{nominal}} ((5.5), \text{TBDY}) = 0.032$
From table 5A.1, TBDY: $\text{esu1}_{\text{nominal}} = 0.08$,
For calculation of $\text{esu1}_{\text{nominal}}$ and y1 , sh1 , ft1 , fy1 , it is considered
characteristic value $\text{fsy1} = \text{fs1}/1.2$, from table 5.1, TBDY.
 y1 , sh1 , ft1 , fy1 , are also multiplied by $\text{Min}(1, 1.25 * (\text{lb}/\text{ld})^{2/3})$, from 10.3.5, ASCE41-17.
with $\text{fs1} = \text{fs} = 313.6681$
with $\text{Es1} = \text{Es} = 200000.00$
 $\text{y2} = 0.00130695$

```

sh2 = 0.00451687
ft2 = 376.4017
fy2 = 313.6681
su2 = 0.005257
    using (30) in Biskinis/Fardis (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 = 0.30356779
    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, ASCE41-17.
    with fs2 = fs = 313.6681
    with Es2 = Es = 200000.00
yv = 0.00130695
shv = 0.00451687
ftv = 376.4017
fyv = 313.6681
suv = 0.005257
    using (30) in Biskinis/Fardis (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 = 0.30356779
    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, ASCE41-17.
    with fsv = fs = 313.6681
    with Esv = Es = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.1256764
2 = Asl,com/(b*d)*(fs2/fc) = 0.1256764
v = Asl,mid/(b*d)*(fsv/fc) = 0.06093401
and confined core properties:
b = 440.00
d = 177.00
d' = 13.00
fcc (5A.2, TBDY) = 22.78316
cc (5A.5, TBDY) = 0.00339158
c = confinement factor = 1.13916
1 = Asl,ten/(b*d)*(fs1/fc) = 0.16701987
2 = Asl,com/(b*d)*(fs2/fc) = 0.16701987
v = Asl,mid/(b*d)*(fsv/fc) = 0.08097933
Case/Assumption: Unconfined full section - Steel rupture
' satisfies Eq. (4.3)
--->
v < vs,y2 - LHS eq.(4.5) is satisfied
--->
su (4.9) = 0.25329952
Mu = MRc (4.14) = 5.9930E+007
u = su (4.1) = 3.4011160E-005

```

Calculation of ratio lb/ld

```

Lap Length: lb/ld = 0.30356779
lb = 300.00
ld = 988.2471
Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
= 1
db = 18.00
Mean strength value of all re-bars: fy = 555.55
fc' = 20.00, but fc^0.5 <= 8.3 MPa (22.5.3.1, ACI 318-14)
t = 1.00
s = 0.80

```

$e = 1.00$
 $cb = 25.00$
 $Ktr = 4.61999$
 $Atr = \text{Min}(Atr_x, Atr_y) = 157.0796$
 where Atr_x, Atr_y are the sum of the area of all stirrup legs along X and Y loxal axis
 $s = 170.00$
 $n = 8.00$

Calculation of Shear Strength $Vr = \text{Min}(Vr1, Vr2) = 265235.248$

Calculation of Shear Strength at edge 1, $Vr1 = 265235.248$

$Vr1 = VCol \text{ ((10.3), ASCE 41-17)} = knl * VCol0$

$VCol0 = 265235.248$

$knl = 1$ (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)

$fc' = 20.00$, but $fc^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$Mu = 2.3992784E-012$

$Vu = 2.9007121E-031$

$d = 0.8 * h = 200.00$

$Nu = 4666.932$

$Ag = 125000.00$

From (11.5.4.8), ACI 318-14: $Vs = 49279.392$

$Av = 157079.633$

$fy = 444.44$

$s = 170.00$

Vs is multiplied by $Col = 0.60$

$s/d = 0.85$

$Vf \text{ ((11-3)-(11.4), ACI 440)} = 109072.851$

$f = 0.95$, for fully-wrapped sections

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

In (11.3) $\sin + \cos$ is replaced with $(\cot + \cot a) \sin a$ which is more a generalised expression,

where a is the angle of the crack direction (see KANEPE).

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

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

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

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

$dfv = d$ (figure 11.2, ACI 440) = 207.00

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

$Ef = 64828.00$

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

with $fu = 0.01$

From (11-11), ACI 440: $Vs + Vf \leq 297085.704$

$bw = 500.00$

Calculation of Shear Strength at edge 2, $Vr2 = 265235.248$

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

$VCol0 = 265235.248$

$knl = 1$ (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)

$fc' = 20.00$, but $fc^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$Mu = 2.3992784E-012$

$Vu = 2.9007121E-031$

$d = 0.8 \cdot h = 200.00$
 $N_u = 4666.932$
 $A_g = 125000.00$
 From (11.5.4.8), ACI 318-14: $V_s = 49279.392$
 $A_v = 157079.633$
 $f_y = 444.44$
 $s = 170.00$
 V_s is multiplied by $\text{Col} = 0.60$
 $s/d = 0.85$
 V_f ((11-3)-(11.4), ACI 440) = 109072.851
 $f = 0.95$, for fully-wrapped sections
 $w_f/s_f = 1$ (FRP strips adjacent to one another).
 In (11.3) $\sin + \cos$ is replaced with $(\cot + \cot a)\sin a$ which is more a generalised expression,
 where a is the angle of the crack direction (see KANEPE).
 This later relation, considered as a function $V_f(\theta, a)$, is implemented for every different fiber orientation a_i ,
 as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.
 orientation 1: $\theta = b1 + 90^\circ = 90.00$
 $V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, a1)|)$, with:
 total thickness per orientation, $t_{f1} = N_L \cdot t / \text{NoDir} = 1.016$
 $d_{fv} = d$ (figure 11.2, ACI 440) = 207.00
 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: $V_s + V_f \leq 297085.704$
 $b_w = 500.00$

 End Of Calculation of Shear Capacity ratio for element: column C1 of floor 1
 At local axis: 3

 Start Of Calculation of Shear Capacity ratio for element: column C1 of floor 1
 At Shear local axis: 2
 (Bending local axis: 3)
 Section Type: rcrcs

Constant Properties

 Knowledge Factor, $\phi = 1.00$
 Mean strength values are used for both shear and moment calculations.
 Consequently:
 Existing material of Primary Member: Concrete Strength, $f_c = f_{cm} = 20.00$
 Existing material of Primary Member: Steel Strength, $f_s = f_{sm} = 444.44$
 Concrete Elasticity, $E_c = 21019.039$
 Steel Elasticity, $E_s = 200000.00$
 #####
 Note: Especially for the calculation of moment strengths,
 the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14
 Existing material: Steel Strength, $f_s = 1.25 \cdot f_{sm} = 555.55$
 #####
 Section Height, $H = 250.00$
 Section Width, $W = 500.00$
 Cover Thickness, $c = 25.00$
 Mean Confinement Factor overall section = 1.13916
 Element Length, $L = 3000.00$
 Primary Member
 Ribbed Bars
 Ductile Steel
 Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
 Longitudinal Bars With Ends Lapped Starting at the End Sections
 Lap Length $l_o = 300.00$
 FRP Wrapping Data
 Type: Carbon
 Cured laminate properties (design values)

Thickness, $t = 1.016$
Tensile Strength, $f_{fu} = 1055.00$
Tensile Modulus, $E_f = 64828.00$
Elongation, $\epsilon_{fu} = 0.01$
Number of directions, $N_{oDir} = 1$
Fiber orientations, $b_i = 0.00^\circ$
Number of layers, $N_L = 1$
Radius of rounding corners, $R = 40.00$

Stepwise Properties

At local axis: 2
EDGE -A-
Shear Force, $V_a = 1.3558547E-031$
EDGE -B-
Shear Force, $V_b = -1.3558547E-031$
BOTH EDGES
Axial Force, $F = -4666.932$
Longitudinal Reinforcement Area Distribution (in 2 divisions)
-Tension: $A_{slt} = 0.00$
-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, $V_e/V_r = 0.23676754$
Member Controlled by Flexure ($V_e/V_r < 1$)
Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 96937.922$
with
 $M_{pr1} = \max(\mu_{u1+}, \mu_{u1-}) = 1.4541E+008$
 $\mu_{u1+} = 1.4541E+008$, 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
 $\mu_{u1-} = 1.4541E+008$, 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
 $M_{pr2} = \max(\mu_{u2+}, \mu_{u2-}) = 1.4541E+008$
 $\mu_{u2+} = 1.4541E+008$, 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
 $\mu_{u2-} = 1.4541E+008$, 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_{u1+}

Calculation of ultimate curvature μ_u according to 4.1, Biskinis/Fardis 2013:
 $\mu_u = 1.4467178E-005$
 $\mu_u = 1.4541E+008$

with full section properties:

$b = 250.00$
 $d = 457.00$
 $d' = 43.00$
 $v = 0.00204242$
 $N = 4666.932$
 $f_c = 20.00$
 ϕ_c (5A.5, TBDY) = 0.002
Final value of ϕ_{cu} : $\phi_{cu} = \text{shear_factor} * \max(\phi_{cu}, \phi_{cc}) = 0.01464474$
The Shear_factor is considered equal to 1 (pure moment strength)
From (5.4b), TBDY: $\phi_{cu} = 0.01464474$
 ϕ_{we} ((5.4c), TBDY) = $a_s e * \phi_{sh,min} * f_{ywe} / f_{ce} + \min(\phi_{fx}, \phi_{fy}) = 0.07762821$
where $f = a_f * p_f * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$f_x = 0.07705054$
 $a_f = 0.45253333$
 $b = 500.00$
 $h = 250.00$
 From EC8 A.4.4.3(6), $p_f = 2t_f/b_w = 0.004064$
 $b_w = 500.00$
 effective stress from (A.35), $f_{f,e} = 837.9178$

$f_y = 0.12936483$
 $a_f = 0.45253333$
 $b = 250.00$
 $h = 500.00$
 From EC8 A.4.4.3(6), $p_f = 2t_f/b_w = 0.008128$
 $b_w = 250.00$
 effective stress from (A.35), $f_{f,e} = 703.4155$

$R = 40.00$
 Effective FRP thickness, $t_f = N_L \cdot t \cdot \cos(b_1) = 1.016$
 $f_{u,f} = 1055.00$
 $E_f = 64828.00$
 $u_{,f} = 0.015$
 $a_{se} ((5.4d), TBDY) = 0.03751166$
 $b_o = 440.00$
 $h_o = 190.00$
 $b_{i2} = 459400.00$
 $p_{sh,min} = \min(p_{sh,x}, p_{sh,y}) = 0.001848$
 Expression ((5.4d), TBDY) for $p_{sh,min}$ has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$p_{sh,x} (5.4d) = 0.001848$
 $A_{sh} = A_{stir} \cdot n_s = 78.53982$
 No stirrups, $n_s = 2.00$
 $b_k = 500.00$

$p_{sh,y} (5.4d) = 0.00369599$
 $A_{sh} = A_{stir} \cdot n_s = 78.53982$
 No stirrups, $n_s = 2.00$
 $b_k = 250.00$

$s = 170.00$
 $f_{ywe} = 555.55$
 $f_{ce} = 20.00$
 From ((5.A5), TBDY), $cc = 0.00339158$
 $c = \text{confinement factor} = 1.13916$
 $y_1 = 0.00130695$
 $sh_1 = 0.00451687$
 $ft_1 = 376.4017$
 $fy_1 = 313.6681$
 $su_1 = 0.005257$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $l_o/l_{ou,min} = l_b/l_d = 0.30356779$
 $su_1 = 0.4 \cdot esu_{1,nominal} ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $esu_{1,nominal} = 0.08$,
 For calculation of $esu_{1,nominal}$ and y_1, sh_1, ft_1, fy_1 , it is considered
 characteristic value $fsy_1 = fs_1/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $\min(1, 1.25 \cdot (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.
 with $fs_1 = fs = 313.6681$
 with $Es_1 = Es = 200000.00$
 $y_2 = 0.00130695$
 $sh_2 = 0.00451687$
 $ft_2 = 376.4017$
 $fy_2 = 313.6681$
 $su_2 = 0.005257$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor

and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $l_o/l_{o,min} = l_b/l_{b,min} = 0.30356779$
 $su_2 = 0.4 * esu_{2,nominal} ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $esu_{2,nominal} = 0.08$,
 For calculation of $esu_{2,nominal}$ and y_2, sh_2, ft_2, fy_2 , it is considered
 characteristic value $fsy_2 = fs_2/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $Min(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.
 with $fs_2 = fs = 313.6681$
 with $Es_2 = Es = 200000.00$
 $y_v = 0.00130695$
 $sh_v = 0.00451687$
 $ft_v = 376.4017$
 $fy_v = 313.6681$
 $suv = 0.005257$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $l_o/l_{o,min} = l_b/l_d = 0.30356779$
 $suv = 0.4 * esuv_{nominal} ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $esuv_{nominal} = 0.08$,
 considering characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY
 For calculation of $esuv_{nominal}$ and y_v, sh_v, ft_v, fy_v , it is considered
 characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $Min(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.
 with $fsv = fs = 313.6681$
 with $Es_v = Es = 200000.00$
 $1 = A_{sl,ten}/(b*d) * (fs_1/f_c) = 0.11385127$
 $2 = A_{sl,com}/(b*d) * (fs_2/f_c) = 0.11385127$
 $v = A_{sl,mid}/(b*d) * (fsv/f_c) = 0.05520062$
 and confined core properties:
 $b = 190.00$
 $d = 427.00$
 $d' = 13.00$
 $f_{cc} (5A.2, TBDY) = 22.78316$
 $cc (5A.5, TBDY) = 0.00339158$
 $c = \text{confinement factor} = 1.13916$
 $1 = A_{sl,ten}/(b*d) * (fs_1/f_c) = 0.1603292$
 $2 = A_{sl,com}/(b*d) * (fs_2/f_c) = 0.1603292$
 $v = A_{sl,mid}/(b*d) * (fsv/f_c) = 0.07773537$
 Case/Assumption: Unconfined full section - Steel rupture
 ' satisfies Eq. (4.3)
 --->
 $v < v_{s,y2}$ - LHS eq.(4.5) is satisfied
 --->
 $su (4.9) = 0.20486988$
 $Mu = MR_c (4.14) = 1.4541E+008$
 $u = su (4.1) = 1.4467178E-005$

Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.30356779$
 $l_b = 300.00$
 $l_d = 988.2471$
 Calculation of $l_{b,min}$ according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
 $= 1$
 $db = 18.00$
 Mean strength value of all re-bars: $fy = 555.55$
 $fc' = 20.00$, but $fc'^{0.5} \leq 8.3 \text{ MPa}$ (22.5.3.1, ACI 318-14)
 $t = 1.00$
 $s = 0.80$
 $e = 1.00$
 $cb = 25.00$
 $K_{tr} = 4.61999$
 $A_{tr} = Min(A_{tr,x}, A_{tr,y}) = 157.0796$
 where $A_{tr,x}, A_{tr,y}$ are the sum of the area of all stirrup legs along X and Y loxal axis

s = 170.00
n = 8.00

Calculation of Mu1-

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

$\phi_u = 1.4467178E-005$

$M_u = 1.4541E+008$

with full section properties:

b = 250.00

d = 457.00

d' = 43.00

$\nu = 0.00204242$

N = 4666.932

$f_{ct} = 20.00$

ϕ_{co} (5A.5, TBDY) = 0.002

Final value of ϕ_{cu} : $\phi_{cu} = \text{shear_factor} * \text{Max}(\phi_{cu}, \phi_{co}) = 0.01464474$

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

From (5.4b), TBDY: $\phi_{cu} = 0.01464474$

ϕ_{ve} ((5.4c), TBDY) = $\text{ase} * \text{sh}_{\min} * f_{yve} / f_{ce} + \text{Min}(\phi_{fx}, \phi_{fy}) = 0.07762821$

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

$\phi_{fx} = 0.07705054$

$\text{af} = 0.45253333$

b = 500.00

h = 250.00

From EC8 A4.4.3(6), $\text{pf} = 2t_f/bw = 0.004064$

bw = 500.00

effective stress from (A.35), $f_{fe} = 837.9178$

$\phi_{fy} = 0.12936483$

$\text{af} = 0.45253333$

b = 250.00

h = 500.00

From EC8 A4.4.3(6), $\text{pf} = 2t_f/bw = 0.008128$

bw = 250.00

effective stress from (A.35), $f_{fe} = 703.4155$

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) = 0.03751166

$b_o = 440.00$

$h_o = 190.00$

$b_{i2} = 459400.00$

$\text{psh}_{\min} = \text{Min}(\text{psh}_x, \text{psh}_y) = 0.001848$

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

psh_x (5.4d) = 0.001848

$A_{sh} = A_{stir} * n_s = 78.53982$

No stirrups, $n_s = 2.00$

$b_k = 500.00$

psh_y (5.4d) = 0.00369599

$A_{sh} = A_{stir} * n_s = 78.53982$

No stirrups, $n_s = 2.00$

$b_k = 250.00$

s = 170.00


```

fywe = 555.55
fce = 20.00
From ((5A.5), TBDY), TBDY: cc = 0.00339158
c = confinement factor = 1.13916
y1 = 0.00130695
sh1 = 0.00451687
ft1 = 376.4017
fy1 = 313.6681
su1 = 0.005257
using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779
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, ASCE41-17.
with fs1 = fs = 313.6681
with Es1 = Es = 200000.00
y2 = 0.00130695
sh2 = 0.00451687
ft2 = 376.4017
fy2 = 313.6681
su2 = 0.005257
using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779
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, ASCE41-17.
with fs2 = fs = 313.6681
with Es2 = Es = 200000.00
yv = 0.00130695
shv = 0.00451687
ftv = 376.4017
fyv = 313.6681
suv = 0.005257
using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779
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, ASCE41-17.
with fsv = fs = 313.6681
with Esv = Es = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.11385127
2 = Asl,com/(b*d)*(fs2/fc) = 0.11385127
v = Asl,mid/(b*d)*(fsv/fc) = 0.05520062
and confined core properties:
b = 190.00
d = 427.00
d' = 13.00
fcc (5A.2, TBDY) = 22.78316
cc (5A.5, TBDY) = 0.00339158
c = confinement factor = 1.13916
1 = Asl,ten/(b*d)*(fs1/fc) = 0.1603292
2 = Asl,com/(b*d)*(fs2/fc) = 0.1603292
v = Asl,mid/(b*d)*(fsv/fc) = 0.07773537
Case/Assumption: Unconfinedsd full section - Steel rupture

```

satisfies Eq. (4.3)

--->

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

--->

$\mu_u (4.9) = 0.20486988$

$\mu_u = M_{Rc} (4.14) = 1.4541E+008$

$u = \mu_u (4.1) = 1.4467178E-005$

Calculation of ratio I_b/I_d

Lap Length: $I_b/I_d = 0.30356779$

$I_b = 300.00$

$I_d = 988.2471$

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

= 1

$d_b = 18.00$

Mean strength value of all re-bars: $f_y = 555.55$

$f_c' = 20.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$c_b = 25.00$

$K_{tr} = 4.61999$

$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$

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

$s = 170.00$

$n = 8.00$

Calculation of μ_{u2+}

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

$u = 1.4467178E-005$

$\mu_u = 1.4541E+008$

with full section properties:

$b = 250.00$

$d = 457.00$

$d' = 43.00$

$v = 0.00204242$

$N = 4666.932$

$f_c = 20.00$

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

Final value of μ_u : $\mu_u^* = \text{shear_factor} * \text{Max}(\mu_u, \mu_{cc}) = 0.01464474$

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

From (5.4b), TBDY: $\mu_u = 0.01464474$

we ((5.4c), TBDY) = $\alpha_{se} * \text{sh}_{min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.07762821$

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

$f_x = 0.07705054$

$\alpha_f = 0.45253333$

$b = 500.00$

$h = 250.00$

From EC8 A.4.4.3(6), $p_f = 2t_f/b_w = 0.004064$

$b_w = 500.00$

effective stress from (A.35), $f_{fe} = 837.9178$

$f_y = 0.12936483$

$\alpha_f = 0.45253333$

$b = 250.00$

$h = 500.00$

From EC8 A.4.4.3(6), $p_f = 2t_f/b_w = 0.008128$

$b_w = 250.00$

effective stress from (A.35), $f_{f,e} = 703.4155$

$R = 40.00$

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

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{f,f} = 0.015$

$a_{se}((5.4d), TBDY) = 0.03751166$

$b_o = 440.00$

$h_o = 190.00$

$b_{i2} = 459400.00$

$p_{sh,min} = \min(p_{sh,x}, p_{sh,y}) = 0.001848$

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

$p_{sh,x}(5.4d) = 0.001848$

$A_{sh} = A_{stir} \cdot n_s = 78.53982$

No stirrups, $n_s = 2.00$

$b_k = 500.00$

$p_{sh,y}(5.4d) = 0.00369599$

$A_{sh} = A_{stir} \cdot n_s = 78.53982$

No stirrups, $n_s = 2.00$

$b_k = 250.00$

$s = 170.00$

$f_{ywe} = 555.55$

$f_{ce} = 20.00$

From ((5.A5), TBDY), TBDY: $c_c = 0.00339158$

c = confinement factor = 1.13916

$y_1 = 0.00130695$

$sh_1 = 0.00451687$

$ft_1 = 376.4017$

$fy_1 = 313.6681$

$su_1 = 0.005257$

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

$l_o/l_{ou,min} = l_b/l_d = 0.30356779$

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

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

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

y_1 , sh_1 , ft_1 , fy_1 , are also multiplied by $\min(1, 1.25 \cdot (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

with $fs_1 = fs = 313.6681$

with $Es_1 = Es = 200000.00$

$y_2 = 0.00130695$

$sh_2 = 0.00451687$

$ft_2 = 376.4017$

$fy_2 = 313.6681$

$su_2 = 0.005257$

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

$l_o/l_{ou,min} = l_b/l_{b,min} = 0.30356779$

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

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

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

y_1 , sh_1 , ft_1 , fy_1 , are also multiplied by $\min(1, 1.25 \cdot (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

with $fs_2 = fs = 313.6681$

with $Es_2 = Es = 200000.00$

$y_v = 0.00130695$

$sh_v = 0.00451687$

$ft_v = 376.4017$

$fy_v = 313.6681$

$su_v = 0.005257$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $l_o/l_{o,min} = l_b/d = 0.30356779$
 $suv = 0.4 * esuv_{nominal} ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $esuv_{nominal} = 0.08$,
 considering characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY
 For calculation of $esuv_{nominal}$ and y_v, shv, ftv, fyv , it is considered
 characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 * (l_b/d)^{2/3})$, from 10.3.5, ASCE41-17.
 with $fsv = fs = 313.6681$
 with $Esv = Es = 200000.00$
 $1 = A_{sl,ten}/(b*d) * (fs_1/fc) = 0.11385127$
 $2 = A_{sl,com}/(b*d) * (fs_2/fc) = 0.11385127$
 $v = A_{sl,mid}/(b*d) * (fsv/fc) = 0.05520062$

and confined core properties:

$b = 190.00$
 $d = 427.00$
 $d' = 13.00$
 $f_{cc} (5A.2, TBDY) = 22.78316$
 $cc (5A.5, TBDY) = 0.00339158$
 $c = \text{confinement factor} = 1.13916$
 $1 = A_{sl,ten}/(b*d) * (fs_1/fc) = 0.1603292$
 $2 = A_{sl,com}/(b*d) * (fs_2/fc) = 0.1603292$
 $v = A_{sl,mid}/(b*d) * (fsv/fc) = 0.07773537$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

$su (4.9) = 0.20486988$
 $Mu = MRc (4.14) = 1.4541E+008$
 $u = su (4.1) = 1.4467178E-005$

Calculation of ratio l_b/d

Lap Length: $l_b/d = 0.30356779$

$l_b = 300.00$

$l_d = 988.2471$

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

= 1

$db = 18.00$

Mean strength value of all re-bars: $f_y = 555.55$

$fc' = 20.00$, but $fc^{0.5} \leq 8.3 \text{ MPa}$ (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 4.61999$

$A_{tr} = \text{Min}(A_{tr,x}, A_{tr,y}) = 157.0796$

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

$s = 170.00$

$n = 8.00$

Calculation of Mu_2 -

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

$u = 1.4467178E-005$

$Mu = 1.4541E+008$

with full section properties:

$b = 250.00$

$d = 457.00$
 $d' = 43.00$
 $v = 0.00204242$
 $N = 4666.932$
 $fc = 20.00$
 $co (5A.5, TBDY) = 0.002$
 Final value of cu : $cu^* = shear_factor * Max(cu, cc) = 0.01464474$
 The Shear_factor is considered equal to 1 (pure moment strength)
 From (5.4b), TBDY: $cu = 0.01464474$
 $w_e ((5.4c), TBDY) = ase * sh_{min} * fy_{we} / f_{ce} + Min(f_x, f_y) = 0.07762821$
 where $f = af * pf * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$f_x = 0.07705054$
 $af = 0.45253333$
 $b = 500.00$
 $h = 250.00$
 From EC8 A.4.4.3(6), $pf = 2tf/bw = 0.004064$
 $bw = 500.00$
 effective stress from (A.35), $ff_e = 837.9178$

$f_y = 0.12936483$
 $af = 0.45253333$
 $b = 250.00$
 $h = 500.00$
 From EC8 A.4.4.3(6), $pf = 2tf/bw = 0.008128$
 $bw = 250.00$
 effective stress from (A.35), $ff_e = 703.4155$

$R = 40.00$
 Effective FRP thickness, $tf = NL * t * Cos(b1) = 1.016$
 $f_{u,f} = 1055.00$
 $E_f = 64828.00$
 $u_{,f} = 0.015$
 $ase ((5.4d), TBDY) = 0.03751166$
 $bo = 440.00$
 $ho = 190.00$
 $bi2 = 459400.00$
 $psh_{min} = Min(psh_x, psh_y) = 0.001848$
 Expression ((5.4d), TBDY) for psh_{min} has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$psh_x (5.4d) = 0.001848$
 $A_{sh} = Astir * ns = 78.53982$
 No stirrups, $ns = 2.00$
 $bk = 500.00$

$psh_y (5.4d) = 0.00369599$
 $A_{sh} = Astir * ns = 78.53982$
 No stirrups, $ns = 2.00$
 $bk = 250.00$

$s = 170.00$
 $fy_{we} = 555.55$
 $f_{ce} = 20.00$
 From ((5A5), TBDY), TBDY: $cc = 0.00339158$
 $c =$ confinement factor $= 1.13916$
 $y1 = 0.00130695$
 $sh1 = 0.00451687$
 $ft1 = 376.4017$
 $fy1 = 313.6681$
 $su1 = 0.005257$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00
 $lo/lou_{min} = lb/d = 0.30356779$
 $su1 = 0.4 * esu1_{nominal} ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $esu1_{nominal} = 0.08$

For calculation of $esu1_{nominal}$ and $y1, sh1, ft1, fy1$, it is considered characteristic value $fsy1 = fs1/1.2$, from table 5.1, TBDY.
 $y1, sh1, ft1, fy1$, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.
 with $fs1 = fs = 313.6681$
 with $Es1 = Es = 200000.00$
 $y2 = 0.00130695$
 $sh2 = 0.00451687$
 $ft2 = 376.4017$
 $fy2 = 313.6681$
 $su2 = 0.005257$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $lo/lou, min = lb/lb, min = 0.30356779$
 $su2 = 0.4 \cdot esu2_{nominal} ((5.5), TBDY) = 0.032$
 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, ASCE41-17.
 with $fs2 = fs = 313.6681$
 with $Es2 = Es = 200000.00$
 $yv = 0.00130695$
 $shv = 0.00451687$
 $ftv = 376.4017$
 $fyv = 313.6681$
 $suv = 0.005257$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $lo/lou, min = lb/ld = 0.30356779$
 $suv = 0.4 \cdot esuv_{nominal} ((5.5), TBDY) = 0.032$
 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, ASCE41-17.
 with $fsv = fs = 313.6681$
 with $Esv = Es = 200000.00$
 $1 = Asl, ten / (b \cdot d) \cdot (fs1 / fc) = 0.11385127$
 $2 = Asl, com / (b \cdot d) \cdot (fs2 / fc) = 0.11385127$
 $v = Asl, mid / (b \cdot d) \cdot (fsv / fc) = 0.05520062$

and confined core properties:

$b = 190.00$
 $d = 427.00$
 $d' = 13.00$
 $fcc (5A.2, TBDY) = 22.78316$
 $cc (5A.5, TBDY) = 0.00339158$
 $c = \text{confinement factor} = 1.13916$
 $1 = Asl, ten / (b \cdot d) \cdot (fs1 / fc) = 0.1603292$
 $2 = Asl, com / (b \cdot d) \cdot (fs2 / fc) = 0.1603292$
 $v = Asl, mid / (b \cdot d) \cdot (fsv / fc) = 0.07773537$

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

--->
 $v < vs, y2$ - LHS eq.(4.5) is satisfied
 --->
 $su (4.9) = 0.20486988$
 $Mu = MRc (4.14) = 1.4541E+008$
 $u = su (4.1) = 1.4467178E-005$

Calculation of ratio lb/ld

Lap Length: $lb/ld = 0.30356779$
 $lb = 300.00$
 $ld = 988.2471$

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

$\lambda = 1$
 $d_b = 18.00$
Mean strength value of all re-bars: $f_y = 555.55$
 $f_c' = 20.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $t = 1.00$
 $s = 0.80$
 $e = 1.00$
 $c_b = 25.00$
 $K_{tr} = 4.61999$
 $A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$
where A_{tr_x} , A_{tr_y} are the sum of the area of all stirrup legs along X and Y loxal axis
 $s = 170.00$
 $n = 8.00$

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 409422.352$

Calculation of Shear Strength at edge 1, $V_{r1} = 409422.352$

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

$V_{Col0} = 409422.352$

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

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

$\lambda = 1$ (normal-weight concrete)
 $f_c' = 20.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $M/Vd = 2.00$
 $\mu_u = 2.8180236E-013$
 $\nu_u = 1.3558547E-031$
 $d = 0.8 * h = 400.00$
 $N_u = 4666.932$
 $A_g = 125000.00$
From (11.5.4.8), ACI 318-14: $V_s = 164264.64$
 $A_v = 157079.633$
 $f_y = 444.44$
 $s = 170.00$
 V_s is multiplied by $\lambda_{Col} = 1.00$
 $s/d = 0.425$
 V_f ((11-3)-(11.4), ACI 440) = 240803.347
 $f = 0.95$, 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: $\theta = \theta_1 + 90^\circ = 90.00$
 $V_f = \text{Min}(|V_f(45, \theta_1)|, |V_f(-45, \theta_1)|)$, with:
total thickness per orientation, $t_{f1} = N_L * t / N_{oDir} = 1.016$
 $d_{fv} = d$ (figure 11.2, ACI 440) = 457.00
 f_{fe} ((11-5), ACI 440) = 259.312
 $E_f = 64828.00$
 $f_{fe} = 0.004$, from (11.6a), ACI 440
with $f_u = 0.01$
From (11-11), ACI 440: $V_s + V_f \leq 297085.704$
 $b_w = 250.00$

Calculation of Shear Strength at edge 2, $V_{r2} = 409422.352$

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

$V_{Col0} = 409422.352$

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

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

= 1 (normal-weight concrete)
 $f_c' = 20.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $M/Vd = 2.00$
 $\mu_u = 2.8180236E-013$
 $\mu_v = 1.3558547E-031$
 $d = 0.8 \cdot h = 400.00$
 $N_u = 4666.932$
 $A_g = 125000.00$
 From (11.5.4.8), ACI 318-14: $V_s = 164264.64$
 $A_v = 157079.633$
 $f_y = 444.44$
 $s = 170.00$
 V_s is multiplied by $\text{Col} = 1.00$
 $s/d = 0.425$
 $V_f ((11-3)-(11.4), \text{ACI } 440) = 240803.347$
 $f = 0.95$, 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, $t_{f1} = N_L \cdot t / N_{\text{Dir}} = 1.016$
 $d_{fv} = d$ (figure 11.2, ACI 440) = 457.00
 $f_{fe} ((11-5), \text{ACI } 440) = 259.312$
 $E_f = 64828.00$
 $f_e = 0.004$, from (11.6a), ACI 440
 with $f_u = 0.01$
 From (11-11), ACI 440: $V_s + V_f \leq 297085.704$
 $b_w = 250.00$

End Of Calculation of Shear Capacity ratio for element: column C1 of floor 1
 At local axis: 2

Start Of Calculation of Chord Rotation Capacity for element: column C1 of floor 1
 At local axis: 2
 Integration Section: (a)
 Section Type: rcrs

Constant Properties

Knowledge Factor, $\phi = 1.00$
 Chord Rotation is generally considered as Deformation-Controlled Action according to Table C7-1, ASCE41-17.
 Mean strengths are used for Deformation-Controlled Actions according to 7.5.1.3, ASCE 41-17
 Consequently:
 Existing material of Primary Member: Concrete Strength, $f_c = f_{cm} = 20.00$
 Existing material of Primary Member: Steel Strength, $f_s = f_{sm} = 444.44$
 Concrete Elasticity, $E_c = 21019.039$
 Steel Elasticity, $E_s = 200000.00$
 Section Height, $H = 250.00$
 Section Width, $W = 500.00$
 Cover Thickness, $c = 25.00$
 Element Length, $L = 3000.00$
 Primary Member
 Ribbed Bars
 Ductile Steel
 Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
 Longitudinal Bars With Ends Lapped Starting at the End Sections
 Lap Length $l_b = 300.00$
 FRP Wrapping Data
 Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $\epsilon_{fu} = 0.01$

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

Bending Moment, $M = 9.9150700E-010$

Shear Force, $V_2 = -4708.27$

Shear Force, $V_3 = -3.5022564E-013$

Axial Force, $F = -4886.081$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: $A_{sl,t} = 1231.504$

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

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, $D_{bL} = 18.66667$

Existing component: From table 7-7, ASCE 41_17: Final chord rotation Capacity $u_R = u = 0.04410058$

$u = y + p = 0.04410058$

- Calculation of y -

$y = (M_y * L_s / 3) / E_{eff} = 0.00620957$ ((4.29), Biskinis Phd))

$M_y = 5.0984E+007$

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

From table 10.5, ASCE 41_17: $E_{eff} = factor * E_c * I_g = 4.1053E+012$

factor = 0.30

$A_g = 125000.00$

$f_c' = 20.00$

$N = 4886.081$

$E_c * I_g = 1.3684E+013$

Calculation of Yielding Moment M_y

Calculation of y and M_y according to Annex 7 -

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

$y_{ten} = 1.0451750E-005$

with ((10.1), ASCE 41-17) $f_y = \text{Min}(f_y, 1.25 * f_y * (I_b / I_d)^{2/3}) = 291.1836$

$d = 207.00$

$y = 0.32705805$

$A = 0.02007406$

$B = 0.01218624$

with $p_t = 0.00801334$

$p_c = 0.00801334$

$p_v = 0.00388525$

$N = 4886.081$

$b = 500.00$

" = 0.20772947

$y_{comp} = 2.5957131E-005$

with $f_c' (12.3, (ACI 440)) = 20.44529$

$f_c = 20.00$

$f_l = 0.9425867$
 $b = 500.00$
 $h = 250.00$
 $A_g = 125000.00$
 From (12.9), ACI 440: $k_a = 0.1506892$
 $g = p_t + p_c + p_v = 0.01991193$
 $r_c = 40.00$
 $A_e/A_c = 0.60275679$
 Effective FRP thickness, $t_f = N_L * t * \cos(b_1) = 1.016$
 effective strain from (12.5) and (12.12), $\epsilon_{fe} = 0.004$
 $f_u = 0.01$
 $E_f = 64828.00$
 $E_c = 21019.039$
 $y = 0.32585609$
 $A = 0.01977712$
 $B = 0.01202411$
 with $E_s = 200000.00$

Calculation of ratio l_b/l_d

Lap Length: $l_d/l_{d,min} = 0.37945973$

$l_b = 300.00$

$l_d = 790.5977$

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

$= 1$

$d_b = 18.00$

Mean strength value of all re-bars: $f_y = 444.44$

$f'_c = 20.00$, but $f_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$c_b = 25.00$

$K_{tr} = 4.61999$

$A_{tr} = \min(A_{tr_x}, A_{tr_y}) = 157.0796$

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

$s = 170.00$

$n = 8.00$

- Calculation of p -

From table 10-8: $p = 0.03789101$

with:

- Columns not controlled by inadequate development or splicing along the clear height because $l_b/l_d \geq 1$

shear control ratio $V_y E / V_{col} E = 0.15063296$

$d = 207.00$

$s = 0.00$

$t = A_v / (b_w * s) + 2 * t_f / b_w * (f_{fe} / f_s) = 0.00$

$A_v = 157.0796$, is the total area of all stirrups parallel to loading (shear) direction

$b_w = 500.00$

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.

$NUD = 4886.081$

$A_g = 125000.00$

$f'_c E = 20.00$

$f_{yE} = f_{yI} E = 0.00$

$p_l = \text{Area_Tot_Long_Rein} / (b * d) = 0.01991193$

$b = 500.00$

$d = 207.00$

$f'_c E = 20.00$

End Of Calculation of Chord Rotation Capacity for element: column C1 of floor 1

At local axis: 2

Integration Section: (a)

Calculation No. 11

column C1, Floor 1

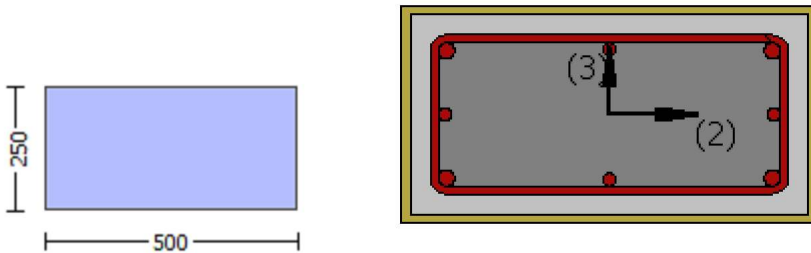
Limit State: Collapse Prevention (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Shear capacity V_{Rd}

Edge: Start

Local Axis: (3)



Start Of Calculation of Shear Capacity for element: column C1 of floor 1

At local axis: 3

Integration Section: (a)

Section Type: rcrcs

Constant Properties

Knowledge Factor, $\gamma = 1.00$

Member Shear Force is generally considered as Force-Controlled Action according to Table C7-1, ASCE41-17.

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

Consequently:

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

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

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of γ for displacement ductility demand, the expected (mean value) strengths are used (7.5.1.3, ASCE41-17) because bending is considered as Deformation-Controlled Action (Table C7-1, ASCE41-17).

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

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

#####

Section Height, $H = 250.00$

Section Width, $W = 500.00$

Cover Thickness, $c = 25.00$

Element Length, $L = 3000.00$
 Primary Member
 Ribbed Bars
 Ductile Steel
 Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
 Longitudinal Bars With Ends Lapped Starting at the End Sections
 Lap Length $l_o = l_b = 300.00$
 FRP Wrapping Data
 Type: Carbon
 Cured laminate properties (design values)
 Thickness, $t = 1.016$
 Tensile Strength, $f_{fu} = 1055.00$
 Tensile Modulus, $E_f = 64828.00$
 Elongation, $\epsilon_{fu} = 0.01$
 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

EDGE -A-
 Bending Moment, $M_a = 9.9150700E-010$
 Shear Force, $V_a = -3.5022564E-013$
 EDGE -B-
 Bending Moment, $M_b = 6.0169508E-011$
 Shear Force, $V_b = 3.5022564E-013$
 BOTH EDGES
 Axial Force, $F = -4886.081$
 Longitudinal Reinforcement Area Distribution (in 2 divisions)
 -Tension: $A_{sl,t} = 1231.504$
 -Compression: $A_{sl,c} = 829.3805$
 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, $D_{bL,ten} = 18.66667$

Existing component: From table 7-7, ASCE 41_17: Final Shear Capacity $V_R = V_n = 248589.15$
 V_n ((10.3), ASCE 41-17) = $k_n \cdot V_{CoI} = 248589.15$
 $V_{CoI} = 248589.15$
 $k_n = 1.00$
 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)
 $f_c' = 16.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $M/Vd = 2.00$
 $M_u = 9.9150700E-010$
 $V_u = 3.5022564E-013$
 $d = 0.8 \cdot h = 200.00$
 $N_u = 4886.081$
 $A_g = 125000.00$
 From ((11.5.4.8), ACI 318-14: $V_s = 44351.896$
 $A_v = 157079.633$
 $f_y = 400.00$
 $s = 170.00$
 V_s is multiplied by $CoI = 0.60$
 $s/d = 0.85$
 V_f ((11-3)-(11.4), ACI 440) = 109072.851
 $f = 0.95$, 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 $Vf(\alpha)$, is implemented for every different fiber orientation α_i , as well as for 2 crack directions, $\alpha = 45^\circ$ and $\alpha = -45^\circ$ to take into consideration the cyclic seismic loading.

orientation 1: $\alpha_1 = \alpha_1 + 90^\circ = 90.00$

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

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

$d_{fv} = d$ (figure 11.2, ACI 440) = 207.00

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: $V_s + V_f \leq 265721.532$

$b_w = 500.00$

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 $\theta = 6.6390666E-020$

$y = (My \cdot L_s / 3) / E_{eff} = 0.00620957$ ((4.29), Biskinis Phd))

$My = 5.0984E+007$

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

From table 10.5, ASCE 41_17: $E_{eff} = \text{factor} \cdot E_c \cdot I_g = 4.1053E+012$

factor = 0.30

$A_g = 125000.00$

$f_c' = 20.00$

$N = 4886.081$

$E_c \cdot I_g = 1.3684E+013$

Calculation of Yielding Moment M_y

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

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

$y_{ten} = 1.0451750E-005$

with ((10.1), ASCE 41-17) $f_y = \text{Min}(f_y, 1.25 \cdot f_y \cdot (I_b / I_d)^{2/3}) = 291.1836$

$d = 207.00$

$y = 0.32705805$

$A = 0.02007406$

$B = 0.01218624$

with $p_t = 0.00801334$

$p_c = 0.00801334$

$p_v = 0.00388525$

$N = 4886.081$

$b = 500.00$

$\alpha = 0.20772947$

$y_{comp} = 2.5957131E-005$

with $f_c' (12.3, (ACI 440)) = 20.44529$

$f_c = 20.00$

$f_l = 0.9425867$

$b = 500.00$

$h = 250.00$

$A_g = 125000.00$

From (12.9), ACI 440: $k_a = 0.1506892$

$g = p_t + p_c + p_v = 0.01991193$

$r_c = 40.00$

$A_e / A_c = 0.60275679$

Effective FRP thickness, $tf = NL \cdot t \cdot \cos(\alpha_1) = 1.016$

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

$f_u = 0.01$

Ef = 64828.00
Ec = 21019.039
y = 0.32585609
A = 0.01977712
B = 0.01202411
with Es = 200000.00

Calculation of ratio lb/l_d

Lap Length: l_d/l_{d,min} = 0.37945973

l_b = 300.00

l_d = 790.5977

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

db = 18.00

Mean strength value of all re-bars: f_y = 444.44

f_c' = 20.00, 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} = 4.61999

A_{tr} = Min(A_{tr_x}, A_{tr_y}) = 157.0796

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

s = 170.00

n = 8.00

End Of Calculation of Shear Capacity for element: column C1 of floor 1

At local axis: 3

Integration Section: (a)

Calculation No. 12

column C1, Floor 1

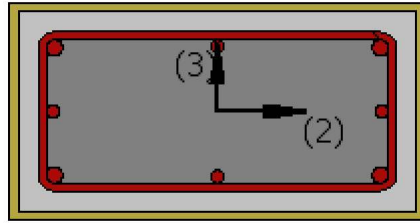
Limit State: Collapse Prevention (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity (u)

Edge: Start

Local Axis: (3)



Start Of Calculation of Shear Capacity ratio for element: column C1 of floor 1

At Shear local axis: 3

(Bending local axis: 2)

Section Type: rcrs

Constant Properties

Knowledge Factor, $\gamma = 1.00$

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

Consequently:

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

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

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

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

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

#####

Section Height, $H = 250.00$

Section Width, $W = 500.00$

Cover Thickness, $c = 25.00$

Mean Confinement Factor overall section = 1.13916

Element Length, $L = 3000.00$

Primary Member

Ribbed Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

Lap Length $l_o = 300.00$

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $\epsilon_{fu} = 0.01$

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

Fiber orientations, $b_i: 0.00^\circ$

Number of layers, $N_L = 1$

Radius of rounding corners, $R = 40.00$

Stepwise Properties

At local axis: 3

EDGE -A-

Shear Force, $V_a = 2.9007121E-031$

EDGE -B-

Shear Force, $V_b = -2.9007121E-031$

BOTH EDGES

Axial Force, $F = -4666.932$

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: $A_{st,mid} = 402.1239$

Calculation of Shear Capacity ratio, $V_e/V_r = 0.15063296$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 39953.171$ with

$M_{pr1} = \text{Max}(M_{u1+}, M_{u1-}) = 5.9930E+007$

$M_{u1+} = 5.9930E+007$, 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

$M_{u1-} = 5.9930E+007$, 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

$M_{pr2} = \text{Max}(M_{u2+}, M_{u2-}) = 5.9930E+007$

$M_{u2+} = 5.9930E+007$, 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

$M_{u2-} = 5.9930E+007$, 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:

$\phi_u = 3.4011160E-005$

$M_u = 5.9930E+007$

with full section properties:

$b = 500.00$

$d = 207.00$

$d' = 43.00$

$v = 0.00225456$

$N = 4666.932$

$f_c = 20.00$

ϕ_c (5A.5, TBDY) = 0.002

Final value of ϕ_u : $\phi_u^* = \text{shear_factor} * \text{Max}(\phi_u, \phi_c) = 0.01464474$

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

From (5.4b), TBDY: $\phi_u = 0.01464474$

ϕ_{we} ((5.4c), TBDY) = $a_s e * \phi_{sh, min} * f_{ywe} / f_{ce} + \text{Min}(\phi_x, \phi_y) = 0.07762821$

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

$\phi_x = 0.07705054$

$a_f = 0.45253333$

$b = 500.00$

$h = 250.00$

From EC8 A4.4.3(6), $\phi_f = 2t_f/bw = 0.004064$

$bw = 500.00$

effective stress from (A.35), $f_{fe} = 837.9178$

$\phi_y = 0.12936483$

$a_f = 0.45253333$

$b = 250.00$

$h = 500.00$

From EC8 A4.4.3(6), $\phi_f = 2t_f/bw = 0.008128$

$bw = 250.00$

effective stress from (A.35), $f_{fe} = 703.4155$

$R = 40.00$

Effective FRP thickness, $t_f = NL * t * \cos(\theta_1) = 1.016$

$f_u, f = 1055.00$
 $E_f = 64828.00$
 $u, f = 0.015$
 $ase((5.4d), TBDY) = 0.03751166$
 $bo = 440.00$
 $ho = 190.00$
 $bi2 = 459400.00$
 $psh, min = \text{Min}(psh, x, psh, y) = 0.001848$
 Expression $((5.4d), TBDY)$ for psh, min has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$psh, x(5.4d) = 0.001848$
 $Ash = Astir * ns = 78.53982$
 No stirrups, $ns = 2.00$
 $bk = 500.00$

$psh, y(5.4d) = 0.00369599$
 $Ash = Astir * ns = 78.53982$
 No stirrups, $ns = 2.00$
 $bk = 250.00$

$s = 170.00$
 $fyw = 555.55$
 $fce = 20.00$

From $((5.A5), TBDY)$, $TBDY$: $cc = 0.00339158$
 $c = \text{confinement factor} = 1.13916$

$y1 = 0.00130695$
 $sh1 = 0.00451687$
 $ft1 = 376.4017$
 $fy1 = 313.6681$
 $su1 = 0.005257$

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

$lo/lo, min = lb/ld = 0.30356779$

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

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, ASCE41-17.

with $fs1 = fs = 313.6681$

with $Es1 = Es = 200000.00$

$y2 = 0.00130695$
 $sh2 = 0.00451687$
 $ft2 = 376.4017$
 $fy2 = 313.6681$
 $su2 = 0.005257$

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

$lo/lo, min = lb/lb, min = 0.30356779$

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

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, ASCE41-17.

with $fs2 = fs = 313.6681$

with $Es2 = Es = 200000.00$

$yv = 0.00130695$
 $shv = 0.00451687$
 $ftv = 376.4017$
 $fyv = 313.6681$
 $suv = 0.005257$

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

$lo/lo, min = lb/ld = 0.30356779$

$\text{suv} = 0.4 \cdot \text{esuv_nominal} ((5.5), \text{TBDY}) = 0.032$
 From table 5A.1, TBDY: $\text{esuv_nominal} = 0.08$,
 considering characteristic value $\text{fsy} = \text{fsv}/1.2$, from table 5.1, TBDY
 For calculation of esuv_nominal and yv , shv , ftv , fyv , it is considered
 characteristic value $\text{fsy} = \text{fsv}/1.2$, 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, ASCE41-17.
 with $\text{fsv} = \text{fs} = 313.6681$
 with $\text{Esv} = \text{Es} = 200000.00$
 $1 = \text{Asl,ten}/(\text{b} \cdot \text{d}) \cdot (\text{fs1}/\text{fc}) = 0.1256764$
 $2 = \text{Asl,com}/(\text{b} \cdot \text{d}) \cdot (\text{fs2}/\text{fc}) = 0.1256764$
 $\text{v} = \text{Asl,mid}/(\text{b} \cdot \text{d}) \cdot (\text{fsv}/\text{fc}) = 0.06093401$

and confined core properties:

$\text{b} = 440.00$
 $\text{d} = 177.00$
 $\text{d}' = 13.00$
 $\text{fcc} (5\text{A.2, TBDY}) = 22.78316$
 $\text{cc} (5\text{A.5, TBDY}) = 0.00339158$
 $\text{c} = \text{confinement factor} = 1.13916$
 $1 = \text{Asl,ten}/(\text{b} \cdot \text{d}) \cdot (\text{fs1}/\text{fc}) = 0.16701987$
 $2 = \text{Asl,com}/(\text{b} \cdot \text{d}) \cdot (\text{fs2}/\text{fc}) = 0.16701987$
 $\text{v} = \text{Asl,mid}/(\text{b} \cdot \text{d}) \cdot (\text{fsv}/\text{fc}) = 0.08097933$

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

--->
 $\text{v} < \text{vs,y2}$ - LHS eq.(4.5) is satisfied
 ---->

$\text{su} (4.9) = 0.25329952$
 $\text{Mu} = \text{MRc} (4.14) = 5.9930\text{E}+007$
 $\text{u} = \text{su} (4.1) = 3.4011160\text{E}-005$

Calculation of ratio lb/ld

Lap Length: $\text{lb}/\text{ld} = 0.30356779$
 $\text{lb} = 300.00$
 $\text{ld} = 988.2471$

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

$= 1$
 $\text{db} = 18.00$
 Mean strength value of all re-bars: $\text{fy} = 555.55$
 $\text{fc}' = 20.00$, but $\text{fc}'^{0.5} \leq 8.3 \text{ MPa}$ (22.5.3.1, ACI 318-14)
 $\text{t} = 1.00$
 $\text{s} = 0.80$
 $\text{e} = 1.00$
 $\text{cb} = 25.00$
 $\text{Ktr} = 4.61999$
 $\text{Atr} = \text{Min}(\text{Atr}_x, \text{Atr}_y) = 157.0796$
 where Atr_x , Atr_y are the sum of the area of all stirrup legs along X and Y loxal axis
 $\text{s} = 170.00$
 $\text{n} = 8.00$

Calculation of Mu1 -

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

$\text{u} = 3.4011160\text{E}-005$
 $\text{Mu} = 5.9930\text{E}+007$

with full section properties:

$\text{b} = 500.00$
 $\text{d} = 207.00$
 $\text{d}' = 43.00$
 $\text{v} = 0.00225456$
 $\text{N} = 4666.932$

```

fc = 20.00
co (5A.5, TBDY) = 0.002
Final value of cu: cu* = shear_factor * Max( cu, cc) = 0.01464474
The Shear_factor is considered equal to 1 (pure moment strength)
From (5.4b), TBDY: cu = 0.01464474
we ((5.4c), TBDY) = ase* sh,min*fywe/fce+Min( fx, fy) = 0.07762821
where f = af*pf*ffe/fce is accounting for FRP contribution like EC8-part3 A.4.4.3(6)
-----
fx = 0.07705054
af = 0.45253333
b = 500.00
h = 250.00
From EC8 A4.4.3(6), pf = 2tf/bw = 0.004064
bw = 500.00
effective stress from (A.35), ffe = 837.9178
-----
fy = 0.12936483
af = 0.45253333
b = 250.00
h = 500.00
From EC8 A4.4.3(6), pf = 2tf/bw = 0.008128
bw = 250.00
effective stress from (A.35), ffe = 703.4155
-----
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) = 0.03751166
bo = 440.00
ho = 190.00
bi2 = 459400.00
psh,min = Min(psh,x , psh,y) = 0.001848
Expression ((5.4d), TBDY) for psh,min has been multiplied by 0.3 according to 15.7.1.3 for members without
earthquake detailing (90° closed stirrups)
-----
psh,x (5.4d) = 0.001848
Ash = Astir*ns = 78.53982
No stirups, ns = 2.00
bk = 500.00
-----
psh,y (5.4d) = 0.00369599
Ash = Astir*ns = 78.53982
No stirups, ns = 2.00
bk = 250.00
-----
s = 170.00
fywe = 555.55
fce = 20.00
From ((5.A5), TBDY), TBDY: cc = 0.00339158
c = confinement factor = 1.13916
y1 = 0.00130695
sh1 = 0.00451687
ft1 = 376.4017
fy1 = 313.6681
su1 = 0.005257
using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779
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, ASCE41-17.
with fs1 = fs = 313.6681

```

```

with Es1 = Es = 200000.00
y2 = 0.00130695
sh2 = 0.00451687
ft2 = 376.4017
fy2 = 313.6681
su2 = 0.005257
using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779
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, ASCE41-17.
with fs2 = fs = 313.6681
with Es2 = Es = 200000.00
yv = 0.00130695
shv = 0.00451687
ftv = 376.4017
fyv = 313.6681
suv = 0.005257
using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779
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, ASCE41-17.
with fsv = fs = 313.6681
with Esv = Es = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.1256764
2 = Asl,com/(b*d)*(fs2/fc) = 0.1256764
v = Asl,mid/(b*d)*(fsv/fc) = 0.06093401
and confined core properties:
b = 440.00
d = 177.00
d' = 13.00
fcc (5A.2, TBDY) = 22.78316
cc (5A.5, TBDY) = 0.00339158
c = confinement factor = 1.13916
1 = Asl,ten/(b*d)*(fs1/fc) = 0.16701987
2 = Asl,com/(b*d)*(fs2/fc) = 0.16701987
v = Asl,mid/(b*d)*(fsv/fc) = 0.08097933
Case/Assumption: Unconfined full section - Steel rupture
'satisfies Eq. (4.3)
--->
v < vs,y2 - LHS eq.(4.5) is satisfied
--->
su (4.9) = 0.25329952
Mu = MRc (4.14) = 5.9930E+007
u = su (4.1) = 3.4011160E-005

```

Calculation of ratio lb/lb

```

Lap Length: lb/lb = 0.30356779
lb = 300.00
lb = 988.2471
Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
= 1
db = 18.00
Mean strength value of all re-bars: fy = 555.55
fc' = 20.00, but fc^0.5 <= 8.3 MPa (22.5.3.1, ACI 318-14)

```

$t = 1.00$
 $s = 0.80$
 $e = 1.00$
 $cb = 25.00$
 $K_{tr} = 4.61999$
 $A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$
 where A_{tr_x} , A_{tr_y} are the sum of the area of all stirrup legs along X and Y loxal axis
 $s = 170.00$
 $n = 8.00$

Calculation of μ_{2+}

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

$\mu = 3.4011160E-005$
 $\mu = 5.9930E+007$

with full section properties:

$b = 500.00$
 $d = 207.00$
 $d' = 43.00$
 $v = 0.00225456$
 $N = 4666.932$
 $f_c = 20.00$
 $\alpha (5A.5, \text{TBDY}) = 0.002$
 Final value of μ : $\mu^* = \text{shear_factor} * \text{Max}(\mu, \alpha) = 0.01464474$
 The Shear_factor is considered equal to 1 (pure moment strength)
 From (5.4b), TBDY: $\mu = 0.01464474$
 $\mu_e ((5.4c), \text{TBDY}) = \alpha * \text{sh}_{\min} * f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.07762821$
 where $f = \alpha * p_f * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$f_x = 0.07705054$
 $\alpha_f = 0.45253333$
 $b = 500.00$
 $h = 250.00$
 From EC8 A.4.4.3(6), $p_f = 2t_f/b_w = 0.004064$
 $b_w = 500.00$
 effective stress from (A.35), $f_{fe} = 837.9178$

$f_y = 0.12936483$
 $\alpha_f = 0.45253333$
 $b = 250.00$
 $h = 500.00$
 From EC8 A.4.4.3(6), $p_f = 2t_f/b_w = 0.008128$
 $b_w = 250.00$
 effective stress from (A.35), $f_{fe} = 703.4155$

$R = 40.00$
 Effective FRP thickness, $t_f = NL * t * \cos(b_1) = 1.016$
 $f_{u,f} = 1055.00$
 $E_f = 64828.00$
 $u_f = 0.015$
 $\alpha_e ((5.4d), \text{TBDY}) = 0.03751166$
 $b_o = 440.00$
 $h_o = 190.00$
 $b_{i2} = 459400.00$
 $p_{sh,\min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.001848$

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

$p_{sh,x} (5.4d) = 0.001848$
 $A_{sh} = A_{stir} * n_s = 78.53982$
 No stirrups, $n_s = 2.00$
 $b_k = 500.00$

psh,y (5.4d) = 0.00369599
 Ash = Astir*ns = 78.53982
 No stirrups, ns = 2.00
 bk = 250.00

s = 170.00
 fywe = 555.55
 fce = 20.00

From ((5.A5), TBDY), TBDY: cc = 0.00339158
 c = confinement factor = 1.13916

y1 = 0.00130695
 sh1 = 0.00451687

ft1 = 376.4017

fy1 = 313.6681

su1 = 0.005257

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779

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, ASCE41-17.

with fs1 = fs = 313.6681

with Es1 = Es = 200000.00

y2 = 0.00130695

sh2 = 0.00451687

ft2 = 376.4017

fy2 = 313.6681

su2 = 0.005257

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779

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, ASCE41-17.

with fs2 = fs = 313.6681

with Es2 = Es = 200000.00

yv = 0.00130695

shv = 0.00451687

ftv = 376.4017

fyv = 313.6681

suv = 0.005257

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779

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, ASCE41-17.

with fsv = fs = 313.6681

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.1256764

2 = Asl,com/(b*d)*(fs2/fc) = 0.1256764

v = Asl,mid/(b*d)*(fsv/fc) = 0.06093401

and confined core properties:

b = 440.00

d = 177.00

d' = 13.00

```

fcc (5A.2, TBDY) = 22.78316
cc (5A.5, TBDY) = 0.00339158
c = confinement factor = 1.13916
1 = Asl,ten/(b*d)*(fs1/fc) = 0.16701987
2 = Asl,com/(b*d)*(fs2/fc) = 0.16701987
v = Asl,mid/(b*d)*(fsv/fc) = 0.08097933
Case/Assumption: Unconfined full section - Steel rupture
'satisfies Eq. (4.3)
--->
v < vs,y2 - LHS eq.(4.5) is satisfied
--->
su (4.9) = 0.25329952
Mu = MRc (4.14) = 5.9930E+007
u = su (4.1) = 3.4011160E-005

```

Calculation of ratio lb/ld

```

Lap Length: lb/ld = 0.30356779
lb = 300.00
ld = 988.2471
Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars
= 1
db = 18.00
Mean strength value of all re-bars: fy = 555.55
fc' = 20.00, but fc^0.5 <= 8.3 MPa (22.5.3.1, ACI 318-14)
t = 1.00
s = 0.80
e = 1.00
cb = 25.00
Ktr = 4.61999
Atr = Min(Atr_x,Atr_y) = 157.0796
where Atr_x, Atr_y are the sum of the area of all stirrup legs along X and Y loxal axis
s = 170.00
n = 8.00

```

Calculation of Mu2-

```

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:
u = 3.4011160E-005
Mu = 5.9930E+007

```

with full section properties:

```

b = 500.00
d = 207.00
d' = 43.00
v = 0.00225456
N = 4666.932
fc = 20.00
co (5A.5, TBDY) = 0.002
Final value of cu: cu* = shear_factor * Max( cu, cc) = 0.01464474
The Shear_factor is considered equal to 1 (pure moment strength)
From (5.4b), TBDY: cu = 0.01464474
we ((5.4c), TBDY) = ase* sh,min*fywe/fce+Min( fx, fy) = 0.07762821
where f = af*pf*ffe/fce is accounting for FRP contribution like EC8-part3 A.4.4.3(6)
fx = 0.07705054
af = 0.45253333
b = 500.00
h = 250.00
From EC8 A.4.4.3(6), pf = 2tf/bw = 0.004064
bw = 500.00
effective stress from (A.35), ff,e = 837.9178

```

$f_y = 0.12936483$
 $a_f = 0.45253333$
 $b = 250.00$
 $h = 500.00$
 From EC8 A.4.4.3(6), $p_f = 2t_f/b_w = 0.008128$
 $b_w = 250.00$
 effective stress from (A.35), $f_{f,e} = 703.4155$

$R = 40.00$
 Effective FRP thickness, $t_f = NL \cdot t \cdot \cos(\beta_1) = 1.016$
 $f_{u,f} = 1055.00$
 $E_f = 64828.00$
 $u_{,f} = 0.015$
 $a_{se}((5.4d), TBDY) = 0.03751166$
 $b_o = 440.00$
 $h_o = 190.00$
 $b_{i2} = 459400.00$
 $p_{sh,min} = \min(p_{sh,x}, p_{sh,y}) = 0.001848$

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

$p_{sh,x}((5.4d)) = 0.001848$
 $A_{sh} = A_{stir} \cdot n_s = 78.53982$
 No stirrups, $n_s = 2.00$
 $b_k = 500.00$

$p_{sh,y}((5.4d)) = 0.00369599$
 $A_{sh} = A_{stir} \cdot n_s = 78.53982$
 No stirrups, $n_s = 2.00$
 $b_k = 250.00$

$s = 170.00$
 $f_{ywe} = 555.55$
 $f_{ce} = 20.00$

From ((5.A5), TBDY), TBDY: $c_c = 0.00339158$
 $c = \text{confinement factor} = 1.13916$

$y_1 = 0.00130695$
 $sh_1 = 0.00451687$
 $ft_1 = 376.4017$
 $fy_1 = 313.6681$
 $su_1 = 0.005257$

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

$l_o/l_{ou,min} = l_b/l_d = 0.30356779$

$su_1 = 0.4 \cdot esu1_{nominal}((5.5), TBDY) = 0.032$

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

For calculation of $esu1_{nominal}$ and y_1, sh_1, ft_1, fy_1 , it is considered characteristic value $fsy_1 = fs_1/1.2$, from table 5.1, TBDY.

y_1, sh_1, ft_1, fy_1 , are also multiplied by $\min(1, 1.25 \cdot (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.

with $fs_1 = fs = 313.6681$

with $Es_1 = Es = 200000.00$

$y_2 = 0.00130695$
 $sh_2 = 0.00451687$
 $ft_2 = 376.4017$
 $fy_2 = 313.6681$
 $su_2 = 0.005257$

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

$l_o/l_{ou,min} = l_b/l_{b,min} = 0.30356779$

$su_2 = 0.4 \cdot esu2_{nominal}((5.5), TBDY) = 0.032$

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

For calculation of $esu2_{nominal}$ and 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 $\min(1, 1.25 \cdot (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.


```

with fs2 = fs = 313.6681
with Es2 = Es = 200000.00
yv = 0.00130695
shv = 0.00451687
ftv = 376.4017
fyv = 313.6681
suv = 0.005257
using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779
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, ASCE41-17.
with fsv = fs = 313.6681
with Esv = Es = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.1256764
2 = Asl,com/(b*d)*(fs2/fc) = 0.1256764
v = Asl,mid/(b*d)*(fsv/fc) = 0.06093401
and confined core properties:
b = 440.00
d = 177.00
d' = 13.00
fcc (5A.2, TBDY) = 22.78316
cc (5A.5, TBDY) = 0.00339158
c = confinement factor = 1.13916
1 = Asl,ten/(b*d)*(fs1/fc) = 0.16701987
2 = Asl,com/(b*d)*(fs2/fc) = 0.16701987
v = Asl,mid/(b*d)*(fsv/fc) = 0.08097933
Case/Assumption: Unconfined full section - Steel rupture
' satisfies Eq. (4.3)
--->
v < vs,y2 - LHS eq.(4.5) is satisfied
--->
su (4.9) = 0.25329952
Mu = MRc (4.14) = 5.9930E+007
u = su (4.1) = 3.4011160E-005

```

Calculation of ratio lb/ld

```

Lap Length: lb/ld = 0.30356779
lb = 300.00
ld = 988.2471
Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
= 1
db = 18.00
Mean strength value of all re-bars: fy = 555.55
fc' = 20.00, but fc^0.5 <= 8.3 MPa (22.5.3.1, ACI 318-14)
t = 1.00
s = 0.80
e = 1.00
cb = 25.00
Ktr = 4.61999
Atr = Min(Atr_x,Atr_y) = 157.0796
where Atr_x, Atr_y are the sum of the area of all stirrup legs along X and Y loxal axis
s = 170.00
n = 8.00

```

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 265235.248$

Calculation of Shear Strength at edge 1, $V_{r1} = 265235.248$

$V_{r1} = V_{Col} ((10.3), ASCE 41-17) = knl * V_{ColO}$

$V_{ColO} = 265235.248$

$knl = 1$ (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)

$f_c' = 20.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$\mu_u = 2.3992784E-012$

$\nu_u = 2.9007121E-031$

$d = 0.8 * h = 200.00$

$N_u = 4666.932$

$A_g = 125000.00$

From (11.5.4.8), ACI 318-14: $V_s = 49279.392$

$A_v = 157079.633$

$f_y = 444.44$

$s = 170.00$

V_s is multiplied by $Col = 0.60$

$s/d = 0.85$

$V_f ((11-3)-(11.4), ACI 440) = 109072.851$

$f = 0.95$, 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: $\theta = \theta_1 + 90^\circ = 90.00$

$V_f = \text{Min}(|V_f(45, \theta_1)|, |V_f(-45, \alpha_1)|)$, with:

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

$d_{fv} = d$ (figure 11.2, ACI 440) = 207.00

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

$E_f = 64828.00$

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

with $f_u = 0.01$

From (11-11), ACI 440: $V_s + V_f \leq 297085.704$

$bw = 500.00$

Calculation of Shear Strength at edge 2, $V_{r2} = 265235.248$

$V_{r2} = V_{Col} ((10.3), ASCE 41-17) = knl * V_{ColO}$

$V_{ColO} = 265235.248$

$knl = 1$ (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)

$f_c' = 20.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$\mu_u = 2.3992784E-012$

$\nu_u = 2.9007121E-031$

$d = 0.8 * h = 200.00$

$N_u = 4666.932$

$A_g = 125000.00$

From (11.5.4.8), ACI 318-14: $V_s = 49279.392$

$A_v = 157079.633$

$f_y = 444.44$

$s = 170.00$

V_s is multiplied by $Col = 0.60$

$s/d = 0.85$

$V_f ((11-3)-(11.4), ACI 440) = 109072.851$

$f = 0.95$, 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 $V_f(\theta, \alpha_i)$, is implemented for every different fiber orientation α_i , as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.
orientation 1: $\theta_1 = \theta_1 + 90^\circ = 90.00$
 $V_f = \text{Min}(|V_f(45, \theta_1)|, |V_f(-45, \theta_1)|)$, with:
total thickness per orientation, $t_{f1} = NL \cdot t / \text{NoDir} = 1.016$
 $d_{fv} = d$ (figure 11.2, ACI 440) = 207.00
 $f_{fe}((11-5), \text{ACI 440}) = 259.312$
 $E_f = 64828.00$
 $f_e = 0.004$, from (11.6a), ACI 440
with $f_u = 0.01$
From (11-11), ACI 440: $V_s + V_f \leq 297085.704$
 $b_w = 500.00$

End Of Calculation of Shear Capacity ratio for element: column C1 of floor 1
At local axis: 3

Start Of Calculation of Shear Capacity ratio for element: column C1 of floor 1
At Shear local axis: 2
(Bending local axis: 3)
Section Type: rcrcs

Constant Properties

Knowledge Factor, $\phi = 1.00$
Mean strength values are used for both shear and moment calculations.
Consequently:
Existing material of Primary Member: Concrete Strength, $f_c = f_{cm} = 20.00$
Existing material of Primary Member: Steel Strength, $f_s = f_{sm} = 444.44$
Concrete Elasticity, $E_c = 21019.039$
Steel Elasticity, $E_s = 200000.00$

Note: Especially for the calculation of moment strengths,
the above steel re-bar strengths are multiplied by 1.25 according to R18.6.5, ACI 318-14
Existing material: Steel Strength, $f_s = 1.25 \cdot f_{sm} = 555.55$

Section Height, $H = 250.00$
Section Width, $W = 500.00$
Cover Thickness, $c = 25.00$
Mean Confinement Factor overall section = 1.13916
Element Length, $L = 3000.00$
Primary Member
Ribbed Bars
Ductile Steel
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
Lap Length $l_o = 300.00$
FRP Wrapping Data
Type: Carbon
Cured laminate properties (design values)
Thickness, $t = 1.016$
Tensile Strength, $f_{fu} = 1055.00$
Tensile Modulus, $E_f = 64828.00$
Elongation, $\epsilon_{fu} = 0.01$
Number of directions, $\text{NoDir} = 1$
Fiber orientations, $\theta_i: 0.00^\circ$
Number of layers, $NL = 1$
Radius of rounding corners, $R = 40.00$

Stepwise Properties

At local axis: 2

EDGE -A-
 Shear Force, $V_a = 1.3558547E-031$
 EDGE -B-
 Shear Force, $V_b = -1.3558547E-031$
 BOTH EDGES
 Axial Force, $F = -4666.932$
 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 , $V_e/V_r = 0.23676754$
 Member Controlled by Flexure ($V_e/V_r < 1$)
 Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 96937.922$
 with
 $M_{pr1} = \text{Max}(Mu_{1+} , Mu_{1-}) = 1.4541E+008$
 $Mu_{1+} = 1.4541E+008$, 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
 $Mu_{1-} = 1.4541E+008$, 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
 $M_{pr2} = \text{Max}(Mu_{2+} , Mu_{2-}) = 1.4541E+008$
 $Mu_{2+} = 1.4541E+008$, 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
 $Mu_{2-} = 1.4541E+008$, 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:
 $\phi_u = 1.4467178E-005$
 $M_u = 1.4541E+008$

with full section properties:

$b = 250.00$
 $d = 457.00$
 $d' = 43.00$
 $v = 0.00204242$
 $N = 4666.932$
 $f_c = 20.00$
 $\phi_{co} (5A.5, TBDY) = 0.002$
 Final value of ϕ_u : $\phi_u^* = \text{shear_factor} * \text{Max}(\phi_u, \phi_{co}) = 0.01464474$
 The Shear_factor is considered equal to 1 (pure moment strength)
 From (5.4b), TBDY: $\phi_u = 0.01464474$
 $\phi_{we} ((5.4c), TBDY) = a_s e * \phi_{sh,min} * f_{ywe}/f_{ce} + \text{Min}(\phi_{fx}, \phi_{fy}) = 0.07762821$
 where $\phi_{fx} = a_f * \phi_{pf} * f_{fe}/f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

 $\phi_{fx} = 0.07705054$
 $a_f = 0.45253333$
 $b = 500.00$
 $h = 250.00$
 From EC8 A.4.4.3(6), $\phi_{pf} = 2t_f/bw = 0.004064$
 $bw = 500.00$
 effective stress from (A.35), $f_{fe} = 837.9178$

$f_y = 0.12936483$
 $a_f = 0.45253333$
 $b = 250.00$
 $h = 500.00$

From EC8 A4.4.3(6), $pf = 2tf/bw = 0.008128$
 $bw = 250.00$
effective stress from (A.35), $ff,e = 703.4155$

$R = 40.00$
Effective FRP thickness, $tf = NL*t*\cos(b1) = 1.016$
 $f_{u,f} = 1055.00$
 $E_f = 64828.00$
 $u_{,f} = 0.015$
 $ase \text{ ((5.4d), TBDY)} = 0.03751166$
 $bo = 440.00$
 $ho = 190.00$
 $bi2 = 459400.00$
 $psh,min = \min(psh,x, psh,y) = 0.001848$

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

$psh,x \text{ (5.4d)} = 0.001848$
 $Ash = Astir*ns = 78.53982$
No stirrups, $ns = 2.00$
 $bk = 500.00$

$psh,y \text{ (5.4d)} = 0.00369599$
 $Ash = Astir*ns = 78.53982$
No stirrups, $ns = 2.00$
 $bk = 250.00$

$s = 170.00$
 $fywe = 555.55$
 $fce = 20.00$

From ((5.A5), TBDY), TBDY: $cc = 0.00339158$
 $c = \text{confinement factor} = 1.13916$

$y1 = 0.00130695$
 $sh1 = 0.00451687$

$ft1 = 376.4017$

$fy1 = 313.6681$

$su1 = 0.005257$

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

$lo/lou,min = lb/ld = 0.30356779$

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

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

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

$y1, sh1, ft1, fy1$, are also multiplied by $\min(1, 1.25*(lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

with $fs1 = fs = 313.6681$

with $Es1 = Es = 200000.00$

$y2 = 0.00130695$
 $sh2 = 0.00451687$

$ft2 = 376.4017$

$fy2 = 313.6681$

$su2 = 0.005257$

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

$lo/lou,min = lb/lb,min = 0.30356779$

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

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

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

$y1, sh1, ft1, fy1$, are also multiplied by $\min(1, 1.25*(lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

with $fs2 = fs = 313.6681$

with $Es2 = Es = 200000.00$

$yv = 0.00130695$
 $shv = 0.00451687$
 $ftv = 376.4017$

```

fyv = 313.6681
suv = 0.005257
using (30) in Biskinis/Fardis (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 = 0.30356779
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, ASCE41-17.
with fsv = fs = 313.6681
with Esv = Es = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.11385127
2 = Asl,com/(b*d)*(fs2/fc) = 0.11385127
v = Asl,mid/(b*d)*(fsv/fc) = 0.05520062
and confined core properties:
b = 190.00
d = 427.00
d' = 13.00
fcc (5A.2, TBDY) = 22.78316
cc (5A.5, TBDY) = 0.00339158
c = confinement factor = 1.13916
1 = Asl,ten/(b*d)*(fs1/fc) = 0.1603292
2 = Asl,com/(b*d)*(fs2/fc) = 0.1603292
v = Asl,mid/(b*d)*(fsv/fc) = 0.07773537
Case/Assumption: Unconfined full section - Steel rupture
' satisfies Eq. (4.3)
--->
v < vs,y2 - LHS eq.(4.5) is satisfied
--->
su (4.9) = 0.20486988
Mu = MRc (4.14) = 1.4541E+008
u = su (4.1) = 1.4467178E-005

```

Calculation of ratio lb/ld

```

Lap Length: lb/ld = 0.30356779
lb = 300.00
ld = 988.2471
Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
= 1
db = 18.00
Mean strength value of all re-bars: fy = 555.55
fc' = 20.00, but fc^0.5 <= 8.3 MPa (22.5.3.1, ACI 318-14)
t = 1.00
s = 0.80
e = 1.00
cb = 25.00
Ktr = 4.61999
Atr = Min(Atr_x,Atr_y) = 157.0796
where Atr_x, Atr_y are the sum of the area of all stirrup legs along X and Y loxal axis
s = 170.00
n = 8.00

```

Calculation of Mu1-

```

Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:
u = 1.4467178E-005
Mu = 1.4541E+008

```

with full section properties:

$$b = 250.00$$

$$d = 457.00$$

$$d' = 43.00$$

$$v = 0.00204242$$

$$N = 4666.932$$

$$f_c = 20.00$$

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

$$\text{Final value of } \alpha: \alpha^* = \text{shear_factor} * \text{Max}(\alpha, \alpha_c) = 0.01464474$$

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

$$\text{From (5.4b), TB DY: } \alpha = 0.01464474$$

$$\alpha_e ((5.4c), \text{TB DY}) = \alpha^* \cdot \text{sh}_{\min} \cdot f_{ywe} / f_{ce} + \text{Min}(\alpha_x, \alpha_y) = 0.07762821$$

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

$$\alpha_x = 0.07705054$$

$$\alpha_f = 0.45253333$$

$$b = 500.00$$

$$h = 250.00$$

$$\text{From EC8 A.4.4.3(6), } \rho_f = 2t_f/bw = 0.004064$$

$$bw = 500.00$$

$$\text{effective stress from (A.35), } f_{fe} = 837.9178$$

$$\alpha_y = 0.12936483$$

$$\alpha_f = 0.45253333$$

$$b = 250.00$$

$$h = 500.00$$

$$\text{From EC8 A.4.4.3(6), } \rho_f = 2t_f/bw = 0.008128$$

$$bw = 250.00$$

$$\text{effective stress from (A.35), } f_{fe} = 703.4155$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = NL \cdot t \cdot \cos(\beta_1) = 1.016$$

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

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$\alpha_e ((5.4d), \text{TB DY}) = 0.03751166$$

$$b_o = 440.00$$

$$h_o = 190.00$$

$$b_i^2 = 459400.00$$

$$\rho_{sh,\min} = \text{Min}(\rho_{sh,x}, \rho_{sh,y}) = 0.001848$$

Expression ((5.4d), TB DY) for $\rho_{sh,\min}$ has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$$\rho_{sh,x} (5.4d) = 0.001848$$

$$A_{sh} = A_{stir} \cdot n_s = 78.53982$$

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

$$b_k = 500.00$$

$$\rho_{sh,y} (5.4d) = 0.00369599$$

$$A_{sh} = A_{stir} \cdot n_s = 78.53982$$

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

$$b_k = 250.00$$

$$s = 170.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 20.00$$

$$\text{From ((5.A5), TB DY), TB DY: } \alpha_c = 0.00339158$$

$$c = \text{confinement factor} = 1.13916$$

$$y_1 = 0.00130695$$

$$sh_1 = 0.00451687$$

$$f_{t1} = 376.4017$$

$$f_{y1} = 313.6681$$

$$su_1 = 0.005257$$

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

and also multiplied by the shear_factor according to 15.7.1.4, with

$$\text{Shear_factor} = 1.00$$

$$l_o/l_{ou,\min} = l_b/d = 0.30356779$$

$su1 = 0.4 \cdot esu1_nominal ((5.5), TBDY) = 0.032$
 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 $Min(1, 1.25 \cdot (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.
 with $fs1 = fs = 313.6681$
 with $Es1 = Es = 200000.00$
 $y2 = 0.00130695$
 $sh2 = 0.00451687$
 $ft2 = 376.4017$
 $fy2 = 313.6681$
 $su2 = 0.005257$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $lo/lou, min = lb/lb, min = 0.30356779$
 $su2 = 0.4 \cdot esu2_nominal ((5.5), TBDY) = 0.032$
 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, ASCE41-17.
 with $fs2 = fs = 313.6681$
 with $Es2 = Es = 200000.00$
 $yv = 0.00130695$
 $shv = 0.00451687$
 $ftv = 376.4017$
 $fyv = 313.6681$
 $suv = 0.005257$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $lo/lou, min = lb/ld = 0.30356779$
 $suv = 0.4 \cdot esuv_nominal ((5.5), TBDY) = 0.032$
 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, ASCE41-17.
 with $fsv = fs = 313.6681$
 with $Esv = Es = 200000.00$
 $1 = Asl, ten / (b \cdot d) \cdot (fs1 / fc) = 0.11385127$
 $2 = Asl, com / (b \cdot d) \cdot (fs2 / fc) = 0.11385127$
 $v = Asl, mid / (b \cdot d) \cdot (fsv / fc) = 0.05520062$

and confined core properties:

$b = 190.00$
 $d = 427.00$
 $d' = 13.00$
 $fcc (5A.2, TBDY) = 22.78316$
 $cc (5A.5, TBDY) = 0.00339158$
 $c = \text{confinement factor} = 1.13916$
 $1 = Asl, ten / (b \cdot d) \cdot (fs1 / fc) = 0.1603292$
 $2 = Asl, com / (b \cdot d) \cdot (fs2 / fc) = 0.1603292$
 $v = Asl, mid / (b \cdot d) \cdot (fsv / fc) = 0.07773537$

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

--->
 $v < vs, y2$ - LHS eq.(4.5) is satisfied
 --->
 $su (4.9) = 0.20486988$
 $Mu = MRc (4.14) = 1.4541E+008$
 $u = su (4.1) = 1.4467178E-005$

Calculation of ratio lb/ld

Lap Length: $lb/ld = 0.30356779$
 $lb = 300.00$

Id = 988.2471

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

db = 18.00

Mean strength value of all re-bars: $f_y = 555.55$

$f_c' = 20.00$, but $f_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

t = 1.00

s = 0.80

e = 1.00

cb = 25.00

Ktr = 4.61999

$A_{tr} = \text{Min}(A_{tr,x}, A_{tr,y}) = 157.0796$

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

s = 170.00

n = 8.00

Calculation of μ_{2+}

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

$\mu = 1.4467178E-005$

$\mu = 1.4541E+008$

with full section properties:

b = 250.00

d = 457.00

d' = 43.00

v = 0.00204242

N = 4666.932

$f_c = 20.00$

ϕ (5A.5, TBDY) = 0.002

Final value of μ : $\mu^* = \text{shear_factor} * \text{Max}(\mu, \phi) = 0.01464474$

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

From (5.4b), TBDY: $\mu = 0.01464474$

we ((5.4c), TBDY) = $a_s * \frac{f_{y, \min} * f_{y, \text{we}}}{f_{c, \text{e}}} + \text{Min}(f_x, f_y) = 0.07762821$

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

$f_x = 0.07705054$

$a_f = 0.45253333$

b = 500.00

h = 250.00

From EC8 A.4.4.3(6), $p_f = 2t_f/bw = 0.004064$

bw = 500.00

effective stress from (A.35), $f_{f, \text{e}} = 837.9178$

$f_y = 0.12936483$

$a_f = 0.45253333$

b = 250.00

h = 500.00

From EC8 A.4.4.3(6), $p_f = 2t_f/bw = 0.008128$

bw = 250.00

effective stress from (A.35), $f_{f, \text{e}} = 703.4155$

R = 40.00

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

$f_{u, f} = 1055.00$

$E_f = 64828.00$

$u, f = 0.015$

a_s ((5.4d), TBDY) = 0.03751166

bo = 440.00

ho = 190.00

bi2 = 459400.00

$p_{sh, \min} = \text{Min}(p_{sh, x}, p_{sh, y}) = 0.001848$

Expression ((5.4d), TBDY) for $p_{sh, \min}$ has been multiplied by 0.3 according to 15.7.1.3 for members without

earthquake detailing (90° closed stirrups)

$$psh,x (5.4d) = 0.001848$$

$$Ash = Astir * ns = 78.53982$$

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

$$bk = 500.00$$

$$psh,y (5.4d) = 0.00369599$$

$$Ash = Astir * ns = 78.53982$$

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

$$bk = 250.00$$

$$s = 170.00$$

$$fywe = 555.55$$

$$fce = 20.00$$

$$\text{From } ((5.45), \text{TB DY}), \text{TB DY: } cc = 0.00339158$$

$$c = \text{confinement factor} = 1.13916$$

$$y1 = 0.00130695$$

$$sh1 = 0.00451687$$

$$ft1 = 376.4017$$

$$fy1 = 313.6681$$

$$su1 = 0.005257$$

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

$$lo/lo_{u,min} = lb/ld = 0.30356779$$

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

From table 5A.1, TB DY: $esu1_{nominal} = 0.08$,

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

$y1, sh1, ft1, fy1$, are also multiplied by $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

$$\text{with } fs1 = fs = 313.6681$$

$$\text{with } Es1 = Es = 200000.00$$

$$y2 = 0.00130695$$

$$sh2 = 0.00451687$$

$$ft2 = 376.4017$$

$$fy2 = 313.6681$$

$$su2 = 0.005257$$

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

$$lo/lo_{u,min} = lb/lb_{min} = 0.30356779$$

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

From table 5A.1, TB DY: $esu2_{nominal} = 0.08$,

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

$y1, sh1, ft1, fy1$, are also multiplied by $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

$$\text{with } fs2 = fs = 313.6681$$

$$\text{with } Es2 = Es = 200000.00$$

$$yv = 0.00130695$$

$$shv = 0.00451687$$

$$ftv = 376.4017$$

$$fyv = 313.6681$$

$$suv = 0.005257$$

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

$$lo/lo_{u,min} = lb/ld = 0.30356779$$

$$suv = 0.4 * esuv_{nominal} ((5.5), \text{TB DY}) = 0.032$$

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

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

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

$y1, sh1, ft1, fy1$, are also multiplied by $\text{Min}(1, 1.25 * (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.

$$\text{with } fsv = fs = 313.6681$$

$$\text{with } Esv = Es = 200000.00$$

$$1 = Asl_{ten}/(b * d) * (fs1/fc) = 0.11385127$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.11385127$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.05520062$$

and confined core properties:

$$b = 190.00$$

$$d = 427.00$$

$$d' = 13.00$$

$$f_{cc} (5A.2, TBDY) = 22.78316$$

$$cc (5A.5, TBDY) = 0.00339158$$

$$c = \text{confinement factor} = 1.13916$$

$$1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.1603292$$

$$2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.1603292$$

$$v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.07773537$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

$$su (4.9) = 0.20486988$$

$$Mu = M_{Rc} (4.14) = 1.4541E+008$$

$$u = su (4.1) = 1.4467178E-005$$

Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.30356779$

$$l_b = 300.00$$

$$l_d = 988.2471$$

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

$$= 1$$

$$d_b = 18.00$$

Mean strength value of all re-bars: $f_y = 555.55$

$$f_c' = 20.00, \text{ but } f_c'^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 25.00$$

$$K_{tr} = 4.61999$$

$$A_{tr} = \min(A_{tr,x}, A_{tr,y}) = 157.0796$$

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

$$s = 170.00$$

$$n = 8.00$$

Calculation of Mu_2 -

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

$$u = 1.4467178E-005$$

$$Mu = 1.4541E+008$$

with full section properties:

$$b = 250.00$$

$$d = 457.00$$

$$d' = 43.00$$

$$v = 0.00204242$$

$$N = 4666.932$$

$$f_c = 20.00$$

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

$$\text{Final value of } cu: cu^* = \text{shear_factor} * \max(cu, cc) = 0.01464474$$

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

$$\text{From (5.4b), TBDY: } cu = 0.01464474$$

$$we ((5.4c), TBDY) = a_{se} * sh_{,min} * f_{ywe}/f_{ce} + \min(f_x, f_y) = 0.07762821$$

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

$$f_x = 0.07705054$$

af = 0.45253333
b = 500.00
h = 250.00
From EC8 A4.4.3(6), $pf = 2tf/bw = 0.004064$
bw = 500.00
effective stress from (A.35), $ff,e = 837.9178$

fy = 0.12936483
af = 0.45253333
b = 250.00
h = 500.00
From EC8 A4.4.3(6), $pf = 2tf/bw = 0.008128$
bw = 250.00
effective stress from (A.35), $ff,e = 703.4155$

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) = 0.03751166
bo = 440.00
ho = 190.00
bi2 = 459400.00
psh,min = Min(psh,x , psh,y) = 0.001848
Expression ((5.4d), TBDY) for psh,min has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

psh,x (5.4d) = 0.001848
Ash = Astir*ns = 78.53982
No stirrups, ns = 2.00
bk = 500.00

psh,y (5.4d) = 0.00369599
Ash = Astir*ns = 78.53982
No stirrups, ns = 2.00
bk = 250.00

s = 170.00
fywe = 555.55
fce = 20.00
From ((5.A5), TBDY), TBDY: cc = 0.00339158
c = confinement factor = 1.13916
y1 = 0.00130695
sh1 = 0.00451687
ft1 = 376.4017
fy1 = 313.6681
su1 = 0.005257
using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779
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, ASCE41-17.
with fs1 = fs = 313.6681
with Es1 = Es = 200000.00
y2 = 0.00130695
sh2 = 0.00451687
ft2 = 376.4017
fy2 = 313.6681
su2 = 0.005257
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00

$l_o/l_{o,min} = l_b/l_{b,min} = 0.30356779$
 $su_2 = 0.4 \cdot esu_{2,nominal} ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $esu_{2,nominal} = 0.08$,
 For calculation of $esu_{2,nominal}$ and y_2, sh_2, ft_2, fy_2 , it is considered
 characteristic value $fsy_2 = fs_2/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.
 with $fs_2 = fs = 313.6681$
 with $Es_2 = Es = 200000.00$
 $y_v = 0.00130695$
 $sh_v = 0.00451687$
 $ft_v = 376.4017$
 $fy_v = 313.6681$
 $suv = 0.005257$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $l_o/l_{o,min} = l_b/l_d = 0.30356779$
 $suv = 0.4 \cdot esuv_{nominal} ((5.5), TBDY) = 0.032$
 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 $\text{Min}(1, 1.25 \cdot (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.
 with $fsv = fs = 313.6681$
 with $Es_v = Es = 200000.00$
 $1 = A_{sl,ten}/(b \cdot d) \cdot (fs_1/f_c) = 0.11385127$
 $2 = A_{sl,com}/(b \cdot d) \cdot (fs_2/f_c) = 0.11385127$
 $v = A_{sl,mid}/(b \cdot d) \cdot (fsv/f_c) = 0.05520062$
 and confined core properties:
 $b = 190.00$
 $d = 427.00$
 $d' = 13.00$
 $f_{cc} (5A.2, TBDY) = 22.78316$
 $cc (5A.5, TBDY) = 0.00339158$
 $c = \text{confinement factor} = 1.13916$
 $1 = A_{sl,ten}/(b \cdot d) \cdot (fs_1/f_c) = 0.1603292$
 $2 = A_{sl,com}/(b \cdot d) \cdot (fs_2/f_c) = 0.1603292$
 $v = A_{sl,mid}/(b \cdot d) \cdot (fsv/f_c) = 0.07773537$
 Case/Assumption: Unconfined full section - Steel rupture
 ' satisfies Eq. (4.3)
 --->
 $v < v_{s,y2}$ - LHS eq.(4.5) is satisfied
 --->
 $su (4.9) = 0.20486988$
 $\mu_u = M_{Rc} (4.14) = 1.4541E+008$
 $u = su (4.1) = 1.4467178E-005$

Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.30356779$
 $l_b = 300.00$
 $l_d = 988.2471$
 Calculation of $l_{b,min}$ according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
 $= 1$
 $db = 18.00$
 Mean strength value of all re-bars: $f_y = 555.55$
 $f_c' = 20.00$, but $f_c'^{0.5} \leq 8.3 \text{ MPa}$ (22.5.3.1, ACI 318-14)
 $t = 1.00$
 $s = 0.80$
 $e = 1.00$
 $cb = 25.00$
 $K_{tr} = 4.61999$
 $A_{tr} = \text{Min}(A_{tr,x}, A_{tr,y}) = 157.0796$
 where $A_{tr,x}, A_{tr,y}$ are the sum of the area of all stirrup legs along X and Y loxal axis
 $s = 170.00$
 $n = 8.00$

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 409422.352$

Calculation of Shear Strength at edge 1, $V_{r1} = 409422.352$

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

$V_{\text{ColO}} = 409422.352$

$k_{nl} = 1$ (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)

$f'_c = 20.00$, but $f'_c^{0.5} \leq 8.3 \text{ MPa}$ (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$\mu_u = 2.8180236E-013$

$V_u = 1.3558547E-031$

$d = 0.8 * h = 400.00$

$N_u = 4666.932$

$A_g = 125000.00$

From (11.5.4.8), ACI 318-14: $V_s = 164264.64$

$A_v = 157079.633$

$f_y = 444.44$

$s = 170.00$

V_s is multiplied by $\text{Col} = 1.00$

$s/d = 0.425$

$V_f ((11-3)-(11.4), \text{ACI } 440) = 240803.347$

$f = 0.95$, 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: $\theta_1 = b_1 + 90^\circ = 90.00$

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

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

$d_{fv} = d$ (figure 11.2, ACI 440) = 457.00

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

$E_f = 64828.00$

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

with $f_u = 0.01$

From (11-11), ACI 440: $V_s + V_f \leq 297085.704$

$b_w = 250.00$

Calculation of Shear Strength at edge 2, $V_{r2} = 409422.352$

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

$V_{\text{ColO}} = 409422.352$

$k_{nl} = 1$ (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)

$f'_c = 20.00$, but $f'_c^{0.5} \leq 8.3 \text{ MPa}$ (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$\mu_u = 2.8180236E-013$

$V_u = 1.3558547E-031$

$d = 0.8 * h = 400.00$

$N_u = 4666.932$

$A_g = 125000.00$

From (11.5.4.8), ACI 318-14: $V_s = 164264.64$

$A_v = 157079.633$

$f_y = 444.44$

$s = 170.00$

Vs is multiplied by Col = 1.00

s/d = 0.425

Vf ((11-3)-(11.4), ACI 440) = 240803.347

f = 0.95, for fully-wrapped sections

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

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

This later relation, considered as a function Vf(α), is implemented for every different fiber orientation αi, as well as for 2 crack directions, α = 45° and α = -45° to take into consideration the cyclic seismic loading.

orientation 1: α1 = α1 + 90° = 90.00

Vf = Min(|Vf(45, α1)|, |Vf(-45, α1)|), with:

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

dfv = d (figure 11.2, ACI 440) = 457.00

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 <= 297085.704

bw = 250.00

End Of Calculation of Shear Capacity ratio for element: column C1 of floor 1
At local axis: 2

Start Of Calculation of Chord Rotation Capacity for element: column C1 of floor 1
At local axis: 3
Integration Section: (a)
Section Type: rcrs

Constant Properties

Knowledge Factor, K = 1.00

Chord Rotation is generally considered as Deformation-Controlled Action according to Table C7-1, ASCE41-17.

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

Consequently:

Existing material of Primary Member: Concrete Strength, fc = fcm = 20.00

Existing material of Primary Member: Steel Strength, fs = fsm = 444.44

Concrete Elasticity, Ec = 21019.039

Steel Elasticity, Es = 200000.00

Section Height, H = 250.00

Section Width, W = 500.00

Cover Thickness, c = 25.00

Element Length, L = 3000.00

Primary Member

Ribbed Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

Lap Length lb = 300.00

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, t = 1.016

Tensile Strength, ffu = 1055.00

Tensile Modulus, Ef = 64828.00

Elongation, efu = 0.01

Number of directions, NoDir = 1

Fiber orientations, bi: 0.00°

Number of layers, NL = 1

Radius of rounding corners, R = 40.00

Stepwise Properties

Bending Moment, $M = -1.4246\text{E}+007$
 Shear Force, $V2 = -4708.27$
 Shear Force, $V3 = -3.5022564\text{E}-013$
 Axial Force, $F = -4886.081$
 Longitudinal Reinforcement Area Distribution (in 2 divisions)
 -Tension: $As_t = 1231.504$
 -Compression: $As_c = 829.3805$
 Longitudinal Reinforcement Area Distribution (in 3 divisions)
 -Tension: $As_{ten} = 829.3805$
 -Compression: $As_{com} = 829.3805$
 -Middle: $As_{mid} = 402.1239$
 Mean Diameter of Tension Reinforcement, $Db_L = 18.66667$

Existing component: From table 7-7, ASCE 41_17: Final chord rotation Capacity $u_R = u = 0.04902323$
 $u = y + p = 0.04902323$

- Calculation of y -

$y = (M_y * L_s / 3) / E_{eff} = 0.00702323$ ((4.29), Biskinis Phd))
 $M_y = 1.1435\text{E}+008$
 $L_s = M/V$ (with $L_s > 0.1 * L$ and $L_s < 2 * L$) = 3025.674
 From table 10.5, ASCE 41_17: $E_{eff} = \text{factor} * E_c * I_g = 1.6421\text{E}+013$
 factor = 0.30
 $A_g = 125000.00$
 $f_c' = 20.00$
 $N = 4886.081$
 $E_c * I_g = 5.4737\text{E}+013$

Calculation of Yielding Moment M_y

Calculation of y and M_y according to Annex 7 -

$y = \text{Min}(y_{ten}, y_{com})$
 $y_{ten} = 4.5289398\text{E}-006$
 with ((10.1), ASCE 41-17) $f_y = \text{Min}(f_y, 1.25 * f_y * (I_b / I_d)^{2/3}) = 291.1836$
 $d = 457.00$
 $y = 0.29656463$
 $A = 0.01818525$
 $B = 0.01001469$
 with $p_t = 0.00725935$
 $p_c = 0.00725935$
 $p_v = 0.00351968$
 $N = 4886.081$
 $b = 250.00$
 $" = 0.0940919$
 $y_{comp} = 1.2978922\text{E}-005$
 with $f_c' (12.3, (ACI 440)) = 20.44585$
 $f_c = 20.00$
 $f_l = 0.9425867$
 $b = 250.00$
 $h = 500.00$
 $A_g = 125000.00$
 From (12.9), ACI 440: $k_a = 0.15087868$
 $g = p_t + p_c + p_v = 0.01803838$
 $rc = 40.00$
 $A_e / A_c = 0.60351471$
 Effective FRP thickness, $t_f = N L * t * \text{Cos}(b_1) = 1.016$
 effective strain from (12.5) and (12.12), $\epsilon_{fe} = 0.004$
 $f_u = 0.01$
 $E_f = 64828.00$
 $E_c = 21019.039$

y = 0.29519565
A = 0.01791625
B = 0.00986782
with Es = 200000.00

Calculation of ratio l_b/l_d

Lap Length: $l_d/l_{d,min} = 0.37945973$

$l_b = 300.00$

$l_d = 790.5977$

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

$db = 18.00$

Mean strength value of all re-bars: $f_y = 444.44$

$f_c' = 20.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 4.61999$

$A_{tr} = \min(A_{tr_x}, A_{tr_y}) = 157.0796$

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

$s = 170.00$

$n = 8.00$

- Calculation of p -

From table 10-8: $p = 0.042$

with:

- Columns not controlled by inadequate development or splicing along the clear height because $l_b/l_d \geq 1$
shear control ratio $V_y E / V_{col} E = 0.23676754$

$d = 457.00$

$s = 0.00$

$t = A_v / (b_w s) + 2 t_f / b_w (f_{fe} / f_s) = 0.00$

$A_v = 157.0796$, is the total area of all stirrups parallel to loading (shear) direction

$b_w = 250.00$

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.

$NUD = 4886.081$

$A_g = 125000.00$

$f_{cE} = 20.00$

$f_{yE} = f_{yI} = 0.00$

$p_l = \text{Area_Tot_Long_Rein} / (b d) = 0.01803838$

$b = 250.00$

$d = 457.00$

$f_{cE} = 20.00$

End Of Calculation of Chord Rotation Capacity for element: column C1 of floor 1

At local axis: 3

Integration Section: (a)

Calculation No. 13

column C1, Floor 1

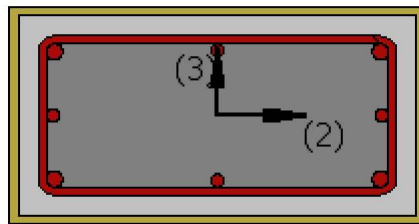
Limit State: Collapse Prevention (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Shear capacity V_{Rd}

Edge: End

Local Axis: (2)



Start Of Calculation of Shear Capacity for element: column C1 of floor 1

At local axis: 2

Integration Section: (b)

Section Type: rcrs

Constant Properties

Knowledge Factor, $\gamma = 1.00$

Member Shear Force is generally considered as Force-Controlled Action according to Table C7-1, ASCE41-17.

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

Consequently:

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

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

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of γ for displacement ductility demand,

the expected (mean value) strengths are used (7.5.1.3, ASCE41-17) because bending is considered as

Deformation-Controlled Action (Table C7-1, ASCE41-17).

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

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

#####

Section Height, $H = 250.00$

Section Width, $W = 500.00$

Cover Thickness, $c = 25.00$

Element Length, $L = 3000.00$

Primary Member

Ribbed Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

Lap Length $l_o = l_b = 300.00$

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $\epsilon_{fu} = 0.01$

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

EDGE -A-

Bending Moment, $M_a = -1.4246E+007$

Shear Force, $V_a = -4708.27$

EDGE -B-

Bending Moment, $M_b = 117197.472$

Shear Force, $V_b = 4708.27$

BOTH EDGES

Axial Force, $F = -4886.081$

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, $Db_{L,ten} = 18.66667$

Existing component: From table 7-7, ASCE 41-17: Final Shear Capacity $V_R = V_n = 366339.577$

$V_n ((10.3), ASCE 41-17) = knl * V_{Col0} = 366339.577$

$V_{Col} = 366339.577$

$knl = 1.00$

$displacement_ductility_demand = 0.18962367$

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)

$f'_c = 16.00$, but $f'_c \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$M_u = 117197.472$

$V_u = 4708.27$

$d = 0.8 * h = 400.00$

$N_u = 4886.081$

$A_g = 125000.00$

From (11.5.4.8), ACI 318-14: $V_s = 147839.654$

$A_v = 157079.633$

$f_y = 400.00$

$s = 170.00$

V_s is multiplied by $Col = 1.00$

$s/d = 0.425$

$V_f ((11-3)-(11.4), ACI 440) = 240803.347$

$f = 0.95$, for fully-wrapped sections

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

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

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

orientation 1: $a_1 = b_1 + 90^\circ = 90.00$

$V_f = \text{Min}(|V_f(45, 1)|, |V_f(-45, a_1)|)$, with:

total thickness per orientation, $tf1 = NL*t/NoDir = 1.016$
 $dfv = d$ (figure 11.2, ACI 440) = 457.00
 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: $Vs + Vf \leq 265721.532$
 $bw = 250.00$

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 $\theta = 0.00013205$
 $y = (My*Ls/3)/Eleff = 0.00069636$ ((4.29), Biskinis Phd))
 $My = 1.1435E+008$
 $Ls = M/V$ (with $Ls > 0.1*L$ and $Ls < 2*L$) = 300.00
From table 10.5, ASCE 41_17: $Eleff = factor*Ec*lg = 1.6421E+013$
 $factor = 0.30$
 $Ag = 125000.00$
 $fc' = 20.00$
 $N = 4886.081$
 $Ec*lg = 5.4737E+013$

Calculation of Yielding Moment My

Calculation of δ and My according to Annex 7 -

$y = \text{Min}(y_{ten}, y_{com})$
 $y_{ten} = 4.5289398E-006$
with ((10.1), ASCE 41-17) $fy = \text{Min}(fy, 1.25*fy*(lb/d)^{2/3}) = 291.1836$
 $d = 457.00$
 $y = 0.29656463$
 $A = 0.01818525$
 $B = 0.01001469$
with $pt = 0.00725935$
 $pc = 0.00725935$
 $pv = 0.00351968$
 $N = 4886.081$
 $b = 250.00$
 $" = 0.0940919$
 $y_{comp} = 1.2978922E-005$
with $fc' (12.3, (ACI 440)) = 20.44585$
 $fc = 20.00$
 $fl = 0.9425867$
 $b = 250.00$
 $h = 500.00$
 $Ag = 125000.00$
From (12.9), ACI 440: $ka = 0.15087868$
 $g = pt + pc + pv = 0.01803838$
 $rc = 40.00$
 $Ae/Ac = 0.60351471$
Effective FRP thickness, $tf = NL*t*\text{Cos}(b1) = 1.016$
effective strain from (12.5) and (12.12), $efe = 0.004$
 $fu = 0.01$
 $Ef = 64828.00$
 $Ec = 21019.039$
 $y = 0.29519565$
 $A = 0.01791625$
 $B = 0.00986782$
with $Es = 200000.00$

Calculation of ratio l_b/l_d

Lap Length: $l_d/l_{d,min} = 0.37945973$

$l_b = 300.00$

$l_d = 790.5977$

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

$= 1$

$d_b = 18.00$

Mean strength value of all re-bars: $f_y = 444.44$

$f'_c = 20.00$, but $f_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$c_b = 25.00$

$K_{tr} = 4.61999$

$A_{tr} = \min(A_{tr_x}, A_{tr_y}) = 157.0796$

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

$s = 170.00$

$n = 8.00$

End Of Calculation of Shear Capacity for element: column C1 of floor 1

At local axis: 2

Integration Section: (b)

Calculation No. 14

column C1, Floor 1

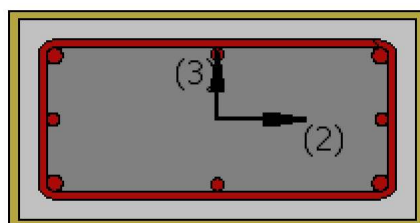
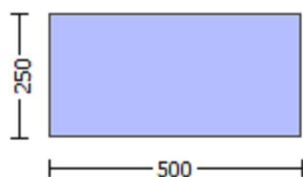
Limit State: Collapse Prevention (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity (ϕ)

Edge: End

Local Axis: (2)



Start Of Calculation of Shear Capacity ratio for element: column C1 of floor 1

At Shear local axis: 3

(Bending local axis: 2)

Section Type: rcrs

Constant Properties

Knowledge Factor, $\gamma = 1.00$

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

Consequently:

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

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

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

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

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

#####

Section Height, $H = 250.00$

Section Width, $W = 500.00$

Cover Thickness, $c = 25.00$

Mean Confinement Factor overall section = 1.13916

Element Length, $L = 3000.00$

Primary Member

Ribbed Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

Lap Length $l_o = 300.00$

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $\epsilon_{fu} = 0.01$

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

Fiber orientations, $b_i: 0.00^\circ$

Number of layers, $N_L = 1$

Radius of rounding corners, $R = 40.00$

Stepwise Properties

At local axis: 3

EDGE -A-

Shear Force, $V_a = 2.9007121E-031$

EDGE -B-

Shear Force, $V_b = -2.9007121E-031$

BOTH EDGES

Axial Force, $F = -4666.932$

Longitudinal Reinforcement Area Distribution (in 2 divisions)

-Tension: $A_{slt} = 0.00$

-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, $V_e/V_r = 0.15063296$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 39953.171$

with

$M_{pr1} = \text{Max}(M_{u1+}, M_{u1-}) = 5.9930E+007$

$M_{u1+} = 5.9930E+007$, is the ultimate moment strength at the edge 1 of the member in the actual moment direction

which is defined for the static loading combination

$Mu1- = 5.9930E+007$, is the ultimate moment strength at the edge 1 of the member in the opposite moment direction which is defined for the static loading combination

$Mpr2 = \text{Max}(Mu2+, Mu2-) = 5.9930E+007$

$Mu2+ = 5.9930E+007$, 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

$Mu2- = 5.9930E+007$, 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 $Mu1+$

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

$\phi_u = 3.4011160E-005$

$Mu = 5.9930E+007$

with full section properties:

$b = 500.00$

$d = 207.00$

$d' = 43.00$

$v = 0.00225456$

$N = 4666.932$

$f_c = 20.00$

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

Final value of ϕ_u : $\phi_u^* = \text{shear_factor} * \text{Max}(\phi_u, \phi_{co}) = 0.01464474$

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

From (5.4b), TBDY: $\phi_u = 0.01464474$

$\phi_{we} ((5.4c), TBDY) = a_{se} * \phi_{sh,min} * f_{ywe} / f_{ce} + \text{Min}(\phi_{fx}, \phi_{fy}) = 0.07762821$

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

$\phi_{fx} = 0.07705054$

$a_f = 0.45253333$

$b = 500.00$

$h = 250.00$

From EC8 A.4.4.3(6), $\phi_{pf} = 2t_f / b_w = 0.004064$

$b_w = 500.00$

effective stress from (A.35), $f_{fe} = 837.9178$

$\phi_{fy} = 0.12936483$

$a_f = 0.45253333$

$b = 250.00$

$h = 500.00$

From EC8 A.4.4.3(6), $\phi_{pf} = 2t_f / b_w = 0.008128$

$b_w = 250.00$

effective stress from (A.35), $f_{fe} = 703.4155$

$R = 40.00$

Effective FRP thickness, $t_f = N L^* t \cos(b_1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{f} = 0.015$

$a_{se} ((5.4d), TBDY) = 0.03751166$

$b_o = 440.00$

$h_o = 190.00$

$b_{i2} = 459400.00$

$\phi_{sh,min} = \text{Min}(\phi_{sh,x}, \phi_{sh,y}) = 0.001848$

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

$\phi_{sh,x} (5.4d) = 0.001848$

$A_{sh} = A_{stir} * n_s = 78.53982$

No stirrups, $n_s = 2.00$

$b_k = 500.00$

$\phi_{sh,y} (5.4d) = 0.00369599$

Ash = Astir*ns = 78.53982
No stirrups, ns = 2.00
bk = 250.00

s = 170.00
fywe = 555.55
fce = 20.00

From ((5A.5), TBDY), TBDY: cc = 0.00339158
c = confinement factor = 1.13916

y1 = 0.00130695
sh1 = 0.00451687

ft1 = 376.4017

fy1 = 313.6681

su1 = 0.005257

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779

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, ASCE41-17.

with fs1 = fs = 313.6681

with Es1 = Es = 200000.00

y2 = 0.00130695

sh2 = 0.00451687

ft2 = 376.4017

fy2 = 313.6681

su2 = 0.005257

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779

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, ASCE41-17.

with fs2 = fs = 313.6681

with Es2 = Es = 200000.00

yv = 0.00130695

shv = 0.00451687

ftv = 376.4017

fyv = 313.6681

suv = 0.005257

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779

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, ASCE41-17.

with fsv = fs = 313.6681

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.1256764

2 = Asl,com/(b*d)*(fs2/fc) = 0.1256764

v = Asl,mid/(b*d)*(fsv/fc) = 0.06093401

and confined core properties:

b = 440.00

d = 177.00

d' = 13.00

fcc (5A.2, TBDY) = 22.78316

cc (5A.5, TBDY) = 0.00339158

$c = \text{confinement factor} = 1.13916$
 $1 = A_{sl,ten}/(b*d)*(f_{s1}/f_c) = 0.16701987$
 $2 = A_{sl,com}/(b*d)*(f_{s2}/f_c) = 0.16701987$
 $v = A_{sl,mid}/(b*d)*(f_{sv}/f_c) = 0.08097933$

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

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

$su(4.9) = 0.25329952$
 $Mu = MRc(4.14) = 5.9930E+007$
 $u = su(4.1) = 3.4011160E-005$

Calculation of ratio l_b/d

Lap Length: $l_b/d = 0.30356779$

$l_b = 300.00$

$l_d = 988.2471$

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

$db = 18.00$

Mean strength value of all re-bars: $f_y = 555.55$

$f'_c = 20.00$, but $f_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$cb = 25.00$

$K_{tr} = 4.61999$

$A_{tr} = \text{Min}(A_{tr,x}, A_{tr,y}) = 157.0796$

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

$s = 170.00$

$n = 8.00$

Calculation of $Mu1$ -

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

$u = 3.4011160E-005$

$Mu = 5.9930E+007$

with full section properties:

$b = 500.00$

$d = 207.00$

$d' = 43.00$

$v = 0.00225456$

$N = 4666.932$

$f_c = 20.00$

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

Final value of cu : $cu^* = \text{shear_factor} * \text{Max}(cu, cc) = 0.01464474$

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

From (5.4b), TBDY: $cu = 0.01464474$

we ((5.4c), TBDY) $= a_{se} * sh_{\min} * f_{ywe}/f_{ce} + \text{Min}(fx, fy) = 0.07762821$

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

$fx = 0.07705054$

$af = 0.45253333$

$b = 500.00$

$h = 250.00$

From EC8 A.4.4.3(6), $pf = 2tf/bw = 0.004064$

$bw = 500.00$

effective stress from (A.35), $ff_e = 837.9178$

$fy = 0.12936483$

af = 0.45253333

b = 250.00

h = 500.00

From EC8 A.4.4.3(6), $pf = 2tf/bw = 0.008128$

bw = 250.00

effective stress from (A.35), $ff,e = 703.4155$

R = 40.00

Effective FRP thickness, $tf = NL*t*\cos(b1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{,f} = 0.015$

$ase((5.4d), TBDY) = 0.03751166$

bo = 440.00

ho = 190.00

bi2 = 459400.00

$psh,min = \min(psh,x, psh,y) = 0.001848$

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

$psh,x(5.4d) = 0.001848$

Ash = Astir*ns = 78.53982

No stirrups, ns = 2.00

bk = 500.00

$psh,y(5.4d) = 0.00369599$

Ash = Astir*ns = 78.53982

No stirrups, ns = 2.00

bk = 250.00

s = 170.00

$f_{ywe} = 555.55$

fce = 20.00

From ((5.A5), TBDY), TBDY: cc = 0.00339158

c = confinement factor = 1.13916

$y1 = 0.00130695$

sh1 = 0.00451687

ft1 = 376.4017

fy1 = 313.6681

su1 = 0.005257

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

$lo/lou,min = lb/ld = 0.30356779$

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

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, ASCE41-17.

with $fs1 = fs = 313.6681$

with $Es1 = Es = 200000.00$

$y2 = 0.00130695$

sh2 = 0.00451687

ft2 = 376.4017

fy2 = 313.6681

su2 = 0.005257

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

$lo/lou,min = lb/lb,min = 0.30356779$

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

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, ASCE41-17.

with $fs2 = fs = 313.6681$

with $Es2 = Es = 200000.00$

```

yv = 0.00130695
shv = 0.00451687
ftv = 376.4017
fyv = 313.6681
suv = 0.005257
using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779
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, ASCE41-17.
with fsv = fs = 313.6681
with Esv = Es = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.1256764
2 = Asl,com/(b*d)*(fs2/fc) = 0.1256764
v = Asl,mid/(b*d)*(fsv/fc) = 0.06093401
and confined core properties:
b = 440.00
d = 177.00
d' = 13.00
fcc (5A.2, TBDY) = 22.78316
cc (5A.5, TBDY) = 0.00339158
c = confinement factor = 1.13916
1 = Asl,ten/(b*d)*(fs1/fc) = 0.16701987
2 = Asl,com/(b*d)*(fs2/fc) = 0.16701987
v = Asl,mid/(b*d)*(fsv/fc) = 0.08097933
Case/Assumption: Unconfined full section - Steel rupture
' satisfies Eq. (4.3)
--->
v < vs,y2 - LHS eq.(4.5) is satisfied
--->
su (4.9) = 0.25329952
Mu = MRc (4.14) = 5.9930E+007
u = su (4.1) = 3.4011160E-005

```

Calculation of ratio lb/ld

```

Lap Length: lb/ld = 0.30356779
lb = 300.00
ld = 988.2471
Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
= 1
db = 18.00
Mean strength value of all re-bars: fy = 555.55
fc' = 20.00, but fc^0.5 <= 8.3 MPa (22.5.3.1, ACI 318-14)
t = 1.00
s = 0.80
e = 1.00
cb = 25.00
Ktr = 4.61999
Atr = Min(Atr_x,Atr_y) = 157.0796
where Atr_x, Atr_y are the sum of the area of all stirrup legs along X and Y loxal axis
s = 170.00
n = 8.00

```

Calculation of Mu2+

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

u = 3.4011160E-005
Mu = 5.9930E+007

with full section properties:

b = 500.00

d = 207.00

d' = 43.00

v = 0.00225456

N = 4666.932

fc = 20.00

co (5A.5, TBDY) = 0.002

Final value of cu: $cu^* = \text{shear_factor} * \text{Max}(cu, cc) = 0.01464474$

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

From (5.4b), TBDY: $cu = 0.01464474$

we ((5.4c), TBDY) = $ase * sh_{min} * fy_{we} / f_{ce} + \text{Min}(fx, fy) = 0.07762821$

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

fx = 0.07705054

af = 0.45253333

b = 500.00

h = 250.00

From EC8 A.4.4.3(6), $pf = 2tf/bw = 0.004064$

bw = 500.00

effective stress from (A.35), $ff_e = 837.9178$

fy = 0.12936483

af = 0.45253333

b = 250.00

h = 500.00

From EC8 A.4.4.3(6), $pf = 2tf/bw = 0.008128$

bw = 250.00

effective stress from (A.35), $ff_e = 703.4155$

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) = 0.03751166

bo = 440.00

ho = 190.00

bi2 = 459400.00

$psh_{min} = \text{Min}(psh_x, psh_y) = 0.001848$

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

psh_x (5.4d) = 0.001848

Ash = $A_{stir} * ns = 78.53982$

No stirrups, ns = 2.00

bk = 500.00

psh_y (5.4d) = 0.00369599

Ash = $A_{stir} * ns = 78.53982$

No stirrups, ns = 2.00

bk = 250.00

s = 170.00

fywe = 555.55

fce = 20.00

From ((5.A5), TBDY), TBDY: $cc = 0.00339158$

c = confinement factor = 1.13916

y1 = 0.00130695

sh1 = 0.00451687

ft1 = 376.4017

fy1 = 313.6681

su1 = 0.005257

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

and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
 $l_o/l_{ou,min} = l_b/l_d = 0.30356779$
 $su_1 = 0.4 * esu_{1,nominal} ((5.5), TBDY) = 0.032$
From table 5A.1, TBDY: $esu_{1,nominal} = 0.08$,
For calculation of $esu_{1,nominal}$ and y_1, sh_1, ft_1, fy_1 , it is considered
characteristic value $fsy_1 = fs_1/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $Min(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.
with $fs_1 = fs = 313.6681$
with $Es_1 = Es = 200000.00$
 $y_2 = 0.00130695$
 $sh_2 = 0.00451687$
 $ft_2 = 376.4017$
 $fy_2 = 313.6681$
 $su_2 = 0.005257$
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
 $l_o/l_{ou,min} = l_b/l_{b,min} = 0.30356779$
 $su_2 = 0.4 * esu_{2,nominal} ((5.5), TBDY) = 0.032$
From table 5A.1, TBDY: $esu_{2,nominal} = 0.08$,
For calculation of $esu_{2,nominal}$ and y_2, sh_2, ft_2, fy_2 , it is considered
characteristic value $fsy_2 = fs_2/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $Min(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.
with $fs_2 = fs = 313.6681$
with $Es_2 = Es = 200000.00$
 $y_v = 0.00130695$
 $sh_v = 0.00451687$
 $ft_v = 376.4017$
 $fy_v = 313.6681$
 $suv = 0.005257$
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
 $l_o/l_{ou,min} = l_b/l_d = 0.30356779$
 $suv = 0.4 * esuv_{nominal} ((5.5), TBDY) = 0.032$
From table 5A.1, TBDY: $esuv_{nominal} = 0.08$,
considering characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY
For calculation of $esuv_{nominal}$ and y_v, sh_v, ft_v, fy_v , it is considered
characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $Min(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.
with $fsv = fs = 313.6681$
with $Esv = Es = 200000.00$
 $1 = Asl_{ten}/(b*d) * (fs_1/fc) = 0.1256764$
 $2 = Asl_{com}/(b*d) * (fs_2/fc) = 0.1256764$
 $v = Asl_{mid}/(b*d) * (fsv/fc) = 0.06093401$
and confined core properties:
 $b = 440.00$
 $d = 177.00$
 $d' = 13.00$
 $f_{cc} (5A.2, TBDY) = 22.78316$
 $cc (5A.5, TBDY) = 0.00339158$
 $c = \text{confinement factor} = 1.13916$
 $1 = Asl_{ten}/(b*d) * (fs_1/fc) = 0.16701987$
 $2 = Asl_{com}/(b*d) * (fs_2/fc) = 0.16701987$
 $v = Asl_{mid}/(b*d) * (fsv/fc) = 0.08097933$
Case/Assumption: Unconfined full section - Steel rupture
'satisfies Eq. (4.3)
--->
 $v < v_{s,y2}$ - LHS eq.(4.5) is satisfied
--->
 $su (4.9) = 0.25329952$
 $Mu = MRc (4.14) = 5.9930E+007$
 $u = su (4.1) = 3.4011160E-005$

Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.30356779$

$l_b = 300.00$

$l_d = 988.2471$

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

$= 1$

$d_b = 18.00$

Mean strength value of all re-bars: $f_y = 555.55$

$f_c' = 20.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$c_b = 25.00$

$K_{tr} = 4.61999$

$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$

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

$s = 170.00$

$n = 8.00$

Calculation of μ_2 -

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

$\mu = 3.4011160E-005$

$\mu_u = 5.9930E+007$

with full section properties:

$b = 500.00$

$d = 207.00$

$d' = 43.00$

$v = 0.00225456$

$N = 4666.932$

$f_c = 20.00$

α (5A.5, TBDY) = 0.002

Final value of μ_u : $\mu_u^* = \text{shear_factor} * \text{Max}(\mu_u, \alpha) = 0.01464474$

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

From (5.4b), TBDY: $\mu_u = 0.01464474$

we ((5.4c), TBDY) = $\alpha * \text{sh}_{\min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.07762821$

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

$f_x = 0.07705054$

$\alpha_f = 0.45253333$

$b = 500.00$

$h = 250.00$

From EC8 A.4.4.3(6), $p_f = 2t_f/bw = 0.004064$

$bw = 500.00$

effective stress from (A.35), $f_{fe} = 837.9178$

$f_y = 0.12936483$

$\alpha_f = 0.45253333$

$b = 250.00$

$h = 500.00$

From EC8 A.4.4.3(6), $p_f = 2t_f/bw = 0.008128$

$bw = 250.00$

effective stress from (A.35), $f_{fe} = 703.4155$

$R = 40.00$

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

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{,f} = 0.015$

α_{se} ((5.4d), TBDY) = 0.03751166

$b_o = 440.00$

$h_o = 190.00$

```

bi2 = 459400.00
psh,min = Min(psh,x , psh,y) = 0.001848
Expression ((5.4d), TBDY) for psh,min has been multiplied by 0.3 according to 15.7.1.3 for members without
earthquake detailing (90° closed stirrups)
-----
psh,x (5.4d) = 0.001848
Ash = Astir*ns = 78.53982
No stirups, ns = 2.00
bk = 500.00
-----
psh,y (5.4d) = 0.00369599
Ash = Astir*ns = 78.53982
No stirups, ns = 2.00
bk = 250.00
-----
s = 170.00
fywe = 555.55
fce = 20.00
From ((5.A5), TBDY), TBDY: cc = 0.00339158
c = confinement factor = 1.13916
y1 = 0.00130695
sh1 = 0.00451687
ft1 = 376.4017
fy1 = 313.6681
su1 = 0.005257
using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779
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, ASCE41-17.
with fs1 = fs = 313.6681
with Es1 = Es = 200000.00
y2 = 0.00130695
sh2 = 0.00451687
ft2 = 376.4017
fy2 = 313.6681
su2 = 0.005257
using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779
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, ASCE41-17.
with fs2 = fs = 313.6681
with Es2 = Es = 200000.00
yv = 0.00130695
shv = 0.00451687
ftv = 376.4017
fyv = 313.6681
suv = 0.005257
using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779
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,min)^ 2/3), from 10.3.5, ASCE41-17.

```

```

with fsv = fs = 313.6681
with Esv = Es = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.1256764
2 = Asl,com/(b*d)*(fs2/fc) = 0.1256764
v = Asl,mid/(b*d)*(fsv/fc) = 0.06093401
and confined core properties:
b = 440.00
d = 177.00
d' = 13.00
fcc (5A.2, TBDY) = 22.78316
cc (5A.5, TBDY) = 0.00339158
c = confinement factor = 1.13916
1 = Asl,ten/(b*d)*(fs1/fc) = 0.16701987
2 = Asl,com/(b*d)*(fs2/fc) = 0.16701987
v = Asl,mid/(b*d)*(fsv/fc) = 0.08097933
Case/Assumption: Unconfined full section - Steel rupture
'satisfies Eq. (4.3)

```

```

--->
v < vs,y2 - LHS eq.(4.5) is satisfied
--->
su (4.9) = 0.25329952
Mu = MRc (4.14) = 5.9930E+007
u = su (4.1) = 3.4011160E-005

```

Calculation of ratio lb/d

```

Lap Length: lb/d = 0.30356779
lb = 300.00
ld = 988.2471
Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
= 1
db = 18.00
Mean strength value of all re-bars: fy = 555.55
fc' = 20.00, but fc^0.5 <= 8.3 MPa (22.5.3.1, ACI 318-14)
t = 1.00
s = 0.80
e = 1.00
cb = 25.00
Ktr = 4.61999
Atr = Min(Atr_x,Atr_y) = 157.0796
where Atr_x, Atr_y are the sum of the area of all stirrup legs along X and Y loxal axis
s = 170.00
n = 8.00

```

Calculation of Shear Strength $V_r = \text{Min}(V_{r1}, V_{r2}) = 265235.248$

```

Calculation of Shear Strength at edge 1, Vr1 = 265235.248
Vr1 = VCol ((10.3), ASCE 41-17) = knl*VColO
VColO = 265235.248
knl = 1 (zero step-static loading)

```

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

```

= 1 (normal-weight concrete)
fc' = 20.00, but fc^0.5 <= 8.3 MPa (22.5.3.1, ACI 318-14)
M/Vd = 2.00
Mu = 2.3992784E-012
Vu = 2.9007121E-031
d = 0.8*h = 200.00
Nu = 4666.932
Ag = 125000.00
From (11.5.4.8), ACI 318-14: Vs = 49279.392

```


$A_v = 157079.633$
 $f_y = 444.44$
 $s = 170.00$
 V_s is multiplied by $\text{Col} = 0.60$
 $s/d = 0.85$
 $V_f ((11-3)-(11.4), \text{ACI } 440) = 109072.851$
 $f = 0.95$, for fully-wrapped sections
 $w_f/s_f = 1$ (FRP strips adjacent to one another).
 $\ln (11.3) \sin + \cos$ is replaced with $(\cot + \cot a) \sin a$ which is more a generalised expression,
 where θ is the angle of the crack direction (see KANEPE).
 This later relation, considered as a function $V_f(\theta)$, 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, $t_{f1} = N_L * t / \text{NoDir} = 1.016$
 $d_{fv} = d$ (figure 11.2, ACI 440) = 207.00
 $f_{fe} ((11-5), \text{ACI } 440) = 259.312$
 $E_f = 64828.00$
 $f_e = 0.004$, from (11.6a), ACI 440
 with $f_u = 0.01$
 From (11-11), ACI 440: $V_s + V_f \leq 297085.704$
 $b_w = 500.00$

Calculation of Shear Strength at edge 2, $V_{r2} = 265235.248$
 $V_{r2} = V_{\text{Col}} ((10.3), \text{ASCE } 41-17) = k_{nl} * V_{\text{ColO}}$
 $V_{\text{ColO}} = 265235.248$
 $k_{nl} = 1$ (zero step-static loading)

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

$\rho = 1$ (normal-weight concrete)
 $f'_c = 20.00$, but $f_c^{0.5} \leq 8.3 \text{ MPa}$ (22.5.3.1, ACI 318-14)
 $M/Vd = 2.00$
 $\mu_u = 2.3992784\text{E-}012$
 $\nu_u = 2.9007121\text{E-}031$
 $d = 0.8 * h = 200.00$
 $N_u = 4666.932$
 $A_g = 125000.00$
 From (11.5.4.8), ACI 318-14: $V_s = 49279.392$
 $A_v = 157079.633$
 $f_y = 444.44$
 $s = 170.00$
 V_s is multiplied by $\text{Col} = 0.60$
 $s/d = 0.85$
 $V_f ((11-3)-(11.4), \text{ACI } 440) = 109072.851$
 $f = 0.95$, for fully-wrapped sections
 $w_f/s_f = 1$ (FRP strips adjacent to one another).
 $\ln (11.3) \sin + \cos$ is replaced with $(\cot + \cot a) \sin a$ which is more a generalised expression,
 where θ is the angle of the crack direction (see KANEPE).
 This later relation, considered as a function $V_f(\theta)$, 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, $t_{f1} = N_L * t / \text{NoDir} = 1.016$
 $d_{fv} = d$ (figure 11.2, ACI 440) = 207.00
 $f_{fe} ((11-5), \text{ACI } 440) = 259.312$
 $E_f = 64828.00$
 $f_e = 0.004$, from (11.6a), ACI 440
 with $f_u = 0.01$
 From (11-11), ACI 440: $V_s + V_f \leq 297085.704$
 $b_w = 500.00$

End Of Calculation of Shear Capacity ratio for element: column C1 of floor 1
 At local axis: 3

Start Of Calculation of Shear Capacity ratio for element: column C1 of floor 1

At Shear local axis: 2

(Bending local axis: 3)

Section Type: rcrs

Constant Properties

Knowledge Factor, $\gamma = 1.00$

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

Consequently:

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

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

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

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

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

#####

Section Height, $H = 250.00$

Section Width, $W = 500.00$

Cover Thickness, $c = 25.00$

Mean Confinement Factor overall section = 1.13916

Element Length, $L = 3000.00$

Primary Member

Ribbed Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

Lap Length $l_o = 300.00$

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $\epsilon_{fu} = 0.01$

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

Fiber orientations, $b_i = 0.00^\circ$

Number of layers, $N_L = 1$

Radius of rounding corners, $R = 40.00$

Stepwise Properties

At local axis: 2

EDGE -A-

Shear Force, $V_a = 1.3558547E-031$

EDGE -B-

Shear Force, $V_b = -1.3558547E-031$

BOTH EDGES

Axial Force, $F = -4666.932$

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 , $V_e/V_r = 0.23676754$

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

Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 96937.922$

with

$M_{pr1} = \text{Max}(M_{u1+}, M_{u1-}) = 1.4541\text{E}+008$

$M_{u1+} = 1.4541\text{E}+008$, 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

$M_{u1-} = 1.4541\text{E}+008$, 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

$M_{pr2} = \text{Max}(M_{u2+}, M_{u2-}) = 1.4541\text{E}+008$

$M_{u2+} = 1.4541\text{E}+008$, 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

$M_{u2-} = 1.4541\text{E}+008$, 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:

$\phi_u = 1.4467178\text{E}-005$

$M_u = 1.4541\text{E}+008$

with full section properties:

$b = 250.00$

$d = 457.00$

$d' = 43.00$

$v = 0.00204242$

$N = 4666.932$

$f_c = 20.00$

ϕ_c (5A.5, TBDY) = 0.002

Final value of ϕ_u : $\phi_u^* = \text{shear_factor} * \text{Max}(\phi_c, \phi_c) = 0.01464474$

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

From (5.4b), TBDY: $\phi_u = 0.01464474$

ϕ_{ue} ((5.4c), TBDY) = $a_s e^* \phi_{ue} / f_{ce} + \text{Min}(\phi_x, \phi_y) = 0.07762821$

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

 $\phi_x = 0.07705054$

$a_s = 0.45253333$

$b = 500.00$

$h = 250.00$

From EC8 A.4.4.3(6), $\phi_f = 2t_f/b_w = 0.004064$

$b_w = 500.00$

effective stress from (A.35), $\phi_{fe} = 837.9178$

$\phi_y = 0.12936483$

$a_s = 0.45253333$

$b = 250.00$

$h = 500.00$

From EC8 A.4.4.3(6), $\phi_f = 2t_f/b_w = 0.008128$

$b_w = 250.00$

effective stress from (A.35), $\phi_{fe} = 703.4155$

$R = 40.00$

Effective FRP thickness, $t_f = N L^* t^* \cos(\beta_1) = 1.016$

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_f = 0.015$

$a_s e$ ((5.4d), TBDY) = 0.03751166

$b_o = 440.00$

$h_o = 190.00$

$b_{i2} = 459400.00$

$\phi_{sh,min} = \text{Min}(\phi_{sh,x}, \phi_{sh,y}) = 0.001848$

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

psh,x (5.4d) = 0.001848
 Ash = Astir*ns = 78.53982
 No stirups, ns = 2.00
 bk = 500.00

psh,y (5.4d) = 0.00369599
 Ash = Astir*ns = 78.53982
 No stirups, ns = 2.00
 bk = 250.00

s = 170.00
 fywe = 555.55
 fce = 20.00

From ((5.A5), TBDY), TBDY: cc = 0.00339158
 c = confinement factor = 1.13916

y1 = 0.00130695
 sh1 = 0.00451687

ft1 = 376.4017

fy1 = 313.6681

su1 = 0.005257

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779

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, ASCE41-17.

with fs1 = fs = 313.6681

with Es1 = Es = 200000.00

y2 = 0.00130695

sh2 = 0.00451687

ft2 = 376.4017

fy2 = 313.6681

su2 = 0.005257

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779

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, ASCE41-17.

with fs2 = fs = 313.6681

with Es2 = Es = 200000.00

yv = 0.00130695

shv = 0.00451687

ftv = 376.4017

fyv = 313.6681

suv = 0.005257

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779

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, ASCE41-17.

with fsv = fs = 313.6681

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.11385127

2 = Asl,com/(b*d)*(fs2/fc) = 0.11385127

v = Asl,mid/(b*d)*(fsv/fc) = 0.05520062

and confined core properties:

$$b = 190.00$$

$$d = 427.00$$

$$d' = 13.00$$

$$fcc(5A.2, TBDY) = 22.78316$$

$$cc(5A.5, TBDY) = 0.00339158$$

$$c = \text{confinement factor} = 1.13916$$

$$1 = A_{s1,ten}/(b*d)*(f_{s1}/f_c) = 0.1603292$$

$$2 = A_{s2,com}/(b*d)*(f_{s2}/f_c) = 0.1603292$$

$$v = A_{s,mid}/(b*d)*(f_{sv}/f_c) = 0.07773537$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

$$s_u(4.9) = 0.20486988$$

$$M_u = M_{Rc}(4.14) = 1.4541E+008$$

$$u = s_u(4.1) = 1.4467178E-005$$

Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.30356779$

$$l_b = 300.00$$

$$l_d = 988.2471$$

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

$$= 1$$

$$d_b = 18.00$$

Mean strength value of all re-bars: $f_y = 555.55$

$$f_c' = 20.00, \text{ but } f_c'^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 25.00$$

$$K_{tr} = 4.61999$$

$$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$$

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

$$s = 170.00$$

$$n = 8.00$$

Calculation of M_u1 -

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

$$u = 1.4467178E-005$$

$$M_u = 1.4541E+008$$

with full section properties:

$$b = 250.00$$

$$d = 457.00$$

$$d' = 43.00$$

$$v = 0.00204242$$

$$N = 4666.932$$

$$f_c = 20.00$$

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

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_o) = 0.01464474$$

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

$$\text{From (5.4b), TBDY: } c_u = 0.01464474$$

$$w_e((5.4c), TBDY) = a_s e^* s_{h,min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.07762821$$

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

$$f_x = 0.07705054$$

$$a_f = 0.45253333$$

$$b = 500.00$$

h = 250.00
From EC8 A4.4.3(6), $pf = 2tf/bw = 0.004064$
bw = 500.00
effective stress from (A.35), $ff,e = 837.9178$

fy = 0.12936483
af = 0.45253333
b = 250.00
h = 500.00
From EC8 A4.4.3(6), $pf = 2tf/bw = 0.008128$
bw = 250.00
effective stress from (A.35), $ff,e = 703.4155$

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) = 0.03751166
bo = 440.00
ho = 190.00
bi2 = 459400.00
psh,min = Min(psh,x , psh,y) = 0.001848
Expression ((5.4d), TBDY) for psh,min has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

psh,x (5.4d) = 0.001848
Ash = Astir*ns = 78.53982
No stirrups, ns = 2.00
bk = 500.00

psh,y (5.4d) = 0.00369599
Ash = Astir*ns = 78.53982
No stirrups, ns = 2.00
bk = 250.00

s = 170.00
fywe = 555.55
fce = 20.00
From ((5.A5), TBDY), TBDY: cc = 0.00339158
c = confinement factor = 1.13916
y1 = 0.00130695
sh1 = 0.00451687
ft1 = 376.4017
fy1 = 313.6681
su1 = 0.005257
using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779
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, ASCE41-17.
with fs1 = fs = 313.6681
with Es1 = Es = 200000.00
y2 = 0.00130695
sh2 = 0.00451687
ft2 = 376.4017
fy2 = 313.6681
su2 = 0.005257
using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779
su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: $es_{u2_nominal} = 0.08$,
 For calculation of $es_{u2_nominal}$ and y_2 , sh_2, ft_2, fy_2 , it is considered
 characteristic value $fs_{y2} = fs_2/1.2$, from table 5.1, TBDY.
 y_1 , sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.
 with $fs_2 = fs = 313.6681$
 with $Es_2 = Es = 200000.00$
 $y_v = 0.00130695$
 $sh_v = 0.00451687$
 $ft_v = 376.4017$
 $fy_v = 313.6681$
 $s_{uv} = 0.005257$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $lo/lo_{u,min} = lb/ld = 0.30356779$
 $s_{uv} = 0.4 \cdot es_{uv_nominal} ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $es_{uv_nominal} = 0.08$,
 considering characteristic value $fs_{yv} = fs_v/1.2$, from table 5.1, TBDY
 For calculation of $es_{uv_nominal}$ and y_v , sh_v, ft_v, fy_v , it is considered
 characteristic value $fs_{yv} = fs_v/1.2$, from table 5.1, TBDY.
 y_1 , sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.
 with $fs_v = fs = 313.6681$
 with $Es_v = Es = 200000.00$
 $1 = As_{l,ten}/(b \cdot d) \cdot (fs_1/f_c) = 0.11385127$
 $2 = As_{l,com}/(b \cdot d) \cdot (fs_2/f_c) = 0.11385127$
 $v = As_{l,mid}/(b \cdot d) \cdot (fs_v/f_c) = 0.05520062$
 and confined core properties:
 $b = 190.00$
 $d = 427.00$
 $d' = 13.00$
 $f_{cc} (5A.2, TBDY) = 22.78316$
 $cc (5A.5, TBDY) = 0.00339158$
 $c = \text{confinement factor} = 1.13916$
 $1 = As_{l,ten}/(b \cdot d) \cdot (fs_1/f_c) = 0.1603292$
 $2 = As_{l,com}/(b \cdot d) \cdot (fs_2/f_c) = 0.1603292$
 $v = As_{l,mid}/(b \cdot d) \cdot (fs_v/f_c) = 0.07773537$
 Case/Assumption: Unconfined full section - Steel rupture
 ' satisfies Eq. (4.3)
 --->
 $v < v_{s,y2}$ - LHS eq.(4.5) is satisfied
 --->
 $su (4.9) = 0.20486988$
 $Mu = MR_c (4.14) = 1.4541E+008$
 $u = su (4.1) = 1.4467178E-005$

Calculation of ratio lb/ld

Lap Length: $lb/ld = 0.30356779$
 $lb = 300.00$
 $ld = 988.2471$
 Calculation of lb_{min} according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
 $= 1$
 $db = 18.00$
 Mean strength value of all re-bars: $fy = 555.55$
 $fc' = 20.00$, but $fc'^{0.5} \leq 8.3 \text{ MPa}$ (22.5.3.1, ACI 318-14)
 $t = 1.00$
 $s = 0.80$
 $e = 1.00$
 $cb = 25.00$
 $K_{tr} = 4.61999$
 $A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$
 where A_{tr_x} , A_{tr_y} are the sum of the area of all stirrup legs along X and Y loxal axis
 $s = 170.00$
 $n = 8.00$

Calculation of μ_{2+}

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

$$\mu = 1.4467178E-005$$

$$\mu = 1.4541E+008$$

with full section properties:

$$b = 250.00$$

$$d = 457.00$$

$$d' = 43.00$$

$$v = 0.00204242$$

$$N = 4666.932$$

$$f_c = 20.00$$

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

$$\text{Final value of } \mu: \mu^* = \text{shear_factor} * \text{Max}(\mu, \alpha) = 0.01464474$$

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

$$\text{From (5.4b), TB DY: } \mu = 0.01464474$$

$$\mu_e ((5.4c), \text{TB DY}) = \alpha * \min(f_{ywe}/f_{ce} + \min(f_x, f_y)) = 0.07762821$$

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

$$f_x = 0.07705054$$

$$\alpha_f = 0.45253333$$

$$b = 500.00$$

$$h = 250.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/bw = 0.004064$$

$$bw = 500.00$$

$$\text{effective stress from (A.35), } f_{fe} = 837.9178$$

$$f_y = 0.12936483$$

$$\alpha_f = 0.45253333$$

$$b = 250.00$$

$$h = 500.00$$

$$\text{From EC8 A.4.4.3(6), } p_f = 2t_f/bw = 0.008128$$

$$bw = 250.00$$

$$\text{effective stress from (A.35), } f_{fe} = 703.4155$$

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u_{,f} = 0.015$$

$$\alpha_e ((5.4d), \text{TB DY}) = 0.03751166$$

$$b_o = 440.00$$

$$h_o = 190.00$$

$$b_{i2} = 459400.00$$

$$p_{sh,min} = \min(p_{sh,x}, p_{sh,y}) = 0.001848$$

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

$$p_{sh,x} (5.4d) = 0.001848$$

$$A_{sh} = A_{stir} * n_s = 78.53982$$

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

$$b_k = 500.00$$

$$p_{sh,y} (5.4d) = 0.00369599$$

$$A_{sh} = A_{stir} * n_s = 78.53982$$

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

$$b_k = 250.00$$

$$s = 170.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 20.00$$

$$\text{From ((5.A5), TB DY), TB DY: } \alpha_c = 0.00339158$$

$$\alpha_c = \text{confinement factor} = 1.13916$$


```

y1 = 0.00130695
sh1 = 0.00451687
ft1 = 376.4017
fy1 = 313.6681
su1 = 0.005257
    using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779
    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, ASCE41-17.
    with fs1 = fs = 313.6681
    with Es1 = Es = 200000.00
y2 = 0.00130695
sh2 = 0.00451687
ft2 = 376.4017
fy2 = 313.6681
su2 = 0.005257
    using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779
    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, ASCE41-17.
    with fs2 = fs = 313.6681
    with Es2 = Es = 200000.00
yv = 0.00130695
shv = 0.00451687
ftv = 376.4017
fyv = 313.6681
suv = 0.005257
    using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779
    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, ASCE41-17.
    with fsv = fs = 313.6681
    with Esv = Es = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.11385127
2 = Asl,com/(b*d)*(fs2/fc) = 0.11385127
v = Asl,mid/(b*d)*(fsv/fc) = 0.05520062
and confined core properties:
b = 190.00
d = 427.00
d' = 13.00
fcc (5A.2, TBDY) = 22.78316
cc (5A.5, TBDY) = 0.00339158
c = confinement factor = 1.13916
1 = Asl,ten/(b*d)*(fs1/fc) = 0.1603292
2 = Asl,com/(b*d)*(fs2/fc) = 0.1603292
v = Asl,mid/(b*d)*(fsv/fc) = 0.07773537
Case/Assumption: Unconfined full section - Steel rupture
' satisfies Eq. (4.3)
---->
v < vs,y2 - LHS eq.(4.5) is satisfied
---->

```

$s_u(4.9) = 0.20486988$
 $\mu_u = MRC(4.14) = 1.4541E+008$
 $u = s_u(4.1) = 1.4467178E-005$

Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.30356779$

$l_b = 300.00$

$l_d = 988.2471$

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

$= 1$

$d_b = 18.00$

Mean strength value of all re-bars: $f_y = 555.55$

$f_c' = 20.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$c_b = 25.00$

$K_{tr} = 4.61999$

$A_{tr} = \min(A_{tr_x}, A_{tr_y}) = 157.0796$

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

$s = 170.00$

$n = 8.00$

Calculation of μ_u

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

$u = 1.4467178E-005$

$\mu_u = 1.4541E+008$

with full section properties:

$b = 250.00$

$d = 457.00$

$d' = 43.00$

$v = 0.00204242$

$N = 4666.932$

$f_c = 20.00$

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

Final value of ϕ_c : $\phi_c^* = \text{shear_factor} * \max(\phi_c, \phi_c) = 0.01464474$

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

From (5.4b), TBDY: $\phi_c = 0.01464474$

we ((5.4c), TBDY) = $\phi_c^* * \phi_{c, \min} * f_{y, \min} / f_{c, \min} + \min(\phi_c, \phi_c) = 0.07762821$

where $\phi_c = \phi_c^* * \phi_{c, \min} / f_{c, \min}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$\phi_c = 0.07705054$

$\phi_c = 0.45253333$

$b = 500.00$

$h = 250.00$

From EC8 A.4.4.3(6), $\phi_c = 2t_f/bw = 0.004064$

$bw = 500.00$

effective stress from (A.35), $f_{f, e} = 837.9178$

$f_y = 0.12936483$

$\phi_c = 0.45253333$

$b = 250.00$

$h = 500.00$

From EC8 A.4.4.3(6), $\phi_c = 2t_f/bw = 0.008128$

$bw = 250.00$

effective stress from (A.35), $f_{f, e} = 703.4155$

$R = 40.00$

Effective FRP thickness, $t_f = NL * t * \cos(\theta_1) = 1.016$

$f_u, f = 1055.00$
 $E_f = 64828.00$
 $u, f = 0.015$
 $ase ((5.4d), TBDY) = 0.03751166$
 $bo = 440.00$
 $ho = 190.00$
 $bi2 = 459400.00$
 $psh, min = \text{Min}(psh, x, psh, y) = 0.001848$
 Expression ((5.4d), TBDY) for psh, min has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$psh, x (5.4d) = 0.001848$
 $Ash = Astir * ns = 78.53982$
 No stirrups, $ns = 2.00$
 $bk = 500.00$

$psh, y (5.4d) = 0.00369599$
 $Ash = Astir * ns = 78.53982$
 No stirrups, $ns = 2.00$
 $bk = 250.00$

$s = 170.00$
 $fyw = 555.55$
 $fce = 20.00$

From ((5.A5), TBDY), TBDY: $cc = 0.00339158$
 $c = \text{confinement factor} = 1.13916$

$y1 = 0.00130695$
 $sh1 = 0.00451687$
 $ft1 = 376.4017$
 $fy1 = 313.6681$
 $su1 = 0.005257$

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

$lo/lo, min = lb/ld = 0.30356779$

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

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, ASCE41-17.

with $fs1 = fs = 313.6681$

with $Es1 = Es = 200000.00$

$y2 = 0.00130695$
 $sh2 = 0.00451687$
 $ft2 = 376.4017$
 $fy2 = 313.6681$
 $su2 = 0.005257$

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

$lo/lo, min = lb/lb, min = 0.30356779$

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

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, ASCE41-17.

with $fs2 = fs = 313.6681$

with $Es2 = Es = 200000.00$

$yv = 0.00130695$
 $shv = 0.00451687$
 $ftv = 376.4017$
 $fyv = 313.6681$
 $suv = 0.005257$

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

$lo/lo, min = lb/ld = 0.30356779$

$suv = 0.4 * esuv_nominal ((5.5), TBDY) = 0.032$
 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, ASCE41-17.
 with $fsv = fs = 313.6681$
 with $Esv = Es = 200000.00$
 $1 = Asl,ten/(b*d)*(fs1/fc) = 0.11385127$
 $2 = Asl,com/(b*d)*(fs2/fc) = 0.11385127$
 $v = Asl,mid/(b*d)*(fsv/fc) = 0.05520062$

and confined core properties:

$b = 190.00$
 $d = 427.00$
 $d' = 13.00$
 $fcc (5A.2, TBDY) = 22.78316$
 $cc (5A.5, TBDY) = 0.00339158$
 $c = \text{confinement factor} = 1.13916$
 $1 = Asl,ten/(b*d)*(fs1/fc) = 0.1603292$
 $2 = Asl,com/(b*d)*(fs2/fc) = 0.1603292$
 $v = Asl,mid/(b*d)*(fsv/fc) = 0.07773537$

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

--->
 $v < vs,y2$ - LHS eq.(4.5) is satisfied
 ---->
 $su (4.9) = 0.20486988$
 $Mu = MRc (4.14) = 1.4541E+008$
 $u = su (4.1) = 1.4467178E-005$

Calculation of ratio lb/ld

Lap Length: $lb/ld = 0.30356779$
 $lb = 300.00$
 $ld = 988.2471$
 Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
 $= 1$
 $db = 18.00$
 Mean strength value of all re-bars: $fy = 555.55$
 $fc' = 20.00$, but $fc'^{0.5} \leq 8.3 \text{ MPa}$ (22.5.3.1, ACI 318-14)
 $t = 1.00$
 $s = 0.80$
 $e = 1.00$
 $cb = 25.00$
 $Ktr = 4.61999$
 $Atr = Min(Atr_x, Atr_y) = 157.0796$
 where Atr_x , Atr_y are the sum of the area of all stirrup legs along X and Y loxal axis
 $s = 170.00$
 $n = 8.00$

Calculation of Shear Strength $Vr = Min(Vr1, Vr2) = 409422.352$

Calculation of Shear Strength at edge 1, $Vr1 = 409422.352$
 $Vr1 = VCol ((10.3), ASCE 41-17) = knl * VCol0$
 $VCol0 = 409422.352$
 $knl = 1$ (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)
 $fc' = 20.00$, but $fc'^{0.5} \leq 8.3 \text{ MPa}$ (22.5.3.1, ACI 318-14)
 $M/Vd = 2.00$

$\mu_u = 2.8180236E-013$
 $\mu_v = 1.3558547E-031$
 $d = 0.8 \cdot h = 400.00$
 $N_u = 4666.932$
 $A_g = 125000.00$
 From (11.5.4.8), ACI 318-14: $V_s = 164264.64$
 $A_v = 157079.633$
 $f_y = 444.44$
 $s = 170.00$
 V_s is multiplied by $\text{Col} = 1.00$
 $s/d = 0.425$
 $V_f ((11-3)-(11.4), \text{ACI } 440) = 240803.347$
 $f = 0.95$, for fully-wrapped sections
 $w_f/s_f = 1$ (FRP strips adjacent to one another).
 In (11.3) $\sin + \cos$ is replaced with $(\cot + \cot a) \sin a$ which is more a generalised expression,
 where a is the angle of the crack direction (see KANEPE).
 This later relation, considered as a function $V_f(\theta, a)$, is implemented for every different fiber orientation a_i ,
 as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.
 orientation 1: $\theta = b_1 + 90^\circ = 90.00$
 $V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, a_1)|)$, with:
 total thickness per orientation, $t_{f1} = N_L \cdot t / \text{NoDir} = 1.016$
 $d_{fv} = d$ (figure 11.2, ACI 440) = 457.00
 $f_{fe} ((11-5), \text{ACI } 440) = 259.312$
 $E_f = 64828.00$
 $f_e = 0.004$, from (11.6a), ACI 440
 with $f_u = 0.01$
 From (11-11), ACI 440: $V_s + V_f \leq 297085.704$
 $b_w = 250.00$

Calculation of Shear Strength at edge 2, $V_{r2} = 409422.352$
 $V_{r2} = V_{\text{Col}} ((10.3), \text{ASCE } 41-17) = k_{nl} \cdot V_{\text{Col}0}$
 $V_{\text{Col}0} = 409422.352$
 $k_{nl} = 1$ (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)
 $f'_c = 20.00$, but $f'_c^{0.5} \leq 8.3 \text{ MPa}$ (22.5.3.1, ACI 318-14)
 $M/Vd = 2.00$
 $\mu_u = 2.8180236E-013$
 $\mu_v = 1.3558547E-031$
 $d = 0.8 \cdot h = 400.00$
 $N_u = 4666.932$
 $A_g = 125000.00$
 From (11.5.4.8), ACI 318-14: $V_s = 164264.64$
 $A_v = 157079.633$
 $f_y = 444.44$
 $s = 170.00$
 V_s is multiplied by $\text{Col} = 1.00$
 $s/d = 0.425$
 $V_f ((11-3)-(11.4), \text{ACI } 440) = 240803.347$
 $f = 0.95$, for fully-wrapped sections
 $w_f/s_f = 1$ (FRP strips adjacent to one another).
 In (11.3) $\sin + \cos$ is replaced with $(\cot + \cot a) \sin a$ which is more a generalised expression,
 where a is the angle of the crack direction (see KANEPE).
 This later relation, considered as a function $V_f(\theta, a)$, is implemented for every different fiber orientation a_i ,
 as well as for 2 crack directions, $\theta = 45^\circ$ and $\theta = -45^\circ$ to take into consideration the cyclic seismic loading.
 orientation 1: $\theta = b_1 + 90^\circ = 90.00$
 $V_f = \text{Min}(|V_f(45, \theta)|, |V_f(-45, a_1)|)$, with:
 total thickness per orientation, $t_{f1} = N_L \cdot t / \text{NoDir} = 1.016$
 $d_{fv} = d$ (figure 11.2, ACI 440) = 457.00
 $f_{fe} ((11-5), \text{ACI } 440) = 259.312$
 $E_f = 64828.00$
 $f_e = 0.004$, from (11.6a), ACI 440
 with $f_u = 0.01$

From (11-11), ACI 440: $V_s + V_f \leq 297085.704$
 $bw = 250.00$

End Of Calculation of Shear Capacity ratio for element: column C1 of floor 1
At local axis: 2

Start Of Calculation of Chord Rotation Capacity for element: column C1 of floor 1
At local axis: 2
Integration Section: (b)
Section Type: rcrs

Constant Properties

Knowledge Factor, $= 1.00$
Chord Rotation is generally considered as Deformation-Controlled Action according to Table C7-1, ASCE41-17.
Mean strengths are used for Deformation-Controlled Actions according to 7.5.1.3, ASCE 41-17
Consequently:
Existing material of Primary Member: Concrete Strength, $f_c = f_{cm} = 20.00$
Existing material of Primary Member: Steel Strength, $f_s = f_{sm} = 444.44$
Concrete Elasticity, $E_c = 21019.039$
Steel Elasticity, $E_s = 200000.00$
Section Height, $H = 250.00$
Section Width, $W = 500.00$
Cover Thickness, $c = 25.00$
Element Length, $L = 3000.00$
Primary Member
Ribbed Bars
Ductile Steel
Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
Longitudinal Bars With Ends Lapped Starting at the End Sections
Lap Length $l_b = 300.00$
FRP Wrapping Data
Type: Carbon
Cured laminate properties (design values)
Thickness, $t = 1.016$
Tensile Strength, $f_{fu} = 1055.00$
Tensile Modulus, $E_f = 64828.00$
Elongation, $ef_u = 0.01$
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, $M = 6.0169508E-011$
Shear Force, $V_2 = 4708.27$
Shear Force, $V_3 = 3.5022564E-013$
Axial Force, $F = -4886.081$
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: $As_{c,com} = 829.3805$
-Middle: $As_{l,mid} = 402.1239$
Mean Diameter of Tension Reinforcement, $Db_L = 18.66667$

Existing component: From table 7-7, ASCE 41_17: Final chord rotation Capacity $u_{R} = * u = 0.04410058$

$$u = y + p = 0.04410058$$

- Calculation of y -

$$y = (M_y * L_s / 3) / E_{eff} = 0.00620957 \text{ ((4.29), Biskinis Phd)}$$

$$M_y = 5.0984E+007$$

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

$$\text{From table 10.5, ASCE 41_17: } E_{eff} = \text{factor} * E_c * I_g = 4.1053E+012$$

$$\text{factor} = 0.30$$

$$A_g = 125000.00$$

$$f_c' = 20.00$$

$$N = 4886.081$$

$$E_c * I_g = 1.3684E+013$$

Calculation of Yielding Moment M_y

Calculation of y and M_y according to Annex 7 -

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

$$y_{ten} = 1.0451750E-005$$

$$\text{with ((10.1), ASCE 41-17) } f_y = \text{Min}(f_y, 1.25 * f_y * (I_b / I_d)^{2/3}) = 291.1836$$

$$d = 207.00$$

$$y = 0.32705805$$

$$A = 0.02007406$$

$$B = 0.01218624$$

$$\text{with } p_t = 0.00801334$$

$$p_c = 0.00801334$$

$$p_v = 0.00388525$$

$$N = 4886.081$$

$$b = 500.00$$

$$" = 0.20772947$$

$$y_{comp} = 2.5957131E-005$$

$$\text{with } f_c' (12.3, \text{ACI 440}) = 20.44529$$

$$f_c = 20.00$$

$$f_l = 0.9425867$$

$$b = 500.00$$

$$h = 250.00$$

$$A_g = 125000.00$$

$$\text{From (12.9), ACI 440: } k_a = 0.1506892$$

$$g = p_t + p_c + p_v = 0.01991193$$

$$r_c = 40.00$$

$$A_e / A_c = 0.60275679$$

$$\text{Effective FRP thickness, } t_f = N L * t * \cos(\theta_1) = 1.016$$

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

$$f_u = 0.01$$

$$E_f = 64828.00$$

$$E_c = 21019.039$$

$$y = 0.32585609$$

$$A = 0.01977712$$

$$B = 0.01202411$$

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

Calculation of ratio I_b / I_d

$$\text{Lap Length: } I_d / I_{d,min} = 0.37945973$$

$$I_b = 300.00$$

$$I_d = 790.5977$$

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

$$= 1$$

$$d_b = 18.00$$

$$\text{Mean strength value of all re-bars: } f_y = 444.44$$

$$f_c' = 20.00, \text{ but } f_c'^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

t = 1.00
s = 0.80
e = 1.00
cb = 25.00
Ktr = 4.61999
Atr = Min(Atr_x, Atr_y) = 157.0796
where Atr_x, Atr_y are the sum of the area of all stirrup legs along X and Y local axis
s = 170.00
n = 8.00

- Calculation of ρ -

From table 10-8: $\rho = 0.03789101$

with:

- Columns not controlled by inadequate development or splicing along the clear height because $l_b/d \geq 1$

shear control ratio $V_y E / V_{col} E = 0.15063296$

d = 207.00

s = 0.00

$t = A_v / (b_w \cdot s) + 2 \cdot t_f / b_w \cdot (f_{fe} / f_s) = 0.00$

$A_v = 157.0796$, is the total area of all stirrups parallel to loading (shear) direction

$b_w = 500.00$

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.

NUD = 4886.081

$A_g = 125000.00$

$f_{cE} = 20.00$

$f_{ytE} = f_{ylE} = 0.00$

$\rho_l = \text{Area_Tot_Long_Rein} / (b \cdot d) = 0.01991193$

b = 500.00

d = 207.00

$f_{cE} = 20.00$

End Of Calculation of Chord Rotation Capacity for element: column C1 of floor 1

At local axis: 2

Integration Section: (b)

Calculation No. 15

column C1, Floor 1

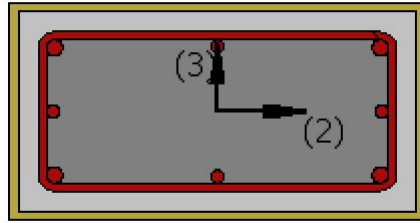
Limit State: Collapse Prevention (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Shear capacity VRd

Edge: End

Local Axis: (3)



Start Of Calculation of Shear Capacity for element: column C1 of floor 1

At local axis: 3

Integration Section: (b)

Section Type: rcrs

Constant Properties

Knowledge Factor, $\gamma = 1.00$

Member Shear Force is generally considered as Force-Controlled Action according to Table C7-1, ASCE41-17.

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

Consequently:

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

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

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of γ for displacement ductility demand, the expected (mean value) strengths are used (7.5.1.3, ASCE41-17) because bending is considered as Deformation-Controlled Action (Table C7-1, ASCE41-17).

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

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

#####

Section Height, $H = 250.00$

Section Width, $W = 500.00$

Cover Thickness, $c = 25.00$

Element Length, $L = 3000.00$

Primary Member

Ribbed Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

Lap Length $l_o = l_b = 300.00$

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $e_{fu} = 0.01$

Number of directions, $NoDir = 1$

Fiber orientations, $bi: 0.00^\circ$

Number of layers, $NL = 1$

Radius of rounding corners, $R = 40.00$

Stepwise Properties

EDGE -A-

Bending Moment, $M_a = 9.9150700E-010$

Shear Force, $V_a = -3.5022564E-013$

EDGE -B-

Bending Moment, $M_b = 6.0169508E-011$

Shear Force, $V_b = 3.5022564E-013$
 BOTH EDGES
 Axial Force, $F = -4886.081$
 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: $As_{c,com} = 829.3805$
 -Middle: $As_{mid} = 402.1239$
 Mean Diameter of Tension Reinforcement, $Db_{L,ten} = 18.66667$

Existing component: From table 7-7, ASCE 41_17: Final Shear Capacity $VR = V_n = 248589.15$
 $V_n ((10.3), ASCE 41-17) = knl * V_{Col0} = 248589.15$
 $V_{Col} = 248589.15$
 $knl = 1.00$
 $displacement_ductility_demand = 0.00$

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

$= 1$ (normal-weight concrete)
 $f'_c = 16.00$, but $f'_c \wedge 0.5 \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $M/Vd = 2.00$
 $\mu_u = 6.0169508E-011$
 $V_u = 3.5022564E-013$
 $d = 0.8 * h = 200.00$
 $N_u = 4886.081$
 $A_g = 125000.00$
 From (11.5.4.8), ACI 318-14: $V_s = 44351.896$
 $A_v = 157079.633$
 $f_y = 400.00$
 $s = 170.00$
 V_s is multiplied by $Col = 0.60$
 $s/d = 0.85$
 $V_f ((11-3)-(11.4), ACI 440) = 109072.851$
 $f = 0.95$, for fully-wrapped sections
 $w_f/s_f = 1$ (FRP strips adjacent to one another).
 In (11.3) $\sin + \cos$ is replaced with $(\cot + \cot a) \sin a$ which is more a generalised expression,
 where a is the angle of the crack direction (see KANEPE).
 This later relation, considered as a function $V_f(,)$, is implemented for every different fiber orientation a_i ,
 as well as for 2 crack directions, $a = 45^\circ$ and $a = -45^\circ$ to take into consideration the cyclic seismic loading.
 orientation 1: $a_1 = b_1 + 90^\circ = 90.00$
 $V_f = \text{Min}(|V_f(45, 1)|, |V_f(-45, a_1)|)$, with:
 total thickness per orientation, $t_{f1} = NL * t / NoDir = 1.016$
 $d_{fv} = d$ (figure 11.2, ACI 440) = 207.00
 $f_{fe} ((11-5), ACI 440) = 259.312$
 $E_f = 64828.00$
 $f_e = 0.004$, from (11.6a), ACI 440
 with $f_u = 0.01$
 From (11-11), ACI 440: $V_s + V_f \leq 265721.532$
 $bw = 500.00$

$displacement_ductility_demand$ is calculated as Δ / y

- Calculation of Δ / y for END B -
 for rotation axis 2 and integ. section (b)

From analysis, chord rotation $\theta = 3.2103728E-020$
 $y = (M_y * L_s / 3) / E_{eff} = 0.00620957$ ((4.29), Biskinis Phd))
 $M_y = 5.0984E+007$
 $L_s = M/V$ (with $L_s > 0.1 * L$ and $L_s < 2 * L$) = 1500.00

From table 10.5, ASCE 41_17: $E_{eff} = factor * E_c * I_g = 4.1053E+012$

factor = 0.30

$A_g = 125000.00$

$f_c' = 20.00$

$N = 4886.081$

$E_c * I_g = 1.3684E+013$

Calculation of Yielding Moment M_y

Calculation of y and M_y according to Annex 7 -

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

$y_{ten} = 1.0451750E-005$

with ((10.1), ASCE 41-17) $f_y = \text{Min}(f_y, 1.25 * f_y * (I_b / I_d)^{2/3}) = 291.1836$

$d = 207.00$

$y = 0.32705805$

$A = 0.02007406$

$B = 0.01218624$

with $p_t = 0.00801334$

$p_c = 0.00801334$

$p_v = 0.00388525$

$N = 4886.081$

$b = 500.00$

$" = 0.20772947$

$y_{comp} = 2.5957131E-005$

with $f_c' (12.3, (ACI 440)) = 20.44529$

$f_c = 20.00$

$f_l = 0.9425867$

$b = 500.00$

$h = 250.00$

$A_g = 125000.00$

From (12.9), ACI 440: $k_a = 0.1506892$

$g = p_t + p_c + p_v = 0.01991193$

$r_c = 40.00$

$A_e / A_c = 0.60275679$

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

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

$f_u = 0.01$

$E_f = 64828.00$

$E_c = 21019.039$

$y = 0.32585609$

$A = 0.01977712$

$B = 0.01202411$

with $E_s = 200000.00$

Calculation of ratio I_b / I_d

Lap Length: $I_d / I_{d,min} = 0.37945973$

$I_b = 300.00$

$I_d = 790.5977$

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

$= 1$

$d_b = 18.00$

Mean strength value of all re-bars: $f_y = 444.44$

$f_c' = 20.00$, but $f_c'^{0.5} \leq 8.3 \text{ MPa}$ (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$c_b = 25.00$

$K_{tr} = 4.61999$

$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$

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

$s = 170.00$

n = 8.00

End Of Calculation of Shear Capacity for element: column C1 of floor 1

At local axis: 3

Integration Section: (b)

Calculation No. 16

column C1, Floor 1

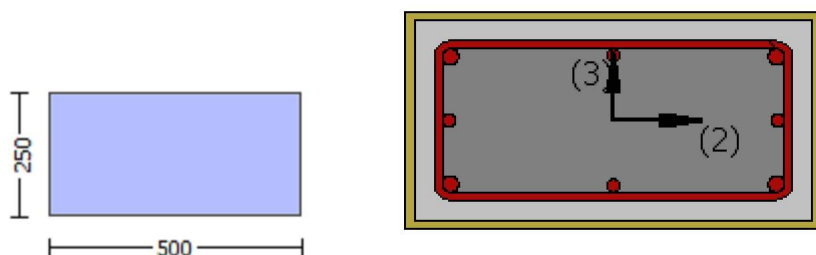
Limit State: Collapse Prevention (data interpolation between analysis steps 1 and 2)

Analysis: Uniform +X

Check: Chord rotation capacity (μ)

Edge: End

Local Axis: (3)



Start Of Calculation of Shear Capacity ratio for element: column C1 of floor 1

At Shear local axis: 3

(Bending local axis: 2)

Section Type: rcrs

Constant Properties

Knowledge Factor, $\gamma = 1.00$

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

Consequently:

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

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

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

#####

Note: Especially for the calculation of moment strengths,

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

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

#####

Section Height, $H = 250.00$

Section Width, $W = 500.00$

Cover Thickness, $c = 25.00$

Mean Confinement Factor overall section = 1.13916
 Element Length, L = 3000.00
 Primary Member
 Ribbed Bars
 Ductile Steel
 Without Detailing for Earthquake Resistance (including stirrups not closed at 135°)
 Longitudinal Bars With Ends Lapped Starting at the End Sections
 Lap Length l_o = 300.00
 FRP Wrapping Data
 Type: Carbon
 Cured laminate properties (design values)
 Thickness, t = 1.016
 Tensile Strength, f_{fu} = 1055.00
 Tensile Modulus, E_f = 64828.00
 Elongation, $ε_{fu}$ = 0.01
 Number of directions, 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 = 2.9007121E-031
 EDGE -B-
 Shear Force, V_b = -2.9007121E-031
 BOTH EDGES
 Axial Force, F = -4666.932
 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 = 0.15063296
 Member Controlled by Flexure ($V_e/V_r < 1$)
 Calculation of Shear Demand from fig. R18.6.5, ACI 318-14 $V_e = (M_{pr1} + M_{pr2})/l_n = 39953.171$
 with
 $M_{pr1} = \text{Max}(\mu_{u1+}, \mu_{u1-}) = 5.9930E+007$
 $\mu_{u1+} = 5.9930E+007$, 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
 $\mu_{u1-} = 5.9930E+007$, 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
 $M_{pr2} = \text{Max}(\mu_{u2+}, \mu_{u2-}) = 5.9930E+007$
 $\mu_{u2+} = 5.9930E+007$, 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
 $\mu_{u2-} = 5.9930E+007$, is the ultimate moment strength at the edge 2 of the member in the opposite moment direction which is defined for the the static loading combination

Calculation of μ_{u1+}

Calculation of ultimate curvature ϕ_u according to 4.1, Biskinis/Fardis 2013:
 $\phi_u = 3.4011160E-005$
 $\mu_u = 5.9930E+007$

with full section properties:
 $b = 500.00$

$d = 207.00$
 $d' = 43.00$
 $v = 0.00225456$
 $N = 4666.932$
 $f_c = 20.00$
 $\alpha (5A.5, TBDY) = 0.002$
 Final value of α : $\alpha^* = \text{shear_factor} * \text{Max}(\alpha, \alpha_c) = 0.01464474$
 The Shear_factor is considered equal to 1 (pure moment strength)
 From (5.4b), TBDY: $\alpha = 0.01464474$
 $\alpha_e ((5.4c), TBDY) = \alpha * \frac{f_{ywe}}{f_{ce}} + \text{Min}(f_x, f_y) = 0.07762821$
 where $f = \alpha * \rho_f * f_{fe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$f_x = 0.07705054$
 $\alpha_f = 0.45253333$
 $b = 500.00$
 $h = 250.00$
 From EC8 A.4.4.3(6), $\rho_f = 2t_f/bw = 0.004064$
 $bw = 500.00$
 effective stress from (A.35), $f_{fe} = 837.9178$

$f_y = 0.12936483$
 $\alpha_f = 0.45253333$
 $b = 250.00$
 $h = 500.00$
 From EC8 A.4.4.3(6), $\rho_f = 2t_f/bw = 0.008128$
 $bw = 250.00$
 effective stress from (A.35), $f_{fe} = 703.4155$

$R = 40.00$
 Effective FRP thickness, $t_f = NL * t * \cos(b_1) = 1.016$
 $f_{u,f} = 1055.00$
 $E_f = 64828.00$
 $u_f = 0.015$
 $\alpha_e ((5.4d), TBDY) = 0.03751166$
 $b_o = 440.00$
 $h_o = 190.00$
 $b_{i2} = 459400.00$
 $\rho_{sh,min} = \text{Min}(\rho_{sh,x}, \rho_{sh,y}) = 0.001848$
 Expression ((5.4d), TBDY) for $\rho_{sh,min}$ has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$\rho_{sh,x} (5.4d) = 0.001848$
 $A_{sh} = A_{stir} * n_s = 78.53982$
 No stirrups, $n_s = 2.00$
 $b_k = 500.00$

$\rho_{sh,y} (5.4d) = 0.00369599$
 $A_{sh} = A_{stir} * n_s = 78.53982$
 No stirrups, $n_s = 2.00$
 $b_k = 250.00$

$s = 170.00$
 $f_{ywe} = 555.55$
 $f_{ce} = 20.00$
 From ((5A5), TBDY), TBDY: $\alpha_c = 0.00339158$
 $c = \text{confinement factor} = 1.13916$
 $y_1 = 0.00130695$
 $sh_1 = 0.00451687$
 $ft_1 = 376.4017$
 $fy_1 = 313.6681$
 $su_1 = 0.005257$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00
 $l_o/l_{ou,min} = l_b/d = 0.30356779$
 $su_1 = 0.4 * esu_{1_nominal} ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $esu_{1_nominal} = 0.08$

For calculation of $esu1_nominal$ 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, ASCE41-17.
 with $fs1 = fs = 313.6681$
 with $Es1 = Es = 200000.00$
 $y2 = 0.00130695$
 $sh2 = 0.00451687$
 $ft2 = 376.4017$
 $fy2 = 313.6681$
 $su2 = 0.005257$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $lo/lou, min = lb/lb, min = 0.30356779$
 $su2 = 0.4 \cdot esu2_nominal \cdot ((5.5), TBDY) = 0.032$
 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, ASCE41-17.
 with $fs2 = fs = 313.6681$
 with $Es2 = Es = 200000.00$
 $yv = 0.00130695$
 $shv = 0.00451687$
 $ftv = 376.4017$
 $fyv = 313.6681$
 $suv = 0.005257$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $lo/lou, min = lb/ld = 0.30356779$
 $suv = 0.4 \cdot esuv_nominal \cdot ((5.5), TBDY) = 0.032$
 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, ASCE41-17.
 with $fsv = fs = 313.6681$
 with $Esv = Es = 200000.00$
 $1 = Asl, ten / (b \cdot d) \cdot (fs1 / fc) = 0.1256764$
 $2 = Asl, com / (b \cdot d) \cdot (fs2 / fc) = 0.1256764$
 $v = Asl, mid / (b \cdot d) \cdot (fsv / fc) = 0.06093401$

and confined core properties:

$b = 440.00$
 $d = 177.00$
 $d' = 13.00$
 $fcc (5A.2, TBDY) = 22.78316$
 $cc (5A.5, TBDY) = 0.00339158$
 $c = \text{confinement factor} = 1.13916$
 $1 = Asl, ten / (b \cdot d) \cdot (fs1 / fc) = 0.16701987$
 $2 = Asl, com / (b \cdot d) \cdot (fs2 / fc) = 0.16701987$
 $v = Asl, mid / (b \cdot d) \cdot (fsv / fc) = 0.08097933$

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

--->
 $v < vs, y2$ - LHS eq.(4.5) is satisfied
 --->
 $su (4.9) = 0.25329952$
 $Mu = MRc (4.14) = 5.9930E+007$
 $u = su (4.1) = 3.4011160E-005$

Calculation of ratio lb/ld

Lap Length: $lb/ld = 0.30356779$
 $lb = 300.00$
 $ld = 988.2471$

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

$\gamma = 1$
 $db = 18.00$
Mean strength value of all re-bars: $f_y = 555.55$
 $f_c' = 20.00$, but $f_c'^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $t = 1.00$
 $s = 0.80$
 $e = 1.00$
 $cb = 25.00$
 $K_{tr} = 4.61999$
 $A_{tr} = \text{Min}(A_{tr,x}, A_{tr,y}) = 157.0796$
where $A_{tr,x}$, $A_{tr,y}$ are the sum of the area of all stirrup legs along X and Y local axis
 $s = 170.00$
 $n = 8.00$

Calculation of μ_1 -

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

$\mu = 3.4011160E-005$

$\mu_u = 5.9930E+007$

with full section properties:

$b = 500.00$

$d = 207.00$

$d' = 43.00$

$v = 0.00225456$

$N = 4666.932$

$f_c = 20.00$

α (5A.5, TBDY) = 0.002

Final value of μ_u : $\mu_u^* = \text{shear_factor} * \text{Max}(\mu_u, \mu_c) = 0.01464474$

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

From (5.4b), TBDY: $\mu_u = 0.01464474$

we ((5.4c), TBDY) = $\alpha \cdot \text{sh}_{\min} \cdot f_{ywe} / f_{ce} + \text{Min}(f_x, f_y) = 0.07762821$

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

$f_x = 0.07705054$

$\alpha_f = 0.45253333$

$b = 500.00$

$h = 250.00$

From EC8 A.4.4.3(6), $p_f = 2t_f/bw = 0.004064$

$bw = 500.00$

effective stress from (A.35), $f_{fe} = 837.9178$

$f_y = 0.12936483$

$\alpha_f = 0.45253333$

$b = 250.00$

$h = 500.00$

From EC8 A.4.4.3(6), $p_f = 2t_f/bw = 0.008128$

$bw = 250.00$

effective stress from (A.35), $f_{fe} = 703.4155$

$R = 40.00$

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

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{f,f} = 0.015$

α_{se} ((5.4d), TBDY) = 0.03751166

$b_o = 440.00$

$h_o = 190.00$

$b_{i2} = 459400.00$

$p_{sh,\min} = \text{Min}(p_{sh,x}, p_{sh,y}) = 0.001848$

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

psh,x (5.4d) = 0.001848
Ash = Astir*ns = 78.53982
No stirups, ns = 2.00
bk = 500.00

psh,y (5.4d) = 0.00369599
Ash = Astir*ns = 78.53982
No stirups, ns = 2.00
bk = 250.00

s = 170.00
fywe = 555.55
fce = 20.00

From ((5.A5), TBDY), TBDY: cc = 0.00339158
c = confinement factor = 1.13916

y1 = 0.00130695
sh1 = 0.00451687
ft1 = 376.4017
fy1 = 313.6681
su1 = 0.005257

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779

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, ASCE41-17.

with fs1 = fs = 313.6681

with Es1 = Es = 200000.00

y2 = 0.00130695
sh2 = 0.00451687
ft2 = 376.4017
fy2 = 313.6681
su2 = 0.005257

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779

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, ASCE41-17.

with fs2 = fs = 313.6681

with Es2 = Es = 200000.00

yv = 0.00130695
shv = 0.00451687
ftv = 376.4017
fyv = 313.6681
suv = 0.005257

using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779

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, ASCE41-17.

with fsv = fs = 313.6681

with Esv = Es = 200000.00

1 = Asl,ten/(b*d)*(fs1/fc) = 0.1256764

2 = Asl,com/(b*d)*(fs2/fc) = 0.1256764

v = Asl,mid/(b*d)*(fsv/fc) = 0.06093401

and confined core properties:

$$b = 440.00$$

$$d = 177.00$$

$$d' = 13.00$$

$$fcc(5A.2, TBDY) = 22.78316$$

$$cc(5A.5, TBDY) = 0.00339158$$

$$c = \text{confinement factor} = 1.13916$$

$$1 = A_{s1,ten}/(b*d)*(f_{s1}/f_c) = 0.16701987$$

$$2 = A_{s2,com}/(b*d)*(f_{s2}/f_c) = 0.16701987$$

$$v = A_{sv,mid}/(b*d)*(f_{sv}/f_c) = 0.08097933$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

$$s_u(4.9) = 0.25329952$$

$$M_u = M_{Rc}(4.14) = 5.9930E+007$$

$$u = s_u(4.1) = 3.4011160E-005$$

Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.30356779$

$$l_b = 300.00$$

$$l_d = 988.2471$$

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

$$= 1$$

$$d_b = 18.00$$

Mean strength value of all re-bars: $f_y = 555.55$

$$f_c' = 20.00, \text{ but } f_c'^{0.5} \leq 8.3 \text{ MPa (22.5.3.1, ACI 318-14)}$$

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 25.00$$

$$K_{tr} = 4.61999$$

$$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$$

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

$$s = 170.00$$

$$n = 8.00$$

Calculation of M_{u2+}

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

$$u = 3.4011160E-005$$

$$M_u = 5.9930E+007$$

with full section properties:

$$b = 500.00$$

$$d = 207.00$$

$$d' = 43.00$$

$$v = 0.00225456$$

$$N = 4666.932$$

$$f_c = 20.00$$

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

$$\text{Final value of } c_u: c_u^* = \text{shear_factor} * \text{Max}(c_u, c_o) = 0.01464474$$

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

$$\text{From (5.4b), TBDY: } c_u = 0.01464474$$

$$w_e((5.4c), TBDY) = a_s e^* s_{h,min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.07762821$$

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

$$f_x = 0.07705054$$

$$a_f = 0.45253333$$

$$b = 500.00$$

h = 250.00
From EC8 A4.4.3(6), $pf = 2tf/bw = 0.004064$
bw = 500.00
effective stress from (A.35), $ff,e = 837.9178$

fy = 0.12936483
af = 0.45253333
b = 250.00
h = 500.00
From EC8 A4.4.3(6), $pf = 2tf/bw = 0.008128$
bw = 250.00
effective stress from (A.35), $ff,e = 703.4155$

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) = 0.03751166
bo = 440.00
ho = 190.00
bi2 = 459400.00
psh,min = Min(psh,x , psh,y) = 0.001848
Expression ((5.4d), TBDY) for psh,min has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

psh,x (5.4d) = 0.001848
Ash = Astir*ns = 78.53982
No stirrups, ns = 2.00
bk = 500.00

psh,y (5.4d) = 0.00369599
Ash = Astir*ns = 78.53982
No stirrups, ns = 2.00
bk = 250.00

s = 170.00
fywe = 555.55
fce = 20.00
From ((5.A5), TBDY), TBDY: cc = 0.00339158
c = confinement factor = 1.13916
y1 = 0.00130695
sh1 = 0.00451687
ft1 = 376.4017
fy1 = 313.6681
su1 = 0.005257
using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779
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, ASCE41-17.
with fs1 = fs = 313.6681
with Es1 = Es = 200000.00
y2 = 0.00130695
sh2 = 0.00451687
ft2 = 376.4017
fy2 = 313.6681
su2 = 0.005257
using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779
su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032

From table 5A.1, TBDY: $es_{u2_nominal} = 0.08$,
 For calculation of $es_{u2_nominal}$ and y_2 , sh_2, ft_2, fy_2 , it is considered
 characteristic value $fs_{y2} = fs_2/1.2$, from table 5.1, TBDY.
 y_1 , sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.
 with $fs_2 = fs = 313.6681$
 with $Es_2 = Es = 200000.00$
 $y_v = 0.00130695$
 $sh_v = 0.00451687$
 $ft_v = 376.4017$
 $fy_v = 313.6681$
 $s_{uv} = 0.005257$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $lo/lo_{u,min} = lb/ld = 0.30356779$
 $s_{uv} = 0.4 \cdot es_{uv_nominal} ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $es_{uv_nominal} = 0.08$,
 considering characteristic value $fs_{yv} = fs_v/1.2$, from table 5.1, TBDY
 For calculation of $es_{uv_nominal}$ and y_v , sh_v, ft_v, fy_v , it is considered
 characteristic value $fs_{yv} = fs_v/1.2$, from table 5.1, TBDY.
 y_1 , sh_1, ft_1, fy_1 , are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.
 with $fs_v = fs = 313.6681$
 with $Es_v = Es = 200000.00$
 $1 = As_{l,ten}/(b \cdot d) \cdot (fs_1/f_c) = 0.1256764$
 $2 = As_{l,com}/(b \cdot d) \cdot (fs_2/f_c) = 0.1256764$
 $v = As_{l,mid}/(b \cdot d) \cdot (fs_v/f_c) = 0.06093401$
 and confined core properties:
 $b = 440.00$
 $d = 177.00$
 $d' = 13.00$
 $f_{cc} (5A.2, TBDY) = 22.78316$
 $cc (5A.5, TBDY) = 0.00339158$
 $c = \text{confinement factor} = 1.13916$
 $1 = As_{l,ten}/(b \cdot d) \cdot (fs_1/f_c) = 0.16701987$
 $2 = As_{l,com}/(b \cdot d) \cdot (fs_2/f_c) = 0.16701987$
 $v = As_{l,mid}/(b \cdot d) \cdot (fs_v/f_c) = 0.08097933$
 Case/Assumption: Unconfined full section - Steel rupture
 ' satisfies Eq. (4.3)
 --->
 $v < v_{s,y2}$ - LHS eq.(4.5) is satisfied
 --->
 $su (4.9) = 0.25329952$
 $Mu = MR_c (4.14) = 5.9930E+007$
 $u = su (4.1) = 3.4011160E-005$

Calculation of ratio lb/ld

Lap Length: $lb/ld = 0.30356779$
 $lb = 300.00$
 $ld = 988.2471$
 Calculation of lb_{min} according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
 $= 1$
 $db = 18.00$
 Mean strength value of all re-bars: $fy = 555.55$
 $fc' = 20.00$, but $fc'^{0.5} \leq 8.3 \text{ MPa}$ (22.5.3.1, ACI 318-14)
 $t = 1.00$
 $s = 0.80$
 $e = 1.00$
 $cb = 25.00$
 $K_{tr} = 4.61999$
 $A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$
 where A_{tr_x} , A_{tr_y} are the sum of the area of all stirrup legs along X and Y loxal axis
 $s = 170.00$
 $n = 8.00$

Calculation of Mu2-

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

$$\mu = 3.4011160E-005$$

$$\mu = 5.9930E+007$$

with full section properties:

$$b = 500.00$$

$$d = 207.00$$

$$d' = 43.00$$

$$v = 0.00225456$$

$$N = 4666.932$$

$$f_c = 20.00$$

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

$$\text{Final value of } \mu: \mu^* = \text{shear_factor} * \text{Max}(\mu, \alpha) = 0.01464474$$

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

$$\text{From (5.4b), TB DY: } \mu = 0.01464474$$

$$\mu_e ((5.4c), \text{TB DY}) = \alpha * \mu_{\min} * f_{ywe} / f_{ce} + \text{Min}(\mu_x, \mu_y) = 0.07762821$$

where $\mu = \alpha * \mu_{\min} * f_{ywe} / f_{ce}$ is accounting for FRP contribution like EC8-part3 A.4.4.3(6)

$$\mu_x = 0.07705054$$

$$\alpha = 0.45253333$$

$$b = 500.00$$

$$h = 250.00$$

$$\text{From EC8 A.4.4.3(6), } \mu_f = 2t_f/bw = 0.004064$$

$$bw = 500.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 837.9178$$

$$\mu_y = 0.12936483$$

$$\alpha = 0.45253333$$

$$b = 250.00$$

$$h = 500.00$$

$$\text{From EC8 A.4.4.3(6), } \mu_f = 2t_f/bw = 0.008128$$

$$bw = 250.00$$

$$\text{effective stress from (A.35), } f_{f,e} = 703.4155$$

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$\mu_{f} = 0.015$$

$$\alpha_e ((5.4d), \text{TB DY}) = 0.03751166$$

$$b_o = 440.00$$

$$h_o = 190.00$$

$$b_{i2} = 459400.00$$

$$\mu_{\min} = \text{Min}(\mu_x, \mu_y) = 0.001848$$

Expression ((5.4d), TB DY) for μ_{\min} has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$$\mu_x (5.4d) = 0.001848$$

$$A_{sh} = A_{stir} * n_s = 78.53982$$

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

$$b_k = 500.00$$

$$\mu_y (5.4d) = 0.00369599$$

$$A_{sh} = A_{stir} * n_s = 78.53982$$

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

$$b_k = 250.00$$

$$s = 170.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 20.00$$

$$\text{From ((5.A5), TB DY), TB DY: } \alpha_c = 0.00339158$$

$$\alpha_c = \text{confinement factor} = 1.13916$$

```

y1 = 0.00130695
sh1 = 0.00451687
ft1 = 376.4017
fy1 = 313.6681
su1 = 0.005257
    using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779
    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, ASCE41-17.
    with fs1 = fs = 313.6681
    with Es1 = Es = 200000.00
y2 = 0.00130695
sh2 = 0.00451687
ft2 = 376.4017
fy2 = 313.6681
su2 = 0.005257
    using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779
    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, ASCE41-17.
    with fs2 = fs = 313.6681
    with Es2 = Es = 200000.00
yv = 0.00130695
shv = 0.00451687
ftv = 376.4017
fyv = 313.6681
suv = 0.005257
    using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779
    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, ASCE41-17.
    with fsv = fs = 313.6681
    with Esv = Es = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.1256764
2 = Asl,com/(b*d)*(fs2/fc) = 0.1256764
v = Asl,mid/(b*d)*(fsv/fc) = 0.06093401
and confined core properties:
b = 440.00
d = 177.00
d' = 13.00
fcc (5A.2, TBDY) = 22.78316
cc (5A.5, TBDY) = 0.00339158
c = confinement factor = 1.13916
1 = Asl,ten/(b*d)*(fs1/fc) = 0.16701987
2 = Asl,com/(b*d)*(fs2/fc) = 0.16701987
v = Asl,mid/(b*d)*(fsv/fc) = 0.08097933
Case/Assumption: Unconfined full section - Steel rupture
'satisfies Eq. (4.3)
---->
v < vs,y2 - LHS eq.(4.5) is satisfied
---->

```

$s_u(4.9) = 0.25329952$
 $\mu = MRC(4.14) = 5.9930E+007$
 $u = s_u(4.1) = 3.4011160E-005$

Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.30356779$

$l_b = 300.00$

$l_d = 988.2471$

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

$= 1$

$d_b = 18.00$

Mean strength value of all re-bars: $f_y = 555.55$

$f'_c = 20.00$, but $f_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$c_b = 25.00$

$K_{tr} = 4.61999$

$A_{tr} = \min(A_{tr_x}, A_{tr_y}) = 157.0796$

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

$s = 170.00$

$n = 8.00$

Calculation of Shear Strength $V_r = \min(V_{r1}, V_{r2}) = 265235.248$

Calculation of Shear Strength at edge 1, $V_{r1} = 265235.248$

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

$V_{Col0} = 265235.248$

$k_{nl} = 1$ (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)

$f'_c = 20.00$, but $f_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$M/Vd = 2.00$

$\mu_u = 2.3992784E-012$

$\nu_u = 2.9007121E-031$

$d = 0.8 * h = 200.00$

$N_u = 4666.932$

$A_g = 125000.00$

From (11.5.4.8), ACI 318-14: $V_s = 49279.392$

$A_v = 157079.633$

$f_y = 444.44$

$s = 170.00$

V_s is multiplied by $\phi_{Col} = 0.60$

$s/d = 0.85$

$V_f((11-3)-(11.4), ACI 440) = 109072.851$

$f = 0.95$, 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: $\theta = b_1 + 90^\circ = 90.00$

$V_f = \min(|V_f(45, \theta)|, |V_f(-45, a_1)|)$, with:

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

$d_{fv} = d$ (figure 11.2, ACI 440) = 207.00

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

$E_f = 64828.00$

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

with $f_u = 0.01$

From (11-11), ACI 440: $V_s + V_f \leq 297085.704$
 $bw = 500.00$

Calculation of Shear Strength at edge 2, $V_{r2} = 265235.248$
 $V_{r2} = V_{Col} ((10.3), ASCE 41-17) = knl * V_{Col0}$
 $V_{Col0} = 265235.248$
 $knl = 1$ (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)
 $f'_c = 20.00$, but $f_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $M/Vd = 2.00$
 $\mu_u = 2.3992784E-012$
 $\nu_u = 2.9007121E-031$
 $d = 0.8 * h = 200.00$
 $N_u = 4666.932$
 $A_g = 125000.00$
From (11.5.4.8), ACI 318-14: $V_s = 49279.392$
 $A_v = 157079.633$
 $f_y = 444.44$
 $s = 170.00$
 V_s is multiplied by $Col = 0.60$
 $s/d = 0.85$
 $V_f ((11-3)-(11.4), ACI 440) = 109072.851$
 $f = 0.95$, for fully-wrapped sections
 $w_f/s_f = 1$ (FRP strips adjacent to one another).
In (11.3) $\sin + \cos$ is replaced with $(\cot + \cot a) \sin a$ which is more a generalised expression,
where a is the angle of the crack direction (see KANEPE).
This later relation, considered as a function $V_f(,)$, is implemented for every different fiber orientation a_i ,
as well as for 2 crack directions, $= 45^\circ$ and $= -45^\circ$ to take into consideration the cyclic seismic loading.
orientation 1: $\theta_1 = b_1 + 90^\circ = 90.00$
 $V_f = \text{Min}(|V_f(45, 1)|, |V_f(-45, a_1)|)$, with:
total thickness per orientation, $t_{f1} = NL * t / NoDir = 1.016$
 $d_{fv} = d$ (figure 11.2, ACI 440) = 207.00
 $f_{fe} ((11-5), ACI 440) = 259.312$
 $E_f = 64828.00$
 $f_e = 0.004$, from (11.6a), ACI 440
with $f_u = 0.01$
From (11-11), ACI 440: $V_s + V_f \leq 297085.704$
 $bw = 500.00$

End Of Calculation of Shear Capacity ratio for element: column C1 of floor 1
At local axis: 3

Start Of Calculation of Shear Capacity ratio for element: column C1 of floor 1
At Shear local axis: 2
(Bending local axis: 3)
Section Type: rcrcs

Constant Properties

Knowledge Factor, $= 1.00$
Mean strength values are used for both shear and moment calculations.
Consequently:
Existing material of Primary Member: Concrete Strength, $f_c = f_{cm} = 20.00$
Existing material of Primary Member: Steel Strength, $f_s = f_{sm} = 444.44$
Concrete Elasticity, $E_c = 21019.039$
Steel Elasticity, $E_s = 200000.00$

Note: Especially for the calculation of moment strengths,

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

$$\phi_u = 1.4467178E-005$$

$$\mu = 1.4541E+008$$

with full section properties:

$$b = 250.00$$

$$d = 457.00$$

$$d' = 43.00$$

$$v = 0.00204242$$

$$N = 4666.932$$

$$f_c = 20.00$$

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

$$\text{Final value of } \phi_u: \phi_u^* = \text{shear_factor} * \text{Max}(\phi_u, \phi_c) = 0.01464474$$

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

$$\text{From (5.4b), TBDY: } \phi_u = 0.01464474$$

$$\omega_e \text{ ((5.4c), TBDY)} = a_s * \frac{\min(f_{ywe}/f_{ce}, \min(f_x, f_y))}{f_c} = 0.07762821$$

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

$$f_x = 0.07705054$$

$$a_f = 0.45253333$$

$$b = 500.00$$

$$h = 250.00$$

$$\text{From EC8 A.4.4.3(6), } \rho_f = 2t_f/bw = 0.004064$$

$$bw = 500.00$$

$$\text{effective stress from (A.35), } f_{fe} = 837.9178$$

$$f_y = 0.12936483$$

$$a_f = 0.45253333$$

$$b = 250.00$$

$$h = 500.00$$

$$\text{From EC8 A.4.4.3(6), } \rho_f = 2t_f/bw = 0.008128$$

$$bw = 250.00$$

$$\text{effective stress from (A.35), } f_{fe} = 703.4155$$

$$R = 40.00$$

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

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

$$E_f = 64828.00$$

$$u_{f,f} = 0.015$$

$$a_s \text{ ((5.4d), TBDY)} = 0.03751166$$

$$b_o = 440.00$$

$$h_o = 190.00$$

$$b_{i2} = 459400.00$$

$$\rho_{sh,min} = \min(\rho_{sh,x}, \rho_{sh,y}) = 0.001848$$

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

$$\rho_{sh,x} \text{ (5.4d)} = 0.001848$$

$$A_{sh} = A_{stir} * n_s = 78.53982$$

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

$$b_k = 500.00$$

$$\rho_{sh,y} \text{ (5.4d)} = 0.00369599$$

$$A_{sh} = A_{stir} * n_s = 78.53982$$

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

$$b_k = 250.00$$

$$s = 170.00$$

$$f_{ywe} = 555.55$$

$$f_{ce} = 20.00$$

$$\text{From ((5.A5), TBDY), TBDY: } \phi_c = 0.00339158$$

$$c = \text{confinement factor} = 1.13916$$

$$y_1 = 0.00130695$$

$$sh_1 = 0.00451687$$

$$f_{t1} = 376.4017$$

$$f_{y1} = 313.6681$$

$$su_1 = 0.005257$$

using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $l_o/l_{ou,min} = l_b/l_d = 0.30356779$
 $su_1 = 0.4 * esu_{1,nominal} ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $esu_{1,nominal} = 0.08$,
 For calculation of $esu_{1,nominal}$ and y_1, sh_1, ft_1, fy_1 , it is considered
 characteristic value $fsy_1 = fs_1/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $Min(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.
 with $fs_1 = fs = 313.6681$
 with $Es_1 = Es = 200000.00$
 $y_2 = 0.00130695$
 $sh_2 = 0.00451687$
 $ft_2 = 376.4017$
 $fy_2 = 313.6681$
 $su_2 = 0.005257$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $l_o/l_{ou,min} = l_b/l_{b,min} = 0.30356779$
 $su_2 = 0.4 * esu_{2,nominal} ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $esu_{2,nominal} = 0.08$,
 For calculation of $esu_{2,nominal}$ and y_2, sh_2, ft_2, fy_2 , it is considered
 characteristic value $fsy_2 = fs_2/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $Min(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.
 with $fs_2 = fs = 313.6681$
 with $Es_2 = Es = 200000.00$
 $y_v = 0.00130695$
 $sh_v = 0.00451687$
 $ft_v = 376.4017$
 $fy_v = 313.6681$
 $suv = 0.005257$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
 and also multiplied by the shear_factor according to 15.7.1.4, with
 Shear_factor = 1.00
 $l_o/l_{ou,min} = l_b/l_d = 0.30356779$
 $suv = 0.4 * esuv_{nominal} ((5.5), TBDY) = 0.032$
 From table 5A.1, TBDY: $esuv_{nominal} = 0.08$,
 considering characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY
 For calculation of $esuv_{nominal}$ and y_v, sh_v, ft_v, fy_v , it is considered
 characteristic value $fsyv = fsv/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $Min(1, 1.25 * (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.
 with $fsv = fs = 313.6681$
 with $Es_v = Es = 200000.00$
 $1 = Asl_{ten}/(b*d) * (fs_1/f_c) = 0.11385127$
 $2 = Asl_{com}/(b*d) * (fs_2/f_c) = 0.11385127$
 $v = Asl_{mid}/(b*d) * (fsv/f_c) = 0.05520062$
 and confined core properties:
 $b = 190.00$
 $d = 427.00$
 $d' = 13.00$
 $f_{cc} (5A.2, TBDY) = 22.78316$
 $cc (5A.5, TBDY) = 0.00339158$
 $c = \text{confinement factor} = 1.13916$
 $1 = Asl_{ten}/(b*d) * (fs_1/f_c) = 0.1603292$
 $2 = Asl_{com}/(b*d) * (fs_2/f_c) = 0.1603292$
 $v = Asl_{mid}/(b*d) * (fsv/f_c) = 0.07773537$
 Case/Assumption: Unconfined full section - Steel rupture
 ' satisfies Eq. (4.3)
 --->
 $v < v_{s,y2}$ - LHS eq.(4.5) is satisfied
 --->
 $su (4.9) = 0.20486988$
 $Mu = MRc (4.14) = 1.4541E+008$
 $u = su (4.1) = 1.4467178E-005$

Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.30356779$

$l_b = 300.00$

$l_d = 988.2471$

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

$= 1$

$d_b = 18.00$

Mean strength value of all re-bars: $f_y = 555.55$

$f'_c = 20.00$, but $f_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$t = 1.00$

$s = 0.80$

$e = 1.00$

$c_b = 25.00$

$K_{tr} = 4.61999$

$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$

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

$s = 170.00$

$n = 8.00$

Calculation of μ_1 -

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

$\mu = 1.4467178E-005$

$\mu_u = 1.4541E+008$

with full section properties:

$b = 250.00$

$d = 457.00$

$d' = 43.00$

$v = 0.00204242$

$N = 4666.932$

$f_c = 20.00$

α_1 (5A.5, TBDY) = 0.002

Final value of μ_u : $\mu_u^* = \text{shear_factor} * \text{Max}(\mu_u, \mu_c) = 0.01464474$

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

From (5.4b), TBDY: $\mu_u = 0.01464474$

we ((5.4c), TBDY) = $\alpha_1 * \text{sh}_{\min} * f_{ywe}/f_{ce} + \text{Min}(f_x, f_y) = 0.07762821$

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

$f_x = 0.07705054$

$\alpha_1 = 0.45253333$

$b = 500.00$

$h = 250.00$

From EC8 A.4.4.3(6), $p_f = 2t_f/bw = 0.004064$

$bw = 500.00$

effective stress from (A.35), $f_{fe} = 837.9178$

$f_y = 0.12936483$

$\alpha_1 = 0.45253333$

$b = 250.00$

$h = 500.00$

From EC8 A.4.4.3(6), $p_f = 2t_f/bw = 0.008128$

$bw = 250.00$

effective stress from (A.35), $f_{fe} = 703.4155$

$R = 40.00$

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

$f_{u,f} = 1055.00$

$E_f = 64828.00$

$u_{,f} = 0.015$

α_1 ((5.4d), TBDY) = 0.03751166

$b_o = 440.00$

$h_o = 190.00$
 $bi2 = 459400.00$
 $psh,min = \text{Min}(psh,x, psh,y) = 0.001848$
 Expression ((5.4d), TBDY) for psh,min has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$psh,x (5.4d) = 0.001848$
 $Ash = Astir*ns = 78.53982$
 No stirrups, $ns = 2.00$
 $bk = 500.00$

$psh,y (5.4d) = 0.00369599$
 $Ash = Astir*ns = 78.53982$
 No stirrups, $ns = 2.00$
 $bk = 250.00$

$s = 170.00$
 $fywe = 555.55$
 $fce = 20.00$
 From ((5.A5), TBDY), TBDY: $cc = 0.00339158$
 $c = \text{confinement factor} = 1.13916$
 $y1 = 0.00130695$
 $sh1 = 0.00451687$
 $ft1 = 376.4017$
 $fy1 = 313.6681$
 $su1 = 0.005257$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00
 $lo/lou,min = lb/ld = 0.30356779$
 $su1 = 0.4*esu1_nominal ((5.5), TBDY) = 0.032$
 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, ASCE41-17.
 with $fs1 = fs = 313.6681$
 with $Es1 = Es = 200000.00$
 $y2 = 0.00130695$
 $sh2 = 0.00451687$
 $ft2 = 376.4017$
 $fy2 = 313.6681$
 $su2 = 0.005257$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00
 $lo/lou,min = lb/lb,min = 0.30356779$
 $su2 = 0.4*esu2_nominal ((5.5), TBDY) = 0.032$
 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, ASCE41-17.
 with $fs2 = fs = 313.6681$
 with $Es2 = Es = 200000.00$
 $yv = 0.00130695$
 $shv = 0.00451687$
 $ftv = 376.4017$
 $fyv = 313.6681$
 $suv = 0.005257$
 using (30) in Biskinis/Fardis (2013) multiplied with shear_factor and also multiplied by the shear_factor according to 15.7.1.4, with Shear_factor = 1.00
 $lo/lou,min = lb/ld = 0.30356779$
 $suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032$
 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.

$y_1, sh1, ft1, fy1$, are also multiplied by $\text{Min}(1, 1.25 \cdot (lb/ld)^{2/3})$, from 10.3.5, ASCE41-17.
 with $fsv = fs = 313.6681$
 with $Esv = Es = 200000.00$
 $1 = Asl_{ten}/(b \cdot d) \cdot (fs1/fc) = 0.11385127$
 $2 = Asl_{com}/(b \cdot d) \cdot (fs2/fc) = 0.11385127$
 $v = Asl_{mid}/(b \cdot d) \cdot (fsv/fc) = 0.05520062$
 and confined core properties:
 $b = 190.00$
 $d = 427.00$
 $d' = 13.00$
 $fcc (5A.2, TBDY) = 22.78316$
 $cc (5A.5, TBDY) = 0.00339158$
 $c = \text{confinement factor} = 1.13916$
 $1 = Asl_{ten}/(b \cdot d) \cdot (fs1/fc) = 0.1603292$
 $2 = Asl_{com}/(b \cdot d) \cdot (fs2/fc) = 0.1603292$
 $v = Asl_{mid}/(b \cdot d) \cdot (fsv/fc) = 0.07773537$
 Case/Assumption: Unconfined full section - Steel rupture
 ' satisfies Eq. (4.3)
 --->
 $v < v_{s,y2}$ - LHS eq.(4.5) is satisfied
 --->
 $su (4.9) = 0.20486988$
 $Mu = MRc (4.14) = 1.4541E+008$
 $u = su (4.1) = 1.4467178E-005$

 Calculation of ratio lb/ld

 Lap Length: $lb/ld = 0.30356779$
 $lb = 300.00$
 $ld = 988.2471$
 Calculation of lb_{min} according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
 $= 1$
 $db = 18.00$
 Mean strength value of all re-bars: $fy = 555.55$
 $fc' = 20.00$, but $fc^{0.5} \leq 8.3 \text{ MPa}$ (22.5.3.1, ACI 318-14)
 $t = 1.00$
 $s = 0.80$
 $e = 1.00$
 $cb = 25.00$
 $Ktr = 4.61999$
 $Atr = \text{Min}(Atr_x, Atr_y) = 157.0796$
 where Atr_x, Atr_y are the sum of the area of all stirrup legs along X and Y loxal axis
 $s = 170.00$
 $n = 8.00$

 Calculation of Mu_{2+}

 Calculation of ultimate curvature u according to 4.1, Biskinis/Fardis 2013:
 $u = 1.4467178E-005$
 $Mu = 1.4541E+008$

 with full section properties:
 $b = 250.00$
 $d = 457.00$
 $d' = 43.00$
 $v = 0.00204242$
 $N = 4666.932$
 $fc = 20.00$
 $co (5A.5, TBDY) = 0.002$
 Final value of cu : $cu^* = \text{shear_factor} \cdot \text{Max}(cu, cc) = 0.01464474$
 The Shear_factor is considered equal to 1 (pure moment strength)
 From (5.4b), TBDY: $cu = 0.01464474$

$w_e ((5.4c), TBDY) = a_{se} \cdot \min(f_{ywe}/f_{ce} + \min(f_x, f_y)) = 0.07762821$
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)

$f_x = 0.07705054$
 $a_f = 0.45253333$
 $b = 500.00$
 $h = 250.00$
From EC8 A.4.4.3(6), $p_f = 2t_f/bw = 0.004064$
 $bw = 500.00$
effective stress from (A.35), $f_{fe} = 837.9178$

$f_y = 0.12936483$
 $a_f = 0.45253333$
 $b = 250.00$
 $h = 500.00$
From EC8 A.4.4.3(6), $p_f = 2t_f/bw = 0.008128$
 $bw = 250.00$
effective stress from (A.35), $f_{fe} = 703.4155$

$R = 40.00$
Effective FRP thickness, $t_f = N_L \cdot t \cdot \cos(b_1) = 1.016$
 $f_{u,f} = 1055.00$
 $E_f = 64828.00$
 $u_{,f} = 0.015$
 $a_{se} ((5.4d), TBDY) = 0.03751166$
 $b_o = 440.00$
 $h_o = 190.00$
 $b_{i2} = 459400.00$
 $p_{sh,min} = \min(p_{sh,x}, p_{sh,y}) = 0.001848$
Expression ((5.4d), TBDY) for $p_{sh,min}$ has been multiplied by 0.3 according to 15.7.1.3 for members without earthquake detailing (90° closed stirrups)

$p_{sh,x} (5.4d) = 0.001848$
 $A_{sh} = A_{stir} \cdot n_s = 78.53982$
No stirrups, $n_s = 2.00$
 $b_k = 500.00$

$p_{sh,y} (5.4d) = 0.00369599$
 $A_{sh} = A_{stir} \cdot n_s = 78.53982$
No stirrups, $n_s = 2.00$
 $b_k = 250.00$

$s = 170.00$
 $f_{ywe} = 555.55$
 $f_{ce} = 20.00$
From ((5.A5), TBDY), TBDY: $c_c = 0.00339158$
 $c = \text{confinement factor} = 1.13916$
 $y_1 = 0.00130695$
 $sh_1 = 0.00451687$
 $ft_1 = 376.4017$
 $fy_1 = 313.6681$
 $su_1 = 0.005257$
using (30) in Biskinis/Fardis (2013) multiplied with shear_factor
and also multiplied by the shear_factor according to 15.7.1.4, with
Shear_factor = 1.00
 $l_o/l_{ou,min} = l_b/l_d = 0.30356779$
 $su_1 = 0.4 \cdot esu_{1,nominal} ((5.5), TBDY) = 0.032$
From table 5A.1, TBDY: $esu_{1,nominal} = 0.08$
For calculation of $esu_{1,nominal}$ and y_1, sh_1, ft_1, fy_1 , it is considered
characteristic value $fsy_1 = fs_1/1.2$, from table 5.1, TBDY.
 y_1, sh_1, ft_1, fy_1 , are also multiplied by $\min(1, 1.25 \cdot (l_b/l_d)^{2/3})$, from 10.3.5, ASCE41-17.
with $fs_1 = fs = 313.6681$
with $Es_1 = Es = 200000.00$
 $y_2 = 0.00130695$
 $sh_2 = 0.00451687$
 $ft_2 = 376.4017$
 $fy_2 = 313.6681$

```

su2 = 0.005257
using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779
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, ASCE41-17.
with fs2 = fs = 313.6681
with Es2 = Es = 200000.00
yv = 0.00130695
shv = 0.00451687
ftv = 376.4017
fyv = 313.6681
suv = 0.005257
using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779
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, ASCE41-17.
with fsv = fs = 313.6681
with Esv = Es = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.11385127
2 = Asl,com/(b*d)*(fs2/fc) = 0.11385127
v = Asl,mid/(b*d)*(fsv/fc) = 0.05520062
and confined core properties:
b = 190.00
d = 427.00
d' = 13.00
fcc (5A.2, TBDY) = 22.78316
cc (5A.5, TBDY) = 0.00339158
c = confinement factor = 1.13916
1 = Asl,ten/(b*d)*(fs1/fc) = 0.1603292
2 = Asl,com/(b*d)*(fs2/fc) = 0.1603292
v = Asl,mid/(b*d)*(fsv/fc) = 0.07773537
Case/Assumption: Unconfined full section - Steel rupture
'satisfies Eq. (4.3)
--->
v < vs,y2 - LHS eq.(4.5) is satisfied
--->
su (4.9) = 0.20486988
Mu = MRc (4.14) = 1.4541E+008
u = su (4.1) = 1.4467178E-005

```

Calculation of ratio lb/lb

```

Lap Length: lb/lb = 0.30356779
lb = 300.00
lb = 988.2471
Calculation of lb,min according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
= 1
db = 18.00
Mean strength value of all re-bars: fy = 555.55
fc' = 20.00, but fc'^0.5 <= 8.3 MPa (22.5.3.1, ACI 318-14)
t = 1.00
s = 0.80
e = 1.00
cb = 25.00
Ktr = 4.61999

```


$$A_{tr} = \text{Min}(A_{tr_x}, A_{tr_y}) = 157.0796$$

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

$$s = 170.00$$

$$n = 8.00$$

Calculation of μ_2 -

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

$$\mu = 1.4467178E-005$$

$$\mu = 1.4541E+008$$

with full section properties:

$$b = 250.00$$

$$d = 457.00$$

$$d' = 43.00$$

$$v = 0.00204242$$

$$N = 4666.932$$

$$f_c = 20.00$$

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

$$\text{Final value of } \mu: \mu^* = \text{shear_factor} * \text{Max}(\mu, \alpha) = 0.01464474$$

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

$$\text{From (5.4b), TBDY: } \mu = 0.01464474$$

$$\mu \text{ ((5.4c), TBDY)} = \alpha * \mu_{\text{min}} * f_{ywe} / f_{ce} + \text{Min}(\mu_x, \mu_y) = 0.07762821$$

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

$$\mu_x = 0.07705054$$

$$\alpha = 0.45253333$$

$$b = 500.00$$

$$h = 250.00$$

$$\text{From EC8 A.4.4.3(6), } \mu_{\text{frp}} = 2t_f / b_w = 0.004064$$

$$b_w = 500.00$$

$$\text{effective stress from (A.35), } f_{fe} = 837.9178$$

$$\mu_y = 0.12936483$$

$$\alpha = 0.45253333$$

$$b = 250.00$$

$$h = 500.00$$

$$\text{From EC8 A.4.4.3(6), } \mu_{\text{frp}} = 2t_f / b_w = 0.008128$$

$$b_w = 250.00$$

$$\text{effective stress from (A.35), } f_{fe} = 703.4155$$

$$R = 40.00$$

$$\text{Effective FRP thickness, } t_f = N L * t * \cos(\theta_1) = 1.016$$

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

$$E_f = 64828.00$$

$$\mu_{u,f} = 0.015$$

$$\alpha \text{ ((5.4d), TBDY)} = 0.03751166$$

$$b_o = 440.00$$

$$h_o = 190.00$$

$$b_{i2} = 459400.00$$

$$\mu_{\text{psh,min}} = \text{Min}(\mu_{\text{psh,x}}, \mu_{\text{psh,y}}) = 0.001848$$

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

$$\mu_{\text{psh,x}} \text{ (5.4d)} = 0.001848$$

$$A_{sh} = A_{\text{stir}} * n_s = 78.53982$$

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

$$b_k = 500.00$$

$$\mu_{\text{psh,y}} \text{ (5.4d)} = 0.00369599$$

$$A_{sh} = A_{\text{stir}} * n_s = 78.53982$$

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

$$b_k = 250.00$$

```

s = 170.00
fywe = 555.55
fce = 20.00
From ((5A.5), TBDY), TBDY: cc = 0.00339158
c = confinement factor = 1.13916
y1 = 0.00130695
sh1 = 0.00451687
ft1 = 376.4017
fy1 = 313.6681
su1 = 0.005257
using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779
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, ASCE41-17.
with fs1 = fs = 313.6681
with Es1 = Es = 200000.00
y2 = 0.00130695
sh2 = 0.00451687
ft2 = 376.4017
fy2 = 313.6681
su2 = 0.005257
using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779
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, ASCE41-17.
with fs2 = fs = 313.6681
with Es2 = Es = 200000.00
yv = 0.00130695
shv = 0.00451687
ftv = 376.4017
fyv = 313.6681
suv = 0.005257
using (30) in Biskinis/Fardis (2013) multiplied with 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 = 0.30356779
suv = 0.4*esuv_nominal ((5.5), TBDY) = 0.032
From table 5A.1, TBDY: esuv_nominal = 0.08,
considering characteristic value fsyv = fsv/1.2, from table 5.1, TBDY
For calculation of esuv_nominal and yv, shv,ftv,fyv, it is considered
characteristic value fsyv = fsv/1.2, from table 5.1, TBDY.
y1, sh1,ft1,fy1, are also multiplied by Min(1,1.25*(lb/d)^ 2/3), from 10.3.5, ASCE41-17.
with fsv = fs = 313.6681
with Esv = Es = 200000.00
1 = Asl,ten/(b*d)*(fs1/fc) = 0.11385127
2 = Asl,com/(b*d)*(fs2/fc) = 0.11385127
v = Asl,mid/(b*d)*(fsv/fc) = 0.05520062
and confined core properties:
b = 190.00
d = 427.00
d' = 13.00
fcc (5A.2, TBDY) = 22.78316
cc (5A.5, TBDY) = 0.00339158
c = confinement factor = 1.13916
1 = Asl,ten/(b*d)*(fs1/fc) = 0.1603292
2 = Asl,com/(b*d)*(fs2/fc) = 0.1603292

```

$$v = A_{sl, mid} / (b \cdot d) \cdot (f_{sv} / f_c) = 0.07773537$$

Case/Assumption: Unconfined full section - Steel rupture

' satisfies Eq. (4.3)

--->

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

--->

$$\mu_u (4.9) = 0.20486988$$

$$\mu_u = M_{Rc} (4.14) = 1.4541E+008$$

$$u = \mu_u (4.1) = 1.4467178E-005$$

Calculation of ratio l_b/l_d

Lap Length: $l_b/l_d = 0.30356779$

$$l_b = 300.00$$

$$l_d = 988.2471$$

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

$$= 1$$

$$d_b = 18.00$$

Mean strength value of all re-bars: $f_y = 555.55$

$f'_c = 20.00$, but $f'_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$$t = 1.00$$

$$s = 0.80$$

$$e = 1.00$$

$$c_b = 25.00$$

$$K_{tr} = 4.61999$$

$$A_{tr} = \min(A_{tr_x}, A_{tr_y}) = 157.0796$$

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

$$s = 170.00$$

$$n = 8.00$$

Calculation of Shear Strength $V_r = \min(V_{r1}, V_{r2}) = 409422.352$

Calculation of Shear Strength at edge 1, $V_{r1} = 409422.352$

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

$$V_{CoI0} = 409422.352$$

$k_{nl} = 1$ (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)

$f'_c = 20.00$, but $f'_c^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)

$$M/Vd = 2.00$$

$$\mu_u = 2.8180236E-013$$

$$V_u = 1.3558547E-031$$

$$d = 0.8 \cdot h = 400.00$$

$$N_u = 4666.932$$

$$A_g = 125000.00$$

From (11.5.4.8), ACI 318-14: $V_s = 164264.64$

$$A_v = 157079.633$$

$$f_y = 444.44$$

$$s = 170.00$$

V_s is multiplied by $Col = 1.00$

$$s/d = 0.425$$

$$V_f ((11-3)-(11.4), ACI 440) = 240803.347$$

$f = 0.95$, for fully-wrapped sections

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

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

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

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

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

total thickness per orientation, $tf1 = NL \cdot t / NoDir = 1.016$
 $dfv = d$ (figure 11.2, ACI 440) = 457.00
 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: $Vs + Vf \leq 297085.704$
 $bw = 250.00$

Calculation of Shear Strength at edge 2, $Vr2 = 409422.352$
 $Vr2 = VCol$ ((10.3), ASCE 41-17) = $knl \cdot VColO$
 $VColO = 409422.352$
 $knl = 1$ (zero step-static loading)

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

$= 1$ (normal-weight concrete)
 $fc' = 20.00$, but $fc^{0.5} \leq 8.3$ MPa (22.5.3.1, ACI 318-14)
 $M/Vd = 2.00$
 $Mu = 2.8180236E-013$
 $Vu = 1.3558547E-031$
 $d = 0.8 \cdot h = 400.00$
 $Nu = 4666.932$
 $Ag = 125000.00$
 From (11.5.4.8), ACI 318-14: $Vs = 164264.64$
 $Av = 157079.633$
 $fy = 444.44$
 $s = 170.00$
 Vs is multiplied by $Col = 1.00$
 $s/d = 0.425$
 Vf ((11-3)-(11.4), ACI 440) = 240803.347
 $f = 0.95$, for fully-wrapped sections
 $wf/sf = 1$ (FRP strips adjacent to one another).
 In (11.3) $\sin + \cos$ is replaced with $(\cot + \cot a) \sin a$ which is more a generalised expression,
 where a is the angle of the crack direction (see KANEPE).
 This later relation, considered as a function $Vf(,)$, is implemented for every different fiber orientation ai ,
 as well as for 2 crack directions, $= 45^\circ$ and $= -45^\circ$ to take into consideration the cyclic seismic loading.
 orientation 1: $1 = b1 + 90^\circ = 90.00$
 $Vf = \text{Min}(|Vf(45, 1)|, |Vf(-45, a1)|)$, with:
 total thickness per orientation, $tf1 = NL \cdot t / NoDir = 1.016$
 $dfv = d$ (figure 11.2, ACI 440) = 457.00
 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: $Vs + Vf \leq 297085.704$
 $bw = 250.00$

End Of Calculation of Shear Capacity ratio for element: column C1 of floor 1
 At local axis: 2

Start Of Calculation of Chord Rotation Capacity for element: column C1 of floor 1
 At local axis: 3
 Integration Section: (b)
 Section Type: rcrs

Constant Properties

Knowledge Factor, $= 1.00$
 Chord Rotation is generally considered as Deformation-Controlled Action according to Table C7-1, ASCE41-17.
 Mean strengths are used for Deformation-Controlled Actions according to 7.5.1.3, ASCE 41-17

Consequently:

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

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

Concrete Elasticity, $E_c = 21019.039$

Steel Elasticity, $E_s = 200000.00$

Section Height, $H = 250.00$

Section Width, $W = 500.00$

Cover Thickness, $c = 25.00$

Element Length, $L = 3000.00$

Primary Member

Ribbed Bars

Ductile Steel

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

Longitudinal Bars With Ends Lapped Starting at the End Sections

Lap Length $l_b = 300.00$

FRP Wrapping Data

Type: Carbon

Cured laminate properties (design values)

Thickness, $t = 1.016$

Tensile Strength, $f_{fu} = 1055.00$

Tensile Modulus, $E_f = 64828.00$

Elongation, $\epsilon_{fu} = 0.01$

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

Bending Moment, $M = 117197.472$

Shear Force, $V_2 = 4708.27$

Shear Force, $V_3 = 3.5022564E-013$

Axial Force, $F = -4886.081$

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: $A_{st,com} = 829.3805$

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

Mean Diameter of Tension Reinforcement, $D_{bL} = 18.66667$

Existing component: From table 7-7, ASCE 41_17: Final chord rotation Capacity $\phi_{u,R} = \phi_u = 0.04269636$

$\phi_u = \phi_y + \phi_p = 0.04269636$

- Calculation of ϕ_y -

$\phi_y = (M_y * L_s / 3) / E_{eff} = 0.00069636 ((4.29), \text{Biskinis Phd})$

$M_y = 1.1435E+008$

$L_s = M/V$ (with $L_s > 0.1 * L$ and $L_s < 2 * L$) = 300.00

From table 10.5, ASCE 41_17: $E_{eff} = \text{factor} * E_c * I_g = 1.6421E+013$

factor = 0.30

$A_g = 125000.00$

$f_c' = 20.00$

$N = 4886.081$

$E_c * I_g = 5.4737E+013$

Calculation of Yielding Moment M_y

Calculation of ϕ_y and M_y according to Annex 7 -

```

y = Min( y_ten, y_com)
y_ten = 4.5289398E-006
with ((10.1), ASCE 41-17) fy = Min(fy, 1.25*fy*(lb/d)^ 2/3) = 291.1836
d = 457.00
y = 0.29656463
A = 0.01818525
B = 0.01001469
with pt = 0.00725935
pc = 0.00725935
pv = 0.00351968
N = 4886.081
b = 250.00
" = 0.0940919
y_comp = 1.2978922E-005
with fc* (12.3, (ACI 440)) = 20.44585
fc = 20.00
fl = 0.9425867
b = 250.00
h = 500.00
Ag = 125000.00
From (12.9), ACI 440: ka = 0.15087868
g = pt + pc + pv = 0.01803838
rc = 40.00
Ae/Ac = 0.60351471
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 = 21019.039
y = 0.29519565
A = 0.01791625
B = 0.00986782
with Es = 200000.00

```

Calculation of ratio lb/d

```

Lap Length: ld/d,min = 0.37945973
lb = 300.00
ld = 790.5977
Calculation of l according to (25.4.3.2), ACI 318-14, using mean values for all the section re-bars.
= 1
db = 18.00
Mean strength value of all re-bars: fy = 444.44
fc' = 20.00, but fc^0.5 <= 8.3 MPa (22.5.3.1, ACI 318-14)
t = 1.00
s = 0.80
e = 1.00
cb = 25.00
Ktr = 4.61999
Atr = Min(Atr_x,Atr_y) = 157.0796
where Atr_x, Atr_y are the sum of the area of all stirrup legs along X and Y loxal axis
s = 170.00
n = 8.00

```

- Calculation of p -

```

From table 10-8: p = 0.042
with:
- Columns not controlled by inadequate development or splicing along the clear height because lb/d >= 1
shear control ratio VyE/VColOE = 0.23676754
d = 457.00
s = 0.00
t = Av/(bw*s) + 2*tf/bw*(ffe/fs) = 0.00

```

$A_v = 157.0796$, is the total area of all stirrups parallel to loading (shear) direction

$b_w = 250.00$

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.

$N_{UD} = 4886.081$

$A_g = 125000.00$

$f_{cE} = 20.00$

$f_{ytE} = f_{ylE} = 0.00$

$\rho_l = \text{Area_Tot_Long_Rein} / (b \cdot d) = 0.01803838$

$b = 250.00$

$d = 457.00$

$f_{cE} = 20.00$

End Of Calculation of Chord Rotation Capacity for element: column C1 of floor 1

At local axis: 3

Integration Section: (b)
