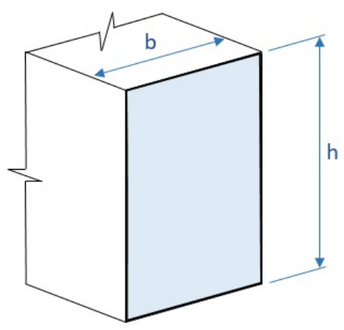
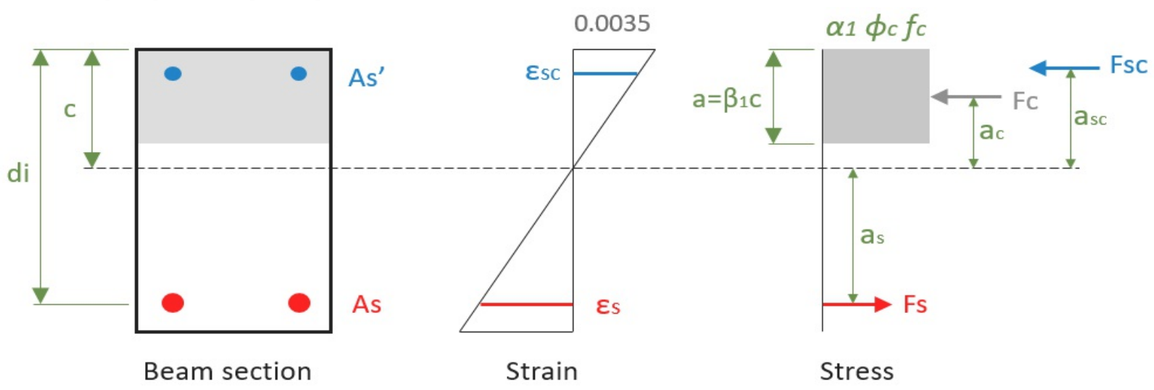
REFERENCES	CALCULATIONS	RESULTS
Code: CSA A23.3-14	# MEMBER #1 (SECTION POSITION 0.0 mm) BEAM DESIGN REPORT **Project details** **Project Name:** **Project ID:** Company: Designer: Client: Project Notes: Project Units: Metric **General member design information** Dimentions:  Height $h = 500\ \text{mm}$ Width $b = 400\ \text{mm}$ Member length = $5000\ \text{mm}$ Material properties: Concrete strength $f_c = 25\ \text{MPa}$ Steel strength of longitudinal rebar $f_y = 400\ \text{MPa}$ Steel strength of shear rebar $f_{yt} = 400\ \text{MPa}$ Limit crack control parameter $z_{lim} = 30000\ \text{N/mm}$ **Load Combinations (Ultimate Limit State)** For axial force in section: LC1: USER = $0\ \text{kN}$ For bending moment in section: LC1: USER = $0\ \text{kN-m}$ For shear force in section: LC1: USER = $0\ \text{kN}$ **Load Combinations (Serviceability Limit State)** For bending moment in section: LC1: USER = $250\ \text{kN-m}$	
8.4, 10.1, 10.5	**Flexure check (Positive bending moment case)** BENDING MOMENT CAPACITY  Section input data: Ultimate strain in concrete $e_{cmax} = 0.0035$ Distance to the outermost layer of tensile reinforcement $d = 447.5\ \text{mm}$ Given bending moment $M = 0.00\ \text{kN-m}$ Concrete resistance factor (8.4.2) $\phi_c = 0.65$ Reinforcement resistance factor (8.4.3) $\phi_s = 0.85$ Design yield strain of rebar $e_y = f_s/E_s = 400/200000 = 0.00200$ Section Rebar	

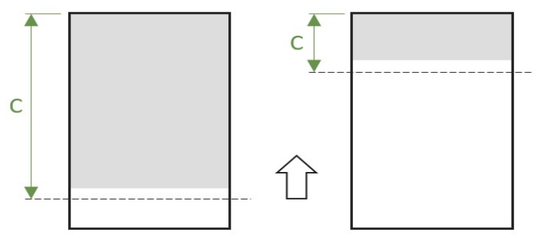
Depth di (mm)	bar diameter (mm)	bar area Asi (mm^2)
447.5	25.23	499.95
447.5	25.23	499.95
447.5	25.23	499.95
447.5	25.23	499.95
387.5	25.23	499.95
387.5	25.23	499.95
387.5	25.23	499.95
387.5	25.23	499.95

Rectangular compression block factors (10.1.7)

$$\alpha_1 = 0.85 - 0.0015 \cdot f_c = 0.85 - 0.0015 \cdot 25 = 0.81$$

$$\beta_1 = 0.97 - 0.0025 \cdot f_c = 0.97 - 0.0025 \cdot 25 = 0.91$$

1. Calculation of neutral axis depth c



Calculation is based on iterative process:
- Assume c
- Calculate concrete force $F_c = \alpha_1 \cdot \phi_c \cdot f_c \cdot \int_{dA} \cdot \beta_1 \cdot c$
- Calculate compression force in steel $F_{cs} = \phi_s \cdot \sum A_{s,i}^{'} \cdot f_{s,i}$
- Calculate tensioning force in steel $F_s = \phi_s \cdot \sum A_{s,i} \cdot f_{s,i}$
- Check equilibrium $F_c + F_{cs} = F_s$

Reinforcement stresses $f_s = \{e_s E_s \ (e_s \leq e_y),\ e_y \ (e_s > e_y)\}$
Reinforcement strains above axis $e_s = e_{cu} \cdot (c - d)/c$
Reinforcement strains below axis $e_s = e_{cu} \cdot (d - c)/c$

Searching of neutral axis c (from 447.5 to 0 mm)

Iter.	c (mm)	a (mm)	Fc (kN)	Fcs (kN)	Fc + Fcs (kN)	Fs (kN)	Ratio
1	447.5	406.1	2144.75	159.54	2304.29	0.00	Infinity
2	438.6	398.0	2101.85	138.51	2240.36	24.28	92.259
3	429.6	389.9	2058.96	116.61	2175.56	49.58	43.881
4	420.7	381.7	2016.06	93.77	2109.83	75.95	27.779
5	411.7	373.6	1973.17	69.94	2043.11	103.47	19.746
6	402.8	365.5	1930.27	45.05	1975.33	132.21	14.941
7	393.8	357.4	1887.38	19.04	1906.41	162.26	11.749
8	384.9	349.3	1844.48	0.00	1844.48	201.89	9.136
9	375.9	341.1	1801.59	0.00	1801.59	263.36	6.841
10	367.0	333.0	1758.69	0.00	1758.69	327.83	5.365
11	358.0	324.9	1715.80	0.00	1715.80	395.52	4.338
12	349.1	316.8	1672.90	0.00	1672.90	466.68	3.585
13	340.1	308.6	1630.01	0.00	1630.01	541.59	3.010
14	331.2	300.5	1587.11	0.00	1587.11	620.54	2.558
15	322.2	292.4	1544.22	0.00	1544.22	703.88	2.194
16	313.3	284.3	1501.32	0.00	1501.32	791.99	1.896
17	304.3	276.2	1458.43	0.00	1458.43	885.27	1.647

18	295.4	268.0	1415.53	0.00	1415.53	984.22	1.438
19	286.4	259.9	1372.64	0.00	1372.64	1089.34	1.260
20	277.5	251.8	1329.74	0.00	1329.74	1151.90	1.154
21	268.5	243.7	1286.85	0.00	1286.85	1207.29	1.066
(Fc + Fcs) < Fs. Updating of iterations							
1	259.6	235.5	1243.95	0.00	1243.95	1266.51	0.982
2	268.3	243.5	1285.99	0.00	1285.99	1208.44	1.064
3	268.1	243.3	1285.13	0.00	1285.13	1209.58	1.062
4	268.0	243.2	1284.28	0.00	1284.28	1210.73	1.061
5	267.8	243.0	1283.42	0.00	1283.42	1211.88	1.059
6	267.6	242.9	1282.56	0.00	1282.56	1213.03	1.057
7	267.4	242.7	1281.70	0.00	1281.70	1214.19	1.056
8	267.2	242.5	1280.84	0.00	1280.84	1215.34	1.054
9	267.1	242.4	1279.99	0.00	1279.99	1216.50	1.052
10	266.9	242.2	1279.13	0.00	1279.13	1217.66	1.050
11	266.7	242.0	1278.27	0.00	1278.27	1218.82	1.049
12	266.5	241.9	1277.41	0.00	1277.41	1219.98	1.047
13	266.4	241.7	1276.55	0.00	1276.55	1221.14	1.045
14	266.2	241.6	1275.70	0.00	1275.70	1222.30	1.044
15	266.0	241.4	1274.84	0.00	1274.84	1223.47	1.042
16	265.8	241.2	1273.98	0.00	1273.98	1224.64	1.040
17	265.6	241.1	1273.12	0.00	1273.12	1225.81	1.039
18	265.5	240.9	1272.26	0.00	1272.26	1226.98	1.037
19	265.3	240.7	1271.41	0.00	1271.41	1228.15	1.035
20	265.1	240.6	1270.55	0.00	1270.55	1229.32	1.034
21	264.9	240.4	1269.69	0.00	1269.69	1230.50	1.032
22	264.7	240.3	1268.83	0.00	1268.83	1231.67	1.030
23	264.6	240.1	1267.98	0.00	1267.98	1232.85	1.028
24	264.4	239.9	1267.12	0.00	1267.12	1234.03	1.027
25	264.2	239.8	1266.26	0.00	1266.26	1235.21	1.025
26	264.0	239.6	1265.40	0.00	1265.40	1236.40	1.023
27	263.8	239.4	1264.54	0.00	1264.54	1237.58	1.022
28	263.7	239.3	1263.69	0.00	1263.69	1238.77	1.020
29	263.5	239.1	1262.83	0.00	1262.83	1239.96	1.018
30	263.3	239.0	1261.97	0.00	1261.97	1241.15	1.017
31	263.1	238.8	1261.11	0.00	1261.11	1242.34	1.015
32	263.0	238.6	1260.25	0.00	1260.25	1243.53	1.013
33	262.8	238.5	1259.40	0.00	1259.40	1244.72	1.012
34	262.6	238.3	1258.54	0.00	1258.54	1245.92	1.010
35	262.4	238.1	1257.68	0.00	1257.68	1247.12	1.008
36	262.2	238.0	1256.82	0.00	1256.82	1248.32	1.007
37	262.1	237.8	1255.96	0.00	1255.96	1249.52	1.005
38	261.9	237.7	1255.11	0.00	1255.11	1250.72	1.004
39	261.7	237.5	1254.25	0.00	1254.25	1251.92	1.002

40	261.5	237.3	1253.39	0.00	1253.39	1253.13	1.000
41	261.3	237.2	1252.53	0.00	1252.53	1254.34	0.999

Final value of c is 261.34 mm, flexural tension reinforcement area is 3999.60 mm^2 and flexural compression reinforcement area is 0.00 mm^2
Working depth of reinforcement $d = 417.50\ \text{mm}$

2. Calculation of moment resistance M_r

$$M_r = F_c \cdot a_c + F_{cs} \cdot a_{cs} + F_s \cdot a_s = 178.81 + 0.00 + 199.04 = 377.85\ \text{kN-m}$$

$$M = 0.00\ \text{kN-m} \leq M_r = 377.85\ \text{kN-m}\ (\text{Ratio: } 0.000)$$

STATUS OK!
Ratio: 0.000

3. Minimum required flexural tension reinforcement in a beam section (10.5.1.2)

Width of tension zone $b_t = 400\ \text{mm}$

$$A_{st,min} = \frac{0.2 \cdot \sqrt{f_c}}{f_y} \cdot b_t \cdot h = \frac{0.2 \cdot \sqrt{25}}{400} \cdot 400 \cdot 500 = 500.00\ \text{mm}^2$$

4. Maximum required flexural tension reinforcement in a beam section

$$A_{st,max} = 0.04 \cdot b \cdot d = 0.04 \cdot 400 \cdot 417.50 = 6680.00\ \text{mm}^2$$

5. Check of required flexural tension reinforcement in a beam section

$$A_{st} = 3999.60\ \text{mm}^2 \leq A_{st,max} = 6680.00\ \text{mm}^2\ (\text{Ratio: } 0.599)$$

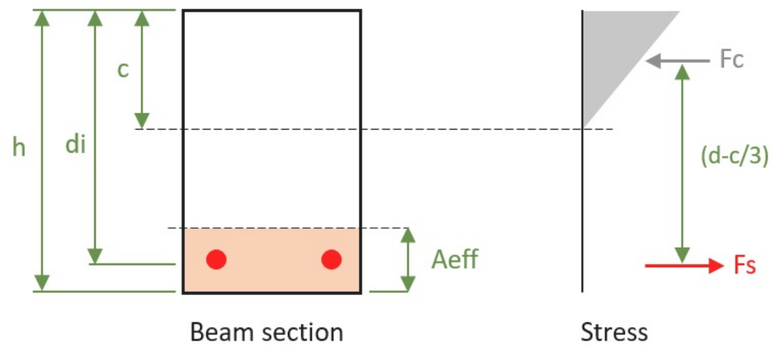
STATUS OK!
Ratio: 0.599

$$A_{st} = 3999.60\ \text{mm}^2 \geq A_{st,min} = 500.00\ \text{mm}^2\ (\text{Ratio: } 0.125)$$

STATUS OK!
Ratio: 0.125

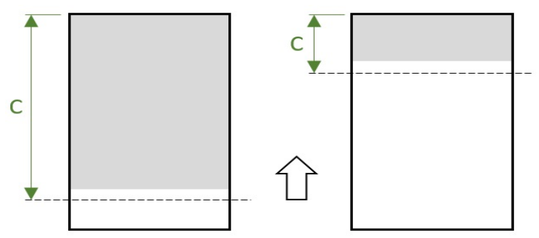
Crack width check (Positive bending moment case)

10.6.1 CRACK CONTROL OF BEAMS



Section input data:
Modulus of elasticity of concrete $E_c = 4500 \cdot \sqrt{f_c} = 4500 \cdot \sqrt{25} = 22500.00\ \text{MPa}$
Modulus of elasticity of steel $E_s = 200000.00\ \text{MPa}$
Modulus Ratio $n = E_s / E_c = 200000 / 22500.00 = 8.89$
Effective tension area of concrete around the main reinforcing $A = 8250.00\ \text{mm}^2$
Cover of the outermost bar $d_c = 52.5\ \text{mm}$
Given bending moment $M_a = 250.00\ \text{kN-m}$

1. Calculation of neutral axis depth c of cracked section



Calculation is based on iterative process:
- Assume c
- Calculate left part of force equilibrium $A_{comp.} \cdot 0.5 \cdot c + \sum n \cdot A_s \cdot \acute{d}_i + \sum n \cdot A_s \cdot d_i$
- Calculate right part of force equilibrium $A_{comp.} + n \cdot A_s + n \cdot \acute{A}_s$

Searching of neutral axis c (from 447.5 to 0 mm)

			Left	Right	

Iter.	c (mm)	As (mm2)	force equil. part (kN)	force equil. part (kN)	Ratio
1	447.50	0.00	54894.21	96012.02	1.749
2	438.55	1999.80	53308.18	92521.77	1.736
3	429.60	1999.80	51754.19	89095.60	1.722
4	420.65	1999.80	50232.24	85733.52	1.707
5	411.70	1999.80	48742.34	82435.51	1.691
6	402.75	1999.80	47284.47	79201.59	1.675
7	393.80	1999.80	45858.65	76031.75	1.658
8	384.85	3999.60	44464.86	72926.00	1.640
9	375.90	3999.60	43103.12	69884.32	1.621
10	366.95	3999.60	41773.42	66906.73	1.602
11	358.00	3999.60	40475.76	63993.22	1.581
12	349.05	3999.60	39210.14	61143.79	1.559
13	340.10	3999.60	37976.56	58358.44	1.537
14	331.15	3999.60	36775.02	55637.17	1.513
15	322.20	3999.60	35605.53	52979.99	1.488
16	313.25	3999.60	34468.07	50386.89	1.462
17	304.30	3999.60	33362.66	47857.87	1.434
18	295.35	3999.60	32289.28	45392.93	1.406
19	286.40	3999.60	31247.95	42992.08	1.376
20	277.45	3999.60	30238.66	40655.30	1.344
21	268.50	3999.60	29261.41	38382.61	1.312
22	259.55	3999.60	28316.20	36174.00	1.278
23	250.60	3999.60	27403.03	34029.48	1.242
24	241.65	3999.60	26521.90	31949.03	1.205
25	232.70	3999.60	25672.82	29932.67	1.166
26	223.75	3999.60	24855.77	27980.39	1.126
27	214.80	3999.60	24070.77	26092.19	1.084
28	205.85	3999.60	23317.80	24268.07	1.041
left part < right part. Updating of iterations					
1	196.90	3999.60	22596.88	22508.03	0.996
2	205.67	3999.60	23303.07	24232.24	1.040
3	205.49	3999.60	23288.35	24196.44	1.039
4	205.31	3999.60	23273.65	24160.66	1.038
5	205.13	3999.60	23258.95	24124.91	1.037
6	204.96	3999.60	23244.27	24089.18	1.036
7	204.78	3999.60	23229.60	24053.48	1.035
8	204.60	3999.60	23214.95	24017.81	1.035
9	204.42	3999.60	23200.30	23982.16	1.034
10	204.24	3999.60	23185.67	23946.53	1.033
11	204.06	3999.60	23171.06	23910.93	1.032
12	203.88	3999.60	23156.45	23875.36	1.031
13	203.70	3999.60	23141.86	23839.82	1.030

14	203.52	3999.60	23127.28	23804.29	1.029
15	203.34	3999.60	23112.72	23768.80	1.028
16	203.17	3999.60	23098.16	23733.33	1.027
17	202.99	3999.60	23083.62	23697.88	1.027
18	202.81	3999.60	23069.10	23662.47	1.026
19	202.63	3999.60	23054.58	23627.07	1.025
20	202.45	3999.60	23040.08	23591.71	1.024
21	202.27	3999.60	23025.59	23556.36	1.023
22	202.09	3999.60	23011.11	23521.05	1.022
23	201.91	3999.60	22996.65	23485.76	1.021
24	201.73	3999.60	22982.20	23450.49	1.020
25	201.55	3999.60	22967.76	23415.25	1.019
26	201.38	3999.60	22953.34	23380.04	1.019
27	201.20	3999.60	22938.93	23344.85	1.018
28	201.02	3999.60	22924.53	23309.69	1.017
29	200.84	3999.60	22910.14	23274.55	1.016
30	200.66	3999.60	22895.77	23239.44	1.015
31	200.48	3999.60	22881.41	23204.36	1.014
32	200.30	3999.60	22867.06	23169.30	1.013
33	200.12	3999.60	22852.72	23134.26	1.012
34	199.94	3999.60	22838.40	23099.25	1.011
35	199.76	3999.60	22824.09	23064.27	1.011
36	199.59	3999.60	22809.79	23029.31	1.010
37	199.41	3999.60	22795.51	22994.38	1.009
38	199.23	3999.60	22781.24	22959.48	1.008
39	199.05	3999.60	22766.98	22924.60	1.007
40	198.87	3999.60	22752.74	22889.74	1.006
41	198.69	3999.60	22738.50	22854.91	1.005
42	198.51	3999.60	22724.28	22820.11	1.004
43	198.33	3999.60	22710.08	22785.33	1.003
44	198.15	3999.60	22695.88	22750.58	1.002
45	197.97	3999.60	22681.70	22715.85	1.002
46	197.80	3999.60	22667.53	22681.15	1.001
47	197.62	3999.60	22653.38	22646.48	1.000

Final value of c is 197.62 mm and tensioning rebar area is $3999.60\ \mathrm{mm}^2$
Working depth of reinforcement $d = 417.50\ \mathrm{mm}$

2. Calculation of stress in tensioning zone of reinforcement

$$f_s = \frac{M_a}{A_s \cdot (d - c/3)} = \frac{250000000}{3999.60 \cdot (417.50 - 197.62/3)} = 177.76\ \mathrm{MPa}$$

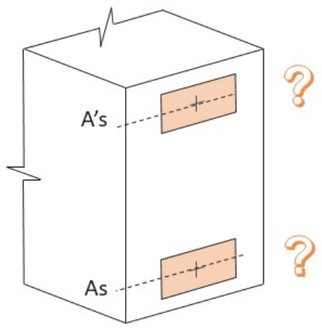
3. Determine the value of z factor (10.6.1)

$$z = f_s \cdot \sqrt[3]{d_c \cdot A} = 177.76 \cdot \sqrt[3]{52.50 \cdot 8250.00} = 13449.65\ \mathrm{N/mm}$$

$$z = 13449.65\ \mathrm{N/mm} \leq z_{lim} = 30000.00\ \mathrm{N/mm}\ (\mathrm{Ratio:}\ 0.448)$$

STATUS OK!
Ratio: 0.448

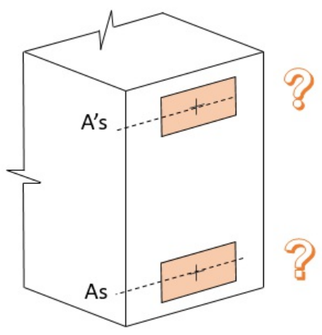
Flexure check (Negative bending moment case)



Bottom Reinforcement is absent in the section. Design checks can't be performed. But as acting moment value is equal to zero no need to check.

STATUS OK!

Crack width check (Negative bending moment case)



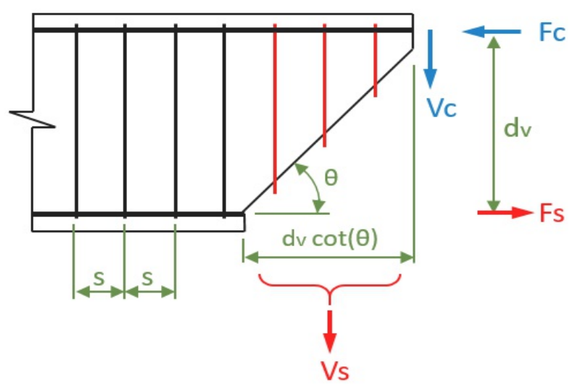
Bottom Reinforcement is absent in the section. Design checks can't be performed. But as acting moment value is equal to zero no need to check.

STATUS OK!

11.2.8.2, 11.3.3, 11.3.4, 11.3.5.1, 11.3.6.3, 11.3.8.1

Shear check

SHEAR FORCE CAPACITY (Members with shear reinforcement)



Section input data:
Mean width of web $b_w = 400\ \text{mm}$
Cross-sectional area of the shear reinforcement $A_v = 157.08\ \text{mm}^2$
Spacing of stirrups $s = 250.00\ \text{mm}$
Given shear force $V = 0.00\ \text{kN}$
Effective shear depth $d_v = max\left\{0.9d, 0.72h\right\} = 375.75$
Concrete density factor $\lambda = 1$
Concrete resistance factor (8.4.2) $\phi_c = 0.65$
Reinforcement resistance factor (8.4.3) $\phi_s = 0.85$
Shear resistance factor $\beta = 0.18$
Angle of diagonal compressive stresses $\theta = 35\ \text{deg}.$

1. Calculate Concrete Shear Capacity (11.3.4)

$$V_c = \phi_c \cdot \lambda \cdot \beta \cdot \sqrt{f_c} \cdot b_w \cdot d_v = 0.65 \cdot 1 \cdot 0.180 \cdot \sqrt{25} \cdot 400 \cdot 375.75 = 87.93\ \text{kN}$$

2. Calculate minimum area of shear reinforcement (11.2.8.2)

$$A_{v,min} = 0.06 \cdot \sqrt{f_c} \cdot \frac{b_w \cdot s}{f_y} = 0.06 \cdot \sqrt{25} \cdot \frac{400 \cdot 250}{400} = 75.00\ \text{mm}^2$$

$$A_v = 157.08\ \text{mm}^2 \geq A_{v,min} = 75.00\ \text{mm}^2$$
$$\rightarrow \text{ area of shear reinforcement is satisfied (Ratio: 0.477)}$$

STATUS OK!
Ratio: 0.477

$$V_s = \frac{\phi_s \cdot A_v \cdot f_y \cdot d_v \cdot cot(\theta)}{s} = \frac{0.85 \cdot 157.08 \cdot 400 \cdot 375.75 \cdot cot(35)}{250} = 114.64 \text{ kN}$$

2. Calculate factored shear resistance (11.3.3)

$$V_r = V_c + V_s = 87.93 + 114.64 = 202.56 \text{ kN}$$

Allowed factored shear resistance

$$V_{r,max} = 0.25 \cdot \phi_c \cdot f_c \cdot b_w \cdot d_v = 0.25 \cdot 0.65 \cdot 25 \cdot 400 \cdot 375.75 = 610.59 \text{ kN}$$

$$V_r \leq V_{r,max}$$

$$V = 0.00 \text{ kN} \leq V_r = 202.56 \text{ kN (Ratio: 0.000)}$$

STATUS OK!
Ratio: 0.000