higher education & training

Department:
Higher Education and Training
REPUBLIC OF SOUTH AFRICA

MARKING GUIDELINE

NATIONAL CERTIFICATE

BUILDING AND STRUCTURAL CONSTRUCTION N6

3 April 2020

This marking guideline consists of 11 pages.

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NOTE TO MARKERS

- This marking guideline conforms to:
  - SANS 10100 (2000) Part 1 Design (The Structural Use of Concrete)
  - SANS 0162 (1984) (The Structural Use of Steel)
- Consider alternate answers.
- Check the candidate's method of obtaining the answer.
- Subtract one mark per answer where references and clauses are not stated.
- Use your discretion.

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QUESTION 1

All references are taken from SANS 10100-1 (2000).

$Fcu = 25$ MPa	Table 2
$Fy = 250$ MPa	cl 4.1.5.1
Span $= 5{,}00$ m	Table 3
Density of reinforced concrete $= 2\,400$ kg/m^3	cl 4.1.5.2
	cl 4.3.1.2

Determine the effective depth of the beam:

Effective depth $=$ span$/16$ — Table 10, cl 4.3.6.2.1

$= 5\,000/16$

$= 312{,}5$ mm✓

Determine the overall depth:

Assume R25 main steel, R10 binders and 25 mm cover

Overall depth $= 312{,}5 + 12{,}5 + 10 + 25$✓

$= 360$ mm

Use overall depth $= 375$ mm.✓

Determine the design dead loads of the beam:

Design dead load $=$ volume $\times$ density $\times\ 9{,}81 \times 10^{-3} \times 1{,}2$Gn — cl 4.2.2.1

$= 0{,}375 \times 0{,}22 \times 1 \times 2\,400$ kg/m$^3 \times 9{,}81 \times 10^{-3} \times 1{,}2$Gn✓

$= 2{,}33$ kN.m✓

cl 4.2.2.1

Design imposed UDL $= 7$ kN.m $\times\ 1{,}6$Qn $= 11{,}2$ kN.m✓

Design imposed point load $= 16$ kN $\times\ 1{,}6$Qn $= 25{,}6$ kN✓

Calculate the bending moment maximum:

$$BM_{max} = \frac{WL^2}{8} + \frac{WL^2}{8} + \frac{WL}{4}$$

$$= \frac{2{,}33 \times 5^2}{8} + \frac{11{,}2 \times 5^2}{8} + \frac{25{,}6 \times 5}{4}$$✓✓

$$= 7{,}28 + 35 + 32$$

$= 74{,}28$ kN.m✓

Calculate the value for K:

$$K = \frac{BM}{fcubd^2}$$ cl 4.3.3.4.1

$$K = \frac{74{,}28 \times 10^6}{25 \times 220 \times 312{,}5^{\,2}}$$ ✓

$K = 0{,}138 < K^1 = 0{,}15$

Provide tension reinforcement only.✓

Calculate the distance of lever arm (Z):

$$Z = d\left\{0{,}5 + \sqrt{0{,}25 - \frac{k}{0{,}9}}\right\} \leq 0{,}95d$$ cl 4.3.3.4.1

$$Z = 312{,}5\left\{0{,}5 + \sqrt{0{,}25 - \frac{0{,}138}{0{,}9}}\right\} \leq 0{,}95 \times 312{,}5$$ ✓

$Z = 312{,}5\{0{,}81\} \leq 296{,}88$

$Z = 253{,}4$ mm < 296,88 mm

Use $Z = 253{,}4$ mm (least).✓

Calculate the tension reinforcement:

$$As = \frac{M}{0{,}87 \times fy \times z}$$ cl 4.3.3.4.1

$$As = \frac{74{,}28 \times 10^6}{0{,}87 \times 250 \times 253{,}41}$$ ✓

$As = 1\,347{,}67\ mm^2$✓

Use 3R25 ($As = 1\,473\ mm^2$).✓

Check for the minimum main reinforcement:

$$\frac{100\ As}{Ac} = \frac{100 \times 1\,473}{375 \times 220}$$ ✓ Table 23 cl 4.11.4

$= 1{,}78$

$1{,}78 > 0{,}8$✓

The reinforcement is sufficient.

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Check for the maximum area of reinforcement:

$4\%\ \text{of AC} = 4\% \times 375 \times 220$ cl 4.11.5.1

$= 3\ 300\ \text{mm}^2$✓

$3\ 300 < 6\ 400$

The reinforcement is sufficient. **[20]**

QUESTION 2

All references are taken from SANS 10100-1 (2000).

$\text{Fcu} = 30\ \text{MPa}$ Table 2
$\text{Fy} = 450\ \text{MPa}$ cl 4.1.5.1
$\text{Axial load} = 8\ 500\ \text{kN}$ Table 3
cl 4.1.5.2

2.1 Calculate the number of longitudinal reinforcements:

$N = 0{,}4\ \text{fcu Ac} + 0{,}67\ \text{fy Asc}$ cl 4.7.4.3

$8\ 500 \times 10^3 = 0{,}4 \times 30 \times \left(\frac{\pi\ 850^2}{4}\right) + 0{,}67 \times 450 \times \text{Asc}$✓✓

$8\ 500 \times 10^3 = 6\ 809\ 402{,}07 + 301{,}5\ \text{Asc}$✓

$8\ 500 \times 10^3 - 6\ 809\ 402{,}07 = 301{,}5\ \text{Asc}$

$\text{Asc} = \frac{1\ 690\ 597{,}93}{301{,}5}$✓

$\text{Asc} = 5\ 607{,}29\ \text{mm}^2$✓

Use 7Y32 ($\text{As} = 5\ 629\ \text{mm}^2$)✓✓

(Minimum spacing between bars = height aggregate + 5 mm) (7)

2.2 Maximum and minimum percentage of the steel reinforcement:

cl 4.11.4.5.2
Table 23

Maximum: 6% of gross sectional area

$6\% \times \left(\frac{\pi\ 850^2}{4}\right) = 34\ 047{,}01\ \text{mm}^2$✓✓

Minimum: 0,4% of gross sectional area

$0{,}4\% \times \left(\frac{\pi\ 850^2}{4}\right) = 2\ 269{,}8\ \text{mm}^2$✓✓ (4)

2.3 Calculate the diameter of the helical binder:

Binders: ¼ of the smallest main bar cl 4.11.4.5.1
$¼ \times 32 = 8$ mm✓
Use R8 helical binder. ✓

Calculate the pitch of the binder:

Spacing of binders: 12 × diameter of smallest main bar cl 4.11.4.5.1
$12 \times 32 = 384$ mm (maximum)✓✓
Use binder pitch = 350 mm.

7y32 main bars with R8 helical binders at 350 mm pitch (4)
[15]

QUESTION 3

3.1 The concrete must be kept moist during the initial stages of hardening. (1)

3.2 The water:cement ratio determines the potential strength,✓ permeability,✓ durability✓ of the hardened concrete. (Any 2 × 1) (2)

3.3
- Iron ore
- Coal
- Limestone
- Recycled steel (Any 3 × 1) (3)

[6]

QUESTION 4

220 × 80 × 29,4 kg/m channel
$I_{yy} = 1,959 \times 10^{-6}$ m⁴
Area $= 3,744 \times 10^{-3}$ m²
$A_y = 21,4$ mm

4.1 Plate: 450 mm × 15 mm

$I_{xx} = \frac{bd^3}{12} = \frac{0,015 \times 0,450^3}{12} = 113,91 \times 10^{-6}$ m⁴ ✓
Area $= 0,45 \times 0,015 = 6,75 \times 10^{-3}$ m²

Plate: 400 mm × 20 mm

$I_{xx} = \frac{bd^3}{12} = \frac{0,4 \times 0,02^3}{12} = 0,267 \times 10^{-6}$ m⁴✓

Area $= 0,4 \times 0,02 = 8 \times 10^{-3}$ m²

Total area $= 3,744 \times 10^{-3}$ m² $+ 6,75 \times 10^{-3}$ m² $+ 8 \times 10^{-3}$ m²

Total area $= 18,5 \times 10^{-3}$ m²✓

Calculate the neutral axis using area moments from the bottom:

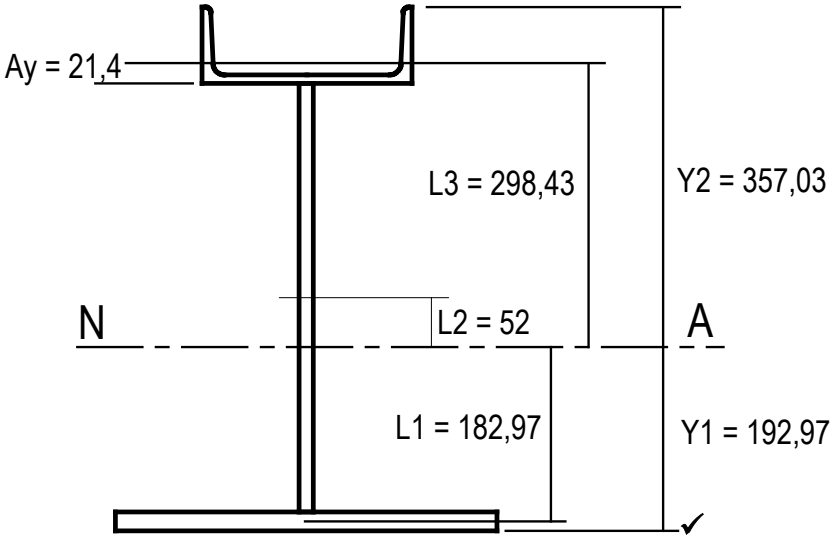
$$18{,}5 \times 10^{-3}\ m^2 \times Y1 = (3{,}744 \times 10^{-3}\ m^2 \times 0{,}4914) + (6{,}75 \times 10^{-3}\ m^2 \times 0{,}245) + (8 \times 10^{-3}\ m^2 \times 0{,}01)$$ ✓

$$Y_1 = \frac{1{,}84 \times 10^{-3}\ m^2 + 1{,}65 \times 10^{-3}\ m^2 + 0{,}08 \times 10^{-3}\ m^2}{18{,}5 \times 10^{-3}\ m^2}$$ ✓

$$Y_1 = \frac{3{,}57 \times 10^{-3}\ m^2}{18{,}5 \times 10^{-3}\ m^2}$$

$$Y_1 = 0{,}19297\ m$$

$$Y_1 = 192{,}97\ mm$$ ✓



(7)

4.2 Calculate the second moment of area:

$$I_{xx\ tot} = (I_{yy}\ channel + al^2) + (I_{xx}\ plate + al^2) + (I_{xx}\ plate + al^2)$$

$$I_{yy\ channel} = (1{,}959 \times 10^{-6} + 3{,}744 \times 10^{-3} \times 0{,}29843^2)$$

$$= (1{,}959 \times 10^{-6} + 333{,}442 \times 10^{-6}) = 335{,}4 \times 10^{-6}\ m^4$$ ✓✓

$$I_{xx\ plate} = (113{,}91 \times 10^{-6} + 6{,}67 \times 10^{-3} \times 0{,}052^2)$$

$$= (113{,}91 \times 10^{-6} + 18{,}036 \times 10^{-6}) = 131{,}95 \times 10^{-6}\ m^4$$ ✓✓

$$I_{xx\ plate} = (0{,}267 \times 10^{-6} + 8 \times 10^{-3} \times 0{,}18297^2)$$

$$= (0{,}267 \times 10^{-6} + 267{,}82 \times 10^{-6}) = 268{,}09 \times 10^{-6}\ m^4$$ ✓✓

$$I_{xx\ total} = 735{,}612 \times 10^{-6}\ m^4$$ ✓

Calculate the bending moment maximum:

Bending stress $= 160$ MPa

$\frac{M}{I} = \frac{f}{y}$ where $M = \frac{I \times f}{y}$

$BM_{max} = \frac{735{,}44 \times 10^6 \times 160}{192{,}97}$ ✓

$BM_{max} = 609{,}79$ kN.m ✓

Calculate the self-weight of the beam:

Channel: $29{,}4 \text{ kg/m} \times 9{,}81 \times 10^{-3} = 0{,}29$ kN.m

Plate: $W = 7\,850 \text{ kg/m}^3 \times 0{,}45 \times 0{,}015 \times 9{,}81 \times 10^{-3} = 0{,}52$ kN.m

Plate: $W = 7\,850 \text{ kg/m}^3 \times 0{,}4 \times 0{,}02 \times 9{,}81 \times 10^{-3} = 0{,}62$ kN.m

Total self-weight $= 1{,}43$ kN.m ✓ (10)

4.3 Calculate the UDL:

$BM = \frac{W l^2}{8} + \frac{W l^2}{8} + \frac{W l^2}{8} + \frac{W l^2}{8}$

$609{,}79 = \frac{29 \times 5{,}5^2}{8} + \frac{0{,}52 \times 5{,}5^2}{8} + \frac{0{,}62 \times 5{,}5^2}{8} + \frac{W \times 5{,}5^2}{8}$ ✓

$W = 109{,}66 + 1{,}97 + 2{,}34 + 3{,}78W$

$W = \frac{609{,}79 - 113{,}97}{3{,}78}$ ✓

$W = 131{,}2$ kN ✓ (3)

[20]

QUESTION 5

5.1 **$\Sigma VC = 0$**

$BF \sin 30° = 152$ kN ✓

$BF = 152 / \sin 30°$

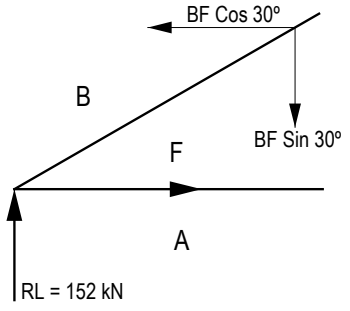
$BF = 304$ kN (strut) ✓✓

$\Sigma HC = 0$

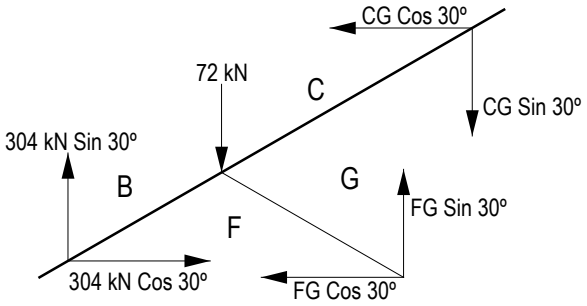
$FA = BF \cos 30°$ ✓

$FA = 304 \times \cos 30°$

$FA = 263{,}27$ kN (tie) ✓✓



$\Sigma VC = 0$
$304\ \text{kN}\sin30° + FG\sin30° = 72\ \text{kN} + CG\sin30°$✓
$152 + 0{,}5FG - 72 = 0{,}5CG$
$80 + 0{,}5FG = 0{,}5CG$✓
$CG = \frac{80 + 0{,}5FG}{0{,}5}$
$CG = 160 + FG$ .....(1)✓



(9)

5.2 $\Sigma HC = 0$
$304\cos30º = CG\cos30° + FG\cos30°$✓
$263{,}27 = \cos30°(160 + FG) + FG\cos30°$
$263{,}27 = 138{,}56 + 0{,}866FG + 0{,}866FG$
$263{,}27 - 138{,}56 = 0{,}866FG + 0{,}866FG$
$124{,}71 = 1{,}732FG$
$FG = \frac{124{,}71}{1{,}732}$
$FG = 72\ \text{kN (strut)}$✓✓
Therefore $CG = 160 + FG$
$CG = 160 + 72 = 232\ \text{kN (strut)}$ ✓✓ (5)
[14]

QUESTION 6

All references are taken from SANS 10100-1 (2000).

$Fcu = 25\ \text{MPa}$	Table 2 cl
$Fy = 250\ \text{MPa}$	4.1.5.1
Eff. span $= 5\ \text{m}$	Table 3 cl
Dead load $= 8{,}25\ \text{kN.m}^2$	4.1.5.2
Imposed load $= 6\ \text{kN.m}^2$	

6.1 <u>Calculate the lever arm distances:</u>

$Z = d\left\{0{,}5 + \sqrt{0{,}25 - \frac{K^1}{0{,}9}}\right\} \leq 0{,}95d$ cl 4.3.3.4.1

$Z = 450\left\{0{,}5 + \sqrt{0{,}25 - \frac{0{,}156}{0{,}9}}\right\}$✓

$Z = 450(0{,}777)$✓

$Z = 349{,}65\ \text{mm}$✓ (3)

6.2 Determine the position of the neutral axis:

$X = \frac{d-z}{0,45}$ cl 4.3.3.4.1

$X = \frac{450 - 349,65}{0,45}$ ✓✓

$X = 223 \text{ mm} > 150 \text{ mm}$ ✓

Therefore, the neutral axis lies below the flange. (3)

6.3 Calculate the total design load:

$W = 1,2(Gn) + 1,6(Qn)$ cl 4.3.3.4.1

$W = 1,2(8,25 \times 1) + 1,6(6 \times 1)$ ✓✓

$W = 10,2 + 9,6$

$W = 19,8 \text{ kN.m}$ ✓ (3)

6.4 Calculate the bending moment due to the concrete:

$BM = \frac{wl^2}{8}$ cl 4.3.3.4.1

$BM = \frac{19,8 \times 5^2}{8}$ ✓

$BM = 61,88 \text{ kN.m}$ ✓ (2)

6.5 Calculate the tension reinforcement:

$As = \frac{m + 0,1 \, fcubwd(0,45d - h_f)}{0,87fy(d - 0,5h_f)}$ cl 4.3.3.4.2

$As = \frac{61,88 \times 10^6 + (0,1 \times 25 \times 270 \times 450)(0,45 \times 450 - 150)}{0,87 \times 250(450 - 0,5 \times 150)}$ ✓✓

$As = \frac{61,88 \times 10^6 + (303\,750)(52,5)}{0,87 \times 250(450 - 0,5 \times 150)}$

$As = \frac{61,88 \times 10^6 + 15\,946\,875}{217,5 \times 375}$ ✓

$As = \frac{77\,816\,875}{81\,562,5}$

$As = 954,08 \text{ mm}^2$ ✓

Use 2R25 bars ($As = 982 \text{ mm}^2$). ✓ (5)

[16]

QUESTION 7

$254 \times 245 \times 73$ kg/m H-profile steel column
Least radius of gyration (r) $= 64{,}6$ mm
Area $= 9{,}292 \times 10^3$ mm^2 Table 19 SABS 0162-1984
$L_{effective} = 3{,}30 \text{ mm} \times 0{,}85$✓
$= 2\,805$ mm✓

Calculate the slenderness ratio:

$L/r = \frac{2\,805}{64{,}6} = 43{,}42$✓✓

From Table 17 (SABS 0162-1984):

$43{,}42 = 137$ MPa✓

Calculate the maximum load:

Load = stress × area

Load $= 137$ N/mm$^2 \times 9{,}292 \times 10^3$ mm^2✓✓

Load $= 1\,273$ kN✓

Suitability:

Yes, the column was suitably designed. The maximum load exceeded the required load by 73 kN.✓ **[9]**

TOTAL: 100

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