higher education & training

Department:
Higher Education and Training
REPUBLIC OF SOUTH AFRICA

MARKING GUIDELINE

NATIONAL CERTIFICATE

BUILDING AND STRUCTURAL CONSTRUCTION N6

3 APRIL 2018

This marking guideline consists of 14 pages.

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INFORMATION AND INSTRUCTIONS

1. This marking guideline conforms to:

   1.1 SANS 10100 (2000) Part 1 Design (The structural use of concrete)

   1.2 SABS 0162-1984 (The structural use of steel)

2. Consider alternate correct answers.

3. Check the candidate's method of obtaining the answer.

4. Subtract ONE mark per answer if references and clauses are not stated.

5. Use your own discretion.

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QUESTION 1

All references taken from SANS 10100-1 (2000)

Fcu = 25 MPa	Table 2 (4.1.5.1)
Fy = 250 MPa	Table 3 (4.1.5.2)
Span = 6,25 metres	CL 4.3.1.2

Loading of the beam	
Design dead load = 7,5 kN/m² × 1 × 1,2 Gn = 9,0 kN/m✓	(CL 4.2.2.1)
Design imposed load = 3,75 kN/m² × 1,6 Qn = 6,0 kN/m✓	(CL 4.2.2.1)

(2)

Calculate bending moment maximum

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

$BM_{max} = \frac{9 \times 6{,}25^2}{8} + \frac{6 \times 6{,}25^2}{8}$✓

$BM_{max} = 43{,}95 + 29{,}30$

$BM_{max} = 73{,}25$ kN/m✓

(2)

Calculate value for K

$K = \frac{BM}{fcu\ b\ d^2}$ (CL 4.3.3.4.1)

$K = \frac{73{,}25 \times 10^6}{25 \times 825 \times 280^2}$✓

$K = 0{,}045 < K^1 = 0{,}156$ ✓

Only tension reinforcement will be required.✓

(3)

Calculate 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)

$Z = 280\left\{0{,}5 + \sqrt{0{,}25 - \frac{0{,}045}{0{,}9}}\right\} \leq 0{,}95 \times 280$✓

$Z = 280(0{,}95) \leq 0{,}95 \times 280$

$Z = 265{,}22$ mm ≤ 266 mm

Use Z = 265,22 mm✓

(2)

Calculate tension reinforcement As $= \frac{BM}{0{,}87\ fy\ z}$ As $= \frac{73{,}25 \times 10^6}{0{,}87 \times 250 \times 265{,}22}$ ✓ As = 1 269,82 mm²✓ Use 3Y25 bars (As = 1 473 mm²)✓	(CL 4.3.3.4.1)

(3)

Check maximum area of reinforcement 4% of AC 4% × (350 × 250) = 3 500 mm² okay✓ 1 473 < 3 500 OK	(CL 4.11.5.4)

(1)

[13]

QUESTION 2

Given info:

I-section 152 × 89 × 17,1 kg/m: Ixx = 8,841 × 10^{-6} m⁴ Area = 2,181 × 10^{-3} m² $\frac{h}{2} = \frac{152{,}4}{2} = 76{,}20$ mm	Plate: 105 mm × 8 mm $I_{xx} = \frac{BD^3}{12} = \frac{0{,}105 \times 0{,}008^3}{12} =$ 0,00448 × 10^{-6} m⁴ Area = 0,105 × 0,008 = 0,84 × 10^{-3} m²

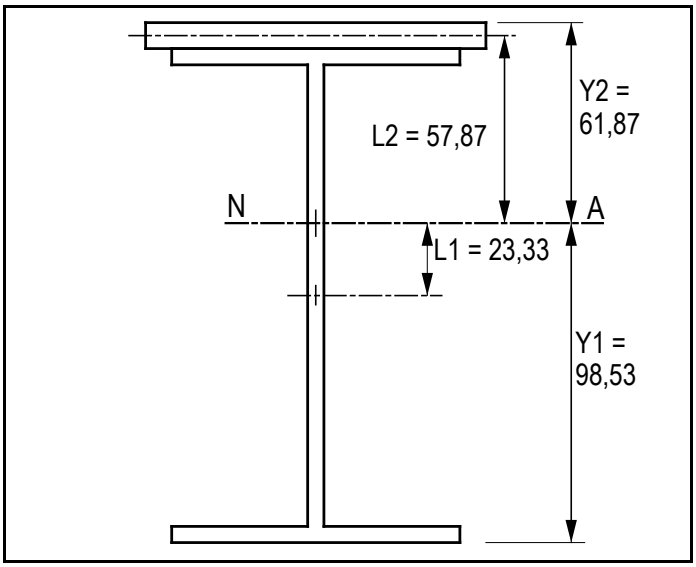
Total area = 2,181 × 10^{-3} m² + 0,84 × 10^{-3} m² Total area = 3,02 × 10^{-3} m²✓

(1)

2.1

Calculate neutral axis using area moments from bottom 3,02 × 10^{-3} m² × Y1 = (2,181 × 10^{-3} m² × 0,0762) ✓ + (0,84 × 10^{-3} m² × 0,1564) 3,02 × 10^{-3} m² × Y1 = (0,166 × 10^{-3} m²) + (0,131 × 10^{-3} m²)✓ Y_1 = 0,298 × 10^{-3} m² 3,02 × 10^{-3} m² Y_1 = 0,09853 m Y_1 = 98,53 mm✓

(3)



Alternate method using area moments:

Calculate neutral axis using mass moments

Take moments about the centre line of the I-beam

Mass of the plate: 0,105 × 0,008 × 7 860 kg/m³✓

Mass of the plate = 6,602 kg/m

Mass of I-beam = 17,1 kg/m

Total mass = 23,702 kg/m ✓

Calculate distance L_1:

$$L_1 = \frac{6{,}602\frac{kg}{m} \times 80{,}2\ \text{m}}{23{,}702\ \text{kg/m}}$$

L_1 = 22,34 mm✓✓

Calculate second moment of area

$I_{xx\ tot} = (Ixx\ beam + \text{al}^2) + (Ixx\ plate + \text{al}^2)$

$I_{xxBeam} = (8{,}841 \times 10^{-6} + 2{,}181 \times 10^{-3} \times 0{,}02233^2)$

$= (8{,}841 \times 10^{-6} + 1{,}088 \times 10^{-6})$=9,929 × 10^{-6} m^4✓✓

$I_{xxPlate} = (0{,}00448 \times 10^{-6} + 0{,}84 \times 10^{-3} \times 0{,}05787^2)$

$(0{,}00448 \times 10^{-6} + 2{,}813 \times 10^{-6})$= 2,817 × 10^{-6} m^4✓✓

$I_{xx\ total}$ = 12,75 × 10^{-6} m^4✓✓ (6)

Calculate bending moment maximum

$\frac{M}{I} = \frac{f}{y}$ where M = $\frac{I\,x\,f}{y}$

$\mathrm{BM_{max}} = \frac{12{,}75 \times 10^6 \times 115}{98{,}53}$ ✓

$\mathrm{BM_{max}} =$ 14,88 kN/m ✓ (2)

Calculate the value of P

Take moments about RL to find P:

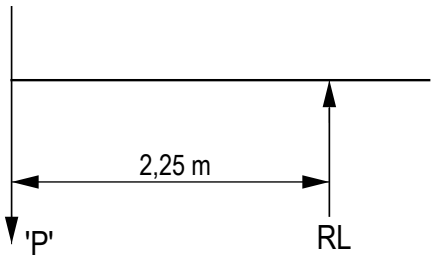
BM at RR: (P × 2,25) ✓

14,88 kN/m = 2,25P

$P = \frac{14{,}88}{2{,}25}$

$P =$ 6,613 kN/m ✓

(OR: 6,613 × 1 000 / 9,81 = 674,14 kg) ✓



(3)

2.2 Calculate the value of the two reactions at RL and RR:

Take moments about RL:

(RR × 4,25) + (6,613 × 2,25) = 0

RR 4,25 minus 14,879 ✓

RR = -14,879 / 4,25

RR = -3,501 kN ✓

(2)

Take moments about RR:

(RL × 4,25) = (6,613 × 6,5)

RL4,25 = 42,985 ✓

RL = 42,985 / 4,25

RL = 10,114 kN ✓

(2)

[19]

QUESTION 3

Calculate the effective height of the column

Effective height (l) = 0,7L✓(SABS 0162-1984 Table 19)

Where: $L_{effective}$= 0,7 × 2,75 metres

= 1,925 m (1 925 mm)✓

(2)

Calculate the effective cross-sectional area of the column

Ac = $\frac{\pi d^2}{4}$ minus $\frac{\pi d^2}{4}$

Ac = $\frac{\pi 220^2}{4}$ minus $\frac{\pi 210^2}{4}$✓

Area = 38 013,27 minus 34 636,06

Cross-sectional area = 3 377,21 mm²✓

(2)

Calculate the second moment of area about the x-x axis

$I_{xx} = I_{yy} = \frac{\pi D^4}{64}$ minus $\frac{\pi d^4}{64}$

$I_{xx} = I_{yy} \frac{\pi\ 220^4}{64}$ minus $\frac{\pi\ 210^4}{64}$✓

$I_{xx} = I_{yy}$114 990 145,10 minus 95 465 637,63✓

$I_{xx} = I_{yy}$ = 19 524 507,47 mm^4✓ (19,52 × 10^{-6} m^4)

(3)

Calculate the radius of gyration

$r = \sqrt{\frac{I}{Area}}$

$r = \sqrt{\frac{19\ 524\ 507{,}47}{3\ 377{,}21}}$✓

r = 76,03 mm✓

(2)

Calculate the slenderness ratio

L/r = $\frac{1\ 925}{76{,}03}$ = 25,32✓

25,32 = 144,68 MPa ✓

From Table 17 (SABS 0162-1984)

(2)

Calculate the maximum load

Load = stress × area

Load = 144,68 N/mm^2 × 3 377,21 mm^2✓

Load = 488,61 kN✓

Note to markers
Markers accept an answer of between 486 kN and 489 kN depending on the stress used. (2)

[13]

QUESTION 4

4.1 All references taken from SANS 10100-1 (2000)

Fcu = 30 MPa	Table 2 (4.1.5.1)
Fy = 250 MPa	Table 3 (4.1.5.2)
Axial load = 3 400 kN	

Calculate the number of longitudinal reinforcement

N = 0,4 fcu Ac + 0,67 fyAsc (CL 4.7.4.3)

3 400 × 10^3 = 0,4 × 30 × (450 × 550) + 0,67 × 250 × Asc✓

3 400 × 10^3 = 2 970 000 + 167,5Asc

3 400 × 10^3 minus 2 970 000 = 167,5Asc✓

Asc = $\frac{430\ 000}{167,5}$

Asc = 2 567,2 mm²✓

Use 8R20 (As = 2 514 mm²) OR Use 8R25 (As = 3 927 mm²) ✓✓

(5)

Calculate the diameter of the binders

Binders: ¼ of the smallest main bar (CL 4.11.4.5.1)

¼ × 20 = 5 mm (not available) ✓

Use: min R6 or R8 binders. ✓

OR

Binders: ¼ of the smallest main bar (CL 4.11.4.5.1)

¼ × 25 = 6,25 mm (not available)

Use: min R8 binders

(2)

Calculate the spacing of the binders

Spacing of binders:

12 × diameter of smallest main bar (CL 4.11.4.5.1)

12 × 20 = 240 mm (maximum) ✓

Use spacings of 200 mm

OR

Spacing of binders:

12 × diameter of smallest main bar (CL 4.11.4.5.1)

12 × 25 = 300 mm (maximum)

Use spacings of 250 mm

(1)

Calculate the minimum and maximum area of the main steel

Minimum area of main steel: 0,4% AC (Table 23)

0,4% × 550 × 450

Minimum area = 990 mm^2 ✓

(1)

Maximum area of main steel: 6% AC (CL 4.11.4.5.2)

6% × 550 × 450

Maximum area = 14 850 mm^2 ✓

Summary of rectangular column:

RC column 550 × 450 mm with 8R20 (8R25) main bars R8 binders at 200 mm centres.

(1)

4.2

Calculate area of pad foundation

Area = $\frac{\Sigma\ of\ Downward\ loads}{Upward\ soil\ pressure}$

Area = $\frac{3\ 400\ \text{kN} + 600\ \text{kN} + 85\ \text{kN}}{220\ \text{kN/m}^2}$ ✓✓

Area = 18, 568 m²✓

Size of foundation = $\sqrt{18{,}568\ m^2}$

4,31 m × 4,31 m✓

Use base size of 4,5 m × 4,5 m

(4)

[14]

QUESTION 5

All references taken from SANS 10100-1 (2000)

Fcu = 25 MPa	Table 2 (4.1.5.1)
Fy = 250 MPa	Table 3 (4.1.5.2)
Width = 1,25 metres	
Density of reinforced concrete	2 410 kg/m³

5.1

Calculate the length of the slope

Length of slope = $\sqrt{2\ 400^2 + 1\ 420^2}$ ✓

Length of slope = 2 788,6 mm (2,789 m)✓

(2)

Load calculations

Waist:

W = Vol × density × g.a × 10^{-3}

W = 2,789 × 1,25 × 0,135 × 2 410 kg/m³ × 9,81 × 10^{-3}✓

W = 11,127 kN✓

Treads or Steps:

W = Vol × density × g.a × 9,81 × 10^{-3}

W = ½bh × width × density × g.a × 9,81 × 10^{-3}

W = ½ × 1,420 × 0,23 × 1,25 × 2 410 kg/m³ × 9,81 × 10^{-3}✓

W = 4,826 kN✓

(4)

Total design dead load 1,2 Gn (11,127 kN + 4,826 kN) = 19,144 kN✓	(CL 4.2.2.1)
Design imposed load 1,6 Qn (6,3 kN/m² × 1,25 m × 2,4 m) = 30,24 kN✓	(CL 4.2.2.1)

(2)

5.2

Calculate bending moment maximum

$BM_{max} = \frac{WL}{10} + \frac{WL}{10}$

$BM_{max} = \frac{19{,}144 \times 2{,}4}{10} + \frac{30{,}24 \times 2{,}4}{10}$ ✓✓

$BM_{max} = 4{,}595 + 7{,}26$

$BM_{max} = 11{,}855$ kN/m✓

(3)

5.3

Calculate value for K

$K = \frac{BM}{fcu\ b\ d^2}$ (CL 4.3.3.4.1)

$K = \frac{11{,}855 \times 10^6}{25 \times 1\,250 \times 110^2}$ ✓

Let eff depth (d) = 135 – 25 cover = 110 mm

$K = 0{,}031 < K^1 = 0{,}156$✓

Only tension reinforcement will be required.✓

(3)

Calculate distance of lever arm (Z) (CL 4.3.3.4.1)

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

$Z = 110\left\{0{,}5 + \sqrt{0{,}25 - \frac{0{,}031}{0{,}9}}\right\} \leq 0{,}95 \times 110$✓

$Z = 110(0{,}964) \leq 0{,}95 \times 110$

$Z = 106{,}07$ mm $> 104{,}5$ mm✓

Use Z = 104,5 mm (least)✓

(3)

5.4

Calculate tension reinforcement As = $\frac{BM}{0{,}87\ fy\ z}$ As = $\frac{11{,}855 \times 10^6}{0{,}87 \times 250 \times 104{,}5}$ ✓ As = 521,6 mm²✓ Use R12 bars @ 200 c/c (As = 565 mm²)✓	(CL 4.3.3.4.1)

(3)

5.5

Determine secondary reinforcement $\frac{100\ AS}{AC}$= 0,24✓ As = $\frac{0{,}24 \times\ AC}{100}$ As = $\frac{0{,}24 \times\ 1\ 250 \times 135}{100}$ ✓ As = 405 mm² Use R10 bars @ 175 c/c (As = 449 mm²)✓	Table 23 (CL 4.11.4.3)

(3)
[23]

QUESTION 6

6.1

- Blast furnace
- Bessemer process
- Electric furnace
- Open-hearth furnace (Any 2 × 1)

(2)

6.2

- Leaving the formwork in place
- Covering the concrete with plastic sheeting
- Applying a membrane-forming compound (Any 2 × 1)

(2)
[4]

QUESTION 7

Calculate the direct shear on each bolt
Force direct = Force/No of bolts

F_{direct} = 25 kN / 4 = 6,25 kN✓ (1)

Calculate the distance from the centroid to the furthest bolt

r = $\sqrt{x^2 + y^2}$

r = $\sqrt{130^2 + 65^2}$✓

r = 145,34 mm✓ (2)

The direct load on the bolts due to the imposed load

Σcwm = Σacwm

(25 × 220) = (F_T × 145,35 × 4)✓✓

$F_T = \frac{25 \times 220}{145{,}34 \times 4}$

F_T = 9,46 kN✓ (3)

The resultant load on each bolt

$F_R = \sqrt{(Fs^2 + Ft^2) + (2\,Ft\,Fs\,Cos\,\phi)}$✓

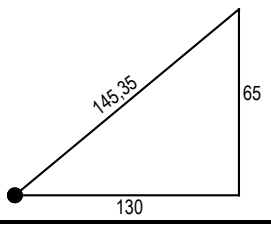
$F_R = \sqrt{(6{,}25^2 + 9{,}46^2) + \left(2 \times 9{,}46 \times 6{,}25 \times \text{Cos}\,\frac{130}{145{,}34}\right)}$

$F_R = \sqrt{(128{,}55) + 105{,}24}$✓✓

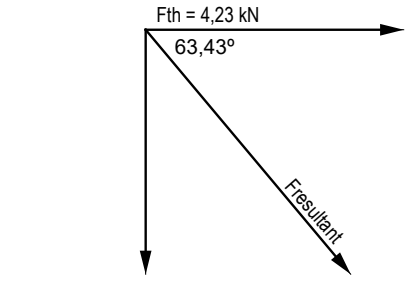
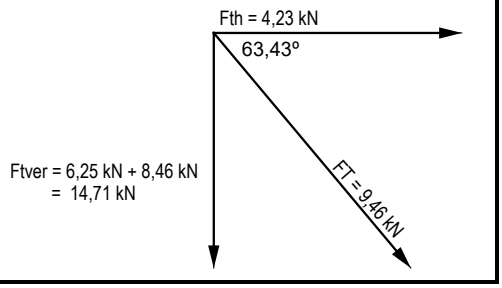
F_R = 15,3 kN✓ (4)

The resultant load on each bolt **(alternate answer)**

Tan ϕ = $\frac{130}{65}$ = 63,43º✓



ALT (1)

<u>The resultant load on each bolt</u> F_{Thor} = Ft × Cos 63,43° = 9,46 × 0,447 F_{Thor} = 4,23 kN✓		**ALT (1)**
F_{Tvert} = Ft × Sin 63,43° = 9,46 × 0,89 F_{Tvert} = 8,46 kN + 6,25 kN = 14,71 kN✓		**ALT (1)**

<u>Resultant force</u> $F_R = \sqrt{4{,}23^2 + 14{,}71^2}$ F_R = 15,3 kN✓		**ALT (1)**

<u>Calculate the size of the bolts.</u>

F_R = shear stress × area of bolt

$\frac{\pi d^2}{4} = \frac{Fr}{shear\ stress}$✓

$d = \sqrt{\frac{Fr \times 4}{\pi \times stress}}$

$d = \sqrt{\frac{15{,}3 \times 10^3 \times 4}{\pi \times 95}}$✓

d= 14,32 mm✓

Use 4M16 bolts✓ (4)

[14]

TOTAL: 100

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