higher education & training

Department:
Higher Education and Training
REPUBLIC OF SOUTH AFRICA

MARKING GUIDELINE

NATIONAL CERTIFICATE

BUILDING AND STRUCTURAL CONSTRUCTION N6

18 November 2022

This marking guideline consists of 9 pages.

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NOTE TO MARKERS

- This marking guideline conforms to:
  - SANS 10 100 (2000) Part 1: Design (the structural use of concrete)
  - SANS 0162 (1984) (the structural use of steel)
- Alternate answers must be considered.
- The marker must check the candidate's method of obtaining the answer.
- Subtract one mark per answer where references and clauses are not stated.
- Use own discretion.

QUESTION 1

All references taken from SANS 10100-1 (2000)

Fcu = 25 MPa	Table 2 (4.1.5.1)
Fy = 450 MPa	Table 3 (4.1.5.2)

1.1 Determine effective span of the beam

Use the lesser of: (cl 4.3.1.2)

The distance between the centres of the bearings

6 000 + (150 + 150) = 6 300 mm✓ OR (1)

The clear distance between the supports plus the effective depth

(6 000 + 410) = 6 410 mm✓ (1)

The effective span therefore equals 6 300 mm.✓ (1)

1.2 **Loading of the beam** (Ignore the self-weight of the beam)

Design-imposed loads:

Point load: 7 kN/m × 1,6 Qn = 27,2 kN/m✓

UDL: 11 kN/m × 1,6 Qn = 17,2 kN/m✓ (cl 4.2.2.1) (2)

Calculate bending moment maximum

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

$BM_{max} = \frac{27,2\ x\ 6,3}{4} + \frac{17,6\ x\ 6,3^2}{8}$✓✓

$BM_{max} = 42,84 + 87,32$

$BM_{max} = 130,16$ kNm✓ (3)

1 **Calculate value for K**

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

$K = \frac{130,16\ x\ 10^6}{25\ x\ 300\ x\ 410^2}$✓✓

$K = 0,1 < K^1\ 0,156$✓

Use tension reinforcement only. (3)

Calculate distance of lever arm (Z)

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

$Z = 410\left\{0{,}5 + \sqrt{0{,}25 - \frac{0{,}1}{0{,}9}}\right\} \leq 0{,}95 \times 410$✓

$Z = 410\{0{,}873\} \leq 389{,}5$

$Z = 357{,}8\ \text{mm} < 389{,}5$

Use Z = 357,8 mm✓ (2)

Calculate tension reinforcement

As = $\frac{M}{fy\ x\ 0{,}87\ x\ z}$ (cl 4.3.3.4.1)

As = $\frac{130{,}16\ x\ 10^6}{450\ x\ 0{,}87\ x\ 357{,}8}$✓✓

As = 929,2 mm^2

Use 3Y20 (As = 942 mm^2)✓ (3)

Check for minimum main reinforcement

$\frac{100\ As}{Ac} = \frac{100\ x\ 942}{300\ x\ 460}$ ✓

0,68 > 0,45 ✓

The reinforcement is sufficient. Table 23 (cl 4.11.4) and O/D = 410 + 50 = 460 mm (2)

Check maximum reinforcement

$4\%\ of\ Ac$ (cl 4.11.5.1)

4% × 460 × 300✓

= 5 520 mm^2

942 mm^2 < 5 520 mm^2 ✓ (2)

[20]

QUESTION 2

Given information:

180 × 70 × 22 kg/m channel:
Iyy = 1,135 × 10^{-6} m^4
Area = 2,797 × 10^{-3} m^2
A_y = 19,2 mm

305 × 165 × 46,1 kg/m I-parallel flange:
Ixx = 99,35 × 10^{-6} m^4
Area = 5,878 × 10^{-3} m^2
$\frac{h}{2} = \frac{307{,}1}{2}$ = 153,55 mm

Plate: 180 mm × 12 mm

$I_{xx} = \frac{bd^3}{12} = \frac{0{,}18\ x\ 0{,}012^3}{12}$ = 0,26 ×10^{-6} m^4✓

Area = 0,18 × 0,012 = 2,16 × 10^{-3} m^2✓ (2)

Total area = 5,878 × 10^{-3} m^2 + 2,16 × 10^{-3} m^2 + 2,797 × 10^{-3} m^2

Total Area = 10,835 × 10^{-3} m^2 ✓ (1)

Calculate neutral axis using area moments from bottom

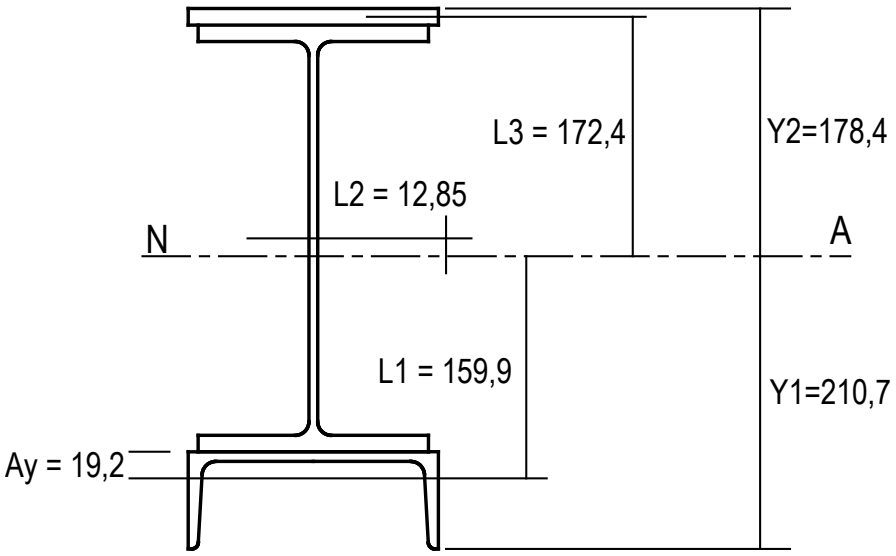
$10{,}835 \times 10^{-3}\ m^2 \times Y_1 = (2{,}797 \times 10^{-3}\ m^2 \times 0{,}0508)$ ✓
$+ (5{,}878 \times 10^{-3}\ m^2 \times 0{,}22355)$ ✓
$+ (2{,}16 \times 10^{-3}\ m^2 \times 0{,}3831) +$ ✓

$Y_1 = \frac{0{,}142 \times 10^{-3} m^2 + 1{,}314\ m^2 \times 10^{-3} + 0{,}827 \times 10^{-3}\ m^2}{10{,}835 \times 10^{-3}\ m^2}$ ✓

$Y_1 = \frac{2{,}283 \times 10^{-3}\ m^2}{10{,}835 \times 10^{-3}\ m^2}$

$Y_1 = 0{,}2107\ m$

$Y_1 = 210{,}7\ mm$ ✓ (5)



Calculate second moment of area (Ixx total)

$I_{xx\ tot} = (Iyy\ Channel + al^2) + (Ixx\ Beam + al^2) + (Ixx\ Plate + al^2)$

$I_{yy\ Channel} = (1{,}135 \times 10^{-6} + 2{,}797 \times 10^{-3} \times 0{,}1599^2)$

$= (1{,}135 \times 10^{-6} + 71{,}51 \times 10^{-6}) =$ 72,6 × 10^{-6} m^4 ✓✓

$I_{xx\ Beam} = (99{,}35 \times 10^{-6} + 5{,}87 \times 10^{-3} \times 0{,}01285^2)$

$= (99{,}35 \times 10^{-6} + 0{,}97 \times 10^{-6}) =$ 100,3 × 10^{-6} m^4 ✓✓

$I_{xx\ Plate} = (0{,}026 \times 10^{-6} + 2{,}16 \times 10^{-3}\ x\ 0{,}1724^2)$

$= (0{,}026 \times 10^{-6} + 64{,}2 \times 10^{-6}) =$ 64,3 × 10^{-6} m^4 ✓✓

$I_{xx\ total} =$ 237,2 × 10^{-6} m^4 ✓ (7)

Calculate bending moment maximum (bending stress = 164 MPa)

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

$BM_{max} = \frac{237{,}2 \times 10^6 \times 160}{210{,}7}$ ✓

$BM_{max} = 180{,}1\ kNm$ ✓ (2)

Calculate the UDL **Ignore the self-weight of the beam**
Include additional load of 12 kN/m

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

180,1 $= \frac{12 \times 9{,}5^2}{8} + \frac{W \times 9{,}5^2}{8}$ ✓

180,1 = 135,38 + 11,28 W

$W = \frac{180{,}1 - 135{,}38}{11{,}28}$ ✓

W = 3,96 kN/m ✓ (3)

[20]

QUESTION 3

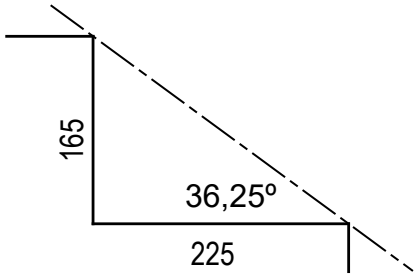
All references taken from SANS 10100-1 (2000)

Fcu = 25 MPa	Table 2 (4.1.5.1)
Fy = 250 MPa	Table 3 (4.1.5.2)
Width = 1,5 metres	
Density of reinforced concrete	2 400 kg/m³

3.1 **The slope formed by one step**

$\text{Tan}\varphi = \frac{165}{225}$ ✓

$\varphi = 36{,}25^{o}$ ✓



(2)

3.2 **Calculate the length of the slope**

Length of slope = $\sqrt{1\,950^2 + 1\,050^2}$ ✓

Length of slope = 2 215 mm ✓ (2)

3.3 **Load Calculations**

Waist:

W = Vol × density × g.a × 10^{-3} × 1,2Gn (cl 4.2.2.1)

W = 2,215 × 1,2 × 0,11 × 2 400 kg/m³ × 9,81 × 10^{-3} × 1,2Gn ✓

W = 8,3 kN ✓ (2)

Treads or steps:

W = Vol × density × g.a × 9,81 × 10^{-3} × 1,2Gn

W = ½bh × width × density × g.a × 9,81 × 10^{-3} × 1,2Gn (cl 4.2.2.1)

W = ½ × 0,225 × 1,05 × 1,2 × 2 400 kg/m³ × 9,81 × 10^{-3} × 1,2Gn ✓

W = 4 kN ✓ (2)

Design-imposed load	
1,6 Qn (3,5 kN/m² × 1,95 m × 1,2 m) = 13,1 kN✓	(cl 4.2.2.1)

(1)

Calculate bending moment maximum

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

$BM_{max} = \frac{(8,3 + 4 + 13,1)\ x\ 1,95}{10}$ ✓✓

BM_{max} = 4,95 kNm✓ (3)

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QUESTION 4

Self-weight of the taper flange beam (102 × 64 × 9,65 kg/m)

Weight = 9,65 kg/m × 9,81 × 10^{-3}✓

Weight = 0,095 kN/m✓ (2)

Bending moment at centre of the taper flange beam	
$\frac{M}{I} = \frac{f}{y}$ Where: $M = \frac{I \times f}{y}$ $M = \frac{2,176 \times 10^6 \times 155}{50,8}$ ✓✓ M = 6,64 kNm✓	Ixx = 2,176 × 10^{-6} m^4 Y = h/2 = 101,6/ 2 = 50,8 mm

(3)

Calculate the maximum point load

$BM = \frac{wl^2}{8} + \frac{wl^2}{8}$

$6,64 = \frac{0,095\ x\ 4,75^2}{8} + \frac{w\ x\ 4,75^2}{8}$ ✓

6,64 = 0,268 + 2,82 w

2,82 w = 6,64 – 0,268

w = 6,64 – 0,268/2,82✓

w = 2,26 kN/m✓ (3)

[8]

QUESTION 5

5.1 All references taken from SANS 0100-2000

Given information:

RC column:	600 mm diameter
Load:	200 kN
Fcu:	25 MPa (Table 2)
Fy:	250 MPa (Table 3)

Calculate suitable reinforcement

N = 0,4 fcu Ac + 0,67 fy Asc (cl 4.7.4.3)

$200 \times 10^3 = (0{,}4 \times 25 \times \frac{\pi\ 600^2}{4}) + (0{,}67\ 250 \times Asc$ ✓

$200 \times 10^3 = (0{,}4 \times 25 \times 282\ 743{,}3) + (0{,}67 \times 250 \times Asc)$✓

$200 \times 10^3 = 2\ 827\ 433{,}4 + 167{,}5\ Asc$

$Asc = \frac{200 \times 10^3 - 2\ 827\ 433{,}4}{167{,}5}$ ✓

Asc = minus 15,686 mm² ✓

No compression bars required✓

Use minimum: Asc = 0,4% AC✓ (6)

Asc = 0,4 %AC

Asc = 0,4 × 282 743,3 mm² = 1 131 mm² ✓ (Table 23)

Use 6R16 (Asc = 1 206 mm²) ✓ (4.11.4.2.2) (2)

The size and spacing of the binders

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

¼ × 16 = 4 mm (not available)✓

Use R8 helical binder ✓

Spacing of binders:

12 × diameter of smallest main bar

12 × 16 = 192 mm✓

Use binder spacings of 175 mm ✓ (4)

5.2 **Calculate the size of the pad foundation**

Working load = 85 kN + 870 kN + 200 kN

= 1 155 kN ✓

$Area = \frac{Force}{Pressure}$

$Area = \frac{1\ 155}{220}$✓

Area = 5,25 m² ✓

For the square base: $\sqrt{5{,}25}$ = 2,29 m × 2, 29 m

Use a base of 2,30 m × 2,30 m ✓ (4)

[16]

QUESTION 6

6.1 Throat area: 112 mm × 12 mm
= 1 344 mm^2✓

Stress = $\frac{Load}{Area}$

Load = stress × area

= 125 $\frac{N}{mm^2}$ × 1 344 mm^2✓

Load = 168 kN✓ (3)

6.2

The effective length of each fillet:	220 mm (with return side fillets)✓
Total effective length:	2 × 220 mm = 440 mm✓
Throat thickness:	Sin45º × 12 = 8,5 mm✓
Total throat area:	440 mm × 8,5 = 3 740 mm^2✓
Safe load:	Stress × area 145 N/mm^2 × 3 740 mm^2✓ = 542,3 kN✓

(6)
[9]

QUESTION 7

Solid circular section with diameter = 132 mm

7.1 $r_{xx} = r_{yy} = \sqrt{\frac{I}{A}}$

$= \sqrt{\frac{\frac{\pi d^4}{64}}{\frac{\pi d^2}{4}}}$ $= \left\{\frac{d}{4}\right\}$✓

$= \sqrt{\frac{\frac{\pi 132^4}{64}}{\frac{\pi 132^2}{4}}}$ ✓

$r_{xx} = r_{yy} = \sqrt{\frac{14\ 902\ 722{,}81}{13\ 684{,}78}}$

$r_{xx} = r_{yy}$ = 33 mm ✓

OR

$\left\{\frac{d}{4}\right\} = \frac{132}{4}$ = 33 mm (3)

7.2 Plated built-up I-section

The cross-sectional area of the steel section
Area = 2(90 × 15) + (12 × 90)✓
= 2 700 + 729 000
Cross-sectional area = 3 780 mm² ✓ (2)

The second moment of area about the y-y axis.

$I_{yy} = 2\left(\frac{d\ x\ b^3}{12}\right) + \left(\frac{d\ x\ b^3}{12}\right)$

$I_{yy} = 2\left(\frac{15\ x\ 90^3}{12}\right) + \left(\frac{90\ x\ 12^3}{12}\right)$✓

= 1 822 500 + 12 960

I_{yy} = 1 835 460 mm^4 ✓ (2)

The second moment of area about the x-x axis.

$I_{xx} = 2\left(\frac{b \times d^3}{12} + al^2\right) + \left(\frac{b \times d^3}{12}\right)$

$I_{xx} = 2\left(\frac{90 \times 15^3}{12} + 90 \times 15 \times 52{,}5^2\right) + \left(\frac{12 \times 90^3}{12}\right)$✓✓

= 7 492 500 + 729 000

I_{xx} = 8 221 500 mm^4 ✓ (3)

Calculate the radius of gyration $\langle r_{yy} \rangle$

$r_{yy} = \sqrt{\frac{Iyy}{Area}}$

$r_{yy} = \sqrt{\frac{1\ 835\ 460}{3\ 780}}$✓

r_{yy} = 22,04 mm✓ (2)

Calculate the radius of gyration $\langle r_{xx} \rangle$

$r_{xx} = \sqrt{\frac{Ixx}{Area}}$

$r_{xx} = \sqrt{\frac{8\ 221\ 500}{3\ 780}}$✓

r_{xx} = 46,64 mm✓ (2)

Minimum radius of gyration = r_{yy} = 22,04 mm✓ (1)
[15]

TOTAL: 100

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