



**higher education
& training**

Department:
Higher Education and Training
REPUBLIC OF SOUTH AFRICA

MARKING GUIDELINE

NATIONAL CERTIFICATE

BUILDING AND STRUCTURAL CONSTRUCTION N6

8 April 2021

This marking guideline consists of 10 pages.

QUESTION 1

All references taken from SANS 10100-1 (2000)

$F_{cu} = 25 \text{ MPa}$

Table 2 (4.1.5.1)

$F_y = 250 \text{ MPa}$

Table 3 (4.1.5.2)

Width = 1,45 metres

Density of reinforced concrete = 2 400 kg/m³

1.1 The length of the slope

$$\text{Length of slope} = \sqrt{2420^2 + 1760^2} \checkmark$$

$$\text{Length of slope} = 2\,992,32 \text{ mm} \checkmark$$

Calculations of load

Waist:

$$W = \text{Vol} \times \text{density} \times g.a. \times 10^{-3}$$

$$W = 2,992 \times 1,45 \times 0,125 \times 2\,400 \text{ kg/m}^3 \times 9,81 \times 10^{-3} \checkmark$$

$$W = 12,77 \text{ kN} \checkmark$$

Treads or steps:

$$W = \text{Vol} \times \text{density} \times g.a. \times 9,81 \times 10^{-3}$$

$$W = \frac{1}{2}bh \times \text{width} \times \text{density} \times g.a. \times 9,81 \times 10^{-3}$$

$$W = \frac{1}{2} \times 1,76 \times 0,220 \times 1,45 \times 2\,400 \text{ kg/m}^3 \times 9,81 \times 10^{-3} \checkmark$$

$$W = 6,609 \text{ kN} \checkmark$$

Total design dead load.

$$1,2 \text{ Gn} (12,77 \text{ kN} + 6,609 \text{ kN}) = 23,255 \text{ kN} \checkmark \quad (\text{Cl 4.2.2.1})$$

Design imposed load.

$$1,6 \text{ Qn} (2,5 \text{ kN/m}^2 \times 1,45 \text{ m} \times 2,420 \text{ m}) = (\text{Cl 4.2.2.1})$$

$$14,036 \text{ kN} \checkmark$$

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1.2 Maximum bending moment

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

$$BM_{\max} = \frac{23,255 \times 2,420}{10} + \frac{14,036 \times 2,420}{10} \checkmark \checkmark$$

$$BM_{\max} = 5,63 + 3,4$$

$$BM_{\max} = 9,02 \text{ kNm} \checkmark$$

(3)

1.3 Value for 'K' (CL 4.3.3.4.1)

$$K = \frac{BM}{f_{cu} b d^2}$$

$$K = \frac{9,02 \times 10^6}{25 \times 1450 \times 100^2} \checkmark$$

$$K = 0,025 < K^1 = 0,156 \checkmark$$

Only tension reinforcement will be required. ✓

Distance of lever arm (Z)

$$Z = d \left\{ 0,5 + \sqrt{0,25 - \frac{K}{0,9}} \right\} \leq 0,95d \quad (\text{CL 4.3.3.4.1})$$

$$Z = 100 \left\{ 0,5 + \sqrt{0,25 - \frac{0,025}{0,9}} \right\} \leq 0,95 \times 100 \checkmark$$

$$Z = 100(0,971) \leq 0,95 \times 100$$

$$Z = 97,1 \text{ mm} > 95 \text{ mm} \checkmark$$

Use Z = 95 mm (least) ✓

(6)

1.4 Tension reinforcement

$$A_s = \frac{BM}{0,87 f_y Z} \quad (\text{CL 4.3.3.4.1})$$

$$A_s = \frac{9,02 \times 10^6}{0,87 \times 250 \times 95}$$

$$A_s = 436,54 \text{ mm}^2 \checkmark$$

Use R10 bars @ 175 c/c (As = 449 mm²) ✓

(3)

1.5 Secondary reinforcement

$$\frac{100 A_s}{AC} = 0,24 \checkmark$$

$$A_s = \frac{0,24 \times AC}{100}$$

$$A_s = \frac{0,24 \times 1450 \times 125}{100} \quad \checkmark$$

$$A_s = 435 \text{ mm}^2$$

Use R10 bars @ 175 c/c (As = 449 mm²) ✓

(3)

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Table 23
(CL 4.11.4.3)

QUESTION 2

2.1 $L_{\text{effective}} = 5,75 \text{ mm} \times 0,7$
 $= 4\,025 \text{ mm} \checkmark$

SABS 0162-1984 (Table 19)

The cross-sectional area of the steel section

$$\text{Area} = 2(375 \times 16) + (12 \times 450) \checkmark$$

$$\text{Area} = 12\,000 + 5\,400$$

$$\text{Cross-sectional area} = 17\,400 \text{ mm}^2 \checkmark \quad (3)$$

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

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

$$I_{xx} = 2 \left(\frac{375 \times 16^3}{12} + 375 \times 16 \times 233^2 \right) + \left(\frac{12 \times 450^3}{12} \right) \checkmark \checkmark$$

$$I_{xx} = 2(128\,000 \text{ mm}^4 + 325\,734\,000 \text{ mm}^4) + 91\,125\,000 \text{ mm}^4$$

$$I_{xx} = 651\,724\,000 \text{ mm}^4 + 91\,125\,000 \text{ mm}^4$$

$$I_{xx} = 742\,849\,000 \text{ mm}^4 \checkmark \quad (3)$$

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

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

$$I_{yy} = 2 \left(\frac{16 \times 375^3}{12} \right) + \left(\frac{450 \times 12^3}{12} \right) \checkmark \checkmark$$

$$I_{yy} = 140\,625\,000 \text{ mm}^4 + 64\,800 \text{ mm}^4$$

$$I_{yy} = 140\,689\,800 \text{ mm}^4 \checkmark \quad (3)$$

2.4 The minimum second moment of area

$$\text{Least second moment of area} = I_{yy} = 140\,689\,800 \text{ mm}^4 \checkmark \quad (1)$$

2.5 The minimum radius of gyration

$$\text{Least second moment of area (I)} = I_{yy} = 121\,396\,248 \text{ mm}^4$$

$$r_{\min} = \sqrt{\frac{I_{yy}}{\text{area}}}$$

$$r_{\min} = \sqrt{\frac{140\,689\,800 \text{ mm}^4}{17\,400 \text{ mm}^2}} \checkmark$$

$$r_{\min} = 89,9 \text{ mm} \quad (\text{Use } 90 \text{ mm}) \checkmark$$

The slenderness ratio

$$L/r = \frac{4025^2}{90} = 44,72 \quad \checkmark$$

From Table 17 (SABS 0162-1984)

$$44,72 = 136,28 \text{ MPa} \quad \checkmark \quad (4)$$

2.6 The maximum axial load

Load = Stress x area

$$\text{Load} = 136,28 \text{ N/mm}^2 \times 17\,400 \text{ mm}^2$$

$$\text{Load} = 2\,371,27 \text{ kN} \quad \checkmark \quad (1)$$

[15]**QUESTION 3**All references taken from SANS 10100-1 (2000) $F_{cu} = 25 \text{ MPa}$

Table 2 (4.1.5.1)

 $F_y = 250 \text{ MPa}$

Table 3 (4.1.5.2)

Span = 7,0 metres

CL 4.3.1.2

The effective width of the beamUse the lesser of the two:

(Cl 4.3.1.5)

$$1. \text{ Web width} + \frac{l_z}{10}$$

$$= 0,300 + \frac{7}{10}$$

$$\text{L-beam width} = 1 \text{ metre wide (1 000 mm)} \quad \checkmark$$

OR

$$2. \text{ Actual width (Not given)}$$

Loading of the beam

$$\text{Design dead load} = 5,5 \text{ kN/m}^2 \times 1 \times 1,2 \text{ Gn}$$

(Cl 4.2.2.1)

$$= 6,6 \text{ kN/m} \quad \checkmark$$

$$\text{Design imposed load} = 2,75 \text{ kN/m}^2 \times 1,6 \text{ Qn} = 4,4 \text{ kN/m} \quad (Cl 4.2.2.1)$$

 $\checkmark$ Bending moment maximum

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

$$BM_{\max} = \frac{6,6 \times 7^2}{8} + \frac{4,4 \times 7^2}{8} \quad \checkmark$$

$$BM_{\max} = 40,43 + 26,95$$

$$BM_{\max} = 67,38 \text{ kNm} \checkmark$$

Distance of lever arm (Z)

$$Z = d \left[0,5 + \sqrt{0,25 - \frac{K}{0,9}} \right] \quad (\text{CL 4.3.3.4})$$

$$Z = 460 \left[0,5 + \sqrt{0,25 - \frac{0,156}{0,9}} \right] \quad \checkmark$$

$$Z = 460 (0,777)$$

$$Z = 357,42 \text{ mm} \quad \checkmark$$

Tension reinforcement

NA is within the flange, therefore:

(CL 4.3.3.4.1)

$$A_s = \frac{BM}{0,87 f_y z}$$

$$A_s = \frac{67,38 \times 10^6}{0,87 \times 250 \times 357,42}$$

$$A_s = 866,75 \text{ mm}^2 \quad \checkmark$$

Use 2Y25 bars ($A_s = 982 \text{ mm}^2$) $\checkmark$

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QUESTION 4

All references taken from SANS 10100-1 (2000)

4.1 $F_{cu} = 30 \text{ MPa}$ Table 2 (4.1.5.1)

$F_y = 450 \text{ MPa}$ Table 3 (4.1.5.2)

4.1.1 The nett area of the concrete

(4)

$$\text{Nett area of the steel} = 6 \left(\frac{\pi d^2}{4} \right) + \left(\frac{\pi d^2}{4} \right) \quad \checkmark$$

$$= 6 \left(\frac{\pi 25^2}{4} \right) + \left(\frac{\pi 75^2}{4} \right) \quad \checkmark$$

$$= 2\,945,24 + 4\,417,86$$

$$\text{Nett area of the steel} = 7\,363,11 \text{ mm}^2 \quad \checkmark$$

$$\text{Nett area of concrete} = (650 \times 330) - 7\,363,11 \text{ mm}^2$$

$$= 207\,136,89 \text{ mm}^2 \checkmark$$

4.1.2 The axial load

$$N = 0,4 f_{cu} A_c + 0,67 f_y A_{sc}$$

(Clause 4.7.4.3)

$$N = (0,4 \times 30 \times 207\,136,89) + (0,67 \times 450 \times 2\,945,24) \checkmark \checkmark$$

$$N = 2\,485\,642,68 + 887\,989,86 \checkmark$$

$$N = 1\,597,65 \text{ kN} \checkmark \quad (4)$$

4.1.3 Diameter and spacing of binders

Binders: $\frac{1}{4}$ of the smallest compression bar (Clause 4.11.4.5.1)

$$\frac{1}{4} \times 25 = 6,25 \text{ mm (not available)} \checkmark$$

Use minimum of R8 binders.

Spacing of binders

12 x diameter of smallest compression bar

$$12 \times 25 = 300 \text{ mm} \quad \checkmark \quad (2)$$

Use spacing of 300 mm.

4.2 Area of pad foundation

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

$$\text{Area} = \frac{1597,65 \text{ kN} + 750 \text{ kN} + 95 \text{ kN}}{210 \text{ kN/m}^2} \checkmark$$

$$\text{Area} = 11,632 \text{ m}^2 \checkmark$$

$$\text{Size of foundation} = \sqrt{11,632 \text{ m}^2}$$

$$3,41 \text{ m} \times 3,41 \text{ m} \checkmark$$

$$\text{Use base size of } 3,5 \text{ m} \times 3,5 \text{ m.} \checkmark \quad (4)$$

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QUESTION 5

GIVEN:

203 × 203 × 53,5 kg/m H-section:Plate: 180 mm × 150 mm × 4 mm HRS

$$I_{xx} = 49,78 \times 10^{-6} \text{ m}^4$$

$$\text{Area} = 6,821 \times 10^{-3} \text{ m}^2$$

$$\frac{H}{2} = \frac{203,9}{2} = 101,95 \text{ mm}$$

$$I_{xx} = \left(\frac{BD^3}{12} \right) - \left(\frac{bd^3}{12} \right)$$

$$I_{xx} = \left(\frac{0,18 \times 0,15^3}{12} \right) \text{ minus } \left(\frac{0,172 \times 0,142^3}{12} \right)$$

$$I_{xx} = 50,625 - 41,04 = 9,585 \times 10^{-6} \text{ m}^4 \checkmark$$

$$\text{Area} = (0,18 \times 0,15) - (0,172 \times 0,142)$$

$$\text{Area} = 2,576 \times 10^{-3} \text{ m}^2 \checkmark$$

$$\text{Total area} = 6,821 \times 10^{-3} \text{ m}^2 + 2,576 \times 10^{-3} \text{ m}^2$$

$$\text{Total Area} = 9,397 \times 10^{-3} \text{ m}^2 \checkmark$$

Neutral axis using area moments from bottom

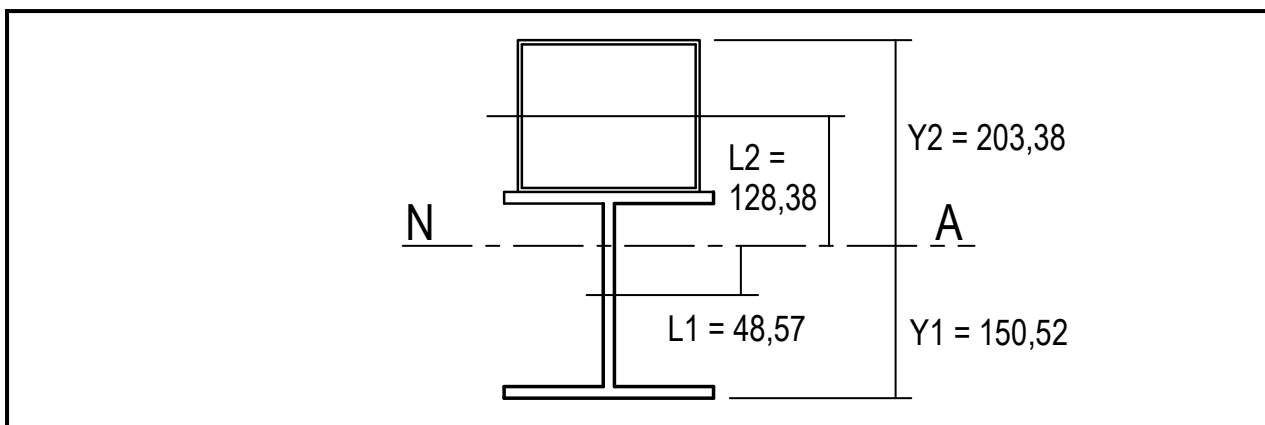
$$9,397 \times 10^{-3} \text{ m}^2 \times Y_1 = (6,821 \times 10^{-3} \text{ m}^2 \times 0,102) + (2,576 \times 10^{-3} \text{ m}^2 \times 0,279)$$

$$0,696 \times 10^{-3} + 0,719 \times 10^{-3} \checkmark \checkmark$$

$$Y_1 = \frac{1,414 \times 10^{-3} \text{ m}^2}{9,397 \times 10^{-3} \text{ m}^2} \checkmark$$

$$Y_1 = 0,15052 \text{ m}$$

$$Y_1 = 150,52 \text{ mm} \checkmark \checkmark$$

Second moment of area

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

$$I_{xx \text{ Beam}} = (49,78 \times 10^{-6} + 6,821 \times 10^{-3} \times 0,04838^2)$$

$$= (49,78 \times 10^{-6} + 15,97 \times 10^{-6}) = 65,75 \times 10^{-6} \text{ m}^4 \checkmark \checkmark$$

$$I_{xx \text{ RHS}} = (9,585 \times 10^{-6} + 2,576 \times 10^{-3} \times 0,12838^2) \\ (9,585 \times 10^{-6} + 42,456 \times 10^{-6}) = \underline{52,041 \times 10^{-6} \text{ m}^4} \checkmark \checkmark$$

$$I_{xx \text{ total}} = \underline{117,791 \times 10^{-6} \text{ m}^4} \checkmark$$

Bending moment maximum (Bending stress = 148 MPa)

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

$$BM_{max} = \frac{117,791 \times 10^6 \times 148}{150,52} \checkmark \checkmark$$

$$BM_{max} = 115,82 \text{ kNm} \checkmark$$

The UDL Assume self-weight to be 1,25 kN/m

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

$$115,82 = \frac{1,25 \times 6,5^2}{8} + \frac{W \times 6,5^2}{8} \checkmark$$

$$W = 6,6 + 5,28 W \checkmark$$

$$W = \frac{115,82 - 6,6}{5,28} \checkmark$$

$$W = 20,69 \text{ kN/m} \checkmark$$

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QUESTION 6

6.1 The number of bolts for the part marked 'B'

Force = Area eff x stress x number

$$N = \frac{\text{Force}}{P_v \times A_{eff}}$$

Stress =
Pv = 100 MPa

$$A_{eff} = \frac{\pi (Dia - 0,9382 P)^2}{4}$$

Clause 9.5.1

$$A_{eff} = \frac{\pi (16 - 0,9382 \times 2)^2}{4} \checkmark$$

$$A_{eff} = 156,67 \text{ mm}^2 \checkmark$$

$$N = \frac{52 \times 10^3}{100 \times 156,67} \checkmark$$

$$N = 3,32 \text{ bolts} \checkmark \text{ (Use 4 M16 bolts) } \checkmark$$

(5)

6.2 Minimum effective length of the weld at 'W'

SABS 0162

The throat thickness = Sin 45° x 5 mm ✓

P = 130 MPa

$$= 3,54 \text{ mm}$$

(Cl 10.7.1.2)

✓

Calculate the effective length:

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$$F = P \times A_{eff}$$

$$F = P \times \text{Throat} \times L$$

$$L = \frac{F}{P \times Throat}$$

$$L = \frac{66 \times 10^3}{130 \times 3,54}$$

$$L = 143,42 \text{ mm} \checkmark$$

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QUESTION 7I-Section parallel flange533 × 210 × 92,5 kg/m:

$$I_{xx} = 553,3 \times 10^{-6} \text{ m}^4$$

$$h/2 = 533,1/2 = 266,5 \text{ mm}$$

$$\text{Bending stress} = 159 \text{ MPa}$$

The self-weight of the beam:

$$W = 92,5 \text{ kg/m} \times 9,81 \times 10^{-3}$$

$$W = 0,907 \text{ kN/m} \checkmark$$

$$\text{BM} = \frac{WL}{4} + \frac{Wl^2}{8} \checkmark$$

$$\text{BM} = \frac{150 \times L}{4} + \frac{0,907 \times l^2}{8} \checkmark$$

$$\text{BM} = (37,5 L + 0,113 l^2) \text{ kN m}$$

The span of the beam:

$$\text{From } \frac{M}{I} = \frac{f}{y}$$

$$\frac{(37,5l + 0,113l^2) 10^6}{553,3 \times 10^6} = \frac{159}{266,5} \checkmark$$

$$(9995,63l + 30,12l^2) = 84\,794,7 \quad (\text{Divide by } 30,12) \checkmark$$

$$L = l^2 + 331,86 l - 2\,815,23$$

$$\text{Span (L)} = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

$$\text{Span (L)} = \frac{-331,86 \pm \sqrt{331,86^2 - 4 \times 1 \times 2\,815,23}}{2 \times 1} \checkmark$$

$$\text{Span (L)} = \frac{-331,86 \pm 348,41}{2}$$

$$\text{Span (L)} = 8,3 \text{ metres} \checkmark$$

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