



**higher education
& training**

Department:
Higher Education and Training
REPUBLIC OF SOUTH AFRICA

MARKING GUIDELINE

NATIONAL CERTIFICATE

BUILDING AND STRUCTURAL CONSTRUCTION N6

1 July 2022

This marking guideline consists of 14 pages.

INSTRUCTIONS AND INFORMATION

1. This marking guideline conforms to:
 - SANS 10100 (2000) Part 1 Design (The structural use of concrete)
 - SANS 0162 (1984) (The structural use of steel)
 2. Assess the candidate's method of obtaining the answer.
 3. Consider alternative answers. Use your discretion.
 4. Subtract 1 mark per answer where references and clauses are not stated.
 5. Mark all questions. Do not mark the entire script – use the question-marking method.
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QUESTION 1

1.1 1.1.1 If the tie bar is welded:

$$A_{\text{eff}} = \frac{3(A_1)^2 + 4A_1A_2}{3A_1 + A_2}$$

SABS 0162
Clause 9.2.1

$$A_1 = t(b - \frac{t}{2})$$

$$A_1 = 5(50 - \frac{5}{2})$$

$$A_1 = 237,5 \text{ mm}^2 \checkmark$$

$$\text{and } A_2 = 237,5 \text{ mm}^2$$

$$A_{\text{eff}} = \frac{3(237,5)^2 + 4(237,5)(237,5)}{3(237,5) + (237,5)} \checkmark$$

$$A_{\text{eff}} = \frac{394843,75}{950}$$

$$A_{\text{eff}} = 415,625 \text{ m}^2 (0,416 \times 10^3 \text{ mm}^2) \checkmark$$

Table 20
SANS 0162

Therefore, tensile force:

$$\text{Force} = P_t \times A_{\text{eff}}$$

$$\text{Force} = 155 \text{ N/mm}^2 \times 415,625 \text{ m}^2 \text{ mm}^2 \checkmark$$

$$\text{Force} = 64,4 \text{ kN} \checkmark$$

The welded tie bar will be able to withstand the given load.

(5)

1.1.2 If the tie bar is bolted:

$$A_{\text{eff}} = \frac{3(A_1)^2 + 4A_1A_2}{3A_1 + A_2}$$

SABS 0162
Clause 9.2.1

$$A_1 = t(b - \frac{t}{2}) - (\text{area of the hole}) \checkmark$$

$$A_1 = 5(50 - \frac{5}{2}) - (18 \times 5) \checkmark \text{ (M16 bolts)}$$

$$A_1 = 237,5 - 90$$

$$A_1 = 147,5 \text{ mm}^2$$

BUILDING AND STRUCTURAL CONSTRUCTION N6
and $A_2 = 237,5 \text{ mm}^2$ ✓

$$A_{\text{eff}} = \frac{3(147,5)^2 + 4(147,5)(237,5)}{3(147,5) + (237,5)}$$

SABS 0162
Table 20

$$A_{\text{eff}} = \frac{205393,75}{680}$$

$$A_{\text{eff}} = 302 \text{ mm}^2 (0,302 \times 10^3 \text{ mm}^2) \checkmark$$

Therefore tensile force:

$$\text{Force} = P_t \times A_{\text{eff}}$$

$$\text{Force} = 155 \text{ N/mm}^2 \times 302 \text{ mm}^2 \checkmark$$

$$\text{Force} = 46,8 \text{ kN} \checkmark$$

The bolted tie bar will be able to withstand the given load.

(6)

1.2 Number of bolts required:

$P_v = 100 \text{ MPa}$
SABS 0162
Table 21

$$F = P_v \times n \times A_{\text{eff}}$$

$$n = \frac{F}{P_v \times A_{\text{eff}}} \checkmark$$

Where:

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

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

$$A_{\text{eff}} = 157 \text{ mm}^2 \checkmark$$

$$n = \frac{64,4 \times 10^3}{100 \times 157}$$

$$n = 4,1 \text{ bolts} \checkmark$$

Use 4 M16 or 5 M16 bolts to attach the tie bar to the gusset plate.

(4)
[15]

QUESTION 22.1 Calculate the effective length:SABS 0162-1984
Table 19Effective height (l) = $0,85 \times L$ ✓

$$L_{\text{effective}} = 0,7 \times 5,5 \text{ m} \checkmark$$

$$= 4\,675 \text{ mm (4,675 m)} \checkmark$$

Calculate the slenderness ratio:

$$L/r = \frac{4,675}{38,2} = 122,4 \checkmark$$

$$3,82 \text{ cm} = 38,2 \text{ mm}$$

From Table 17 (SABS 0162-1984):

$$122,4 = 57,6 \text{ MPa} \checkmark$$

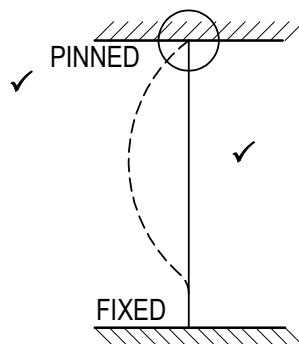
Calculate the maximum load:Load = Stress $\times$ Area

$$38,4 \text{ cm}^2 = 3,84 \text{ mm}^2$$

$$\text{Load} = 57,6 \text{ N/mm}^2 \times 3,84 \times 10^3 \text{ mm}^2 \checkmark$$

$$\text{Load} = 221,18 \text{ kN} \checkmark$$

(7)

2.2 SABS 0162 -1984 Table 19 states that the compression member will be effectively held in position at both ends, restrained against rotation at one end only.Symbol:**MARK ALLOCATION**

Code and reference stated 1 mark

Description correct 1 mark

Drawing 2 marks

(4)

[11]

QUESTION 3

All references taken from SANS 0100-1 (2000)

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

$F_y = 450 \text{ MPa}$

Span = 6 850 mm

Imposed live load

Table 2 4.1.5.1

Table 3 4.1.5.2

Clause 4.3.1.2

15,0 kN/m²

Determine the design of the dead loads of the beam:

Design imposed load = 15,0 kN/m² × 1 × 1,6Qn

Clause 4.2.2.1

Design imposed load = 24,0 kN/m²✓

Calculate bending moment maximum:

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

$$BM_{\max} = \frac{24 \times 6,85^2}{8}$$

$$BM_{\max} = 140,8 \text{ kNm} \checkmark$$

Calculate value for K:

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

$$K = \frac{140,8 \times 10^6}{25 \times 1000 \times 415^2} \checkmark$$

$$K = 0,033 \checkmark$$

$$K < K^1 = 0,156 \text{ (only tension reinforcement required)} \checkmark$$

Calculate distance of lever arm (Z):

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

Clause 4.3.3.4.1

$$Z = 415 \left\{ 0,5 + \sqrt{0,25 - \frac{0,033}{0,9}} \right\} \leq 0,95 \times 415 \checkmark$$

$$Z = 415 [0,96] \leq 394,25 \text{ mm}$$

$$Z = 398,4 \text{ mm} < 394,25 \text{ mm}$$

$$\text{Use lever arm} = 394,25 \text{ mm} \checkmark$$

Calculate tension reinforcement:

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

Clause 4.3.3.4.1

$$A_s = \frac{140,8 \times 10^6}{0,87 \times 450 \times 394,25} \checkmark$$

$$A_s = 912,2 \text{ mm}^2$$

Use Y16 at 200 centres. ($A_s = 1\,005 \text{ mm}^2$) $\checkmark$

Check for minimum main reinforcement:

$$\frac{100 A_s}{A_c} = 0,13 \checkmark$$

Table 23
Clause 4.11.4

$$\frac{100 \times 1005}{1000 \times 450} = 0,22$$

$$0,22 > 0,13 \checkmark$$

The reinforcement is sufficient.

Determine secondary reinforcement:

$$\frac{100 A_s}{A_c} = 0,13$$

Clause 4.11.4.3.1
&
Table 23

$$A_s = \frac{0,13 \times 1000 \times 450}{100} \checkmark$$

$$A_s = 585 \text{ mm}^2 \checkmark$$

Use Y10 at 125 centres. ($A_s = 628 \text{ mm}^2$) $\checkmark$

[15]

QUESTION 4

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 = 1,5 m

Density of reinforced concrete

2 400 kg/m³

Calculate the length of the slope:

$$\text{Length of slope} = \sqrt{2860^2 + 1500^2} \checkmark$$

$$\text{Length of slope} = 3\,229,5 \text{ mm} \quad (2\,230 \text{ mm}) \checkmark$$

Load calculations:

Waist:

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

Clause 4.2.2.1

$$W = 3,23 \times 0,15 \times 1,5 \times 2\,400 \text{ kg/m}^3 \times 9,81 \times 10^{-3} \times 1,2 \text{ Gn} \checkmark$$

$$W = 20,53 \text{ kN} \checkmark$$

Treads or steps:

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

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

$$W = \frac{1}{2} \times 0,26 \times 1,5 \times 1,5 \times 2\,400 \text{ kg/m}^3 \times 9,81 \times 10^{-3} \times 1,2 \text{ Gn} \checkmark$$

$$W = 8,26 \text{ kN} \checkmark$$

Clause 4.2.2.1

Design imposed load:

$$1,6 \text{ Qn} \quad (6,5 \text{ kN/m}^2 \times 1,5 \text{ m} \times 2,86 \text{ m}) = 44,62 \text{ kN} \checkmark$$

Clause 4.2.2.1

Calculate bending moment maximum:

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

$$BM_{\max} = \frac{(20,53 + 8,26) \times 2,86}{10} + \frac{44,62 \times 2,86}{10} \checkmark$$

$$BM_{\max} = 8,23 + 12,76$$

$$BM_{\max} = 20,99 \text{ kNm} \checkmark$$

Calculate value for K:

Clause 4.3.3.4.1

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

Let Eff depth (d) =

150 – 30 cover =

120 mm

$$K = \frac{20,99 \times 10^6}{20 \times 1500 \times 120^2} \checkmark$$

$$K = 0,05 < K^1 = 0,156 \checkmark$$

Only tension reinforcement will be required.

Calculate distance of lever arm (Z):

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

Clause 4.3.3.4.1

$$Z = 120 \left\{ 0,5 + \sqrt{0,25 - \frac{0,05}{0,9}} \right\} \leq 0,95 \times 120 \checkmark$$

$$Z = 120(0,94) \leq 0,95 \times 120$$

$$Z = 112,8 \text{ mm} < 114 \text{ mm}$$

Use $Z = 112,8 \text{ mm}$ (least). $\checkmark$

Calculate tension reinforcement:

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

Clause 4.3.3.4.1

$$A_s = \frac{20,2 \times 10^6}{0,87 \times 250 \times 112,92} \checkmark$$

$$A_s = 822,5 \text{ mm}^2 \checkmark$$

Use R12 bars @ 125 c/c. ($A_s = 905 \text{ mm}^2$) $\checkmark$

Determine secondary reinforcement:

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

Table 23
Clause 4.11.4.3

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

$$A_s = \frac{0,24 \times 1500 \times 150}{100} \checkmark$$

$$A_s = 540 \text{ mm}^2$$

Use R12 bars @ 200 c/c. ($A_s = 565 \text{ mm}^2$) $\checkmark$

[20]

QUESTION 5160 × 65 × 18,8 kg/m channel:Plate: 160 mm × 10 mm

$$I_{yy} = 0,8505 \times 10^{-6} \text{ m}^4$$

$$\text{Area} = 2,401 \times 10^{-3} \text{ m}^2$$

$$A_y = 18,4 \text{ mm}$$

$$I_{xx} = \frac{bd^3}{12} = \frac{0,16 \times 0,012^3}{12} = 0,023 \times 10^{-6} \text{ m}^4$$

$$\text{Area} = 0,16 \times 0,012 = 1,92 \times 10^{-3} \text{ m}^2$$

2/200 × 75 × 25,3 kg/m channel:

$$I_{xx} = 2/19,11 \times 10^{-6} \text{ m}^4 = 2,956 \times 10^{-6} \text{ m}^4$$

$$\text{Area} = 2/3,218 \times 10^{-3} \text{ m}^2 = 6,436 \times 10^{-3} \text{ m}^2$$

$$\text{Total area} = 2,401 \times 10^{-3} \text{ m}^2 + 6,436 \times 10^{-3} \text{ m}^2 + 1,92 \times 10^{-3} \text{ m}^2$$

$$\text{Total area} = 10,757 \times 10^{-3} \text{ m}^2$$

Calculate neutral axis using area moments from the bottom:

$$10,757 \times 10^{-3} \text{ m}^2 \times Y_1 = (1,92 \times 10^{-3} \text{ m}^2 \times 0,006) + 2(3,218 \times 10^{-3} \text{ m}^2 \times 0,112)$$

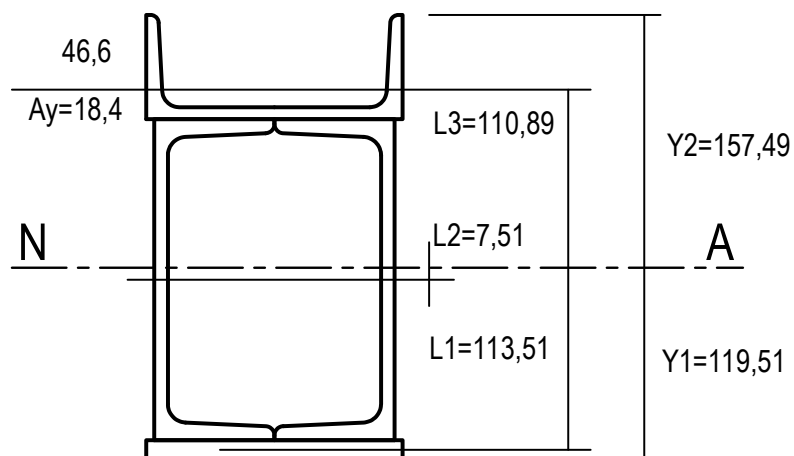
$$+ (2,401 \times 10^{-3} \text{ m}^2 \times 0,2304) \checkmark \checkmark$$

$$Y_1 = \frac{0,0115 \times 10^{-3} \text{ m}^2 + 0,721 \times 10^{-3} \text{ m}^2 + 0,553 \times 10^{-3} \text{ m}^2}{10,757 \times 10^{-3} \text{ m}^2} \checkmark$$

$$Y_1 = \frac{1,286 \times 10^{-3} \text{ m}^2}{10,757 \times 10^{-3} \text{ m}^2}$$

$$Y_1 = 0,11951 \text{ m}$$

$$Y_1 = 119,51 \text{ mm} \checkmark$$



Calculate second moment of area:

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

$$I_{xx \text{ Plate}} = (0,023 \times 10^{-6} + 1,92 \times 10^{-3} \times 0,112^2) \\ = (0,023 \times 10^{-6} + 24,738 \times 10^{-6}) = 24,761 \times 10^{-6} \text{ m}^4 \checkmark \checkmark$$

$$I_{xx \text{ Channels}} = 2(19,11 \times 10^{-6} + 3,218 \times 10^{-3} \times 0,00751^2) \\ \checkmark 2(19,11 \times 10^{-6} + 0,181 \times 10^{-6}) = 38,583 \times 10^{-6} \text{ m}^4 \checkmark \checkmark$$

$$I_{yy \text{ Channel}} = (0,8505 \times 10^{-6} + 2,401 \times 10^{-3} \times 0,11098^2) \\ \checkmark (0,8505 \times 10^{-6} + 29,572 \times 10^{-6}) = 30,423 \times 10^{-6} \text{ m}^4 \checkmark \checkmark$$

$$I_{xx \text{ total}} = 93,767 \times 10^{-6} \text{ m}^4 \checkmark$$

Calculate bending moment maximum (bending stress = 151 MPa)

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

$$BM_{\text{max}} = \checkmark \frac{93,767 \times 10^6 \times 151}{119,51} \checkmark$$

$$BM_{\text{max}} = \checkmark 118,474 \text{ kNm} \checkmark$$

The self-weight of the beam:

$$\text{Channel: } 18,8 \text{ kg/m} \times 9,81 \times 10^{-3} = 0,184 \text{ kN/m}$$

$$\text{Channels: } 2 \times 25,3 \text{ kg/m} \times 9,81 \times 10^{-3} = 0,5 \text{ kN/m}$$

$$\text{Plate: } 7 \text{ 850 kg/m}^3 \times 0,16 \times 0,012 \times 9,81 \times 10^{-3} = 0,148 \text{ kN/m}$$

$$\text{Total self-weight} = 0,832 \text{ kN/m} \checkmark$$

Calculate the maximum imposed UDL:

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

$$118,474 = \frac{0,832 \times 4,5^2}{8} + \frac{w \times 6,75^2}{8} \checkmark$$

$$W = 2,12 + 5,7W$$

$$W = \checkmark \frac{118,474 - 2,12}{5,7} \checkmark$$

$$W = \checkmark 20,4 \text{ kN} \checkmark$$

[18]

QUESTION 6

- 6.1
- Iron ore
 - Coal
 - Limestone
 - Recycled steel
- (Any 2 × 1) (2)
- 6.2
- Aluminium
 - Copper
 - Lead
 - Zinc
- (Any 2 × 1) (2)
- 6.3 The mix will allow the materials to separate thus causing the water, cement and sand to part from the stone. (2)
- [6]**

QUESTION 7

All references taken from SANS 0100-1 (2000)

$$F_{cu} = 30 \text{ MPa}$$

Table 2 4.1.5.1

$$F_y = 450 \text{ MPa}$$

Table 3 4.1.5.2

$$\text{Bending moment maximum} = 160 \text{ kNm}$$

$$\text{Eff. depth} = 350 \text{ mm}$$

Calculate value for K:

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

Clause 4.3.3.4.1

$$K = \frac{160 \times 10^6}{30 \times 230 \times 350^2} \checkmark$$

$$K = 0,19 > K^1 = 0,156 \checkmark$$

Tension and compression reinforcement required.

Calculate compression reinforcement:

$$A'_s = \frac{(k - k^1) F_{cu} b d^2}{F_{yc} (d - d^1)}$$

Clause 4.3.3.4.1

Figure 2

$$\gamma_m = 1,15$$

Clause 3.3.3.2

$$\text{Where: } F_{yc} = \frac{F_y}{1,15 + \frac{F_y}{2000}}$$

$$= \frac{450}{1,15 + \frac{450}{2000}}$$

$$= 327 \text{ MPa} \checkmark$$

Use $d^1 = 50 \text{ mm}$

$$A'_s = \frac{(0,19 - 0,156) 30 \times 230 \times 350^2}{327 (350 - 50)} \checkmark$$

$$A'_s = 293 \text{ mm}^2$$

$$\text{Use } 3Y12 \quad (A_s = 339 \text{ mm}^2) \checkmark$$

Check for minimum compression reinforcement:

$$\frac{100 A_s}{A_c} = 0,4$$

Table 23

Clause 4.11.4

$$\frac{100 \times 339}{600 \times 300} = 0,19 \checkmark$$

$$0,19 < 0,4 \checkmark$$

The reinforcement is not sufficient.

Calculate distance of lever arm (Z):

$$Z = d \left(0,5 + \sqrt{0,25 - \frac{k^1}{0,9}} \right)$$

Clause 4.3.3.4.1

$$Z = 350 \left(0,5 + \sqrt{0,25 - \frac{0,156}{0,9}} \right) \checkmark$$

$$Z = 350 (0,777)$$

$$Z = 271,95 \text{ mm} \checkmark$$

Calculate tension reinforcement:

$$A_s = \frac{K^1 f_{cu} b d^2}{0,87 f_y Z} + \frac{A' S f_{yc} b d^2}{0,87 f_y}$$

Clause 4.3.3.4.1

$$A_s = \frac{0,156 \times 30 \times 230 \times 350^2}{0,87 \times 450 \times 271,95} + \frac{339 \times 327}{0,87 \times 450}$$

$$A_s = \frac{131859000}{106468,425} + \frac{110944,53}{391,5} \checkmark$$

$$A_s = 1238,48 + 283,15$$

$$A_s = 1521,63 \text{ mm}^2$$

Use 5Y20 bars. ($A_s = 1571 \text{ mm}^2$) $\checkmark$

Check for minimum main reinforcement:

$$\frac{100 A_s}{A_c} = 0,45$$

Table 23
Clause 4.11.4

$$\frac{100 \times 1571}{600 \times 300} = 0,87 \checkmark$$

$$0,45 < 0,87 \checkmark$$

The reinforcement is sufficient.

[15]

TOTAL: 100