higher education & training

Department:
Higher Education and Training
REPUBLIC OF SOUTH AFRICA

MARKING GUIDELINE

NATIONAL CERTIFICATE

BUILDING AND STRUCTURAL CONSTRUCTION N6

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This marking guideline consists of 13 pages.

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QUESTION 1

Given information:

Taper flange: 203 × 102 × 25,3 kg/m

$I_{xx} = 22,97 \times 10^{-6}\ m^4$

$Area = 3,226 \times 10^{-3}\ m^2$

$h/2 = 203,2/2 = 101,6\ mm$

Total area = $3,226 \times 10^{-3}\ m^2 + 2,797 \times 10^{-3}\ m^2 + 1,02 \times 10^{-3}\ m^2$

Total area = $7,043 \times 10^{-3}\ m^2$ ✓

Channel: 180 mm × 70 mm × 22 kg/m

$I_{yy} = 1,135 \times 10^{-6}\ m^4$

$Area = 2,797 \times 10^{-3}\ m^2$

$Ay = 19,2\ mm$

$t_1 = 8\ mm$

Plate: 102 mm x 10 mm

$I_{xx} = \frac{bd^3}{12} = \frac{1,02\ x\ 0,01^3}{12}$

$= 0,085 \times 10^{-6}\ m^4$ ✓

$Area = 0,102 \times 0,01$

$= 1,02 \times 10^{-3}\ m^2$ ✓

(3)

Calculate Neutral Axis using area moments from bottom

$7,043 \times 10^{-3}\ m^2 \times Y_1 = (2,797 \times 10^{-3}\ m^2 \times 0,0192) = (0,054 \times 10^{-3})$

$+ (3,226 \times 10^{-3}\ m^2 \times 0,1096) = (0,354 \times 10^{-3})$

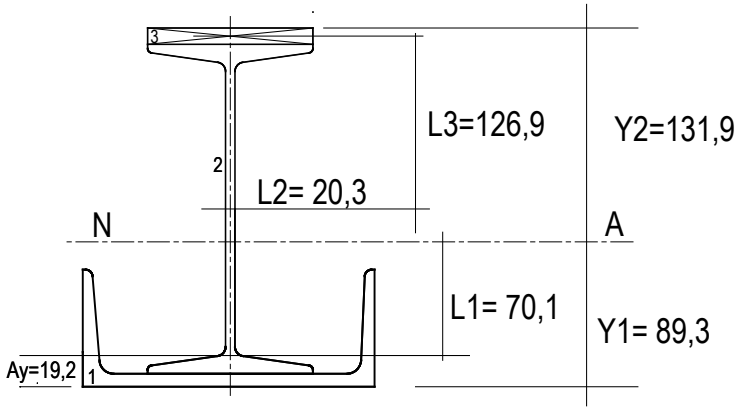
$+ (1,02 \times 10^{-3}\ m^2 \times 0,2162) = \underline{(0,221 \times 10^{-3})}$ ✓✓

$\underline{T\ A \quad 0,629 \times 10^{-3}}$ ✓

$$NA = \frac{0,629\ x\ 10^{-3}\ m^2}{7,043\ x\ 10^{-3}\ m^2} \checkmark$$

$NA\ (Y_1) = 89,3\ mm$ ✓ (0,0893 m)

(5)



Calculate Second Moment of Area

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

$Ixx\,Channel = (1{,}135\ x\ 10^{-6} + 2{,}797\ x\ 10^{-3}\ x\ 0{,}0701^2)$
$= (1{,}135x\ 10^{-6} + 29{,}54\ x\ 10^{-6}) = \underline{14{,}879 \text{ x } 10^{-6}\ m^4}$✓✓

$I\,xx\,flange = (22{,}97\ x\ 10^{-6} + 3{,}226\ x\ 10^{-3}\ x\ 0{,}0203^2)$
$= (22{,}97\ x\ 10^{-6} + 0{,}494\ x\ 10^{-6}) = \underline{24{,}299 \text{ x } 10^{-6}\ m^4}$✓✓

$Ixx\,Plate = (0{,}085\ x\ 10^{-6} + 1{,}02\ x\ 10^{-3}\ x\ 0{,}1269^2)$
$= (0{,}085\ x\ 10^{-6} + 16{,}425\ x\ 10^{-6}) = \underline{16{,}511 \text{ x } 10^{-6}\ m^4}$✓✓

$Ixx\,total = \underline{55{,}689 \text{ x } 10^{-6}\ m^4}$✓ (5)

Calculate Bending Moment Maximum (Bending Stress = 170 MPa)

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

$\mathbf{BM_{max}} = \frac{170\ x\ 55{,}689\ x10^6}{89{,}3}$✓

$\mathbf{BM_{max}} = 106\ \mathbf{kNm}$✓ (2)

Calculate the Uniformly distributed load (UDL)

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

$106 = \frac{W\ x\ 8{,}5^2}{8}$✓

$106 \text{ x } 8 = w \text{ x } 8{,}5^2$

$W = \frac{848}{72{,}25}$✓

$W = 11{,}74\ kN/m$✓ (3)

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QUESTION 2

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

Fcu = 20 MPa	Table 2 (4.1.5.1)
Fy = 250 MPa	Table 3 (4.1.5.2)
Width of staircase	1,15 metres (1 150 mm)
Density of reinforced concrete	2 400 kg/m³

Calculate the length of the slope

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

$\text{Length of slope} = 2\,215 \text{ mm}$✓ (1)

Load Calculations

Waist:

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

$W = 2{,}215 \text{ x } 1{,}15 \text{ x } 0{,}11 \text{ x } 2\,400 \text{ kg/m}^3 \text{ x } 9{,}81 \text{ x } 10^{-3}$✓

$W = 6{,}6 \text{ kN}$✓ (2)

Treads or Steps:

$W = ½ \text{ x Vol x density x g.a x } 9{,}81 \text{ x } 10^{-3}$

$W = ½ \text{ x thread x height x width x density x g.a x } 9{,}81 \text{ x } 10^{-3}$

$W = ½ \text{ x } 0{,}225 \text{ x } 1{,}05 \text{ x } 1{,}15 \text{ x } 2\,400 \text{ kg/m}^3 \text{ x } 9{,}81 \text{ x } 10^{-3}$✓

$W = 3{,}198 \text{ kN}$✓ (2)

Total design dead load.

$1{,}2 \text{ Gn } (6{,}6 \text{ kN} + 3{,}198 \text{ kN}) = 11{,}76 \text{ kN}$✓ (Cl 4.2.2.1)

Design imposed load.

$1{,}6 \text{ Qn } (12{,}5 \text{ kN/m}^2 \text{ x } 1{,}15 \text{ m x } 1{,}95 \text{ m}) = 46{,}85 \text{ kN}$✓ (Cl 4.2.2.1) (2)

Calculate bending moment maximum

$\text{BM}_{\text{max}} = \frac{WL}{10} + \frac{WL}{10}$

$\text{BM}_{\text{max}} = \frac{11{,}76\ x\ 1{,}95}{10} + \frac{46{,}85\ x\ 1{,}95}{10}$✓✓

BM max = 2,29 + 9,14

BM max = 11,43 kNm✓ (3)

Calculate value for 'K' (CL 4.3.3.4.1)

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

Let Eff depth (d)
= 110 – 25 cover
= 90 mm

$$K = \frac{11{,}43\ x\ 10^6}{20\ x\ 1\ 150\ x\ 85^2}$$ ✓

$K = 0{,}069 < K^1 = 0{,}156$✓

Only tension reinforcement will be required.✓ (3)

Calculate distance of lever arm (Z)

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

$$Z = 85\left\{0{,}5 + \sqrt{0{,}25 - \frac{0{,}069}{0{,}9}}\right\} \leq 0{,}95 \text{ x } 85$$✓ (CL 4.3.3.4.1)

$$Z = 85(0{,}916) \leq 0{,}95 \text{ x } 85$$

$$Z = 77{,}86 \text{ mm} > 80{,}75 \text{ mm}$$

Use $Z = 77{,}86$ mm (least)✓ (2)

Calculate tension reinforcement

$$As = \frac{BM}{0{,}87\ fy\ z}$$ (CL 4.3.3.4.1)

$$As = \frac{11{,}43\ x\ 10^6}{0{,}87x\ 250\ x\ 77{,}86}$$ ✓

$As = 675 \text{ mm}^2$✓

Use R12 bars @ 150 c/c $(As = 754 \text{ mm}^2)$✓ (3)

Determine secondary reinforcement

Table 23
(CL 4.11.4.3)

$$\frac{100\ AS}{AC} = 0{,}24$$

$$As = \frac{0{,}24\ x\ AC}{100}$$

$$As = \frac{0{,}24\ x\ 1\ 150\ x\ 110}{100}$$ ✓

$As = 303{,}64 \text{ mm}^2$

Use R08 bars @ 150 c/c $(As = 335 \text{ mm}^2)$✓ (2)

[20]

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QUESTION 3.1

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

Fcu = 30 MPa Fy = 450 MPa Axial load = 2 250 kN	Table 2 (4.1.5.1) Table 3 (4.1.5.2)

3.1.1 **Calculate the number of longitudinal reinforcement** (Clause 4.7.4.3)

N = 0,4 fcu Ac + 0,67 fy Asc

$2\ 250 \times 10^3 = 0{,}4 \times 30 \times \left(\frac{\pi\ 425^2}{4}\right) + 0{,}67 \times 450 \times$ Asc✓

$2\ 250 \times 10^3 = 1\ 702\ 350{,}5 + 301{,}5$ Asc

$2\ 250 \times 10^3$ minus 1 702 350,5 = 301,5 Asc✓

$\text{Asc} = \frac{2\ 547\ 649{,}5}{301{,}5}$

Asc = 1 816,4 mm²✓

Use 6Y20 (As = 1 885 mm²)✓
(Minimum spacing between bars = height aggregate + 5 mm) (4)

3.1.2 **Maximum and minimum percentage of the steel reinforcement**

Maximum: 6% of gross cross-sectional area
$6\% \times \left(\frac{\pi\ 425^2}{4}\right) = 8\ 511{,}75\ \text{mm}^2$✓✓ (Clause 4.11.4.5.2) (2)

Minimum: 0,4% of gross cross sectional area
$0{,}4\% \times \left(\frac{\pi\ 425^2}{4}\right) = 567{,}5\ \text{mm}^2$✓✓ (Clause 4.11.4.5) (2)

Calculate the diameter of the helical binder (Clause 4.11.4.5)

Binders: ¼ of the smallest main bar
¼ × 20 = 5 mm✓ (not available)
Use: R8 Helical binder.✓ (2)

Calculate the pitch of the binder.
Spacing of binders: (Clause 4.11.4.5)

12 × diameter of smallest main bar
12 × 20 = 240 mm (maximum)
Use Binder pitch = 200 mm✓

Summary:
6Y20 main bars with R8 helical binders at 200 mm pitch.✓ (2)

3.2 **Calculate the size of the pad foundation**

$\text{Working load} = 95\ \text{kN} + 950\ \text{kN} + 200\ \text{kN}$

$= 1\ 155\ \text{kN}$✓

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

$\text{Area} = \frac{1\ 155}{220}$

$\text{Area} = 5{,}25\ \text{m}^2$✓

For the square base $\sqrt{5{,}25} = 2{,}29\ \text{m x } 2{,}29\ \text{m}$✓

Use a base of 2,30 m x 2,30 m✓ (4)

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QUESTION 4:

4.1 THE WELDED CONNECTION

Force = 160 kN

Select trial section: 100 x 100 x 8 mm.

Allowable stress = 155 MPa (SABS 0162 Table 20)

Calculate effective area (A_{eff})

$A_{eff} = \frac{3(A1)^2+4\ A1\ A2}{3A1 + A2}$

A_1 = Connected leg (no holes)

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

$A_1 = 8(100 - \frac{8}{2})$

$A_1 = 768\ mm^2$ ✓

(SABS 0162 Clause 9.2.1)

And:

A_2 (unconnected leg) = 768 mm^2 (no holes) ✓

Where A_1 is the connected leg and A_2 is the unconnected leg

$A_{eff} = \frac{3(768)^2+ 4(768)(768)}{3(768)+ (768)}$ ✓

$A_{eff} = \frac{4\ 128\ 768}{3\ 072}$

$A_{eff} = 1\ 344\ mm^2$ ($1{,}344 \times 10^3\ mm^2$) ✓ (4)

4.1 Tensile force:

Force = Pt x Aeff

Force = 155 N/mm^2 x $1{,}344 \times 10^3\ mm^2$ ✓

(Table 20 SANS 10162)

Force = 208,32 kN. ✓

The welded tie bar will withstand the load of 160 kN. ✓ (3)

4.2 THE BOLTED CONNECTION

$A_{eff} = \frac{3(A1)^2+4\ A1\ A2}{3A1 + A2}$

<u>A_1 = Connected leg</u>

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

$A_1 = 8(100 - \frac{8}{2})$ *minus* 22 mm x 8 mm (M20 bolts)✓

768 mm *minus* 176 mm

$A_1 = 592\ mm^2$

And;

$A_2 = 768\ mm^2$ ✓

$A_{eff} = \frac{3(592)^2+ 4(592)(768)}{3(592)+ (768)}$ ✓

$A_{eff} = \frac{2\ 870\ 016}{2\ 544}$

$A_{eff} = 1128{,}15\ mm^2$ (Use $1{,}128 \times 10^3\ mm^2$)✓ (4)

(SABS 0162 Clause 9.2.1)

Where A_1 is the connected leg and A_2 is the unconnected leg

<u>Tensile force</u>:

Force = Pt x Aeff

Force = $155\ N/mm^2 \times 1{,}128 \times 10^3\ mm^2$✓

Force = 174,86 kN✓

The bolted tie bar will withstand the load of 160 kN.✓ (3)

(Table 20 SANS 10162)

4.3 Number of bolts required

$F = Pv \times n \times A_{eff}$

$n = \frac{F}{Pv\ x\ Aeff}$ ✓

Where:

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

$A_{eff} = \frac{\pi(20 - 0{,}9382\ x\ 2)^2}{4}$ ✓

$A_{eff} = 244{,}8\ mm^2$ ✓

(Pv = 100 MPa) (SABS 0162 Table 21)

(The screw thread is within the shearing plane)

$n = \frac{160\ x10^3}{100\ x\ 244{,}8}$

n = 6,34 bolts✓

Use 7M20 bolts to attach tie bar to the gusset plate. (4)

[18]

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)
Span	6,750 metres
Density of reinforced concrete	2 425 kg/m^3

Determine steel in tension

$As = 3 \text{ x } \frac{\pi d^2}{4}$

$As = 3 \times \frac{\pi\ 20^2}{4}$

As = 942 mm²✓ (1)

Check minimum area reinforcement

$\frac{100\ AS}{AC}$ Table 23

$\frac{100\ x\ 942}{270\ X\ 475}$ = 0,73 > 0,45 OK✓

Check maximum area of reinforcement

4% of AC (CL 4 11.5.4)

4% × (475 × 270) = 5 130 mm²✓ okay (2)

Calculate distance of lever arm (Z)

$Z = d\left\{0{,}5 + \sqrt{0{,}25 - \frac{K^1}{0{,}9}}\right\}$ CL 4.3.3.4)

$Z = 425\left\{0{,}5 + \sqrt{0{,}25 - \frac{0{,}156}{0{,}9}}\right\}$✓

$Z = 425\ (0{,}777)$

$Z = 330{,}2$ mm✓ (2)

Determine the maximum moment of resistance in tension

$As = \frac{M}{0{,}87\ fy\ z}$ (CL 4.3.3.4)

$M = As \text{ x } 0{,}87 \text{ x } fy \text{ x } Z$

$M = 942\ mm^2 \text{ x } 0{,}87 \text{ x } 250\ N/mm^2 \text{ x } 330{,}2\ mm$✓

$M = 67{,}7$ kNm✓ (2)

Determine the total load

Bending moment max = $\frac{wl^2}{8}$

$67,7 = \frac{w\ x\ 6,75^2}{8}$ ✓

$w = 67,7 \times 8/6,75^2$

$w = 11,89$ kN/m✓ (2)

Determine the dead load

Dead load = Vol x density x g a x 10^{-3}

Dead load = 0,475 x 0,27 x 1 x 2 425 kg/m^3 x 9,81 x 10^{-3}✓

Dead load = 3,05 kN/m✓ (2)

Determine the max distributed load

Total load = 1,2(Gn) + 1,6 (Qn) (CL 4.2.2.1)

11,89 kN/m = 1,2 (3,05) + 1,6 (Qn)✓

11,89 kN/m minus 3,66 = 1,6(Qn)✓

Qn = 8,23/1,6

Max Distributed Load = 5,14 kN/m✓ (3)

[14]

QUESTION 6

Channel section 280 × 95 × 41,8 kg/m:

I_{xx} = 62,76 × 10^{-6} m^4

Ay = 25,3 mm

Bending stress = 155 MPa

Self-weight of the channel (356 × 171 × 56,7 kg/m)

Weight = 41,8 kg/m × 9,81 × 10^{-3}

Weight = 0,41 kN/m✓ (1)

Calculate the bending moment

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

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

$M = \frac{155\ x\ 62,76\ x\ 10^6}{25,3}$✓

M = 384,5 kNm✓ (2)

Calculate the span

$$\text{BM} = \frac{WL}{4} + \frac{w\,l^2}{8}$$

$$384{,}5 = \frac{118\,x\,L}{4} + \frac{0{,}41\,x\,L^2}{8} \checkmark$$

$$384{,}5 = 23{,}5\ \text{L} + 0{,}051\ \text{L}^2$$

$$\text{Span (L)} = 0{,}051\ \text{L}^2 + 29{,}4\ \text{L} \text{ minus } 384{,}5 \checkmark$$

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

$$\text{Span (L)} = \frac{-29{,}4 \pm \sqrt{29{,}4^2 - 4\,x\,0{,}051\,x\,-348{,}5}}{2\,x\,0{,}51} \checkmark\checkmark$$

$$\text{Span (L)} = \frac{-29{,}4 \pm 30{,}71}{0{,}102}$$

$$\text{Span(L)} = 12 \text{ metres} \checkmark$$ (5)

[8]

QUESTION 7

7.1
- Iron ore
- Coal
- Limestone
- Recycled steel

(Any 2 × 1) (2)

7.2 *Fine aggregate:* These are aggregates that will pass through a 4,76 mm sieve. Particles smaller than 4,76 mm. (2)

[4]

TOTAL: 100

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