higher education & training

Department:
Higher Education and Training
REPUBLIC OF SOUTH AFRICA

MARKING GUIDELINE

NATIONAL CERTIFICATE

BUILDING AND STRUCTURAL CONSTRUCTION N6

31 JULY 2019

This marking guideline consists of 10 pages.

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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)
Span = 9 metres — Clause 4.3.1.2
Density of reinforced concrete = 2 425 kg/m^3

1.1 **Design dead loads of the slab:**

Design dead load — Clause 4.2.2.1
= Volume × density × 9,81 × 10^{-3} × 1,2 Gn
= 0,475 × 0,33 × 1 × 2 425 kg/m³ × 9,81 × 10^{-3} × 1,2 Gn✓
= 4,475 kN/m✓

Design imposed point load = 55 kN × 1,6 Qn — Clause 4.2.2.1
= 88,0 kN/m✓

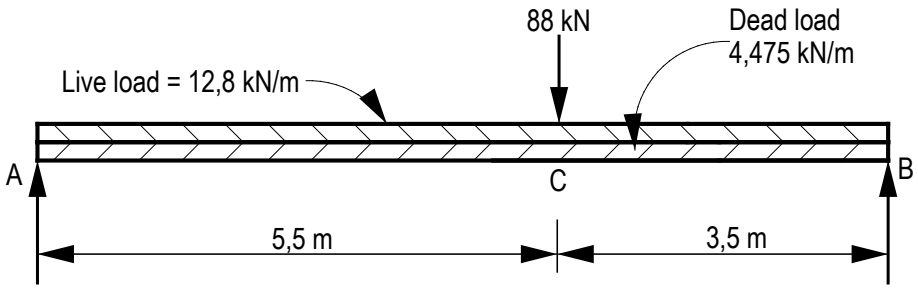
Design imposed live load = 8 kN/m × 1,6 Qn
= 12,8 kN/m✓ (4)

1.2 **Take moments about RL:**

(RR × 9) = (12,8 × 9 × 4,5) + (4,475 × 9 × 4,5) + (88 × 5,5)
RR = 518,4 + 181,24 + 484/9(1 183,64/9)
RR = 131,52 kN✓

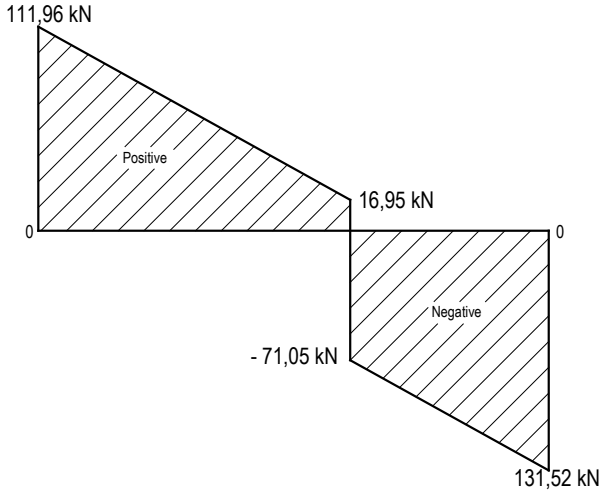
Take moments about RR:

(RL × 9) = (12,8 × 9 × 4,5) + (4,475 × 9 × 4,5) + (88 × 3,5)
RL = 518,4 + 181,24 + 308/9(1 007,64/9)
RL = 111,96 kN✓



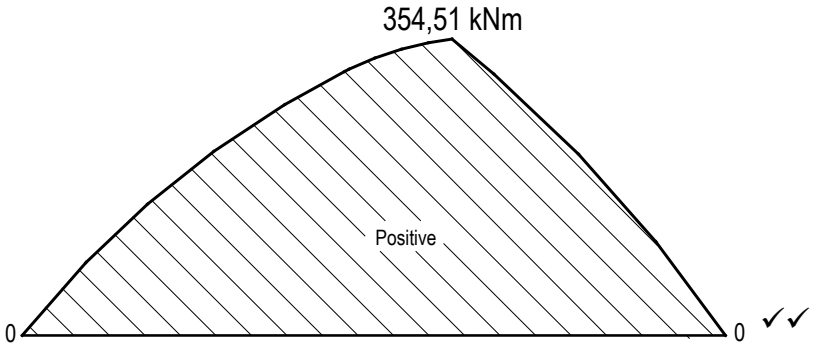
(2)

1.3



(2)

1.4 BM at C = (131,52 × 3,5) – (12,8 × 3,5 × 1,75) – (4,475 × 3,5 × 1,75)
= 460,32 –78,4 – 27,41✓
= 354,51 kN.m✓



✓✓

(4)

1.5 $K = \frac{BM}{fcu\ b\ d^2}$

Clause 4.3.3.4.1

$K = \frac{354{,}51 \times 10^6}{25 \times 330 \times 425^2}$✓

$d = 475 - 50$ cover
$= 425$ mm

$K = 0{,}238$✓

$K < K^1 = 0{,}156$ Compression reinforcement will therefore be required.✓

(3)
[15]

QUESTION 2

Effective height of the column:

Effective height (l) = 1,00 × L✓ Table 19 (SABS 0162-1984)
Where: $L_{effective}$ = 1 × 3,25 metres
= 3,25 m (3 250 mm)✓

Effective cross-sectional area of the column:

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

$$Ac = \frac{\pi 100^2}{4} - \frac{\pi 94^2}{4} \checkmark\checkmark$$

$$Area = 7\,854{,}98 - 6\,939{,}78$$

$$\text{Cross-sectional area} = 914{,}2\ mm^2 \checkmark$$

Second moment of area about the x-x axis:

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

$$I_{xx} = I_{yy} = \frac{\pi\ 100^4}{64} - \frac{\pi\ 94^4}{64} \checkmark$$

$$I_{xx} = I_{yy} = 4\,908\,738{,}52 - 3\,832\,492{,}49 \checkmark\checkmark$$

$$I_{xx} = I_{yy} = 1\,076\,246{,}03\ mm^4 \checkmark\ (1{,}08 \times 10^{-6}\ m^4)$$

Radius of gyration:

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

$$r = \sqrt{\frac{1\,076\,246{,}03}{914{,}2}} \checkmark$$

$$r = 34{,}3\ mm \checkmark$$

Slenderness ratio:

$$L/r = \frac{3\,250}{34{,}3} = 94{,}75 \checkmark$$ From Table 17 (SABS 0162-1984)

$$94{,}75 = 85{,}25\ MPa \checkmark$$

Maximum load:

Load = Stress × Area

Load = 85,25 N/mm^2 × 914,2 mm^2✓

Load = 77,94 kN✓ **[15]**

QUESTION 3

I-section $178 \times 102 \times 21,5$ kg/m:

$I_{xx} = 15,13 \times 10^{-6}\ m^4$
Area $= 2,730 \times 10^{-3}\ m^2$
$\frac{h}{2} = \frac{177,8}{2} = 88,9$ mm

Channel $140 \times 60 \times 16$ kg/m:

$I_{yy} = 0,6249 \times 10^{-6}\ m^4$
Area $= 2,037 \times 10^{-3}\ m^2$
Ay $= 17,5$ mm
t1 $= 7$ mm

Total area $= 2,730 \times 10^{-3}\ m^2 + 2,037 \times 10^{-3}\ m^2$
$= 4,767 \times 10^{-3}\ m^2$ ✓

Neutral axis using area moments from bottom:

$4,767 \times 10^{-3}\ m^2 \times Y1 = (2,730 \times 10^{-3}\ m^2 \times 0,0175) + (2,037 \times 10^{-3}\ m^2 \times 0,0959)$✓✓

$Y_1 = \frac{0,0356 \times 10^{-3} m^2 + 0,262 \times 10^{-3} m^2}{4,767 \times 10^{-3}\ m^2}$✓

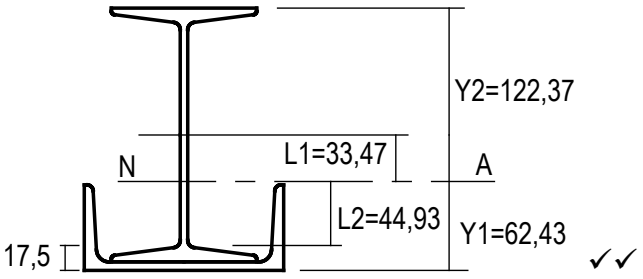
$Y_1 = \frac{0,297 \times 10^{-3}\ m^2}{4,767 \times 10^{-3}\ m^2}$✓

$Y_1 = 0,06243$ m

$Y_1 = 62,43$ mm✓

L1 $= 122,37 - 88,9 = 33,47$ mm

L2 $= 62,43 - 17,5 = 44,93$



✓✓

Second moment of area:

$I_{xx\,tot} = (Ixx\ beam + al^2) + (Iyy\ channel + al^2)$
$I_{xx\,beam} = (15,13 \times 10^{-6} + 2,73 \times 10^{-3} \times 0,03347^2)$
$= (15,13 \times 10^{-6} + 3,058 \times 10^{-6})$
$= 18,19 \times 10^{-6}\ m^4$ ✓✓

$I_{yy\,channel} = (0,6249 \times 10^{-6} + 2,037 \times 10^{-3} \times 0,04493^2)$
$= (0,6249 \times 10^{-6} + 4,11 \times 10^{-6})$
$= 4,737 \times 10^{-6}\ m^4$ ✓✓
$I_{xx\,total} = 22,927 \times 10^{-6}\ m^4$✓✓

Bending moment maximum:

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

$BM_{max} = \frac{22{,}927 \times 10^6 \times 163}{62{,}43}$ ✓✓

$BM_{max} = 59{,}86$ kN.m✓

Maximum point load:

$BM = \frac{WL}{4}$

$59{,}86 = \frac{W \times 8{,}75}{4}$ ✓

$59{,}86 = 2{,}188\ W$ ✓

$W = \frac{59{,}86}{2{,}188}$ ✓

$W = 27{,}36$ kN ✓✓ **[20]**

QUESTION 4

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)

Longitudinal compression reinforcement:

$N = 0{,}4\ Fcu\ Ac + 0{,}67\ Fy\ Asc$ Clause 4.7.4.3

$421{,}57 \times 10^3 = (0{,}4 \times 25 \times 375 \times 375) + (0{,}67 \times 450 \times Asc)$ ✓✓

$421{,}57 \times 10^3 = 1\ 406\ 250 + (301{,}5\ Asc)$

$Asc = \frac{421{,}57 \times 10^3 - 1\ 406\ 250}{301{,}5}$ ✓

$N = -3\ 265{,}94$ kN ✓

No compression reinforcement required.✓ Use minimum reinforcement (Table 23).

Minimum required reinforcement:

Minimum area of main steel = 0,4% AC — Table 23
= 0,4% × 375 × 375✓
= 562,5 mm²✓
Use 6Y12 main bars.✓

Diameter and spacings of the binders:

Binders = ¼ of the smallest main bar — Clause 4.11.4.5.1
= ¼ × 12
= 3 mm (not available)✓
Use min R8 binders (R6 discontinued).

Spacing of binders
= 12 × diameter of main bar
= 12 × 12
= 144 mm

Use spacing of 140 mm.✓ **[10]**

QUESTION 5

Effective length per side = 220 – (2 × 8)✓ — SABS 0162-1984
= 204 mm✓ — 10.7.2.1

Total E_{ff} length = 204 × 2✓
= 408 mm✓

Throat thickness = Sin45° × 8 mm
= 5,66 mm✓

Throat area = 204 mm × 5,66 mm
= 1 154,64 mm²✓

Maximum force P:

Stress = load/area — P = 130 MPa
Load = stress × area✓ — 10.7.1.2
Load = 130 N/mm² × 1 154,64 mm²
Load = 155,1 kN✓ **[8]**

QUESTION 6

If the tie bar is bolted: Clause 9.2.1 (SABS 0162)

Force = 110 kN
Bolt = M16
Hole = 18 mm
Select a trial section = 60 × 60 × 10 RSA

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

Effective area of unconnected leg:

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

$A_2 = t(b - \frac{t}{2})$ ✓

$A_2 = 10(60 - \frac{10}{2})$ ✓

$A_2 = 550\ mm^2$ ✓ (no holes)

If the tie bar is bolted: Clause 9.2.1 (SABS 0162)

Force = 110 kN
Bolt = M16
Hole = 18 mm

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

Select a trial section 60 × 60 × 10 RSA:

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

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

$A_1 = 10(60 - \frac{10}{2})$ – (18 × 10) ✓ (M16 bolts)

$A_1 = 550 - 180$

$A_1 = 370\ mm^2$ ✓

$$A_{eff} = \frac{3(370)^2 + 4\ (370)(550)}{3(370) + (550)}$$

$$A_{eff} = \frac{1\ 224\ 700}{1\ 660}$$

$A_{eff} = 737{,}77\ mm^2\ \ (0{,}738 \times 10^3\ mm^2)$ ✓

Therefore tensile force:

Force = Pt × Aeff

Force = 155 N/mm² × 737,77 mm² ✓

Force = 114,35 kN ✓

The bolted tie bar will be able to withstand the given load of 110 kN. ✓ Table 20 (SABS 0162) **[10]**

QUESTION 7

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 = 5,25 metres — Clause 4.3.1.2
Density of reinforced concrete = 2 450 kg/m^3

Effective depth of the slab: — Table 10 (4.3.6.2.1)

Effective depth = span/16
Eff d = 5 250/16
Eff d = 328,13 mm✓

Overall depth:

Assume R16 main steel and cover of 25 mm.
Overall depth = 328,13 + 16/2 + 25 cover✓
= 361,13 mm (Use overall depth = 370 mm)✓

Design dead loads of the slab: — Clause 4.2.2.1

Design dead load
= Volume × density × 9,81 × 10^{-3} × 1,2Gn
= 0,37 × 1 × 1 × 2 450 kg/m³ × 9,81 × 10^{-3} × 1,2 Gn✓ — Clause 4.2.2.1
= 10,67 kN/m✓

Design imposed load
= 7,5 kN/m^2 × 1 × 1,6 Qn
= 12,0 kN/m✓

Total design load = 10,67 + 12,0 = 22,38 kN/m✓

Bending moment maximum:

$$BM_{max} = \frac{WL^2}{8}$$
$$BM_{max} = \frac{22{,}67 \times 5{,}25^2}{8}$$✓
$$BM_{max} = 78{,}11 \text{ kN.m}$$✓

Value of K:

$$K = \frac{BM}{fcu\ b\ d^2}$$
$$K = \frac{78{,}11 \times 10^6}{25 \times 1\,000 \times 328{,}13^2}$$✓
$$K = 0{,}029$$✓
$K < K^1 = 0{,}156$ therefore only tension reinforcement required.✓

Distance of lever arm (Z):

$$Z = d\left\{0{,}5 + \sqrt{0{,}25 - \frac{k}{0{,}9}}\right\} \leq 0{,}95\text{d}$$ Clause 4.3.3.4.1

$$Z = 328{,}13\left\{0{,}5 + \sqrt{0{,}25 - \frac{0{,}029}{0{,}9}}\right\} \leq 0{,}95\text{d}\checkmark$$

$$Z = 328{,}13\{0{,}97\}\checkmark \quad \leq 0{,}95 \times 328{,}13$$

$$Z = 317{,}19\text{ mm}\checkmark \quad \leq 311{,}72\text{ mm} \leq 0{,}95\text{d}$$

Tension reinforcement:

$$\text{As} = \frac{M}{0{,}87 \times fy \times z}$$ Clause 4.3.3.4.1

$$\text{As} = \frac{77{,}11 \times 10^6}{0{,}87 \times 250 \times 317{,}19}\checkmark$$

$$\text{As} = 1\,117{,}72\text{ mm}^2\checkmark$$

Use R16 at 175 centres. $(\text{As} = 1\,149\text{ mm}^2)\checkmark$

Minimum main reinforcement:

$$\frac{100\,As}{Ac} = \frac{100 \times 1\,149}{1\,000 \times 360}\checkmark$$ Table 23 Clause 4.11.4

$$= 0{,}32$$

$$0{,}24 = 0{,}32\checkmark$$

The reinforcement is sufficient.

Secondary reinforcement:

$$\frac{100\,As}{Ac} = 0{,}24$$ Clause 4.11.4.3.1 and Table 23

$$\text{As} = \frac{0{,}24 \times 1\,000 \times 360}{100}\checkmark$$

$$\text{As} = 864\text{ mm}^2$$

Use R12 at 125 centres. $(\text{As} = 905\text{ mm}^2)\checkmark$ **[22]**

TOTAL: 100

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