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CIVIL ENGINEERING

CONVENTIONAL Practice Sets

CONTENTS

RCC & PRESTRESSED CONCRETE

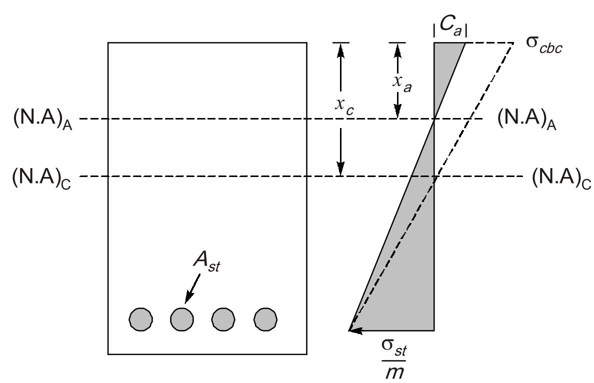
CHAPTER 1

Working Stress Method

Q.1 Explain under reinforced and over reinforced failure of a reinforced concrete beam.

Solution:

Under reinforced failure: An 'under reinforced section' is one in which the area of tension steel (A_{st}) is such that the permissible stress is reached in the steel before the permissible stress is reached in the extreme fibre of the concrete.



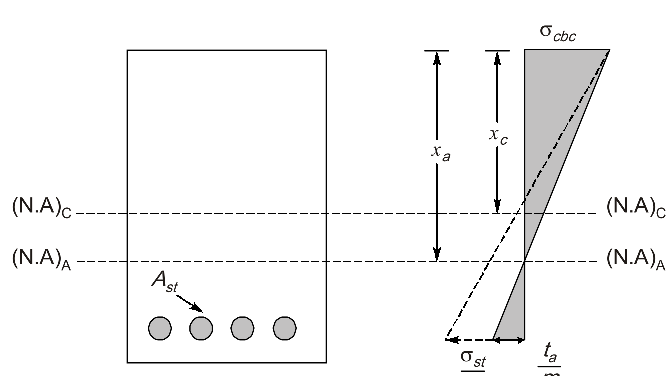
In this case,

(i) $x_a < x_c$ (ii) $C_a < \sigma_{cbc}$

(iii) $t_a = \sigma_{st}$ (iv) $A_{st\ provided} < A_{st\ balanced}$

A slight increase in the load, at this stage causes the beam to yield and elongate. In this case failure is due to failure of steel. It is known as tension failure or ductile failure. This give sufficient warning before failure. Hence an under reinforced section is always preferred.

Over reinforced failure: An 'over reinforced' section is one in which the area of tension steel (A_{st}) is such that permissible stress in extreme fibre of concrete is reached before the permissible stress in the steel.



In this case,

(i) $x_a > x_c$ (ii) $C_a = \sigma_{cbc}$

(iii) $t_a < \sigma_{st}$ (iv) $A_{st\ provided} > A_{st\ balanced}$

The concrete fails in compression before the steel reaches its permissible stress. Hence this type of failure is known as compression failure or Brittle failure. The failure occurs without warning, hence an over reinforced section is always undesirable.

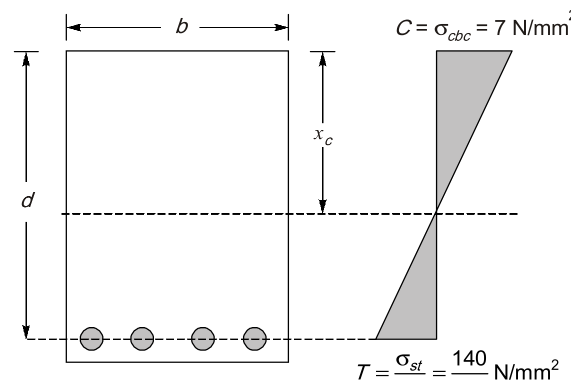
Q.2 Analyze the balance concrete section:
(i) When M20 concrete and Fe250 steel is used.
(ii) When M20 concrete and Fe415 steel is used.
Use W.S.M.

Solution:

(i)

$$\sigma_{cbc} = 7 \text{ N/mm}^2$$
$$\sigma_{st} = 140 \text{ N/mm}^2$$
$$\boxed{m = \frac{280}{3\sigma_{cbc}}}$$

From similarity condition in the stress diagram,



Balanced section

$$\boxed{\frac{C}{T} = \frac{x_c}{d - x_c}}$$

$$m = \frac{280}{3\sigma_{cbc}} = \frac{280}{3 \times 7}$$
$$= 13.33$$

$$\therefore \quad \frac{7}{\frac{140}{13.33}} = \frac{x_c}{d - x_c}$$

$$x_c = 0.4\,d$$

Lever arm $\boxed{LA = d - \frac{x_c}{3} = 0.87d}$

$$\text{Moment of resistance} = \frac{1}{2} b x_c \cdot C_x \cdot L.A.$$
$$= \frac{b(0.4d)7}{2} \times 0.87\,d = 1.213\,bd^2$$

Equating total compression = Total tension

$$\boxed{\frac{1}{2} b x_c \, \sigma_{cbc} = A_{st} . \sigma_{st}}$$

$$\frac{1}{2} b(0.4d) \times 7 = A_{st} \cdot 140$$

$$\frac{A_{st}}{bd} = 0.01$$

Hence, A_{st} = 1% of bd for balanced section
if $A_{st} <$ 1% of $bd \Rightarrow$ underreinforced section
if $A_{st} >$ 1% of $bd \Rightarrow$ overreinformced

(ii)

$$\sigma_{cbc} = 7 \text{ N/mm}^2$$
$$\sigma_{st} = 230 \text{ N/mm}^2$$
$$m = \frac{280}{3\sigma_{cbc}} = \frac{280}{3 \times 7} = 13.33$$

From similarity condition in stress diagram,

$$\frac{C}{T} = \frac{x_c}{d - x_c}$$

$$\frac{\frac{7}{230}}{13.33} = \frac{x_c}{d - x_c}$$

$$x_c = 0.289\,d$$

$$\text{Lever arm L.A.} = d - \frac{x_c}{3} = 0.904\,d$$

$$\text{Moment of resistance} = \frac{1}{2} b x_c \cdot c \times L.A.$$

$$= \frac{1}{2} \times b \times 0.289\,d \times 7 \times 0.904\,d$$

$$= 0.914\,bd^2$$

$$\text{Equating total compression} = \text{Total tension}$$

$$\frac{1}{2} b x_c\, \sigma_{cbc} = A_{st} \times \sigma_{st}$$

$$\frac{1}{2} b(0.289\,d) \times 7 = A_{st} \times 230$$

$$\frac{A_{st}}{bd} = 0.0044$$

Hence, $A_{st} = 0.44\%$ of bd for balanced section

if $A_{st} < 0.44\%$ of $bd \Rightarrow$ underreinforced section

if $A_{st} > 0.44\%$ of $bd \Rightarrow$ overreinformced

Q.3 A rectangular *RC* section 25 cm wide and 50 cm overall deep is reinforced with 3-16 mm diameter HYSD bars at an effective cover of 4 cm from bottom face. If permissible stresses in concrete in bending compression and steel are 50 kg/cm^2 and 2300 kg/cm^2 respectively, modular ratio m =19, calculate the moment of resistance of the section using WSM.

Solution:

Given data: B = 25 cm = 250 mm, D = 50 cm = 500 mm, $A_{st} = 3 \times \frac{\pi}{4} \times 16^2 = 603.19$ mm^2, Effective cover = 4 cm = 40 mm, $\sigma_{cbc} = c = 50$ kg/cm^2 = 5 N/mm^2, $\sigma_{st} = t = 2300$ kg/cm^2 = 230 N/mm^2, m = 19, $d = D - 40 = 500 - 40 = 460$ mm

(i) **Calculating critical depth of NA:**

$$\boxed{x_c = \left(\frac{mc}{t + mc}\right) d}$$

$$= \left(\frac{19 \times 5}{230 + (19 \times 5)}\right) 460 = 134.46 \text{ mm}$$

(ii) **Calculating actual depth of NA** by equating moment of area of compression side and tension side about NA.

$$\Rightarrow \quad \boxed{\frac{Bx_a^2}{2} = mA_{st}\left(d - x_a\right)}$$

$$\Rightarrow \qquad \frac{250}{2}x_a^2 = 19 \times 603.19 \times (460 - x_a)$$

$$\Rightarrow \qquad x_a = 164.578 \text{ mm}$$

$\because x_a > x_c$, therefore section is over reinforced.

i.e. $\qquad c_a = \sigma_{cbc} = c$

$$t_a < \sigma_{st} = t$$

$$\because \qquad \boxed{MR = B.x_a.\frac{c_a}{2}\left(d - \frac{x_a}{3}\right)}$$

$$= 250 \times 164.578 \times \frac{5}{2} \times \left(460 - \frac{164.578}{3}\right)$$

$$MR = 41.67 \text{ kN-m}$$

Q.4 Design a rectangular RCC beam for a simply supported span of 8 m subjected to a load of 45 kN/m (excluding the self wt.). Use M25 and Fe 500. Size of beam is restricted to 400 × 850 mm

Solution:

$\sigma_{cbc} = 8.5$ MPa $\qquad \sigma_{st} = 275$ MPa $\qquad m = 11$

(i) Calculating Load and B.M.

$$\text{D.L.} = 0.4 \times 0.85 \times 25 = 8.5 \text{ kN/m}$$

$$\text{L.L} = 45 \text{ kN/m}$$

$$\text{Total load} = 53.5 \text{ kN/m}$$

$$\text{Bending Momeny} = \frac{wl^2}{8} = 428 \text{ kN-m}$$

(ii) Calculating steel requirement

$$\boxed{MR_1 = B \cdot x_c \cdot \frac{\sigma_{cbc}}{2}\left(d - \frac{x_c}{3}\right)}$$

$$= \frac{1}{2} \times 8.5 \times 0.9154 \times 0.2537 \times 400 \times 800^2 = 252.98 \text{ kN-m}$$

For Balanced Section:

$$\boxed{A_{st_1} = \frac{MR_1}{\sigma_{st}\left(d - \frac{x_c}{3}\right)}}$$

$$= \frac{252.98 \times 10^6}{275\left(800 - \frac{202.96}{3}\right)} = 1256.13 \text{ mm}^2$$

$$MR_2 = 428 - 252.98 = 175.02 \text{ kN-m}$$

$$\Rightarrow \qquad \sigma_{st} \cdot A_{st_2}(d - d_c) = 175.02 \times 10^6$$

$$\Rightarrow \qquad A_{st_2} = 848.58 \text{ mm}^2$$

$$175.02 \times 10^6 = (1.5\text{ m} - 1)\, A_{sc}(d - d_c)$$

$$\Rightarrow \qquad A_{sc} = \frac{15055.48}{C'}$$

$$\frac{C'}{152.96} = \frac{C}{202.96}$$

$$C' = 6.406 \text{ MPa}$$
$$A_{sc} = 2350.2 \text{ mm}^2$$
$$A_{st} = A_{st_1} + A_{st_2} = 2104.61 \text{ mm}^2$$

Q.5 A rectangular *RC* beam simply supported at ends over an effective span of 5.0 m carries a UDL of 2000 kg/m including its own weight. If σ_{cbs} = 70 kg/cm^2, σ_{st} = 1900 kg/cm^2 and m = 13, design the beam section for flexure only by WSM. The size of the beam is restricted to 40 cm wide × 40 cm overall deep. Assume effective cover = 4.0 cm. Stress in compression reinforcement, if needed may be taken as 1.5 m times the stress in surrounding concrete.

Solution:

Given: l_{eff} = 5 m, w = 2000 kg/m = 20 kN/m, σ_{cbc} = c = 70 kg/cm^2 = 7 N/mm^2, $t = \sigma_{st}$ = 1900 kg/cm^2 = 190 N/mm^2, m = 13, B = 40 cm = 400 mm, D = 40 cm = 400 mm, Effective cover = 4.0 cm = 40 mm, $d = D - 40 = 400 - 40 = 360$ mm

(i) Maximum $BM = \dfrac{w\,l_{eff}^2}{8} = \dfrac{20 \times 5 \times 5}{8} = 62.5$ kN-m

(ii) Design constants:

$$\boxed{k = \left(\frac{mc}{t + mc}\right)}$$
$$= \frac{13 \times 7}{190 + (13 \times 7)} = 0.3238$$

$$\boxed{j = 1 - \frac{k}{3}}$$
$$= 0.8920$$

$$\boxed{Q = \frac{1}{2} cjk}$$
$$= \frac{1}{2} \times 7 \times 0.8920 \times 0.3238 = 1.011$$

(iii) *MR* of the balanced section:

$$\boxed{M_1 = QBd^2}$$
$$= 1.011 \times 400 \times 360 \times 360 = 52.41 \text{ kN-m}$$

(iv) BM > M_1, therefore a doubly reinforced section is required.

(v) Calculating area of steel for singly reinforced balanced section.

$$\boxed{A_{st_1} = \frac{M_1}{\sigma_{st}\left(d - \frac{x_a}{3}\right)}}$$

$$= \frac{52.41 \times 10^6}{190\left(360 - \frac{0.3238 \times 360}{3}\right)} \qquad [\because x_a = x_c = kd]$$

$$A_{st_1} = 858.94 \text{ mm}^2$$

(vi) A_{st_2}, area of remaining tensile steel in the section with compression reinforcement

$$\boxed{A_{st_2} = \frac{M_2}{\sigma_{st}\,(d - d_c)}}$$

$$= \frac{BM - M_1}{\sigma_{st}(d - d_c)} = \frac{(62.5 - 52.41) \times 10^6}{190 \times (360 - 40)}$$

$$A_{st_2} = 165.95 \text{ mm}^2$$

(vii) Total tensile steel, $A_{st} = A_{st_1} + A_{st_2} = 858.94 + 165.95 = 1024.89 \text{ mm}^2$.

(viii) A_{sc}, area of compression reinforcement,

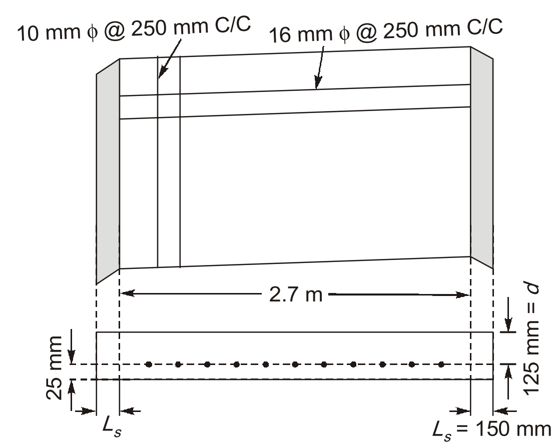
$$\boxed{A_{sc} = \frac{m(d - x_a)}{(1.5m - 1)(x_a - d_c)} \times A_{st_2}} \qquad [\because x_a = x_c = kd]$$

$$= \frac{13 \times (360 - 116.57)}{(1.5 \times 13 - 1)(116.57 - 40)} \times 165.95$$

$$A_{sc} = 370.74 \text{ mm}^2$$

Q.6 A rectangular RC slab 2 m × 3 m is simply supported along shorter edges such that clear distance between the supporting wall is 2.7 m. The slab is 15 cm thick and reinforced with 16 mm diameter mild steel bars spaced at 25 cm c/c at effective cover of 25 mm along longer edges and with 10 mm diameter bars along shorter edges spaced at 25 cm c/c. Concrete used is M15 grade for which permissible stresses in bending, shear (nominal) and bond are 50, 3 and 6 kg/cm² respectively. Permissible tensile stresses in mild steel = 1400 kg/cm², m = 19. Calculate maximum safe intensity of load that the slab can carry in addition to its self-weight.

Solution:



Assuming clear cover = 25 mm,
Width of support = 150 mm

Effective span for simply supported slab:

(i) Clear span + effective depth
$= L_0 + d = 2.7 + 0.125$
$= 2.825$ m

(ii) Centre to centre distance between supports
$= L_0 + L_s = 2.7 + 0.15$
$= 2.850$ m

Lesser of (i) and (ii) is adopted.

∴ Effective span, $l_e = 2.825$ m

Let the total load including self-weight of slab that can be carried by slab = w kN/m²

$$\text{Maximum bending moment} = \frac{wl_e^2}{8} = \frac{w \times (2.825)^2}{8}$$

$$= 0.998\, w \text{ kN-m} = 0.998 \times 10^6\, w \text{ N-mm}$$

Now, $m = 19$, $c = 50$ kg/cm² = 5 MPa, $t = 1400$ kg/cm² = 140 MPa

$$\boxed{x_c = \left(\frac{mc}{t + mc}\right)d}$$

$$= \left[\frac{19 \times 5}{140 + (19 \times 5)}\right] \times 125 = 50.53 \text{ mm}$$

$$A_{st} = \frac{1000}{250} \times \frac{\pi}{4} \times 16^2 = 804.25 \text{ mm}^2$$