The Shirpur Education Society's

R. C. Patel College of Engineering and Polytechnic, Shirpur

Department of Mechanical Engineering

NAME OF COURSE: - Strength of Materials

CODE OF COURSE: - 313308

SEMESTER: - SYME-3K

SUBJECT TEACHER: - Mr. Laxmikant Y.Borse

The Shirpur Education Society's

R. C. Patel College of Engineering and Polytechnic, Shirpur

QUESTION BANK

CHAPTER 5.Direct and Bending Stresses

Program Name: Mechanical Engineering
Program Code: ME3k
Name of Subject & Code : Strength of Materials (313308)
Semester : Third
Date & Time Slot:

Q. NO.	QUESTION	DETAIL	MAPPING
1	State the middle third rule.	W24 Q1g 2M	CO 5.3R
2	Define axial load and eccentric load.*	S26 &W25 Q1g&c2M	CO 5.2 R
3	Draw a neat sketch to show core of rectangular section of (B × D) dimensions.	S25 Q1g 2M	CO 5.3 U
4	State the condition of no tension at the base of column	S25 Q1g 2M	CO 5.2 R
5	State the Rankin's formula with meaning of each term used in it.*	W24&25 Q4d &C 4M	CO 5.5 A
6	A short column of hollow rectangular c/s has external dimensions 2.4 m × 1.8 m and is 20 mm thick. It carries a vertical load of 500 kN at an eccentricity of 30 mm from the geometric axis of the section bisecting the longer side. Find maximum and minimum stress intensities	W24 Q4e 4M	CO 5.2 A
7	State Euler's formula and Rankine's formula giving meaning of symbols used in it. State the effective length of column for various end conditions.*	S26& S25 Q4E&D 4M	CO 5.5 R
8	A rectangular column 150 mm wide and 100 mm thick carries a load of 150 kN at an eccentricity of 50 mm in the plane bisecting the thickness. Find maximum and minimum intensities of stress in the section	S25 Q3d 4M	CO 5.2 &5.3 A
9	A hollow circular steel column having external diameter 300 mm and thickness 2 mm carries an eccentric load of 100 kN acting at an eccentricity of 100 mm. Calculate maximum and minimum stresses.	S26 Q4D 4M	CO5.2 A
10	A solid circular column of diameter 150 mm carries a vertical load of 50 kN at outer edge of the column. Calculate 6 max and 6 min.	W25 Q5C 6M	CO 5.3 A
11	A C.I. hollow circular column has external diameter of 250 mm and internal diameter of 200 mm. It is subjected to a vertical load of 20 kN at a distance of 400 mm from the vertical axis of the column. Calculate the maximum and minimum stress of the base of column	W25 Q6C 6M	CO 5.2 A
12	Determine the limit of eccentricity for a hollow circular section having D = 300 mm and d =100 mm also draw stress distribution diagram	W24 Q5B 6M	CO 5.1 A
13	A rectangular column is 200 mm and 100 mm thick is subjected to a load of 180 kN at eccentricity of 100 mm in plane bisecting the thickness. Draw the combined stress distribution diagram showing their values.	S25 Q6A 6M	CO 5.2 A
14	A rectangular pier 750 mm * 1000 mm is subjected to a compressive load of 500 kN with an eccentricity of 250 mm along the axis bisecting 1000 mm side. Determine the resultant stresses at the base cross section of the pier. Also draw the resultant stress distribution diagram showing all stresses.	S26 Q6C 4M	CO 5.2 A

27/06/26

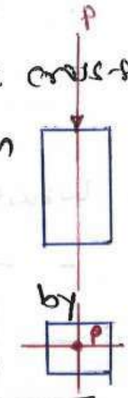
27/6/24

Unit No:- 05

-: Direct and Bending Stresses :-

5.1 Introduction to Direct and Eccentric Loads

1) **Direct Load:-**
A loads that acts through the centroid or centre of gravity of a cross-section along it's longitudinal axis called direct load.



- Characteristics :-
  i) Produced uniform stress over the entire cross-section.
  ii) Causes only axial tension or compression
  iii) No bending moment is produced.

$\therefore$ stress due to direct load is given by

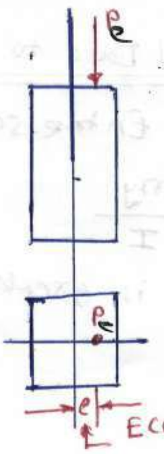
$$\sigma = \frac{P}{A} = \frac{\text{Applied load (N)}}{\text{cross-sectional area (A)}}$$

σ = Direct stress in N/mm^2

e.g. A steel rod subjected to a tensile force acting through it's centre.

2) **Eccentric load :-** (P_e)
It is a load whose line of action does not pass through the centroid. of the section.

- Characteristics :-
① It produced both direct & Bending stress
② Causes non-uniform stress distribution
③ creates bending moment



> **Note:- Eccentricity (e)**
> The $\perp^{er}$ distance betn line of action of the load & centroid of the section.
> $\therefore \; e = \frac{M}{P} = \frac{\text{Bending moment}}{\text{Applied load}}$

* Eccentricity About one Principal Axis:-

When the load is displaced from the centroid along only one principal axis (X-X or Y-Y), the member is subjected to Direct stress and bending stress about that axis.

∴ Combined stress Equation is given by

$$\sigma = \frac{P}{A} \pm \frac{My}{I}$$

Where,

- $\frac{P}{A}$ = Direct stress in N/mm^2
- $\frac{My}{I}$ = Bending stress ~~in~~ N/mm^2
- $M = P \times e$ ∴ Bending moment in N·mm
- y = Distance from Netural axis in mm
- I = moment of inertia in mm^4.

Note:-

① maximum stress $(\sigma_{max}) = \frac{P}{A} + \frac{My}{I}$

② minimum — " — $(\sigma_{min}) = \frac{P}{A} - \frac{My}{I}$

(*) Nature of stresses Due to Eccentric loading.

① Case - I :- Consider Entire section in compression.

When $\frac{P}{A} > \frac{My}{I}$

ie Direct stress is greater than Bending stress

Case - II : Part of compression and part of Tension.

then Bending stress is greater than Direct stress.

ie $\frac{My}{I} > \frac{P}{A}$

5.1 :- Resultant stress intensities :-

Resultant stress = Direct stress $\pm$ Bending stress

$$= \sigma_0 \pm \sigma_b = \frac{P}{A} \pm \frac{M}{Z}$$

$$OR = \frac{P}{A} \pm \frac{M.y}{I}$$

Where,

Z = section modulus = $\frac{I}{y}$

M = moment produced due to eccentric load

$= P \times e$

P = load.

e = eccentricity.

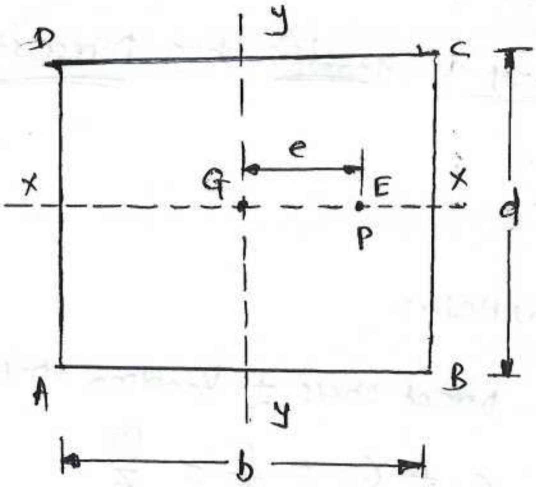
$\therefore$ Resultant stress at base of column is calculated by

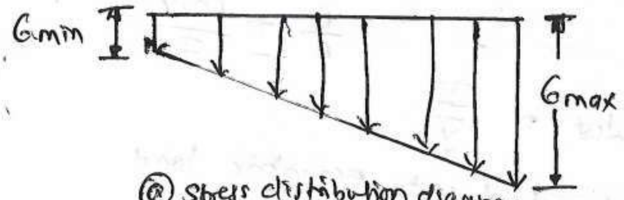
$$\sigma_{max} = \sigma_0 + \sigma_b$$

$$\sigma_{min} = \sigma_0 - \sigma_b.$$

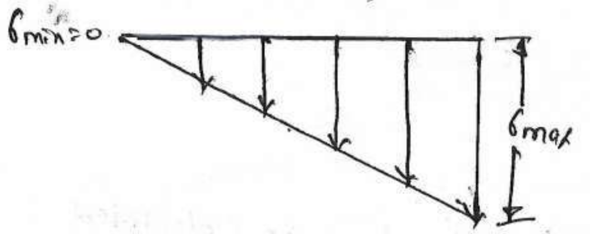
5.2 Resultant stress variation.

When a section ~~ABCD~~ ABCD is acted upon by an eccentric load P with an eccentricity 'e'. The eccentric load is acting on the X-X axis as shown in fig. (1) due to which bending moment will be produced ie $M = P \times e$ and due to eccentric loading max^m and min^m stresses will be formed and it should be calculated by as follows.

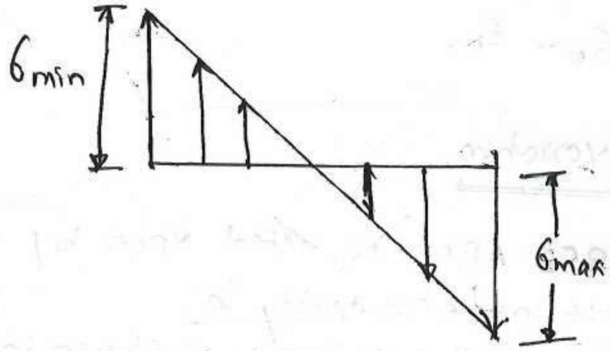




(a) Stress distribution diagram ($\sigma_0 > \sigma_b$)



(b) Stress distribution diagram ($\sigma_0 = \sigma_b$)



(c) Stress distribution diagram ($\sigma_0 < \sigma_b$)

- maximum stress (σ_{max})

$$\sigma_{max} = \sigma_0 + \sigma_b$$

- min^m stress (σ_{min})

$$\sigma_{min} = \sigma_0 - \sigma_b$$

Where,

σ_0 = Direct stress = $\frac{P}{A}$

σ_b = Bending stress = $\frac{My}{I}$ or $\frac{M}{Z}$

Where $M = P \times e$ & $Z = \frac{I}{y}$

Case (I)

(a) If $\sigma_0 > \sigma_b$

$\sigma_{max} = (\sigma_0 + \sigma_b)$, the stress distribution will be of compressive nature at the base of the column as well as $\sigma_{min} = \sigma_0 - \sigma_b$ will be compressive nature at base of column.

(b) If $\sigma_0 = \sigma_b$

σ_{max} the stress distribution will be of compressive nature at base of the column. and $\sigma_{min} = 0$ ie ($\sigma_0 = \sigma_b$) $\therefore \sigma_{min} = 0$.

(c) If $\sigma_0 < \sigma_b$

'σ_{max}' so the stress distribution will be of compressive nature at the base of the column. and 'σ_{min}', so stress distribution will be of tensile nature at the base of the column.

5.2. No Tension Condition OR Zero stress condition:

- If there is no tension at the base of the column, then the condition is called as no tension condition.

ie $\sigma_{min} = 0$

$\therefore \sigma_0 - \sigma_b = 0$ ...... $\{ \because \sigma_0 = \sigma_b$

5.3 ① Limit of Eccentricity:- (e)

It's(e) no tension condition is very important, so direct stress (σ_0) should be greater than or equal to bending stress (σ_b)

ie Direct stress (σ_0) $\geq$ Bending stress (σ_b)

$\therefore (\sigma_0) \geq (\sigma_b)$

$\therefore \frac{P}{A} \geq \frac{P \times e}{Z}$ ...... $\{ M = P \times e)$

$\frac{Z}{A} \geq e$

$\therefore \boxed{e \leq \frac{Z}{A}}$

So for the limiting eccentricity 'e' it should be less than or equal to $\frac{Z}{A}$

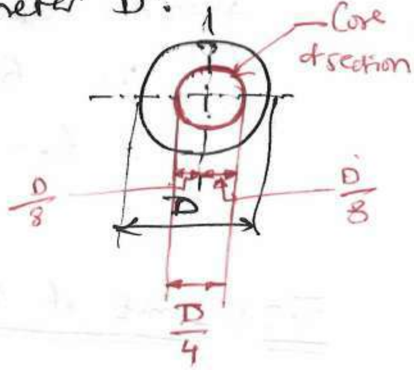
ie $e = \frac{Z}{A}$ OR $e < \frac{Z}{A}$.

② Core of section:-

It is the region within which the resultant compressive load must act so that the entire section remains under compression & no tension develop. called core of section.

3. Core of a circular section:-

Consider a circular section of diameter 'D'.



$\therefore$ Area = $A = \frac{\pi}{4} \times D^2$

- section modulus (Z)

$$Z = \frac{\pi D^3}{32}$$

- limit of eccentricity (e)

$$e = \frac{Z}{A} = \frac{\frac{\pi D^3}{32}}{\frac{\pi}{4} \times D^2}$$

$$\therefore \boxed{e = \frac{D}{8}}$$

4.) Middle third Rule for Rectangular section:-

Statement:- It state that, for a rectangular section subjected to an eccentric compressive load, the line of action of the load must lie within the middle one-third of the section to ensure that no tensile stress develops anywhere in the section.

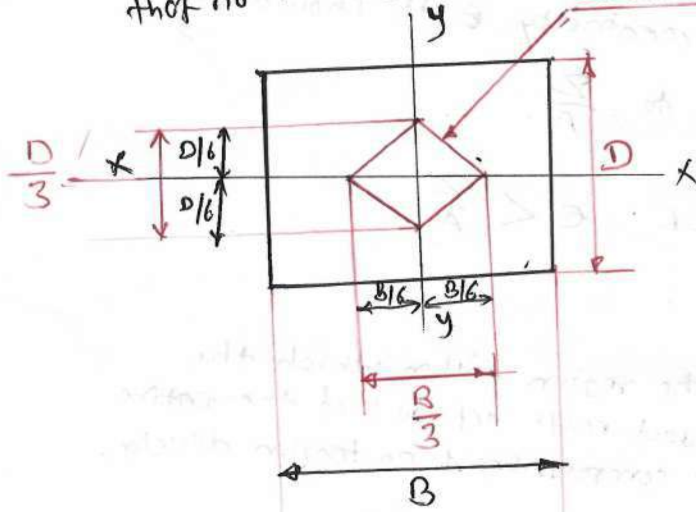


Fig. middle third Rule for rectangular section

Using No tension cond^n

$(\sigma_0 = \sigma_b)$

$$\therefore \frac{P}{A} = \frac{M}{I_{xx}} \times y$$

$$\frac{\cancel{P}}{B \times \cancel{D}} = \frac{\cancel{P} \times e_{xx} \times \frac{\cancel{D}}{2}}{\frac{B D^{\cancel{3}}}{12}}$$

$$1 = \frac{12 e_x}{2D}$$

$$\therefore \boxed{e_{xx} = \frac{D}{6}}$$

5.4 (A) Compression members:-

It is a structural element subjected primarily to axial compressive load. It main function is to resist crushing and buckling.

e.g. Building columns, struts in roof trusses, machine frame and Bridge members etc.

Compression members may be classified in two groups.

① Short Columns
② Long Columns.

① Short columns:-

i) Fail mainly by crushing
ii) small length compared to cross-sectional dimensions.

② Long Columns:-

i) Fail by buckling
ii) Large length compared to cross-sectional dimensions.

(B) Effective length of column:-

It is the length of an equivalent pin-ended column having the same buckling load of actual column.

$$L_e = KL$$

Where,
L_e = Effective length
K = Effective length factor
L = Actual Length.

Note:- The effective length depends on the condition of the column.

(C) Radius of Gyration:-

It is the distance from the centroidal axis at which the entire area of section may be assumed concentrated without changing its moment of inertia.

$$K = \sqrt{\frac{I_{xx}}{A}} \quad \text{or} \quad K = \sqrt{\frac{I}{A}}$$

Where,

K = Radius of gyration in 'mm'

I = moment of Inertia, in mm^4

A = cross-sectional Area in mm^2

(D) Slendness Ratio :- (λ)

It is the ratio of effective length to the least radius of gyration.

mathematically

$$\text{Slendness ratio } (\lambda) = \frac{\text{Effective length}}{\text{Radius of gyration}}$$

$$\therefore \lambda = \frac{L_e}{k_{mm}}$$

Note :-

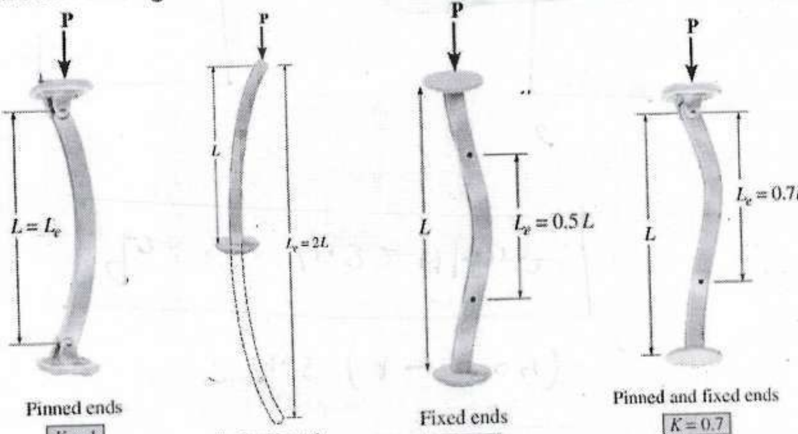
(1) Determines whether a column behaves as short, intermediate or long.

(2) Higher Slendness ratio greater tendency to buckle.

(E) **COLUMNS HAVING VARIOUS TYPES OF SUPPORTS**

9.7 Answer (B)

Effective length



(a) Pinned ends $K = 1$	(b) Fixed and free ends $K = 2$	(c) Fixed ends $K = 0.5$	(d) Pinned and fixed ends $K = 0.7$
a) Both ends Hinged $L_e = L$	(b) one end fixed and other free $L_e = 2L$	(c) Both ends are fixed $\therefore L_e = \frac{L}{2}$	(d) one End fixed and other end Hinged $\therefore L_e = \frac{L}{\sqrt{2}}$

Where L = Actual length of column section.

5.5 Buckling (OR Crippling) load of columns

It is the maximum axial compressive load at which a column just begins to bend laterally and becomes unstable.

- When the applied load exceed this value, the column fails by buckling rather than crushing.

Q.7. (i)
Ans. ① Euler's formula :- It is used for long and slender columns.

Formula :- $$P_{cr} = \frac{\pi^2 EI}{L_e^2}$$

Where

P_{cr} = Critical buckling (crippling) load in (N)

E = Young's modulus of elasticity (N/mm²)

I = Least or minimum moment of Inertia of the cross-section (mm⁴)

L_e = Effective length of the column (mm)

\# Using Radius of Gyration

$$I = Ak^2$$

∴ Euler's formula can also be written as

$$P_{cr} = \frac{\pi^2 E A k^2}{L_e^2}$$

or

$$P_{cr} = \frac{\pi^2 EA}{\left(\frac{L_e}{k}\right)^2}$$

Where,
A = cross-sectional area
k = radius of Gyration
$\left(\frac{L_e}{k}\right)$ = slenderness ratio

Assumption of Euler's Theory:-

1. Column is initially perfectly straight.
2. material is homogenous & isentropic.
3. Load acts axially through the centroid.
4. Column is long and slender.
5. material remains within elastic limit.

Limitation:-

1. Euler's formula is applicable only for long columns. It's not suitable for short & intermediate columns.

9.7 ①ii Ans

(B) Rankine's formula:-

It is combined the effect of crushing and buckling and proposed a formula applicable to all types of columns.

$$P_R = \frac{\sigma_c \cdot A}{1 + \alpha\left(\frac{L_e}{K}\right)^2}$$

Where,

P_R = Rankine crippling load in (N)

σ_c = Crushing stress of material (N/mm^2)

A = cross-sectional area (mm^2)

α = Rankine constant.

L_e = effective length in (mm)

K = Radius of gyration in (mm)

$\frac{L_e}{K}$ = slenderness ratio

Defn

① Buckling load :-

The axial compressive load at which a column becomes laterally unstable and bends is called the buckling load or critical load.

② Crippling load :-

The maximum compressive load that a column can carry without buckling is called the crippling load.

: Numericals :-

Q.6) A short column of hollow rectangular C/s has external dimensions 2.4m × 1.8m and is 20 mm thick. It carries a vertical load of 500 kN at an eccentricity of 30mm from the geometric axis of the section bisecting the longerside. find maximum and minimum stress intensities. (W-24 Q.4e)

⇒ Given :- (A) Extend dimension:

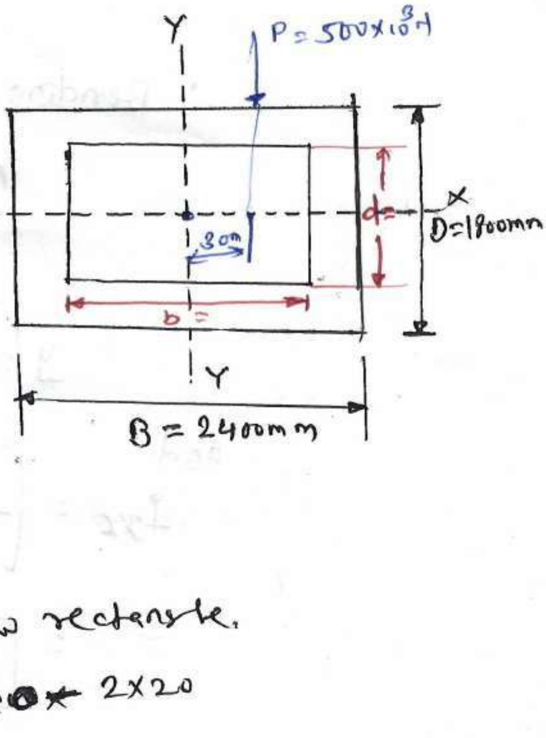
① $B = 2.4\,6m = 2.4 \times 10^{2}$ mm

② $D = 1.8\,6m = 1.8 \times 10^{2}$ mm

③ $t = 20$ mm

④ $P = 500$ kN $= 500 \times 10^{3}$ N

⑤ $e = 30$ mm



To find :- ① $\sigma_{max} = ?$

② $\sigma_{min} = ?$

Soln :- Internal dimension of Hollow rectangle.

is $b = 2400 - 2 \times t = 240 - 2 \times 20$

$\therefore b = 200$ mm

$d = 180 - 2 \times 20 = \underline{140\text{mm}}$.

$\therefore b = 180$ mm and $d = 140$mm.

∴ Area of Hollow rectangle

$$A = [(B \times D) - (b \times d)]$$

$$= [(240 \times 180) - (200 \times 140)]$$

$$= 43200 - 28000$$

$$\boxed{A = 15200\ mm^2}$$

(2) Direct stress $(\sigma_0) = \frac{P}{A} = \frac{500 \times 10^3}{15200}$

$$\therefore \boxed{\sigma_0 = 32.89\ N/mm^2}$$

(3) Bending stress $(\sigma_b) = \frac{My}{I_{xx}}$ — (A)

∴ Bending moment $= (M) = P \times e$

$$M = 500 \times 10^3 \times 30$$

$$= 15 \times 10^6\ N\text{-}mm$$

$$y = \frac{D}{2} = \frac{180}{2} = 90\ mm$$

and

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

$$= \left[\frac{240 \times (180)^3}{12} - \frac{200 \times (140)^3}{12}\right]$$

$$= 116.64 \times 10^6 - 45.73 \times 10^6$$

$$I_{xx} = 70.91 \times 10^6\ mm^4$$

put all values in eqn (A) becomes.

$$\sigma_b = \frac{My}{I_{yy}} = \frac{15\times10^6\times90}{70.91\times10^6}$$

$$\boxed{\sigma_b = 19.04\ N/mm^2}$$

(4) i) maximum stress $(\sigma_{max}) = \sigma_0 + \sigma_b$

$$\sigma_{max} = 32.89 + 19.04$$

$$\boxed{\sigma_{max} = 51.93\ N/mm^2}$$

ii) minimum stress $(\sigma_{min}) = \sigma_0 - \sigma_b$

$$\sigma_{min} = 32.89 - 19.04$$

$$\boxed{\sigma_{min} = 13.85\ N/mm^2}$$

Q.8) A rectangular column 150mm wide and 100mm thick carries a load of 150 KN at an eccentricity of 50mm in the plane bisecting thickness. find maximum and minimum intensities stress in the section. (Q.3 d at S.25)

⇒ Given :-
1) width (b) = 150mm
2) Thickness (d) = 100mm
3) P = load = 150 KN = 150×10^3 N
4) Eccentricity (e) = 50mm

To find :- ① σ_{max} = ? ② σ_{min} = ?

Sol^n ① A = Area = $b\times d$ = 150×100 = $15\times10^3\ mm^2$

$$A = 15000\ mm^2$$

② Direct stress $(\sigma_0) = \frac{P}{A} = \frac{150\times10^3}{15000} = 10\ N/mm^2$ (Compression)

(3) Bending stress $(\sigma_b) = \dfrac{M \times y}{I_{yy}}$ — (A)

i) M = Bending moment = $P \times e$

$$M = 150 \times 10^3 \times 50$$

$$M = 7.5 \times 10^6 \ N.mm.$$

ii) $y = \dfrac{b}{2} = \dfrac{150}{2} = 75.00mm = \underline{\underline{75mm}}$

iii) moment of inertia about y-y Axis.

$$I_{yy} = \frac{db^3}{12} = \frac{150 \times (100)^3}{12}$$

$$I_{yy} = 28.125 \times 10^6 \ mm^4$$

from eqn (A) becomes

$$\sigma_b = \frac{7.5 \times 10^6 \times 75}{28.125 \times 10^6}$$

$$\boxed{\sigma_b = 20 \ N/mm^2}$$

(4) i) $\sigma_{max} = \sigma_0 + \sigma_b = 10 + 20 = 30 N/mm^2$

$\boxed{\sigma_{max} = 30 N/mm^2}$ — compression

ii) $\sigma_{min} = \sigma_0 - \sigma_b = 10 - 20 = -10 N/mm^2$

$\boxed{\sigma_{min} = -10 N/mm^2}$ — Tension.

The negative sign indicates $\underline{\underline{\text{tension}}}$.

Q.9) A Hollow circular steel column having external diameter 300 mm and thickness 2 mm carries an eccentric load 100 KN acting at an eccentricity of 100 mm, calculate maximum and minimum stresses. [S.26 Q.4D]

⇒ Given :- ① $D = 300$ mm
② $t = 2$ mm
③ $d = D - 2t = 300 - 2\times2 = 296$ mm
④ $P = 100$ KN $= 100\times10^3$ N
⑤ $e = 100$ mm

To find :- i) σ_{max} = ?
ii) σ_{min} = ?

Soln :- ① Area = $A = \frac{\pi}{4}(D^2 - d^2)$

$= \frac{\pi}{4}\left[(300)^2 - (296)^2\right]$

$= 1872.4$ mm²

② Direct stress $(\sigma_0) = \frac{P}{A}$

$= \frac{100\times10^3}{1872.4}$

$\sigma_0 = 53.41$ N/mm²

③ Bending stress $(\sigma_b) = \frac{My}{I}$

∴ i) Bending moment $(M) = P \times e$

$= 100\times10^3 \times 100$

$= 10\times10^6$ N mm

ii) $y = \frac{D}{2} = \frac{300}{2} = 150$ mm

iii) $I = \frac{\pi}{64}(D^4 - d^4)$

$$I = \frac{\pi}{64}\left[(300)^4 - (296)^4\right]$$

$$= \underline{2.067 \times 10^7 \ mm^4}$$

from eq^n (A) becomes.

$$\sigma_b = \frac{10 \times 10^6 \times 150}{2.067 \times 10^7}$$

$$\boxed{\sigma_b = 72.56 \ N/mm^2}$$

(4) i) maximum stress $(\sigma_{max}) = \sigma_o + \sigma_b$

$$\therefore \sigma_{max} = 53.41 + 72.56$$

$$\boxed{\sigma_{max} = 125.97 \ N/mm^2} \text{ — Compression}$$

ii) Minimum stress $(\sigma_{min}) = \sigma_o - \sigma_b$

$$= 53.41 - 72.56$$

$$\boxed{\sigma_{min} = -19.15 \ N/mm^2} \text{ — Tension}$$

$\therefore$ Negative sign indicates tension.

Q.10] A solid circular column of diameter 150 mm carries a vertical load of 50 KN at outer edge of the column. Calculat σ_{max} and σ_{min}. [W.25 Q.5.C - 6 marks]

⇒ Given: ① $D = 150$ mm

② $P = 50 \times 10^3$ N

③ Load acts at outer edge of column.

∴ eccentricity $(e) = \frac{D}{2} =$

∴ $e = \frac{150}{2} = 75$ mm

To find

① $\sigma_{max} = ?$

② $\sigma_{min} = ?$

Sol^n: i) $A = \frac{\pi}{4} D^2 = 0.7854 (150)^2$

$A = 17671.46 \text{ mm}^2$

ii) Direct stress $(\sigma_0) = \frac{P}{A} = \frac{50 \times 10^3}{17671.46}$

$(\sigma_0) = 2.83 \text{ N/mm}^2$

iii) Bending stress $(\sigma_b) = \frac{M \times y}{I}$ — (A)

(a) Bending moment (M)

$M = P \times e = 50 \times 10^3 \times 75$

$= 3.75 \times 10^6$ N.mm

(b) y = Distance from extreme fibre,

$y = \frac{D}{2} = \frac{150}{2} = 75$ mm

(c) Moment of inertia for solid circular section

$I = \frac{\pi}{64} \times D^4 = \frac{\pi}{64} (150)^4$

$= 2.485 \times 10^6 \text{ mm}^4$

from eq^n (A) becomes.

Bending stress (σ_b) = $\frac{M \cdot y}{I}$

$$\therefore \sigma_b = \frac{(3.75 \times 10^6)(75)}{2.485 \times 10^6}$$

$$\underline{\underline{\sigma_b = 11.32 \ N/mm^2}}$$

(4) i) maximum Stress (σ_{max}) = $\sigma_0 + \sigma_b$

$$\therefore \sigma_{max} = 2.83 + 11.32$$

$$\boxed{\sigma_{max} = 14.15 \ N/mm^2} \text{ — Compression}$$

ii) Minimum stress (σ_{min}) = $\sigma_0 - \sigma_b$

$$\therefore \sigma_{min} = 2.83 - 11.32$$

$$\boxed{\sigma_{min} = -8.49 \ N/mm^2} \text{ — Tension}$$

Q.12) Determine the limit of eccentricity for a hollow circular section having D = 300 mm and d = 100 mm also draw stress distribution diagram. [W-24 Q.5.B-6 marks]

⟹ Given: ① D = 300 mm
② d = 100 mm

To find:- Limit of eccentricity = (e_{lim} = ?)

Solⁿ:- No tension condition, the limit of eccentricity is give by.

$$e_{lim} = \frac{I}{A y} \quad \text{— (A)}$$

Where,
I = M.I. of given section
A = Area of section
y = Distance from extreme fibre from centroid = $\frac{D}{2}$

Q.12 Ans

(1) Area of Hollow circular section

$$A = \frac{\pi}{4}\left[D^2 - d^2\right]$$

$$= \frac{\pi}{4}\left[(300)^2 - (100)^2\right]$$

$$= 62831.85 \text{ mm}^2$$

(2) moment of inertia (I)

$$I = \frac{\pi}{64}\left[(D)^4 - (d)^4\right]$$

$$= \frac{\pi}{64}\left[(300)^4 - (100)^4\right]$$

$$= \frac{\pi}{64}\left[(8.1\times10^9) - (0.1\times10^9)\right]$$

$$I = 3.927 \times 10^8 \text{ mm}^4$$

(3) Distance from extreme fibre.

$$y = \frac{D}{2} = \frac{300}{2} = 150 \text{ mm}$$

(4) Limit of Eccentricity (e_{lim})

$$e_{lim} = \frac{I}{Ay}$$

$$= \frac{3.927\times10^8}{62831.85 \times 150}$$

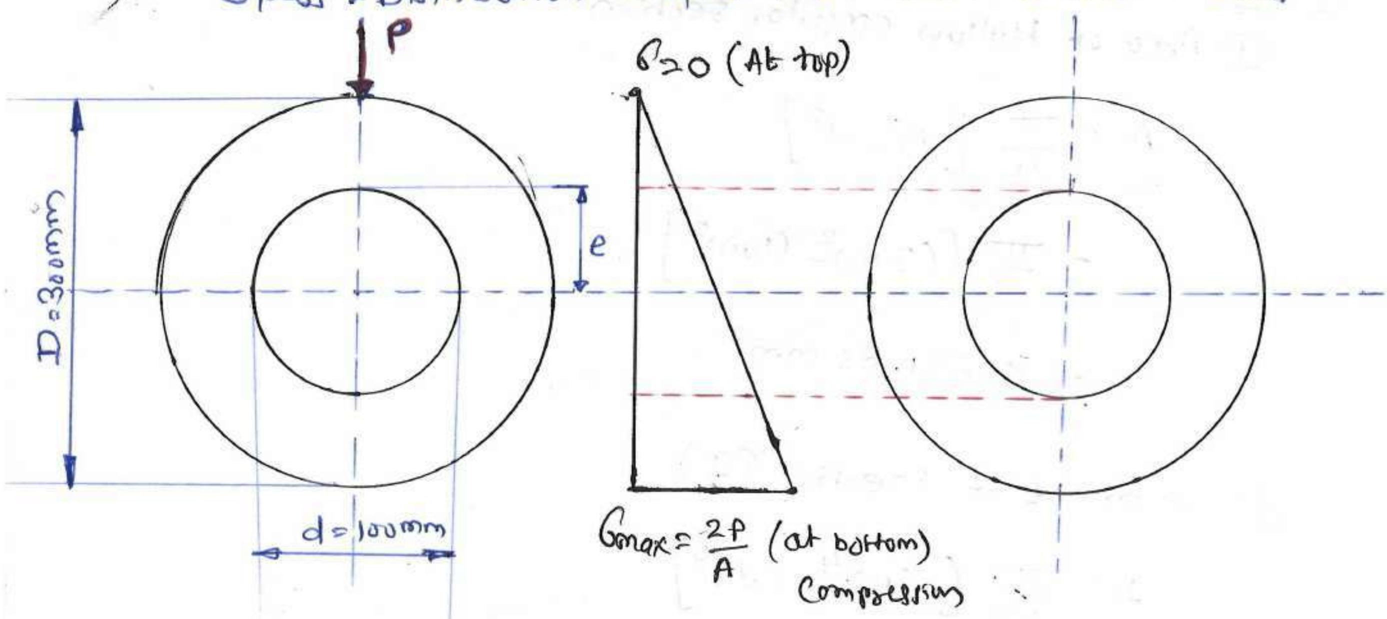
$$\boxed{e_{lim} = 41.67 \text{ mm}}$$

OR

$$e_{lim} = \frac{D^2 + d^2}{8D} = \frac{(300)^2 + (100)^2}{8\times300} = \frac{100000}{2400}$$

$$\boxed{e_{lim} = 41.67 \text{ mm}}$$

Stress - Distribution diagram for Hollow circular section.



Limit of Eccentricity
e = 41.67mm

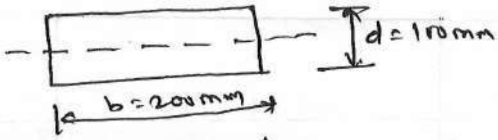
1) minimum stress, $\sigma_{min} = 0$ at the top
2) maximum stress, $\sigma_{max} = \frac{2P}{A}$ at the bottom
3) stress varies linearly from zero at top extreme fiber to maximum compression at bottom fiber.
4) Entire section is in compression.

Q.13) A rectangular column 200mm and 100 mm thick is subjected to a load of 180 kN at eccentricity of 100mm in plane bisecting the thickness. Draw the combined stress distribution diagram showing their values. [S.25, Q.6A – 6 marks]

⇒ Given :- 1) width = b = 200mm
2) thickness = d = 100mm
3) load = P = 180 kN = 180×10^3 N
4) eccentricity = e = 100mm (In plane bisecting the thickness)

Q. 13) <u>To find</u> :- i) $\sigma_{max} = ?$ iii) Combined stress distribution diagram.

ii) $\sigma_{min} = ?$



<u>Soln</u> :-

① Area = $b \times d = 200 \times 100 = 2 \times 10^4 \ mm^2$

② Direct stress $(\sigma_0) = \frac{P}{A} = \frac{180 \times 10^3}{2 \times 10^4} = 9 \ N/mm^2$

③ Bending stress = $(\sigma_b) = \frac{My}{I_{yy}}$ — Ⓐ

i) Bending moment $(M) = P \times e = 180 \times 10^3 \times 100$

$\therefore M = 18 \times 10^6 \ N \cdot mm$

ii) y (distance from extreme fibre) $= \frac{b}{2} = \frac{200}{2}$

$\therefore y = 100mm$

iii) I_{yy} = M.I. $= \frac{db^3}{12} = \frac{100 \times (200)^3}{12}$

$\Rightarrow \therefore I_{yy} = 66.67 \times 10^6 \ mm^4$

from eqn Ⓐ becomes

$\therefore \sigma_b = \frac{18 \times 10^6 \times 100}{66.67 \times 10^6} = 27 \ N/mm^2$

$\boxed{\sigma_b = 27 \ N/mm^2}$

④ i) Maximum ~~bend~~ stress $(\sigma_{max}) = \sigma_0 + \sigma_b$

$\therefore \sigma_{max} = 9 + 27 = 36 \ N/mm^2$ - Compression

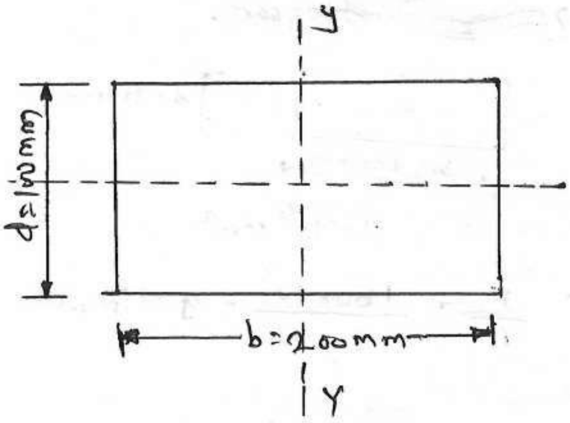
$\boxed{\sigma_{max} = 36 \ N/mm^2}$

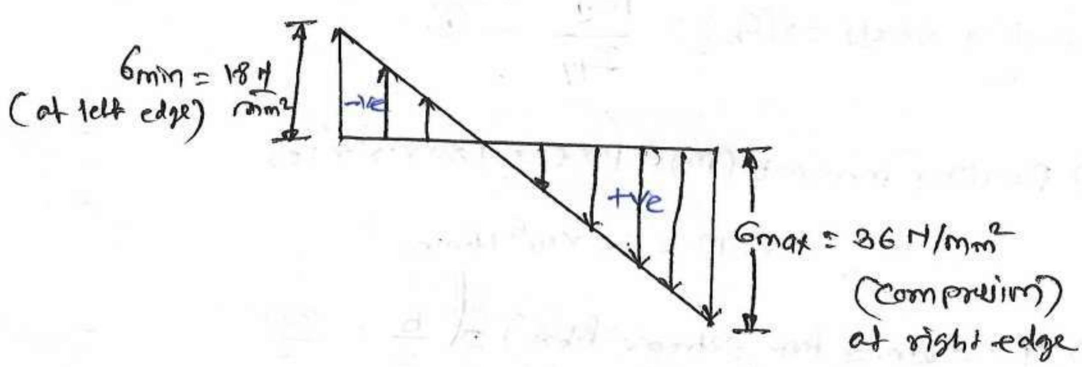
ii) minimum stress $(\sigma_{min}) = \sigma_0 - \sigma_b$

$= 9 - 27 = -18 \ N/mm^2$

$\boxed{\sigma_{min} = -18 \ N/mm^2}$ — Tension.

Q.
(13) Ans. (iii) Stress distribution diagram Rectangular section





* Fig. (a) stress distribution diagram *

—— x ——

Q.14) A rectangular pier 750 mm X 1000 mm is subjected to a compressive load of 500 KN with an eccentricity of 250 mm along the axis bisecting 1000 mm side. Determine the resultant stresses at the base cross-section of the pier. Also Draw the resultant stress distribution diagram showing all stresses. [S.26 Q.6.C - 6 marks]

⇒ Given :- $b = 750\ mm$

$d = 1000\ mm$

$P = 500\ KN = 500 \times 10^3\ N$

$e = 250\ mm$ - along the axis bisecting 1000 mm side (ie along x-x-axis)

To find :- (1) $\sigma_{max} = ?$,

(2) $\sigma_{min} = ?$

(3) Stress distribution diagram showing all parameters.

$soln$: ① Area = $A = b \times d = 750 \times 1000 = 0.75 \times 10^6\ mm^2$

$\therefore A = \underline{\underline{0.75 \times 10^6\ mm^2}}$

② Direct stress $(\sigma_0) = \frac{P}{A} = \frac{500 \times 10^3}{0.75 \times 10^6}$

$\therefore \sigma_0 = \underline{\underline{0.67\ N/mm^2}}$

③ Bending stress $(\sigma_b) = \frac{My}{I_y}$ — (A)

i) Bending moment $(M) = P \times e$

$\therefore M = 500 \times 10^3 \times 250$

$= \underline{\underline{125 \times 10^6\ N \cdot mm}}$

ii) $y = \frac{b}{2} = \frac{750}{2} = \underline{\underline{375\ mm}}$

↓ Distance from extreme edge

iii) Moment of Inertia about y-y axis

$\therefore I_{yy} = \cancel{\frac{bd^3}{12}} = \frac{db^3}{12}$

$\therefore I_{yy} = \frac{1000 \times (750)^3}{12} =$

$\boxed{I_{yy} = 35.156 \times 10^9\ mm^4}$

from eqn (A) becomes,

$\sigma_b = \frac{125 \times 10^6 \times 375}{35.156 \times 10^9}$

$\boxed{\sigma_b = 1.336\ N/mm^2}$

(4) i) Maximum Stress (σ_{max}) = $\sigma_0 + \sigma_b$

∴ $\sigma_{max} = 0.67 + 1.336$

$\boxed{\sigma_{max} = 2.003\ N/mm^2}$ — (Compression at right edge)

ii) Minimum stress (σ_{min}) = $\sigma_0 - \sigma_b$

∴ $\sigma_{min} = 0.67 - 1.336$

$\boxed{\sigma_{min} = -0.669\ N/mm^2}$ — (Tension at left edge)

(5)

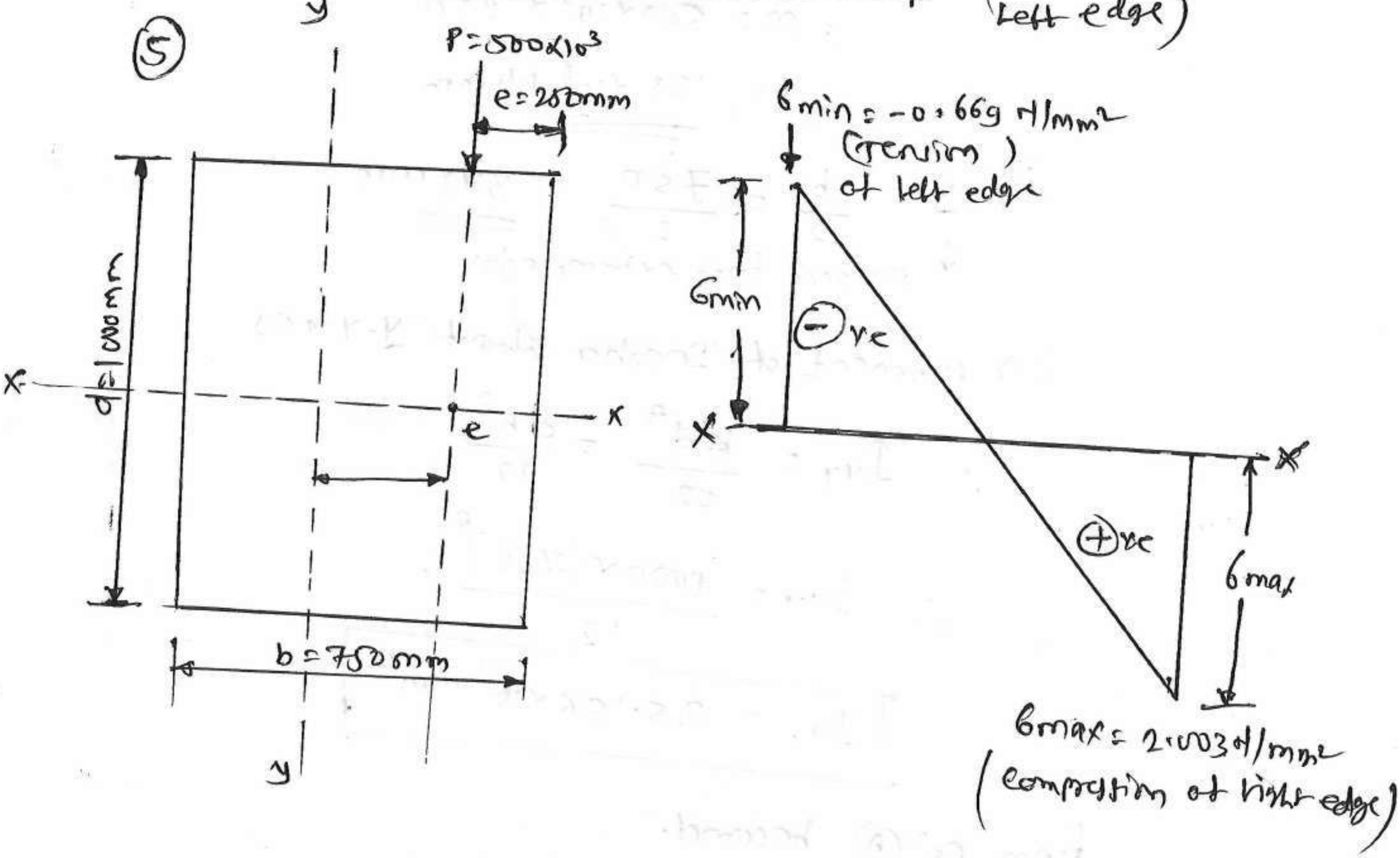


Fig. (a) shows stress distribution diagram

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