A LECTURE NOTE
ON
TH 2- STRENGTH OF MATERIAL
SEMESTER -3

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Sr. Lecture Mechanical Engineering

Mechanical Engineering

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Columns with Eccentric load :-

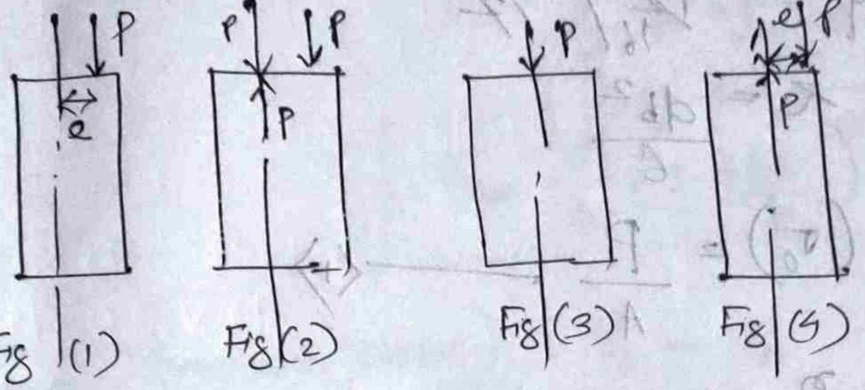


Fig (1) Fig (2) Fig (3) Fig (4)

Fig(1) — The given load P, acting at an eccentricity of (e).

fig(2) — Put two equal and opposite forces (P) along the axis of strut.

Fig (3) - One of 3 forces acting along the axis of strut which cause direct stress.

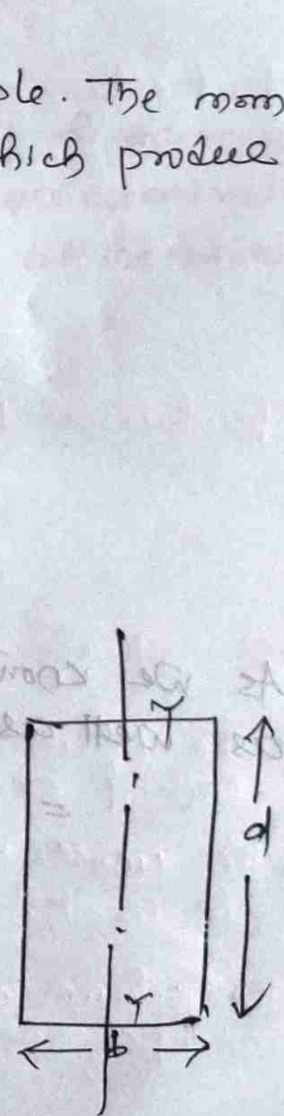
Fig (4) - The othere two forces will form a couple. The moment of this couple will be equal to $P \times e$ which produce a bending stress.

Maximum & Minimum stress

Let P = Eccentric load on the column
e = eccentricity of load
b = width of column
d = depth/thickness of column

Area of column section $A = b \times d$

Moment of inertia of column about Y-Y axis $I = \frac{db^3}{12}$



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From section modulus

$$Z = \frac{I}{Y} = \frac{db^3}{12} \Big/ \frac{b}{2}$$

$$Z = \frac{db^2}{6}$$

Direct stress $(\sigma_0) = \dfrac{P}{A}$ ⟶ ⟨1⟩

from bending eq^n $\dfrac{M}{I} = \dfrac{\sigma_b}{Y}$

$$\sigma_b = \frac{M \times Y}{I}$$

$$= \frac{M}{(I/Y)} \qquad \left\{ M = P \times e \right.$$

$$= \frac{P \times e}{db^2/6}$$

$$= \frac{6Pe}{db \cdot b}$$

$$= \frac{6Pe}{A \cdot b} \longrightarrow \langle 2 \rangle$$

As we know eccentric load causes direct stress as well as bending stress, Thus total stress

$$= \sigma_0 \pm \sigma_b$$

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σ_{max} (maximum stress) $= \sigma_0 + \sigma_b$

$$= \frac{P}{A} + \frac{6Pe}{Ab}$$

$$\boxed{\sigma_{max} = \frac{P}{A}\left(1 + \frac{6e}{b}\right)}$$

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

$$= \frac{P}{A} - \frac{6Pe}{A \cdot b}$$

$$\boxed{\sigma_{min} = \frac{P}{A}\left(1 - \frac{6 \cdot e}{b}\right)}$$

A rectangulare column of width 120mm and of thickness 100mm carreies a point load of 120KN at an eccentricity of 10mm. Determine the max & min stress at the base of column.

Data Given

$b = 120$ mm

$t = 100$ mm

$P/W = 120KN = 120 \times 10^3 N$

$e = 10$ mm

$$\sigma_{max} = \frac{P}{A}\left(1 + \frac{e \cdot 6}{b}\right)$$

$$= \frac{120 \times 10^3}{120 \times 100}\left(1 + \frac{10 \times 6}{120}\right)$$

$$= 15\ N/mm^2$$

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$$\sigma_{min} = \frac{P}{A}\left(1 - \frac{6.e}{b}\right)$$

$$= \frac{120\times10^3}{120\times100}\left(1 - \frac{6\times10}{120}\right)$$

$$= 5\ N/mm^2$$

Column

A membere of struckurce ore bare which carrcies an axial compressive load is called strut.

It the member of structures is vertical i.e perpendicular or inclined at 90° to the surface/horizontal is known as column.

Short column :– Column which have lengths less than 8 times there respective diameter.

Long column :– Column which have lengths more than 30 times there respective diameter.

Slenderness Ratio (K) - It is the ratio of unsupported of length of the column to the minimum radius of gyration of the crossection.

Assumptions Made in Eulers Column Theory :–

1) The column is initially perfectly straight and the load is applied axially.

2) The cross-section of the column is uniform throughout its length.

3) The column material is perfectly elastic, homogeneous & isotropic and obey Hookes Law.

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4) The length of the column is very large as compared to its lateral dimensions.

5) The direct stress is very small as compared to the bending stress.

6) The column weight will fail by buckling alone well negligible.

Crippling/ Buckling/ Critical load:-

It is the load at which the column will start to bend, is known as crippling load.

(or)

It is the max compressive load of a column can withstand before it buckles or collapses.

According Euler's column theory

~~l = length of column~~
~~p = actual lo.~~

l = actual length of column
l_e = effective length
P = load on column
E = Young's Modulus
I = Moment of inertia

$$\boxed{\text{Crippling load / Buckling load} = \frac{\pi^2 E I}{l_e^2}}$$

Effective Length (*Le*)

Sr. No.	End Condition	Eff. Length	Euler's Formula
1	Both Ends Fixed	Le = L/2	$P_E = \frac{4\,\pi^2\,E\,I_{min}}{L^2}$
2	One end is Fixed and Other End Hinged	Le = L/$\sqrt{2}$	$P_E = \frac{2\,\pi^2\,E\,I_{min}}{L^2}$
3	Both Ends Hinged	Le= L	$P_E = \frac{\pi^2\,E\,I_{min}}{L^2}$
4	One end is Fixed and Other is free	Le= 2L	$P_E = \frac{\pi^2\,E\,I_{min}}{4L^2}$