FAQ's

1. Give the Rankine's formula and explain the terms?

$$P = \frac{S}{1+\alpha\left(\frac{l}{r}\right)^2}$$

Where,

p = allowable unit stress for the column

$s = \sigma_c/A$

σ_c= crushing stress of column material

A = crossectional area of the column

a = Rankine's constant

l = length of column

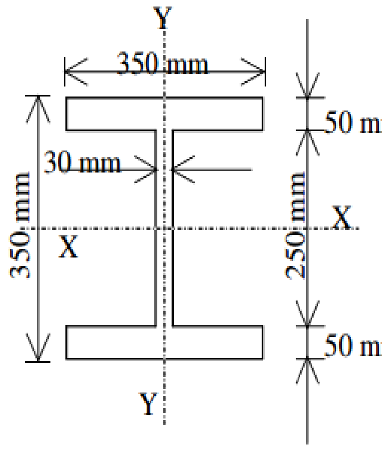
r = radius of gyration in reference to an axis normal to a plane in which flexure takes place

2. Give the expression of factor of safety?

Factor of safety = crippling load / safe load

Factor of safety is a term describing the load carrying capacity of a system beyond the expected or actual loads. Essentially, the factor of safety is how much stronger the system is than it usually needs to be for an intended load. Safety factors are often calculated using detailed analysis because comprehensive testing is impractical on many projects, such as bridges and buildings, but the structure's ability to carry load must be determined to a reasonable accuracy.

3. A steel column with a height of 8 m is fixed at its bottom. At the top of the column, it is braced in its weaker direction and it is free to move in its stronger direction. The cross-section of the column is shown in the figure. Determine the allowable load that the column can carry if a factor of safety of 3 is used. Use E = 205 GPa and σ_{yield} = 275 MPa.



Area of the section, $A = (350^2 - 320*250) = 42500\ mm^2$
Moment of Inertia $I_{xx} = (350^4 - 320*250^3) / 12 = 8.339*10^8\ mm^4$
Moment of Inertia $I_{yy} = 2*50*350^3 / 12 + 250*30^3 / 12 = 3.579*10^8\ mm^4$

Effective length when buckling about x-x axis,
$l_{ex} = K_x*L = 2*8 = 16$ m (Fixed – Free support condition)

Effective length when buckling about y-y axis,
$l_{ey} = K_y*L = 0.707*8 = 5.656$ m (Fixed – Pinned support condition)

Buckling load about x-x axis,

$$\boldsymbol{P_{crx} = \frac{\pi^2 EI_{xx}}{l_{ex}^{\ 2}} = \frac{\pi^2 \cdot 205x10^3 \cdot 8.339x10^8}{16000^2} = 6590600\ N\ =\ 6590.6\ kN}$$

Buckling load about y-y axis,

$$\boldsymbol{P_{cry} = \frac{\pi^2 EI_{yy}}{l_{ey}^{\ 2}} = \frac{\pi^2 \cdot 205x10^3 \cdot 3.579x10^8}{5656^2} = 22635800\ N\ =\ 22635.8\ kN}$$

As $P_{crx} < P_{cry}$, the buckling load of the column is:-
$P_{crx} = 6590.6$ kN

$\sigma_{cr} = P_{crx} / A = 6590.6*10^3 / 42500 = 155.1\ N/mm^2$
$< \sigma_y = 275\ N/mm^2$
$\therefore$ Euler's Formula can be used.

$P_{allow} = P_{crx} / F.S. = 6590.6 / 3 = 2196.9$ kN

4. A circular hollow aluminum tube is used as an axially loaded column. The column is fixed at the bottom and is pinned at the top. The tube is 4.5 m long, has an outside diameter of 60 mm and an inside diameter of 40 mm. Calculate the allowable load that the column can carry if a factor of safety of 2.5 is used. Use E = 75 GPa and σ_{yield} = 150 MPa.

Effective length $l_e = K*L = 0.707*4.5 = 3.1815\text{m}$

Cross-sectional area = $\frac{\pi}{4}\left(60^2 - 40^2\right) = 1571\ \text{mm}^2$

$$I = \frac{\pi}{64}\left(60^4 - 40^4\right) = 510509\ \text{mm}^4$$

The Euler buckling load is:-

$$P_{cr} = \frac{\pi^2 EI}{l_e^{\,2}} = \frac{\pi^2 \cdot 75x10^3 \cdot 510509}{3181.5^2} = 37330N \quad = 37.33\ \text{kN}$$

The critical stress is:-

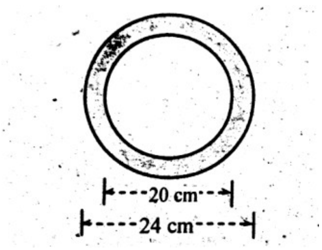
$$\sigma_{cr} = \frac{P_{cr}}{A} = \frac{37330}{1571} = 23.8\ \text{MPa} < \sigma_{\text{yield}} = 150\ \text{MPa}$$

$\therefore$ **Euler formula can be used.**

The allowable load is:-

$P_{allow} = P_{cr}$ / F.S. = 37.33 / 2.5 = 14.93 kN

5. A column of a building looks not safe. CEO of a company hired civil engineer to check whether the column is safe or not. Column is of mild steel whose length is 3 meters and both ends are fixed. Load coming on that column is 400 N. Critical stress coming on that column is 320×10^2 N/m^2. Cross-section of column can be shown below. Now, check whether column is safe or not?



External diameter of a column = D = 24 cm

Internal diameter of a column = d = 20 cm

Length of column = L = 3m = 300 cm

Critical Stress = fc = 320 x 10^6 N/m^2

As column is of mild steel. Value of Rankine's Constant;

a = 1/7500

First, calculate the equivalent length(effective length);

Equivalent Length
$l = L/2 = 300/2$
Equivalent Length = 150 cm

Cross-section Area
$A = \pi(D^2 - d^2)/4$
Put value of external and internal diameter.

$A = \pi(24^2 - 20^2)/4$
$A = 138.23\ cm^2$

Now, calculate the least moment of inertia. In the design of columns, least radius of gyration is used. For that, take least value of moment of inertia.

Least moment of Inertia $= I = \pi(D^4 - d^4)/64$
Put the required values;

Least moment of Inertia $= I = \pi(24^4 - 20^4)/ 64$
I=8432.035 cm4

Now put values of I& A in least radius of gyration formula;

K = 7.81 cm
Crushing Load
Use Rankine's Formula for the calculation of critical load;

$P = f_c A_1 + a(lk)^2$
By placing values;

$P = 32\times 138.231 + (17500)(1507.81)^2$
Crushing Load = P = 4216 N