## Elastic Instability of Columns

1. A column with a length of 7.2m has a tubular cross section with internal radius 70mm and external radius of 75mm. It is to be used as a pin-ended column carrying compressive load along its axis. The material is steel with elastic limit at 250MPa and Young's modulus 200GPa. Find out the maximum allowable axial load so that it does not buckle.
2. For P=5.2kN, determine the factor of safety for the structure shown in Fig. 1. Assume E = 200GPa and consider buckling only in the plane of structure.

| Member | Diameter (mm) | Length (m) |
|---|---|---|
| AB | 18 | 1.2 |
| AC | 18 | 1.2 |
| BC | 22 | $1.2\sqrt{2}$ |

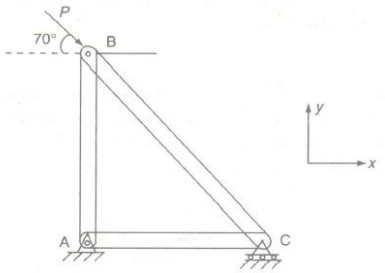


**Fig. 1**

3. A column with rectangular cross-section is pin-supported at its ends (Fig. 2). It is restrained in the plane of the figure but free to deflect in a plane perpendicular to it. Find out the ratio h:b such that the critical load is same for buckling in two principal planes of the column.

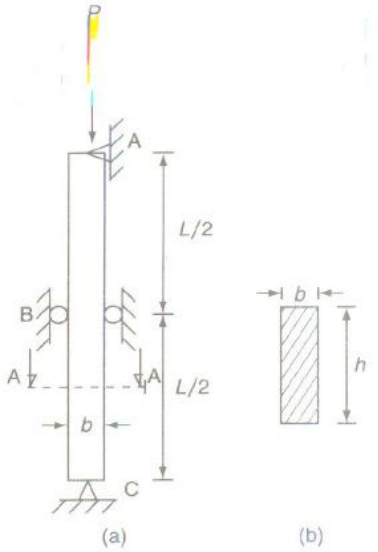


**Fig. 2.**

4. Determine the l/r ration for the following two columns.

(i). A square column, of side 300mm and length 4m, with both ends hinged.

(ii). A hollow circular cross section column of outer diameter 300mm, thickness 5cm, and length 6m, with one end fixed and other end hinged.

5. Determine the safe load that can be carried by a timber column, 300mm diameter and 3m long, if both its ends are hinged. Use a factor of safety of 2.5. If the proportional limit is 35MPa, determine the minimum length up to which Euler's formula can apply. E = 12 GPa.
6. A hollow circular column of steel, of outer diameter 200mm and thickness 5mm, has a length of 4m, with both ends fixed. Find the Euler critical load if E = 200GPa. If the yield stress is 300MPa, determine the length below which Euler's formula cannot be applied.
7. Compare the critical stresses of columns with slenderness ratios of 40, 80, 120, 160 and 200 using Euler's formulae. E = 200 GPa and $\sigma_y$ = 320MPa.
8. An extruded nickel steel tube has outside diameter 5cm and wall thickness, 0.3cm. It is 3.6m long and to be used as a both sides pin ended column. If Young's modulus is 2.1 x $10^6$ Kg/cm$^2$, find out the critical compressive stress.

9. A steel bar has a rectangular cross-section of 2.5 cm x 5 cm. It is to be used as a column with pinned ends. What is the shortest length 'L' for which Euler's equation applies if E = 2 x $10^6$ Kg/cm$^2$ and proportional limit is 2100 Kg/cm$^2$?
10. Find the Euler's crushing load for a hollow cylinder Cast Iron column, 15 cm external diameter and 2cm thick. If it is to 6m long and hinged at both ends. E = 80GPa.
11. A column having T-section with a flange 120mm x 16mm and Web 150mm x 16mm is 3m long. Assuming the column to be hinged at both ends find the crippling load using Euler's formula. E = 200GPa.
12. A T-section 150 mm x 120 mm x 20 mm is used as a strut of 4 m long with hinged at its both ends. Calculate the crippling load if modulus of elasticity for the material be 2.0 x $10^5$ N/mm$^2$.
13. A tubular strut pin-jointed at both ends has outer and inner diameters as 40mm and 36mm, respectively and is 2.4m long. Compare the crippling loads given by Euler's and Rankine's formulae. Consider E = 204 GPa and Yield Stress = 310MPa, a = 1/7500. Also find the length below which the Euler's formulae cease to apply.
14. Determine the maximum allowable load P that may be applied to the aluminum frame shown in Fig. 3. Use Euler's formula and take factor of safety as 2.5. E = 70GPa.

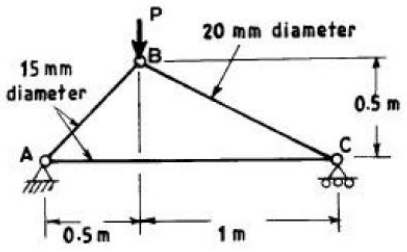


**Fig. 3.**

15. The capacity of the jib crane is given as 20 kN as shown in Fig. 4. What size of steel pipe AB should be used if thickness/diameter ratio of the pipe is 1/10 and E = 200 GPa. Use Euler's formula with a factor of safety 2.5 and neglect the self weight.

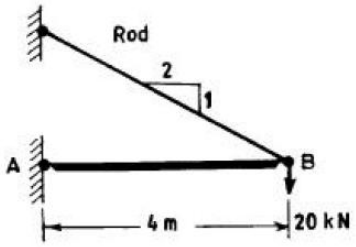


**Fig. 4.**

16. A solid round bar of 60 mm diameter and 2.5 m long is used as a strut. Find the safe compressive load for the strut using Euler's formula if (a) both ends are hinged (b) both ends are fixed. Take E = 2 × 105 N/mm$^2$ and factor of safety = 3.
17. What is the ratio of the strength of a solid steel column of 150 mm diameter to that of a hollow circular steel column of the same cross-sectional area and a wall thickness of 15 mm? The two columns have the same length and similar end conditions.
18. Using Euler's formula, find the ratio of the critical load of a solid circular column to that of hollow circular cross-section (inner diameter is 0.8 times external diameter) for identical end conditions and length. Both columns have equal area of cross-section.
19. A column of length L and rectangular cross-section (a x b) has a fixed end B and support a centric load at A as shown in Fig. 5. Two smooth and rounded fixed plates restrain end A from moving in one of the plane of symmetry of the column and allow it to move in the other plane. Determine the ratio a/b for most efficient design against buckling.

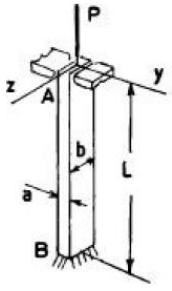


**Fig. 5.**

20. The effective length of a composite column shown in Fig. 6 is 5m. Obtain the dimension b so that the column has equal chances of buckling along the principal directions. Determine the safe load carrying capacity of the column. Take E = 200 GPa and factor of safety as 2.

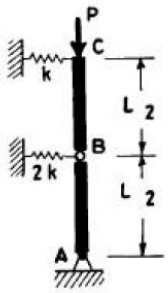


**Fig. 6.**

21. Find the Euler's crushing load for a hollow cylindrical cast iron column 120 mm external diameter and 20 mm thick, if it is 4.2 m long and is hinged at both ends. Take E = 80 kN/mm2. Compare this load with the crushing load as given by Rankine's formula using constants fc = 550 N/mm$^2$ and a = 1/1600. For what length of strut does the Euler's formula cease to apply?
22. An ISLB 300 section is provided with a flange plate 200 mm × 12 mm for each flange. The composite member is used as a column with one end fixed and the other end hinged. Calculate the length of the column for which, crippling loads given by Rankine's formula and Euler's formula will be the same. Take E = 210 kN/mm$^2$, fc = 330 N/mm$^2$, a = 1/7500. Properties of ISLB 300 section are: Overall width = 150 mm, Overall depth = 300 mm, Thickness of flange = 9.4 mm, Thickness of web = 6.7 mm, Ixx = 73.329 × 10$^6$ mm$^4$, Iyy = 3.762 × 10$^6$ mm$^4$, A = 4808 mm$^2$.
23. A built up steel column, 8 m long and ends firmly fixed is having cross-section as shown in Fig. 7. The properties of I-section are Area = 9300 mm$^2$, Ixx = 3 × 10$^6$ mm$^4$, Iyy = 8.4 × 10$^6$ mm$^4$. Determine:
    (i). The safe axial load the column can carry with a factor of safety of 3.5 using (a) Euler's Formula, (b) Rankine's Formula.
    (ii). The length of the column for which both formulae give the same crippling load.
    (iii). The length of the column for which the Euler's formula ceases to apply. Take E = 2 × 10$^5$ N/mm$^2$, $f_c$ = 330 N/mm$^2$, a = 1/7500

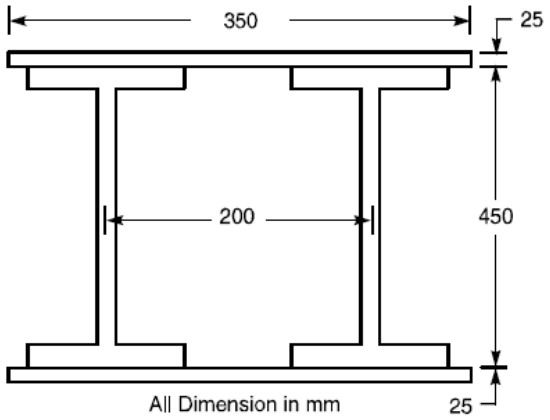


**Fig. 7:** A built-up steel column

24. A hollow circular column of internal diameter 20 mm and external diameter 40 mm has a total length of 5m. One end of the column is fixed and the other end is hinged. Find out the crippling stress of the column if $E$ = 2 × 10$^5$ N/mm$^2$. Also find out the shortest length of this column for which Euler's formula is valid taking the yield stress equal to 250 N/mm$^2$
25. A cast iron hollow cylindrical column 3 m in length when hinged at both ends, has a critical buckling load of P kN. When this column is fixed at both the ends, its critical load rises to P+300 kN. If the ratio of external diameter to internal diameter is 1.25 and E = 1.0x10$^5$ N/mm$^2$. Determine the external diameter of the column.