EXPERIMENT NO. 4(A)
SLENDER COLUMN TEST

OBJECTIVES

a. To find the critical load of slender columns for different end conditions.

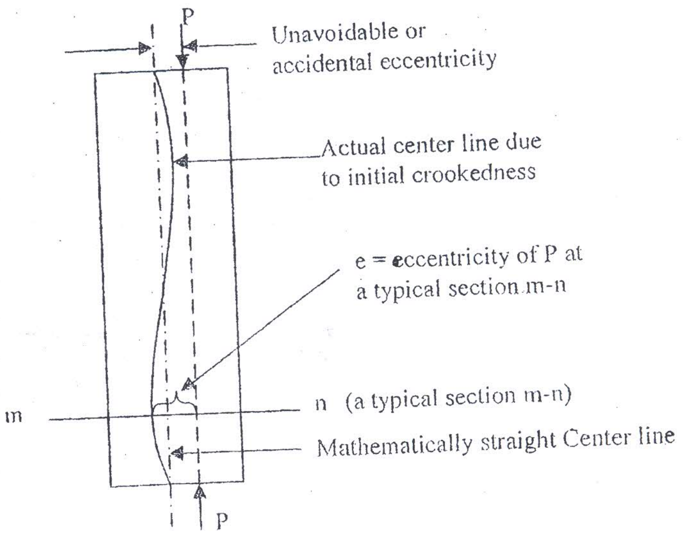
b. Compare the experimental critical load with that given by the Euler's equation.

THEORY

Column is a compression member that is very slender compared to its length. Under compressive load column fails by buckling. Buckling loads are considerably less than those required to cause failure by crushing. A compression member is generally considered to be a column when its unsupported length is more than 10 times its least lateral dimension.

Columns may be subdivided into three groups – long, intermediate and short compression block. Long columns fail by buckling or excessive lateral bending; intermediate columns by a combination of buckling and crushing; short compression blocks by crushing.

Theoretically, a slender column is a perfectly straight, homogeneous slender member having its ends held against movement in certain directions. Actual columns will always have small imperfections of material and fabrication as well as unavoidable accidental eccentricities of load.



Figire-1: Factors contributing to eccentricity of loads in columns.

The initial crookedness of the column together with the placement of the load causes an indeterminate eccentricity of e with respect to the centroid of a typical section m-n. The resultant stress is due to a combination of a direct compressive and a flexural stress. For this reason, slender columns under axial load will have a tendency to buckle or bend. The load which is just sufficient to hold the column in a bent condition is called the critical load or buckling load for the column. It is also the greatest load the column will support. Theoretically, the critical load P for slender column is given by Euler's Formula –

$$P_{cr} = \frac{\pi^2 EI}{L_e^2} \text{ or, } \frac{P_{cr}}{A} = \frac{\pi^2 E}{(L_e/k)^2},$$

In the above expression

P = Axial load

A = Cross-sectional area of the column

Le = Effective length of the column, depends on the loading condition

K = Least radius of gyration

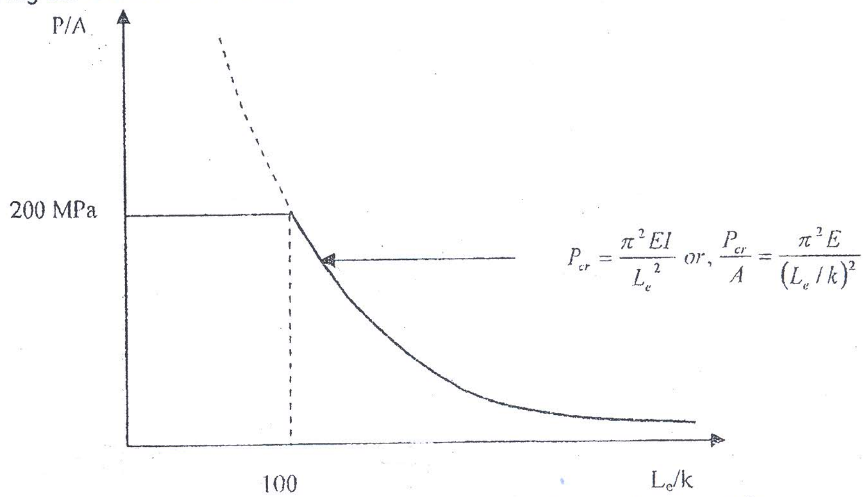
E = Modulus of elasticity of column material

The ration (L_e/k) is called the slenderness ratio of the column. For circular cross-section, $k = \frac{d}{4}$, where d is the diameter of the column. For mild steel that has a proportional limit of about 200 MPa and E = 200 GPa, the limiting slenderness ratio is,

$(L_e/k)^2 = (200000 \times \pi^2)/200 = 10000$ or $(L_e/k) = 100$.

The Euler's equation is only valid if $(L_e/k) \geq 100$ for mild steel

The following curve shows the relation between the critical stress $(P/A)_{cr}$ with the slenderness ratio.



Figire-2: Variation of critical stress with slenderness ratio.

This table shows the effective length of column for different end conditions

End Condition	Effective Length (L_e)
Fixed end	½ L
One end fixed, the other hinged	0.7 L
Both ends hinged	L
One end fixed, the other end free	2 L

* Buckling is also termed as instability of equilibrium.

SPECIMEN

M. S. Columns of different lengths.

APPARATUS

1. Dead weight column testing apparatus
2. Grips for different end conditions

3. Slide calipers
4. Steel tape etc.

DIFFERENT LOADING CONDITIONS

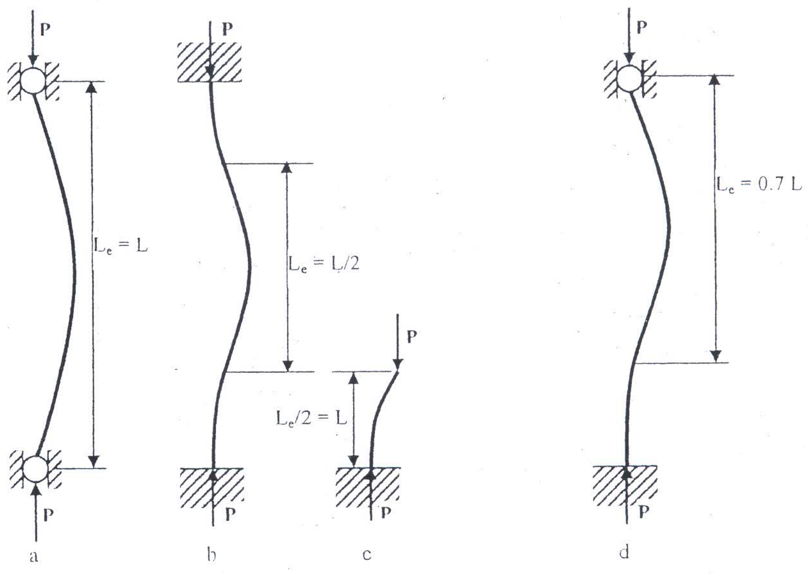
Figure 3 shows different end conditions of the columns.

a - Both ends hinged

b - Both ends fixed

c - One end fixed, other end free

d - One end fixed, other end hinged



Figire-3: Different end conditions.

PROCEDURE

1. First check whether the top sliding spindle moves smoothly. Also take the weight of the spindle.
2. Measure the dimensions (length and diameter) of the columns to be tested.
3. Position the column between the bottom and top grippers of the apparatus for a certain end condition. Calculate its theoretical P_{cr}.
4. Put loads step-by-step on the sliding spindle. Record load.
5. At each step of loading apply small lateral force (knock) at the middle (approximately) of the column and check whether the column straightens back.
6. Find out the load at which column does not straighten back after the knock. This is the critical load.
7. Place this column by changing the grips to change the end condition and repeat the steps to find the critical load.
8. Do the same procedure for other columns to find the critical load at different end conditions.
9. Plot the graph of experimental and theoretical buckling loads versus slenderness ratios for each end conditions and compare them.

DATA TABLE

Table-1

No. of Observations	Column Length L (mm)	Diameter D (mm)	Cross-Sectional Area A (mm2)	Moment of Inertia $I = (\pi d^4)/64$ (mm)	Radius of Gyration $K = \sqrt{(I/A)}$ (mm)
1					
2					
...					
...					

Table-2

No. of Obs.	End Cond.	Length L (mm)	Cross-Sectional Area A (mm2)	Radius of Gyration K (mm)	Slenderness Ratio (L/k)	Effective Slenderness Ratio (L_e/k)	Theoretical $P_{cr}/A = (\pi^2 E)/(L_e/k)^2$ (N/mm^2)	Measured P_{cr} (N)	Actual P_{cr}/A (N/mm^2)
1									
2									
...									

GRAPHS

Plot graphs of experimental and theoretical (i,e., Euler) buckling loads versus slenderness ratios for each end conditions.

DISCUSSIONS

Discuss on the following points.

a. Shape/pattern of the graphs.

b. Reasons if there is difference between the experimental and theoretical critical/buckling loads.

c. Effect of the test speed of the testing machine.

d. Effect of imperfection in the column.

e. Reasons of the imperfection of the column.

f. The placement of the column in the testing machine.

g. The effect of slenderness ratio.

h. The effect of end condition on the critical loads of the columns.

i. How to improve the testing procedure.

j. How to improve the critical load or buckling load.

k. Limitations of Euler's formula.

EXPERIMENT NO. 4(B)
STUDY OF BEAMS

OBJECTIVES

To find the load deflection curve of the beam with different end conditions.

THEORY

A beam is a structural member that carries transverse loads. Beams may be classified based on the types of supports as simple, cantilever, overhanging etc. The loads can also be of various types such as distributed, concentrated etc.

OBJECTIVES

To find the load-deflection curve of a cantilever beam and find the modulus of elasticity from the curve.

APPARATUS

1. Height gage
2. Dead weight
3. Test setup
4. Cantilever beams

PROCEDURE

1. Measure the beam dimensions (length and X-sectional area).
2. Apply dead weight P, gradually increase it and measure the elastic deflection δ. (At the point of maximum deflection)
3. Draw the graph of load versus deflection.
4. Find the modulus of elasticity for different beams. ($\delta = PL^3/3EI$)

QUESTIONS

1. Which physical and geometrical factors govern the elastic deflection of the beam?
2. Distinguish between a column, beam and a shaft.
3. Locate the point of maximum deflection.
4. Sketch the distribution of the normal and shear stress along the cross section of the beams used.

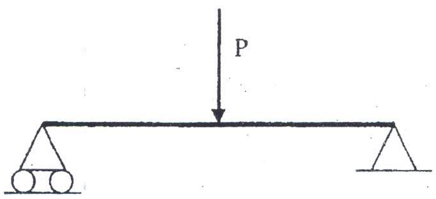


Fig – Simply supported Beam

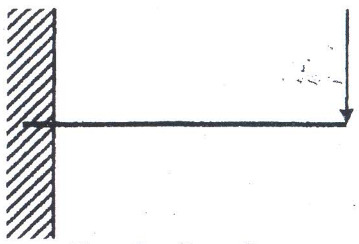


Fig – Cantilever Beam