

LABORATORY MANUAL

ENGINEERING MECHANICS LAB

ME-213-F

LIST OF EXPERIMENTS

S.No.	NAME OF EXPERIMENTS	PAGE No.	
		FROM	TO
1.	Verification of reciprocal theorem of deflection using a simply supported beam.		
2.	Verification of moment area theorem for slopes and deflections of the beam.		
3.	Deflections of a truss-horizontal deflections & vertical deflections of various joints of a pin-jointed truss.		
4.	Elastic displacements (vertical & horizontal) of curved members.		
5.	Experimental and analytical study of 3 hinged arch and influence line for horizontal thrust.		
6.	Experimental and analytical study of behavior of struts with various end conditions.		
7.	To determine elastic properties of a beam.		
8.	Experiment on a two-hinged arch for horizontal thrust & influence line for Horizontal thrust.		
9	Experimental and analytical study of a 3 bar pin jointed Truss.		
10	Experimental and analytical study of deflections for unsymmetrical bending of a Cantilever beam.		

Note:-

- 1. At least eight experiments are to be performed in the semester.**
- 2. At least six experiments should be performed from the above list. Remaining two experiments may either be performed from the above list or designed & set by the concerned institute as per the scope of the syllabus.**

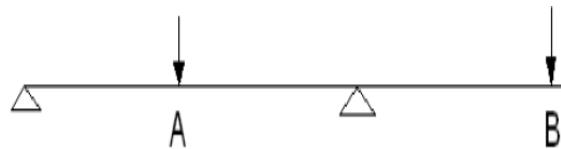
..

EXPERIMENT NO.-1

AIM:- Verification of reciprocal theorem of deflection using a simply supported beam.

Apparatus:

The model consists of a 1 meter long simply supported steel beam supported by two rigid pillars 70 cms apart with a 30 cm overhang on one side. The beam has 10 notches separated by 0.1 meter distance. Two small hangers are provided to apply the weights.



Theory:

Maxwell theorem in its simplest form states that deflection of any point A of any elastic structure due to load P at any point B is same as the deflection of beam due to same load applied at A.

It is, therefore easily derived that the deflection curve for a point in a structure is the same as the deflected curve of the structure when unit load is applied at the point for which the influence curve was obtained.

Procedure:

1. Apply a load either at the centre of the simply supported span or at the free end of the beam, the deflected form can be obtained.
2. Measure the height of the beam at certain distance by means of a dial gauge before and after loading and determine the deflection before and after at each point separately.
3. Now move a load along the beam at certain distance and for each positions of the

load, the deflection of the point was noted where the load was applied in step 1. This deflection should be measured at each such point before and after the loading, separately.

4. Plot the graph between deflection as ordinate and position of point on abscissa the plot for graph drawn in step 2 and 3. These are the influence line ordinates for deflection of the beam.

Observations:

Distance from pinned end	Load at A (Kg)	Deflection at B (mm)	Load at B (Kg)	Deflection at A (mm)

Precautions:

- i) Apply the loads without any jerk.
- ii) Perform the experiment at a location, which is away from any external disturbance.
- iii) Ensure that the supports are rigid.
- iv) Gently tap the dial gauge before observing the readings.
- v) The load applied should be within the allowed limits for the apparatus.

Result:

Compare and study both the cases. A graph can also be plotted for both the

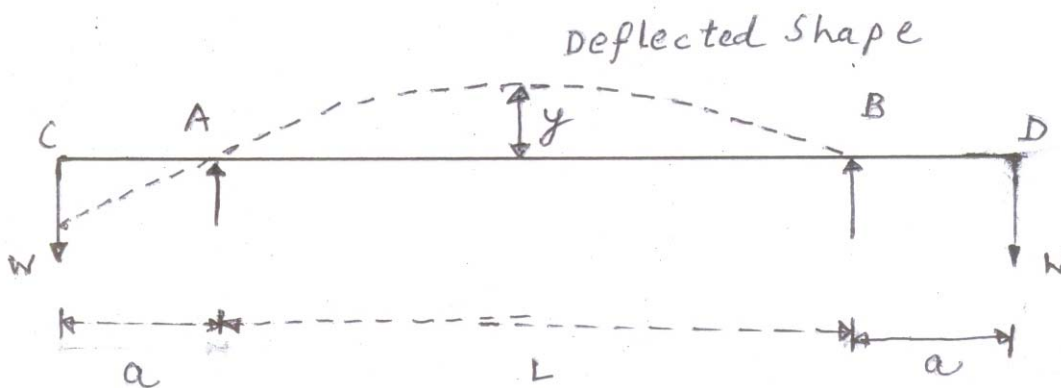
points.

EXPERIMENT NO.-2

AIM:- Verification of moment area theorem for slopes and deflections of the beam.

Apparatus:

The apparatus consists of a flexible beam supported by two rigid supports equally distant from the ends of the beam. This set up provides two over hangs at the ends of the beam. The beam has notches separated by 0.1 meter distance. Two hangers are provided at the free ends of the beam to suspend the loads at the ends.



Theory:

According to moment area theorem:

1. The change of slope of the tangents of the elastic curve between any two points of the deflected beam is equal to the area of M/EI diagram between these two points.
2. The deflection of any point relative to tangent at any other point is equal to the moment of the area of the M/EI diagram between the two point at

$$\text{Slope at B} = \frac{y_2}{b}$$

Since the tangent at C is horizontal due to symmetry,

$$\begin{aligned} \text{Slope at B} &= \text{shaded area} / EI \\ &= \frac{1}{EI} \left[\frac{Wa^2}{2} + Wa \left(\frac{L}{2} - a \right) \right] \end{aligned}$$

Displacement at B with respect to tangent at C

$$= (y_1 + y_2) = \text{Moment of shaded area about B} / EI$$

$$= \frac{1}{EI} \left\{ \left[\frac{Wa^2}{2} \left(b + \frac{2}{3}a \right) \right] + Wa \left(\frac{L}{2} - a \right) \left(b + \frac{a}{2} + \frac{L}{2} \right) \right\}$$

Procedure:

1. Measure a, b and L of the beam
2. Place the hangers at equal distance from the supports A and load them with equal loads.
3. Measure the deflection by dial gauges at the end B (y_2) and at the center C (y_1)
4. Repeat the above steps for different loads.

Observations:

Span of the beam, L =

Length of overhang on each side, a =

Modulus of elasticity, $E = 2 \times 10^6$

S. No.	Load at each hanger (Kg)	Deflection at C, y_1 (cm)	Deflection at B, y_2 (cm)	Slope at B y_2/b	Deflection at C = Deflection at B (y_1)

Calculations:

1. Calculate the slope at B as y_2/ b (measured value)
2. Compute slope and deflection at B theoretically from B.M.D. and compare with experimental values
3. Deflection at C = y_1 (measured value)

Result:

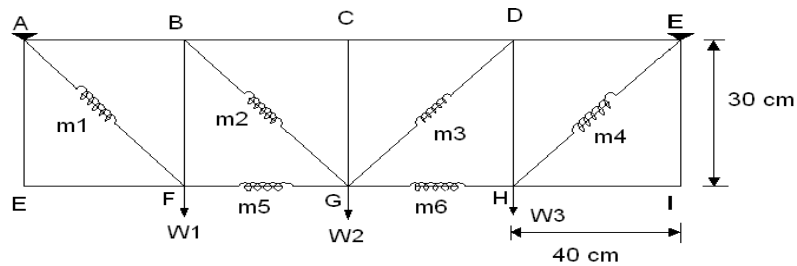
Compare the slope and deflection obtained with the slope and deflection using moment area method.

EXPERIMENT NO.-3

AIM:- Deflections of a truss-horizontal deflections & vertical deflections of various joints of a pin-jointed truss.

Apparatus:

The model consists of a 4 panel of a Pratt truss, each panel being 40cm in horizontal direction and 30cm in vertical direction. The truss is hanging and supported by joints A and E with firm supports. Load can be applied on each panel point. All tension members are provided with detachable spring so as to obtain appreciable deformation of the member. Direction of the diagonal members may be changed. Apparatus can be used to illustrate visually the nature of forces set up in various members of the truss.



Theory:

The deflection of a node of truss under a given load is given by:

$$\Delta = \sum \frac{F \cdot U \cdot L}{A \cdot E} \quad \text{----- (1)}$$

Where,

F = force in any member under the given system of loading

U = force in any member under a unit load which acts in the direction of deflection.

L = length of any member

A = area of cross section of any member

E = modulus of elasticity of the member

Here, L/AE is a property of a member, which is equal to the extension per unit load. It may be determined for each member separately by suspending a load from it and noting the extension.

Procedure:

1. Each member with a spring is isolated and its stiffness is determined by suspending a load from it and noting the extension.
2. The truss is loaded with 0.25 Kg load at each node and this is assumed to be the initial position.
3. Now additional loads are applied at the nodes where the deflection is required. The deflection is observed.
4. The deflection for the required node is calculated from the eq. (1).

Observations:

Member	Stiffness K	Load $W_1 = W_2 = W_3$	Node N_1	Node N_2	Node N_3
			Δ	Δ	Δ
m1					
m2					
m3					
m4					
m5					
m6					

Precautions:

- i) Apply the loads without any jerk.
- ii) Perform the experiment at a location, which is away from any external disturbance.
- iii) Ensure that the supports are rigid.
- iv) The load applied should be within the allowed limits for the apparatus.

Result:

The deflections at various nodes are:

$\Sigma\Delta$ for node $N_1 =$

$\Sigma\Delta$ for node $N_2 =$

$\Sigma\Delta$ for node $N_3 =$

EXPERIMENT NO.-4

AIM:- Elastic displacements (vertical & horizontal) of curved members.

Apparatus:

The apparatus consists of a steel bar which is used as different curved members viz. circle, semi circle with straight arm, quadrant of a circle and quadrant of a circle with straight arm. The bottom ends of the members are fixed to the base to impart rigidity to the structures. Under the application of a load at free end its horizontal and vertical deflection is measured with the help of a dial gauge.

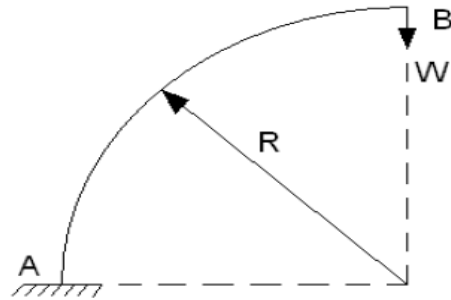
Theory:

The theorem used to find elastic displacement is the Castigliano's First Theorem which states that 'Partial derivative of the total strain in energy of a structure with respect to any force gives the displacement of the point of its application in the direction of the force.

The total strain energy of the structure is determined in terms of all other loads with their actual values and a fictitious load at the point at which the deflection is required acting in the direction of the deflection. After partial differentiation with respect to P , the actual value (if P is an actual load) of zero is substituted for P . The result is the deflection required.

a. Quadrant of a circle

Fixed at A and free at B (radius R) and subjected to a concentrated load W at free end.

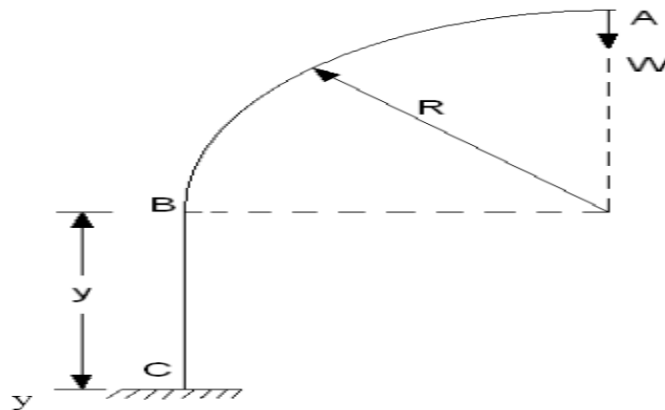


Vertical displacement of load point B = $\Delta_{BV} = \frac{\pi WR^3}{4EI}$

Horizontal displacement of load point B = $\Delta_{BH} = \frac{WR^3}{2EI}$

b. Quadrant with a straight leg

From A to B, quadrant of a circle of radius R, from B to C straight length of

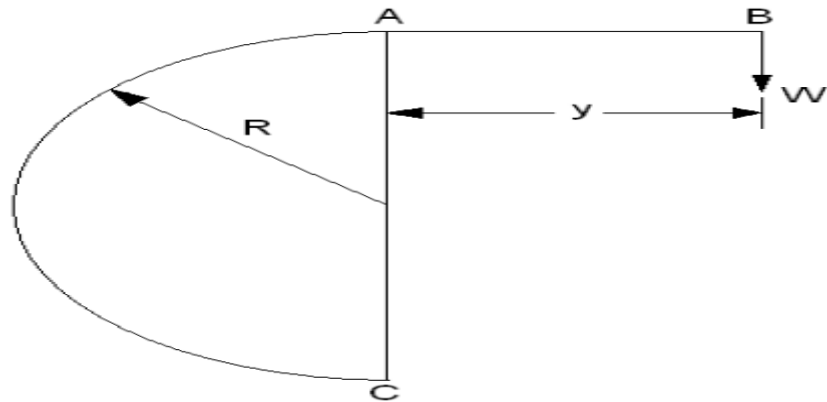


Vertical displacement of load point A = $\Delta_{AV} = \frac{\pi WR^3}{4EI} + \frac{WR^2 y}{EI}$

Horizontal displacement of load point A = $\Delta_{AH} = \frac{WR}{2EI} (R+y)^2$

c. Semi circle with straight arm

From A to C semi circle of radius R, A to B straight length of y

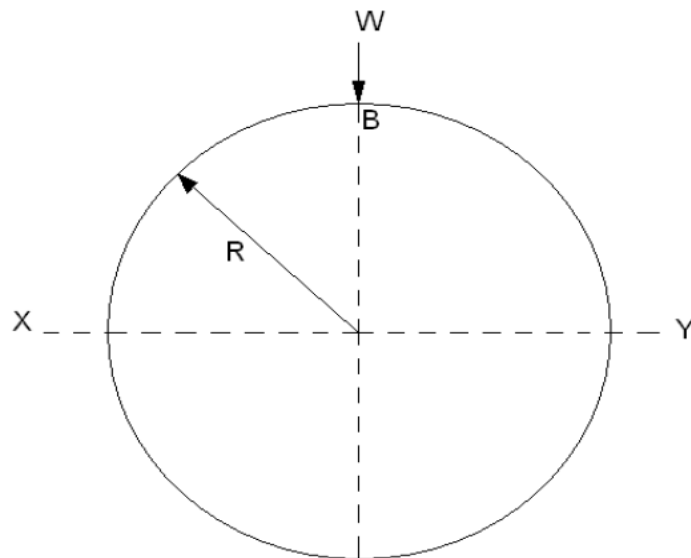


Vertical displacement of load point B =

$$\Delta_{BV} = \frac{W}{6EI} [2y^3 + 3R(2\pi y^2 + 8yR + \pi R^2)]$$

Horizontal displacement of load point B = $\Delta_{BH} = \frac{WR^2}{EI} (\pi y + 2R)$

d. Circle of radius R



Vertical displacement of loaded point B = $\Delta_{BV} = \frac{WR^3}{4\pi EI} (\pi^2 - 8)$

Procedure:

1. Place an initial load of 200gm on the hanger. Fix the dial gauge for horizontal and vertical deflections. Set the dial gauge to zero. Assume this position as initial.
2. Add load at the following rates and tabulate the values of the dial gauge readings. In the cases of quadrant, quadrant with straight arm and semi circle, 200gm steps and in the case of circle, 1kg steps.
3. Measure the vertical displacement in y-axis and the horizontal displacement in x-axis for each loading positions.
4. Repeat the process for desired no. of times for different set of loads.
5. Measure the same parameters for unloading the weights.

Width of section = d

Breadth of section = b

$$\text{Least moment of inertia, } I = \frac{bd^3}{12}$$

Modulus of elasticity, $E = 2 \times 10^6 \text{ Kg/cm}^2$

Observations:

a. Quadrant of a circle

S. No.	Load applied (Kg)	Dial gauge reading (mm)		Deflection (mm)	
		Horizontal	Vertical	Horizontal	Vertical

b. Quadrant with straight leg

S. No.	Load applied (Kg)	Dial gauge reading (mm)		Deflection (mm)	
		Horizontal	Vertical	Horizontal	Vertical

c. Semicircle with straight leg

S. No.	Load applied (Kg)	Dial gauge reading (mm)		Deflection (mm)	
		Horizontal	Vertical	Horizontal	Vertical

d. Circle with radius R

S. No.	Load applied (Kg)	Dial gauge reading (mm)		Deflection (mm)	
		Horizontal	Vertical	Horizontal	Vertical

Precautions:

- i) Apply the loads without any jerk.
- ii) Perform the experiment at a location, which is away from any external disturbance.
- iii) Ensure that the supports are rigid.
- iv) Gently tap the dial gauge before observing the readings.
- v) The load applied should be within the allowed limits for the apparatus.

Result:

Measure the value of R and straight length in each case. Find width and breadth of steel section and calculate the value of I

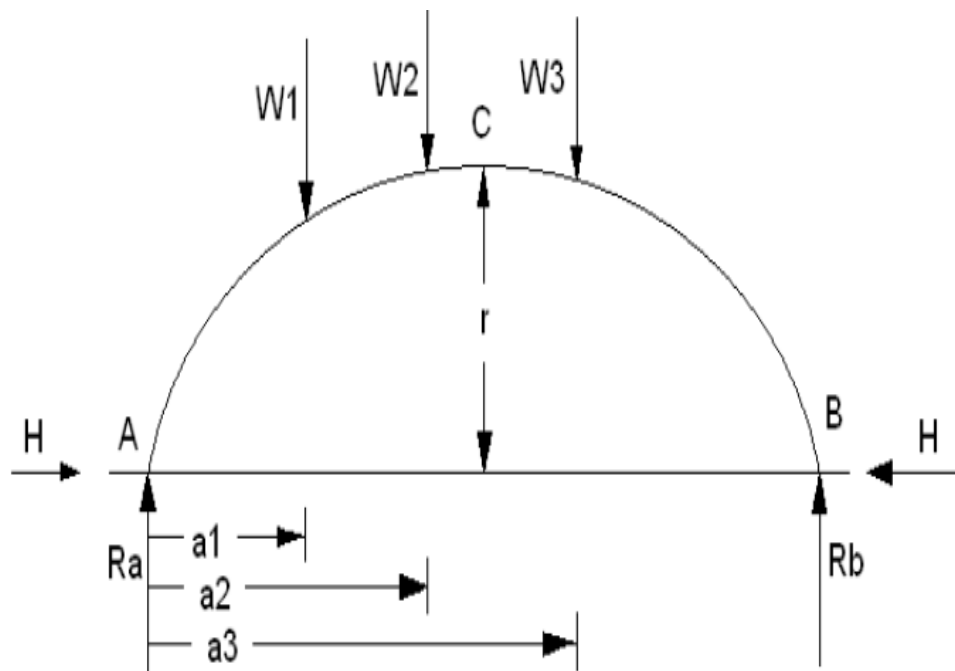
EXPERIMENT NO.-5

AIM:- Experimental and analytical study of 3 hinged arch and influence line for horizontal thrust.

Apparatus:

A three hinged arch is statically determined with the axial thrust assisting in maintaining the stability. The model has a span of 100cm and rise of 25cm with hinges at supports and crown. One of the ends rests on rollers along the horizontal span of the applications of load. This marked at the equidistant for the application of load. This being a statically determined structure, the horizontal thrust developed under the action of any load system can be theoretically calculated and will also be measured directly by neutralization of the outward movement of the roller end.

Theory:



Taking moment about A

$$R_B \times L = W_1 a_1 + W_2 a_2 + W_3 a_3$$

$$R_B = \frac{W_1 a_1 + W_2 a_2 + W_3 a_3}{L}$$

Taking moment about B

$$R_A \times L = W_1(L-a_1) + W_2(L-a_2) + W_3(L-a_3)$$

$$R_A = \frac{W_1(L-a_1) + W_2(L-a_2) + W_3(L-a_3)}{L}$$

Taking the moment of all the forces on left hand side about C. we get,

$$H \times r + W_1 \frac{L}{2} - a_1 + W_2 \frac{L}{2} - a_2 = R_A \times \frac{L}{2}$$

$$H = \frac{1}{r} \frac{1}{2} [W_1(L-a_1) + W_2(L-a_2) + W_3(L-a_3)] - W_1 \frac{L}{2} - a_1 - W_2 \frac{L}{2} - a_2$$

Procedure:

1. Balance the self weight of the arch by putting load on the thrust hanger till the appropriate equilibrium conditions are obtained. The moveable end of the arch is positioned such that it shows a tendency to move inside on tapping the supporting table.
2. Place a few loads on the arch in any chosen positions. Balance these by placing additional weights on the hanger for horizontal thrust. The additional weights on the thrust hanger give the experimental value of the horizontal thrust.
3. Measure the distances a_1 , a_2 and a_3 from A with respect to the loads applied, W_1 , W_2 and W_3 .

Observations:Span of the arch, $L =$ Central rise, $r =$

Initial load on the thrust hanger for balancing =

S. No.	Loads on hanger members from the roller end		Distance from left hand support (cm)	Additional load on the thrust hanger, H (Kg)
	Set No.	Load (Kg)		
1.	W_1		$a_1 =$	
2.	W_2		$a_2 =$	
3.	W_3		$a_3 =$	

Precautions:

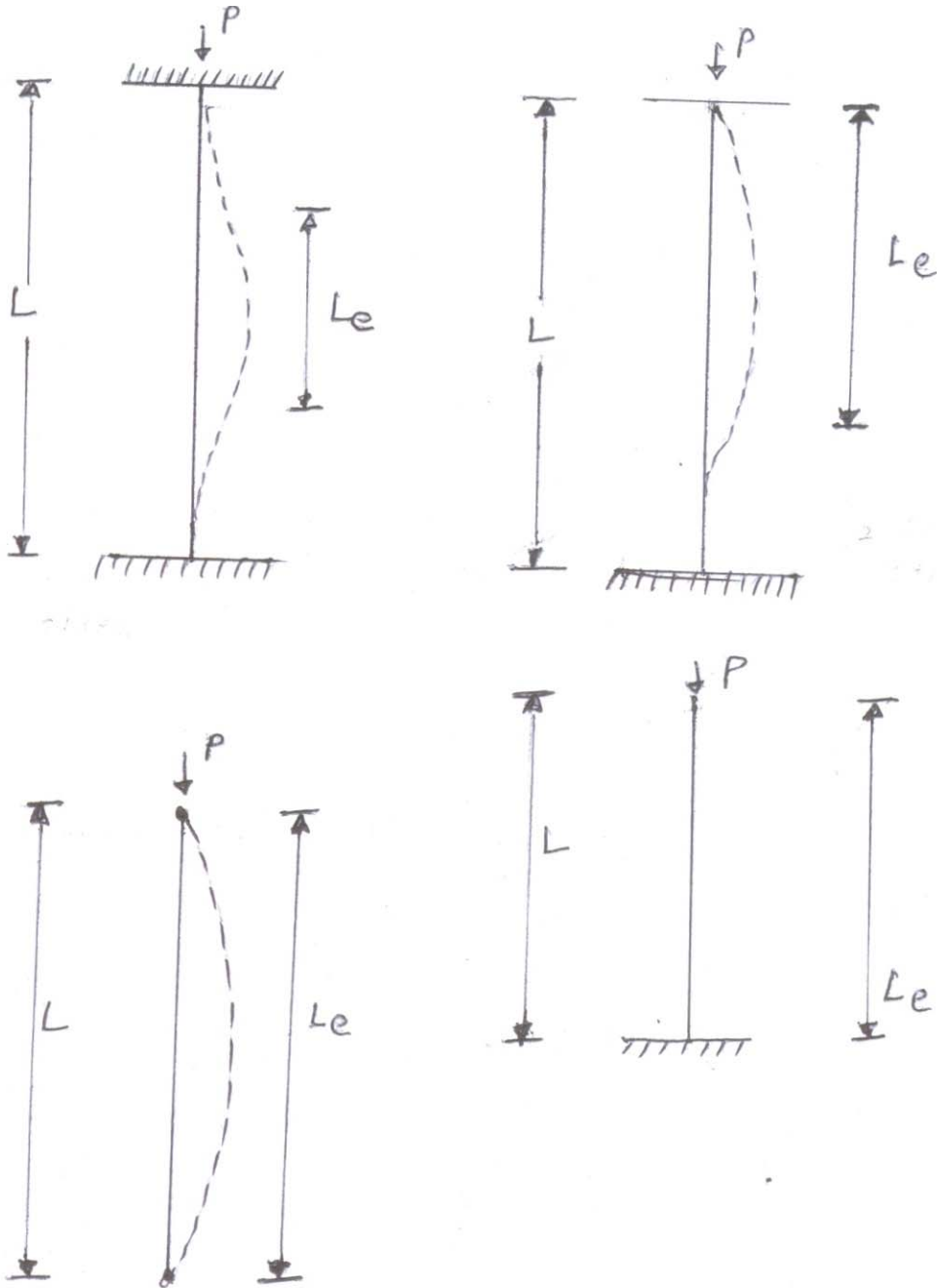
- i) Apply the loads without any jerk.
- ii) Perform the experiment at a location, which is away from any external disturbance.
- iii) Ensure that the supports are rigid.
- iv) The load applied should be within the allowed limits for the apparatus.

Result:

Compare the horizontal thrust obtained theoretically with the values obtained experimentally.

EXPERIMENT NO.-6

AIM:- Experimental and analytical study of behavior of struts with various end conditions.



Apparatus:

Apparatus consists of four spring steel columns, which are put along a vertical wooden board. These four columns have different end conditions as below:

1. Both ends pinned
2. Both ends fixed
3. One end pinned and other fixed
4. One end fixed and other end free

Theory:

If compressive load is applied on a column, the member may fail either by crushing or by buckling depending on its material, cross section and length. If member is considerably long in comparison to its lateral dimensions it will fail by buckling. If a member shows signs of buckling the member leads to failure with small increase in load. The load at which the member just buckles is called as crushing load. The buckling load, as given by Euler, can be found by using following expression:

$$P = \frac{\pi^2 EI}{L_e^2}$$
$$I = \frac{bd^3}{12}$$

Where,

E = Modulus of Elasticity= 2×10^5 N/mm² for steel

I = Least moment of inertia of column section

L_e = Effective length of column

b = breadth of column

d = width of column

Depending on support conditions, four cases may arise. The effective length for each of which are given as:

1. Both ends are fixed, $L_e = L/2$
2. One end is fixed and other is pinned, $L_e = L/\sqrt{2}$
3. Both ends are pinned, $L_e = L$
4. One end is fixed and other is free, $L_e = 2L$

Where,

L = Length of the column

Procedure:

1. Pin a graph paper on the wooden board behind the column.
2. Apply the load at the top of columns.
3. Note the buckling patterns for each of the four columns.
4. Trace the deflected shapes of the columns over the graph paper. Mark the points of change of curvature of the curves and measure the effective or equivalent length for each case separately.
5. Calculate the theoretical effective lengths and thus buckling loads by the expressions given above and compare them with the observed values

Observations:

S. No.	End conditions	Theoretical load	Observed load

Result:

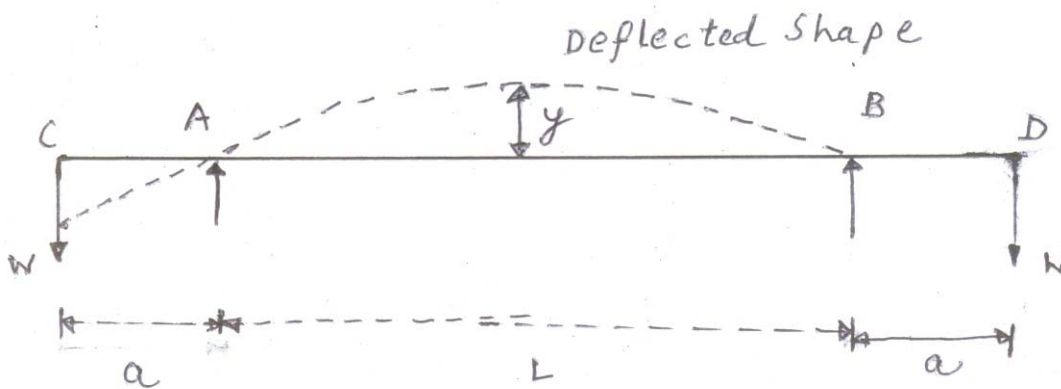
1. Calculate the buckling load for each case
2. Study the shape of the curve and the points of buckling traced at the graph paper.

EXPERIMENT NO.-7

AIM:- To determine elastic properties of a beam.

Apparatus:

The apparatus consists of a flexible beam supported by two rigid supports equally distant from the ends of the beam. This set up provides two over hangs at the ends of the beam. The beam has notches separated by 0.1 meter distance. Two hangers are provided at the free ends of the beam to suspend the loads at the ends.



Theory

Where,

a = length of overhang on each side

W = load applied at the free ends

L = main span

E = modulus of elasticity of the material of the beam $E = 2 \times 10^6$ for steel

I = moment of inertia of cross section of the beam

Therefore,

$$EI = \frac{WaL^2}{8y} \text{----- (2)}$$

Also it is known that EI for the beam = $\frac{E \times bd^3}{12}$ ----- (3)

Where, b = width of the beam

d = depth of the beam

Procedure:

1. Find b and d of the beam with the help of a vernier calipers
2. Calculate the theoretical value of (EI) from equation (3) and the above parameters.
3. Measure the main span and overhang span of the beam with a scale
4. By applying equal loads at the free ends of the overhang beam, find the central deflection y. Repeat the process for different values of loads.

Observations:

Span of the beam, $L =$
Length of overhang on each side, $a =$
Width of beam, $b =$
Depth of beam, $d =$
Modulus of elasticity, $E = 2 \times 10^6$

S. No.	Equal loads at the two ends (Kg)	Deflection at the mid span of the beam (cm)	(EI) from Eq. (3)	(EI) from Eq. (2)

Precautions:

- i) Apply the loads without any jerk.
- ii) Perform the experiment at a location, which is away from any external disturbance.
- iii) Ensure that the supports are rigid.
- iv) The load applied should be within the allowed limits for the apparatus.

Result:

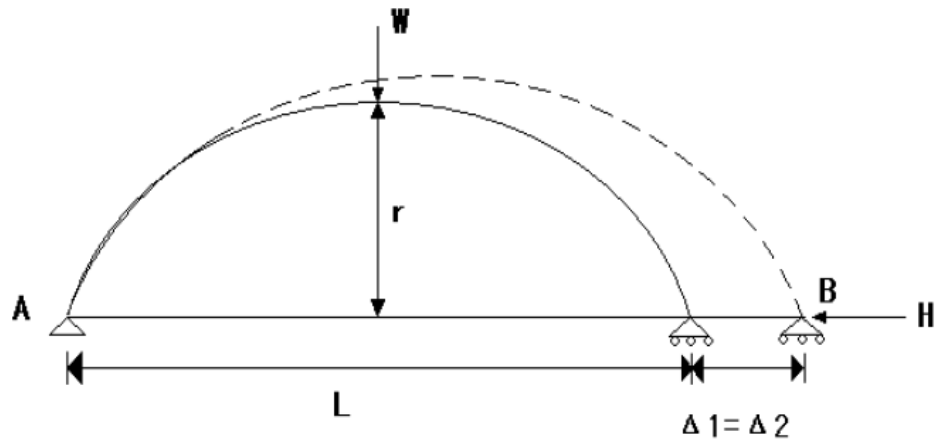
Compare the experimental value of (EI) with the theoretically obtained value.

EXPERIMENT NO.-8

AIM:- Experiment on a two-hinged arch for horizontal thrust & influence line for Horizontal thrust.

Apparatus:

A two hinged arch is statically indeterminate structure of first degree. The model has a span of 100cm and rise of 25cm. Both ends are hinged but one end is also free to move longitudinally. Load may be applied at various points equidistant along the horizontal span of the arch horizontal movement of one end due to the load can be neutralized by applying a known horizontal inward force with the help of a lever arrangement fitted at this end. Thus the horizontal thrust is measured.



Theory:

Two hinged arch is made determinate by treating it as a simply supported curved beam and horizontal thrust as a redundant reaction. The arch spreads out under external load as shown in figure. This results in a horizontal displacement of support B by Δ_1 . Since, the support conditions dictate that the final displacement at support B should be zero, horizontal reaction H should be such that displacement Δ_2 caused by H must satisfy the condition.

$$\Delta_1 + \Delta_2 = 0$$

$$\Delta_1 + f \times H = 0$$

Where, f is the displacement caused by a unit force applied in the direction of H .

$$H = - \frac{\Delta_1}{f} \text{----- (1)}$$

The horizontal displacement Δ_1 is given by:

$$\Delta_1 = \frac{5}{48} \frac{WL^2R}{EI_0} \text{----- (2)}$$

Where,

L = span of the arch

R = rise of the arch

I_0 = moment of inertia at the crown

Procedure:

1. Fix the dial gauge to measure the movement of the roller end of the model and keep the lever out of contact.
2. Now add 1 kg weights to the central hanger and tabulated the horizontal movement of the roller end with increase in the load in steps of 1 kg. Take the reading until a considerable deflection is observed.
3. Now move the lever in contact and add weights to provide the horizontal thrust. Keep adding the weights until reading of the dial gauge is restored to zero. Note down the values of the weight applied to provide the horizontal thrust.
4. Now remove all the loads and note down the deflection caused by a unit load applied horizontally.

Observations:

Span of the arch = L =

General rise of arch = r =

$$\text{Moment of the arch at crown} = I_0 = \frac{bd^3}{12}$$

S. No.	Central Load (Kg)	Observed horizontal thrust	Calculated horizontal thrust

Result:

Compare and analyse the value of horizontal thrust observed with the values obtained theoretically.

EXPERIMENT NO.-9

AIM:- Experimental and analytical study of a 3 bar pin jointed Truss.

Apparatus:

The model consists of three suspension members (spring balances) of different or same stiffness, which are joined at a point to form the redundant joint. The upper ends of the suspension members being tied in a position to a vertical wooden board. Arrangement is provided to apply a vertical load at the joint and to measure its horizontal and vertical displacement on a paper and also by the help of a dial gauge.

Theory:

If v and h are the vertical and horizontal movement of the point d under load W , the extension of various members can be calculated as follows:

Length of the member $AD = L_1$

Length of the member $CD = L_2$

Length of the member $BD = c$

If the change of orientation of various members is neglected, then

Extension of $BD = v$

Extension of $AD = v \sin x - h \cos x$

Extension of $CD = v \sin y + h \cos y$

Also, $\sin x = c/L_1$, $\sin y = c/L_2$

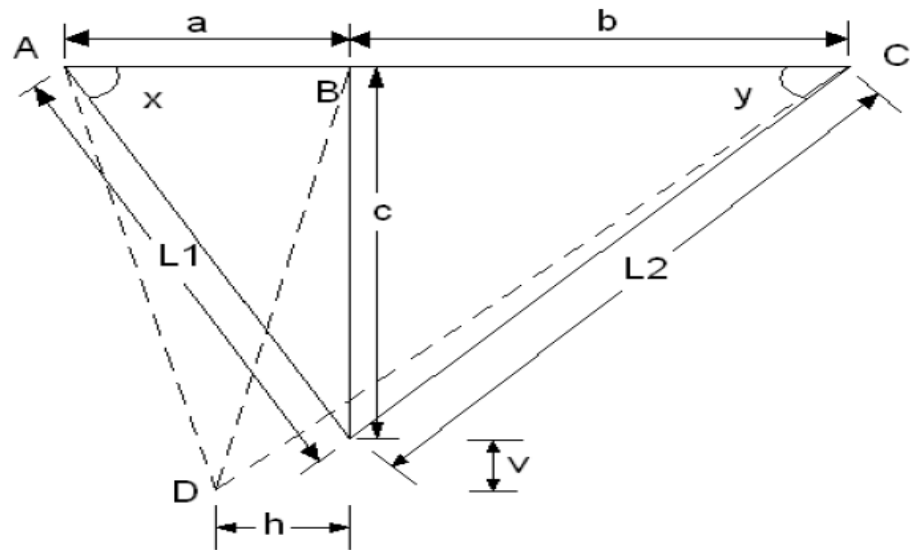
$\cos x = a/L_1$, $\cos y = b/L_2$

Where, $AB = a$, $BC = b$

Therefore, if the force in the member $AD = T_1$

force in the member $CD = T_2$

force in the member $BD = T_3$



Then, extension of BD = $v = T_3 / K_3$

$$\text{Extension of AD} = \frac{(cv - ah)}{L_1} = \frac{T_1}{K_1}$$

$$\text{Extension of DC} = \frac{(cv + bh)}{L_2} = \frac{T_2}{K_2}$$

Therefore, from above equations

$$T_1 = \frac{(cv - ah)K_1}{L_1} \text{----- (1)}$$

$$T_2 = \frac{(cv + bh)K_2}{L_2} \text{----- (2)}$$

$$T_3 = K_3 v \text{----- (3)}$$

Now equating the vertical and horizontal forces at point D, we have,

$$T_1 \sin x + T_3 + T_2 \sin y = W \text{----- (4)}$$

$$T_1 \cos x - T_2 \cos y = 0 \text{----- (5)}$$

Now we have five equations for five unknowns T_1, T_2, T_3, v and h

Precautions:

- i) Apply the loads without any jerk.
- ii) Perform the experiment at a location, which is away from any external disturbance.
- iii) Ensure that the supports are rigid.
- iv) Gently tap the dial gauge before observing the readings.
- v) The load applied should be within the allowed limits for the apparatus.

EXPERIMENT NO.-10

AIM:- Experimental and analytical study of deflections for unsymmetrical bending of a Cantilever beam.

Apparatus:

The apparatus consists of an angle of size 1"×1"×1/8" or in equivalent metric units of length 80cm is tied as a cantilever beam. The beam is fixed at one end such that the rotation of 45° intervals can be given and clamped such that the principle axis of its cross section may be inclined at any angle with the horizontal and vertical planes. Also arrangement is provided to apply vertical load at free end of the cantilever and to measure horizontal and vertical deflection of the free end.



Theory:

One of the basic assumptions in deriving the flexural formula $F = My/I$ is that the plane of load is perpendicular to the neutral axis. Every cross-section has got two mutually perpendicular principle axis of inertia, about one of which the moment of inertia is the maximum and about the other a minimum. It can be shown that a symmetrical axis of cross section is one of the principle axis and one at right angles to the same will be the other principle axis.

For beams having unsymmetrical cross section such as angle (L) or channel (I) sections, if the plane of loading is not coincident with or parallel to one of

the principle axis, unsymmetrical or non-uniplaner bending.

In this experiment for a cantilever beam, the plane of loading is always kept vertical and the angle iron cantilever beam itself is rotated through angles in steps of 45°.

Procedure:

1. Clamp the beam at zero position and suspend a 500gm load from the hanger and take this as zero loading on the beam to activate the member.
2. Attach and adjust the dial gauge at the free end to measure vertical and horizontal displacements.
3. Load the beam in steps of 1kg up to 3kg and each time note down the deflection. Apply the loads gradually without jerk.
4. Repeat steps 1 to 4 turning the beam through 45° intervals.
5. Plot a graph for the deflection observed against the load applied. Ideally the graph should produce a straight line.

Observations:

Initial load on free end =

S. No.	Angle (degree)	Load (Kg) (N)	Observed deflection (mm)	
			x	y

Precautions:

- i) Apply the loads without any jerk.
- ii) Perform the experiment at a location, which is away from any external

disturbance.

iii) Ensure that the supports are rigid.

iv) Gently tap the dial gauge before observing the readings.

v) The load applied should be within the allowed limits for the apparatus.

Result:

Study the pattern of bending of the beam with the help of the graph