Figure 3.1 Young’s modulus - Non-uniform bending

Figure 3.2 Model Graph
AIM
To find the Young’s modulus of the given material of the beam by non-uniform bending.

GENERAL OBJECTIVE
To evaluate the elastic behavior of the given wooden beam by pin and microscope experimental method and to find its Young’s modulus

SPECIFIC OBJECTIVES
1. To measure the thickness and breadth of the given wooden beam using screw gauge and vernier caliper, respectively
2. To determine the depression of the given wooden beam loaded at its midpoint by non-uniform bending method
3. To find the slope from the graph drawn between the load versus depression
4. To calculate the Young’s modulus of the wooden beam from the mean depression and slope obtained from table and graph, respectively
5. To analyze the elastic behavior of the given wooden beam from the results obtained

APPARATUS REQUIRED
- Wooden beam
- Weight hanger with slotted weights
- Knife edges
- Travelling microscope
- Vernier caliper
- Screw gauge
- Metre scale
LEAST COUNT FOR SCREW GAUGE

Least Count (LC) = \frac{Pitch}{\text{Number of head scale divisions}}

Pitch = \frac{\text{Distance moved}}{\text{Number of rotations given}} = \frac{5 \text{ mm}}{5} = 1\text{mm}

LC = \frac{1\text{ mm}}{100} = 0.01\text{mm}

TABLE - I

To determine the thickness (d) of the beam using screw gauge

Zero Error (ZE) : ........... divisions                        Zero Correction (ZC) : ...........mm

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Pitch Scale Reading ( (10^{-3} \text{ m}) )</th>
<th>Head Scale Coincidence ( \text{HSC} ) (divisions)</th>
<th>Observed Reading ( \text{OR} = \text{PSR} + ( \text{HSC} \times \text{LC} ) ) ( (10^{-3} \text{ m}) )</th>
<th>Correct Reading ( \text{CR} = \text{OR} \pm \text{ZC} ) ( (10^{-3} \text{ m}) )</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
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<td>5</td>
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</tbody>
</table>

Mean \( (d) = ......... \times 10^{-3} \text{m} \)
FORMULA

Young’s modulus of the material of the beam

\[ Y = \frac{MgL^3}{4sbd^3} \text{ (N/m}^2) \]

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Explanation</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Y</td>
<td>Young’s modulus of the material of the beam</td>
<td>N/m²</td>
</tr>
<tr>
<td>M</td>
<td>Load applied</td>
<td>kg</td>
</tr>
<tr>
<td>L</td>
<td>Distance between the knife edges</td>
<td>m</td>
</tr>
<tr>
<td>g</td>
<td>Acceleration due to gravity</td>
<td>m /s²</td>
</tr>
<tr>
<td>b</td>
<td>Breadth of the beam</td>
<td>m</td>
</tr>
<tr>
<td>d</td>
<td>Thickness of the beam</td>
<td>m</td>
</tr>
<tr>
<td>s</td>
<td>Depression produced for ‘M’ kg load</td>
<td>m</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Unit</th>
<th>Equivalent Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>N/m²</td>
<td>kg m⁻¹ s⁻²</td>
</tr>
</tbody>
</table>

PREREQUISITE KNOWLEDGE

1. **Stress**
   Stress is a dimension quantity defined as force per unit area.

2. **Strain**
   Strain is the relative change in shape or size of an object due to externally applied forces. It is dimensionless quantity and has no units.

3. **Young’s modulus**
   Young’s modulus is defined as the ratio between linear stress and linear strain.
LEAST COUNT FOR VERNIER CALIPER

Least Count (LC) = Value of 1 Main Scale Division (MSD)/ Number of divisions in the vernier

10 MSD = 1 cm

Value of 1 MSD = 1/10 cm = 0.1 cm

Number of divisions in the vernier = 10

LC = 0.1/ 10 = 0.01 cm

TABLE-II

To determine the breadth (b) of the beam using vernier caliper

LC = 0.01 cm Zero error (ZE): ............ Zero Correction (ZC): ............

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Main Scale Reading MSR (10^-2 m)</th>
<th>Vernier Scale Coincidence VSC (divisions)</th>
<th>Observed Reading OR = MSR + (VSC×LC) (10^-2 m)</th>
<th>Correct Reading CR = OR ± ZC (10^-2 m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
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</table>

Mean (b) = ........... ×10^-2 m
4. **Uniform and non-uniform bending**
   In uniform bending, the beam is elevated due to load, and non-uniform bending, the beam is depressed due to load.
   In uniform bending, every element of the beam is bent with the same radius of curvature whereas in non-uniform bending, the radius of curvature is not the same for all the elements in the beam.

**PROCEDURE**
1. The given beam is supported on two knife edges separated by a distance ‘L’.
   A pin is fixed vertically at the mid-point. A weight hanger is suspended at the mid-point of the beam. The beam is brought to the elastic mood by loading and unloading it several times.
2. With the dead load ‘W’, the pin is focused through microscope. The microscope is adjusted so that the horizontal crosswire coincides with the tip of the pin. The microscope reading is taken.
3. The load is changed in steps of 0.05 kg and in each case the microscope reading is taken during loading and unloading. The readings are tabulated. The depression at the mid-point for ‘M’ kg is calculated.
4. The distance between the knife edges (L) is measured using a metre scale. The breadth (b) and thickness (d) of the beam are found using vernier caliper and screw gauge, respectively.
LEAST COUNT FOR TRAVELLING MICROSCOPE

Least Count (LC) = Value of 1 Main Scale Division (MSD)/ Number of divisions in the vernier

20 MSD = 1 cm

Value of 1 MSD = 1/20cm = 0.05 cm

Number of divisions in the vernier = 50

LC = 0.05/50 = 0.001 cm

TABLE -III

To find depression‘s’

LC = 0.001 cm

\[ \text{Mean} (s) = \ldots \ldots \times 10^{-2} \text{m} \]

<table>
<thead>
<tr>
<th>Load M (10^{-3} kg)</th>
<th>Microscope reading</th>
<th>Depression ‘s’ for M kg (10^{-2} m)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Loading</td>
<td>Unloading</td>
</tr>
<tr>
<td></td>
<td>MSR (10^{-2} m)</td>
<td>VSC (div)</td>
</tr>
<tr>
<td>W</td>
<td></td>
<td></td>
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<tr>
<td>W + 50</td>
<td></td>
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<tr>
<td>W + 100</td>
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<tr>
<td>W + 150</td>
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<tr>
<td>W + 200</td>
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</tbody>
</table>

*Note: Total Reading (TR) = Main Scale Reading (MSR) + (VSC \times LC)
RESULT

The Young’s modulus of the material of the given beam \( Y = \ldots \times 10^{10} \text{ N/m}^2 \)

APPLICATIONS

AFM probe, wings of air craft, helicopter rotator, marine fittings, designing of bridges, bicycle frames and wind mill turbine blades.

VIVA VOCE QUESTIONS

1. Define elastic limit.

2. When a beam is loaded at its midpoint, it is then said to be under non-uniform bending. Why?

3. Differentiate between elasticity and plasticity.

4. Give the significance of neutral axis.
OBSERVATION

Mass for the depression $M = \ldots \times 10^{-3}$ kg
Distance between the two knife edges $L = \ldots \times 10^{-2}$ m
Acceleration due to gravity $g = \ldots$ m/s$^2$
Breadth of the beam $b = \ldots \times 10^{-2}$ m
Thickness of the beam $d = \ldots \times 10^{-3}$ m
Depression produced for ‘M’ kg of load $s = \ldots \times 10^{-2}$ m

CALCULATION

Young’s Modulus of the material of the beam

$$Y = \frac{MgL^3}{4sbd^3} \text{ (N/m}^2\text{)}$$
STIMULATING QUESTIONS

1. What happens to the Young’s modulus of the material if its dimension is increased?

2. Defense force is not allowed to do march past on the bridges. Reason out

3. Load vs depression plots for copper and steel are given. Which material is stiffer? Justify.