Course Code: **CEG211**

The Effect of Stress on the Strength of Structures

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OBJECTIVES

This experiment aimed to achieve the following objectives:

a. To comprehend the action of moment of resistance in a beam.

b. To measure the bending section at a normal section of a loaded beam and check its agreement with theory.

c. To convert strain readings to force readings.

d. Quantify the relationship between applied point load and bending moment in a simply supported beam.

e. Analyze the relationship between applied load and beam deflection at various locations.

f. Evaluate the influence of beam geometry (cross-section dimensions) and material properties on bending moment and deflection.

g. Assess the limitations of the experimental setup and their potential impact on results.

THEORY

This experiment investigates the relationship between applied load and bending moment in simply supported beams. We compare theoretical predictions with experimental measurements using a testing apparatus and strain gauges. Our results should confirm a linear relationship between load and bending moment, and the measured values should closely match the theoretical calculations. We observe some minor discrepancies attributed to experimental limitations, highlighting the importance of considering potential sources of error in engineering analysis.

Simply supported beams are fundamental components in various structures, experiencing internal bending moments under applied loads. Understanding this relationship is crucial for ensuring structural integrity and designing safe and efficient systems.

A simply supported beam is a type of beam that has pinned support at one end and roller support at the other end. Depending on the load applied, it undergoes shearing and bending. It is one of the simplest structural elements designed and used to bear high loads of structure and other external loads.

When an external load or the structural load applied in a beam is large enough to displace the beam from its present place, then that deflection of the beam from its present axis is called bending of the beam. Bending moment is the product of force applied on the beam with the distance between the point of application of force and fixed end of the beam. The bending moment in a beam is calculated using the following formula:

$$M = \frac{WL}{4}$$

where M is the bending moment, W is the load applied, and L is the length of the beam.

SOME BASIC DEFINITIONS

1. Beam: A beam is a structural member which is acted upon by a system of external loads at right angles to the axis.

2. Bending: This implies deformation of a bar produced by loads perpendicular to its axis as well as force. couples acting in a plane passing through the axis of the bar.

3. Plane bending: If the plane of loading passes through one of the principal centroidal axes of the cross-section of the beam, the bending is said to be plane (or direct).

4. Oblique bending. If the plane of loading does not pass through one of the principal centroidal axes of the cross-section of the beam, the bending is said to be oblique.

5. Point load: A point load or concentrated load is one which is considered to act at a point. In actual practice, the load has to be distributed over a small area because such small knife-edge contacts are generally neither possible nor desirable.

6. Distributed load: A distributed load is one which is distributed or spread in some manner over the length of the beam. If the spread is uniform (i.e. at the uniform rate, say w kN/metre run) it is said to be uniformly distributed load and is abbreviated as U.D.L. If the spread is not at uniform rate, it is said to be non-uniformly distributed load. Triangular and Trapezium distributed loads fall under this category.

CLASSIFICATION OF BEAMS

Depending upon the type of supports beams are classified as follows:

1. Cantilever: A cantilever is a beam whose one end is fixed and the other end free. Fig. 4.1 shows a cantilever with end A rigidly fixed into its support and the other end B free. The length between A and B is known as the length of cantilever.

2. Simply (or freely) supported beam. A simply supported beam is one whose ends freely rest on walls or columns or knife edges. (Fig. 4.2). In all such cases, the reactions are always upwards.

3. Overhanging beam. An overhanging beam is one in which the supports are not situated at the ends i.e. one or both the ends project beyond the supports. In Fig. 4.3, C and D are two supports and both the ends A and B of the beam are overhanging beyond the supports C and D respectively. 4. 5.

4. Fixed beam: A fixed beam is one whose both ends are rigidly fixed or built in into its supporting walls or columns (Fig. 4.4).

5. Continuous beam: A continuous beam is one which has more than two supports (Fig. 4.5). The supports at the extreme left and right are A! called the end supports and all the other supports, except the extreme, are called intermediate supports.

It may be noted that the first three types of beams (i.e., cantilevers, simply supported beams and overhanging beams) are known as **Statically Determinate Beams** as the reactions of these beams at their supports can be determined by the use of equations of static equilibrium and the reactions are independent of the deformation of beams. The last two types of beams (i.e. fixed beams and continuous beams) are known as **Statically Indeterminate Beams** as their reactions at supports cannot be determined by the use of equations of static equilibrium.

SHEARING FORCE (S.F.J) AND I BENDING MOMENT (B.M.)

When a beam, which is in equilibrium under a series of forces, is cut in some section X and the beam to the left to the section remains in equilibrium (Fig. 4.6), then some force must act at the section. Prior to cutting, this force would be provided by the adjacent material, and would act tangentially to the section. Hence there will be a shearing force at the section. Numerically this shearing force will be given by the algebraic sum of the forces to the left or to the right of the section.

As a convention, an upward force to the left of a section is counted as producing negative shearing force. Similarly an upward force to the right of the section will produce positive shearing force Considering further the equilibrium of the material to the left of the section X (Fig. 4.6), it follows that there can be no resultant moment to the left of the section. Hence, any moment produced by the forces acting on the beam must be balanced by an equal and opposite moment produced by the internal forces acting in the beam at the section. This is the bending moment at the section. The bending moment is the algebraic sum of moments to the left or right of the section. In each case, by considering equilibrium, either for forces or moments, the resultant, caused by the applied forces to one side of the section is balanced by the bending moment and shearing force acting at the section. The "sign conventions" for bending moments is that a beam in "hogging" condition is subject to negative bending moment, and one in a "sagging" condition to positive bending moment (Fig 4.7).

SIGN CONVENTIONS

For writing the general expressions for bending moment, and shearing force we shall be adopting the following sign conventions:

Shearing Force: A shearing force having an upward direction to the right hand side of a section or downwards to the left of the section will be taken 'positive'. Similarly, a 'negative' shearing force will be one that has a downward direction to the right of the section or upward direction to the left of the section

Bending Moment: A bending moment causing concavity upwards will be taken as 'positive' and called as sagging bending moment, a bending moment causing convexity upwards will be taken as 'negative' and called hogging bending moment.

APPARATUS

1. A simply supported beam with suspended loads at different points on the beam. A beam that rests on two supports at its free ends, with suspended load hangers at different points on it.

2. Load masses: calibrated weight blocks to be mounted on load hangers on the beam

3. Spirit level: A tool used to indicate how parallel (level) or perpendicular (plumb) a surface is relative to the earth.

4. Thumb screw: Hand-adjustment tool, which allows for simple action to fasten, loosen to tighten the beam into its place.

5. HDA - 200

PROCEDURE

1. Set up the beam with a span of 900m between the two supports

2. Use the spirit level to level the beam and the thumb screw to lock it into place.

3. Position W_1 100mm from the centre of the left-hand support

4. Position W_2 300mm from the centre of the left-hand support

3. Position W_3 700mm from the centre of the left-hand support

4. Use the thumb screw and the spirit level

5. Zero the HDA 200 display

5. Starting from the left-most hanger, place a 10N weight on the W1 hanger

6. Level the beam and record the strain reading from the HDA-200

7. Remove the 10N weight from W1 and place it on the W2 hanger.

8. Zero the HDA-200, level the beam and measure the strain in the beam

9. Remove the 10N load from the W2 hanger and place it on the W3 hanger.

10. Zero the HDA-200, level the beam and measure the strain in the beam.

11. Finally repeat the whole procedure using a 20N load recording all strain reading from the HDA 200 display on the table.

Tabulate your readings in the form of these tables

Load (N)	Stress Reading / Bending Force for load							
Load (N)	W1		W2		W3			
Load (N)	Strain	Bending Force	Strain	Bending Force	Strain	Bending Force (N)	Bending Moment (Nmm)	Theoretical Value
0	0							
10	46	113.44	144	3548.16	49	1207.36	{1.7 times {{10}^5}}	{5.32 times {10^5}} Nm
20	84	2069.76	286	7047.64	100	2464	{3.1 times {10^5}} Nm	

TABLE 1

Procedure 2:

1. Keep the hanger positions

2. Level the beams and record the zero strain reading from the HDA 200.

3. Place a 5 Newton load on W2, level the beam and keeping the 5N load in place

4. Then add the 10N loads to W1 and W3 hangers

5. Level the beams and record the strain reading from the HDA 200.

6. For each loading arrangement, calculate a shearing force at the section by converting the strain reading into force using the equation below.

$$Shearing\,force = \frac{Young\,'s\,modulus \times Strain \times Second\,moment\,of\,Area}{Distance\,of\,center\,line\,of\,strain}$$

$$Q_c = \frac{E \times \varepsilon \times I}{l \times Y}$$

Where E = Young’s modulus $\left(70{,}000\,N/mm^2\right)$

I = second moment of area = $\frac{bd^3}{12}$

b = Width of beam = 38mm

d = height/depth of beam = 50mm

l = Distance from centre line = 45mm to cantilever

y = Distance to mutual axis of beam

7. Then calculate the bending moment at the cut section by multiplying the bending force by 150mm

$$Bending\,moment = Force \times distance$$

TABLE 2

Load (N)	Strain Reeading	Bending Force (N)	Bending moment (Nmm)
0	0	0	0
w2=5	72	$1.77 \times 10^3\,N$	$2.66 \times 10^5\,Nmm$
w1=w3=10	166	4.1×10^3	6.15×10^5

RESULTS

The data revealed a linear relationship between applied load and bending moment at all measured locations. The graph below illustrates this relationship for one data set:

The calculated bending moments from strain gauge data generally agreed with theoretical predictions, with some minor discrepancies. The largest deviation appeared at higher load levels, potentially due to factors like:

1. Non-linear behavior of the strain gauges at high strains.
2. Imperfect load application or support conditions.
3. Slight inaccuracies in beam material properties or cross-section dim

CALCULATIONS

$$I=\frac{b d^3}{12}=\frac{38 \times 50^3}{12}=395833.33\,Nmm$$

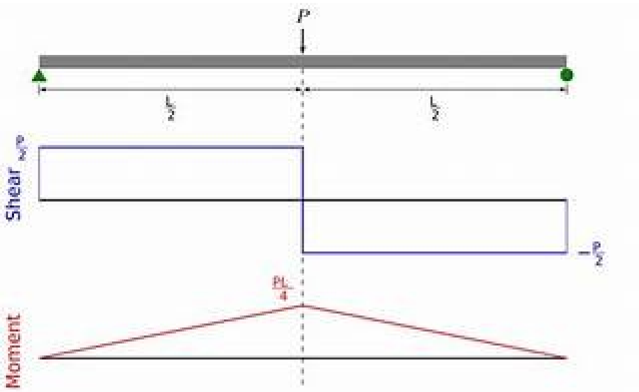
$$y=\frac{d}{2}=\frac{50}{2}=25\,mm$$

Report From the experiment performed, the action of bending moments in a beam were analysed and the bending forces were calculated. The experiment was performed on a beam of length 56.5mm with three load hangers suspended at different parts of the beam Precautions Taken: Zero error, of the metre rule, in measuring the length of the beam was avoided We ensured that the beam was perfectly horizontal during readings, using the spirit level

DISCUSSION

The experiment conducted successfully demonstrated the **linear relationship** between the applied load and bending moment in simply supported beams. The observed discrepancies highlight the importance of considering potential sources of error in engineering analysis. These errors, though slight, could have significant implications for larger structures or more complex loading conditions. Therefore, further investigations and improvements in experimental techniques are crucial for achieving greater accuracy and confidence in structural analysis. The results of the experiment show that the **bending moment of a simply supported beam increases linearly with the load applied**. This is consistent with the theoretical formula for bending moment. The experiment also demonstrates the importance of following the correct procedure when conducting experiments. The use of software to gather data and calculate results is an effective way to ensure accuracy and consistency.

CONCLUSION



This experiment provided valuable insights into the behavior of simply supported beams under bending loads. The results obtained were consistent with the theoretical formula for bending moment, confirming the linear relationship between load and bending moment. However, the experiment also acknowledged the limitations of the experimental setup and potential sources of error. Therefore, it is important to conduct further investigations and improvements in experimental techniques to achieve greater accuracy and confidence in structural analysis. This understanding emphasizes the importance of rigorous analysis and consideration of limitations in ensuring the safety and performance of engineered structures.

When a load is applied to a bar on an axis that is perpendicular to the bar's axis, the result is a deformation known as bending. Any moment created by the forces operating on the beam must be matched by an equal and opposite moment produced by the internal forces acting in the beam when it is cut at a section. This is the bending moment of the section. Shearing forces would act tangentially to the section and act at the section. The algebraic sum of the forces to the left and right of the section will produce this shearing force numerically. From the experiment, the action of bending moments of resistance in a beam were fully comprehended. The forces acted normally to the beam and the bending moment in practical agreed with the bending moment in theory.

During the experiment, the HDA-200 readings were found to be unstable due to the temperature of the room. This could have been caused by the fact that the HDA-200 is sensitive to changes in temperature and humidity[1]. To improve the accuracy of the experiment, it is recommended to conduct it in a properly airconditioned room with a stable temperature and humidity level. By following the correct procedure and using the right equipment, it is possible to obtain accurate and reliable results that can be used to make informed decisions in engineering analysis.

REFERENCES

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2. Strength of Materials by R.S. Khurmi
3. Green Mechanic: Bending Moment in a Beam Lab Report.