MECHANICS LAB
AM 317

EXP 3
BENDING STRESS IN A BEAM

I. OBJECTIVES

I.1 To compare the experimentally determined stresses in a beam with those predicted from the simple beam theory (a.k.a. Euler-Bernoull beam theory).

I.2 To compare the location of the neutral axis determined by:

- **a. Hand calculation using the centroid equation.**
- **b. Experimentally determined from the strain data.**

I.3 To obtain measurements from strain gauges and to investigate the distribution of stress in the beam.

II. INTRODUCTION AND BACKGROUND

Strain gauges are the most frequently used devices in stress-strain relation. The electrical strain gauge operates on the direct relationship between the change in electrical resistance of a wire as it is stretched and the strain ε developed within the material. The ability to precisely measure the change in electrical resistance gives a direct, precise measure of the strain.

As a wire is stretched, its length increases and its cross sectional area decreases, which increases the resistance of the wire. By bonding the strain gauge to a structural member and measuring the change in resistance as the load is applied, the corresponding strain can be measured. The experimental value of stress σ may be determined from the measured strain ε by using Hooke's Law for uniaxial stress, $\sigma = E\varepsilon$. E is the modulus of elasticity of the beam material. The beam used in this experiment is made of aluminum which has a modulus of elasticity of E = 73.1 GPa.

The theoretical maximum stress developed within a beam is calculated using the flexure formula over the linear range of stress and strain. The expression of the maximum bending stress is

$$\sigma_{\max} = \frac{Mc}{I} \tag{3.1}$$

where:

M **- the maximum internal moment**
I **- the moment of inertia of the cross-sectional area about the neutral axis**
c **- the perpendicular distance from the neutral axis to a point farthest away from the neutral axis**

The moment of inertia of an area about an arbitrary axis is obtained by use of the parallel axis theorem.

$$I_o = \bar{I} + Ad^2 \qquad 3.2$$

where:

$\bar{I}$ - the moment of inertia of the area about the centroidal axis

A - the corresponding area

d - the perpendicular distance between the centroidal axis and any parallel axis

The location of the centroid of a composite area can be determined from the following equation:

$$\bar{y} = \frac{\sum_{i=1}^{n} A_i y_i}{\sum_{i=1}^{n} A_i} \qquad 3.3$$

III. EQUIPMENT LIST

III.1 Structures test frame

III.2 T-beam with strain gauges

III.3 Digital force display and digital strain display

III.4 Load cell

III.5 Two power supplies for the digital force display and the strain display

III.7 Calipers and tape measure

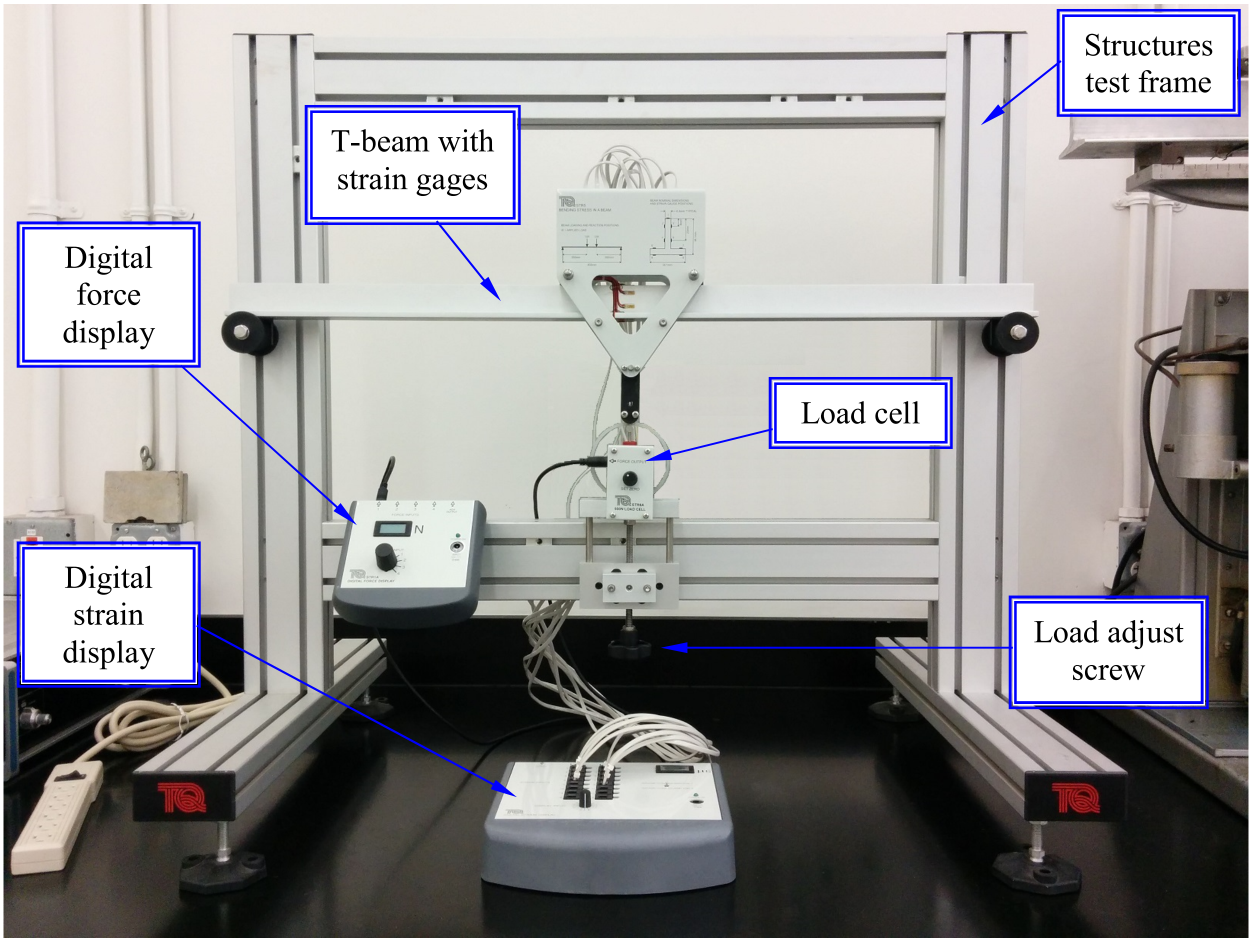


Figure 1 Test Set-up for T-Beam Experiment

IV. PROCEDURE

IV.1. Measure and record all necessary dimensions of the T-beam, load and support points, and the location of all the strain gauges with respect to the bottom of the beam. Do not remove the beam from the test fixture as the strain gauges are easily damaged.

IV.2. Calculate the location of the centroid and the moment of inertia of the cross-sectional area with respect to the neutral axis. Check the result with your instructor.

IV.3. Calculate the maximum load P that can be applied to the beam given an allowable bending stress of 70 MPa. Check your result with the instructor before starting the experiment.

IV.4 Calculate the bending stress at each position for a load P = 100 N. Calculate

the corresponding strain, which will allow you to check the experimental result you measure later.

IV.5 Connect the power supplies to the Force Display and the Strain Display. Make sure they are "on". Leave the system for 5 minutes to warm up and reach a steady state. Make sure the Strain Display is set to Gauge Configuration 1.

IV.6 Read the initial strain values and, if necessary, adjust the Load Adjust Screw to make sure the strain values are in the range of $\pm 40\mu$. Then, turn the small black knob on the Load Cell to adjust the load reading to zero.

IV.7 Record the strain values for each gauge for P = 0 load case. Then, use the Load Adjust Screw to increase the load, recording the strain values in each gauge for 100, 200, 300, 400 and 500-N loads. Do NOT exceed 500 N.

IV.8 The strain data you recorded for the five load cases must be adjusted or calibrated by subtracting the strain values measured for the unloaded (P = 0) case to give the proper stain results.

IV.8 Check the theoretical strain value you calculated in section IV.4 with the experimental value to see if your measurement is reasonable.

IV.9 Use the load adjust screw to return the load to zero.

IV.10 Unplug and disconnect the power supplies.

<u>NEVER</u> apply excessive loads to any part of the equipment or strike the Load Cell.

V. REPORT

V.1. Beam Properties

For the beam, include the tabulated beam information recorded in Table I along with a table of the position of the nine strain gauges with respect to the bottom of the beam (Table II) in the Results section. Calculations for the moment of inertia, the location of the centroid and the maximum allowable load, should be put in the Appendix.

V.2. Graphs and Calculations

Results should include a graph of the experimental stress, calculated from $\sigma = E\varepsilon$, versus the gauge position (with respect to the bottom of the beam). Tensile stress is positive and compressive stress is negative. A sample

graph is shown in Fig. 2. Plot the five load cases on this same graph. From this graph, determine the location of the neutral axis.

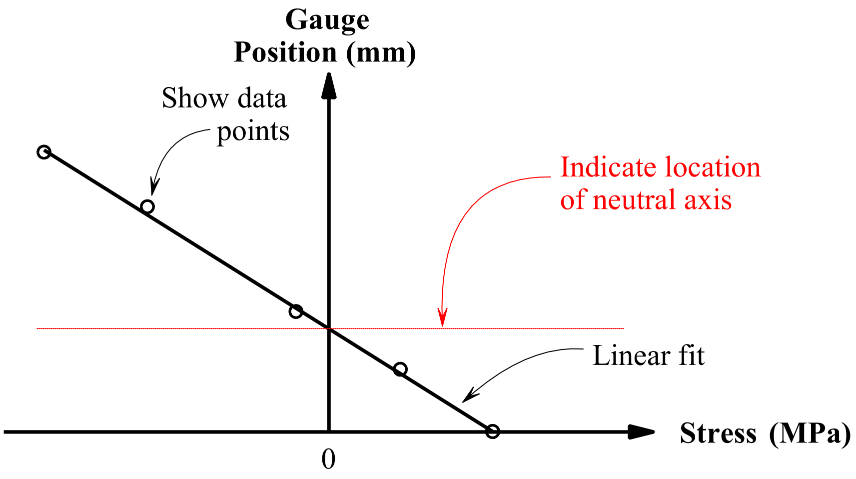


Figure 2 Sample Graph of Experimental Stress Results for One Load Case

Plot the experimental and theoretical stress for any two load cases (as shown in Fig. 3).

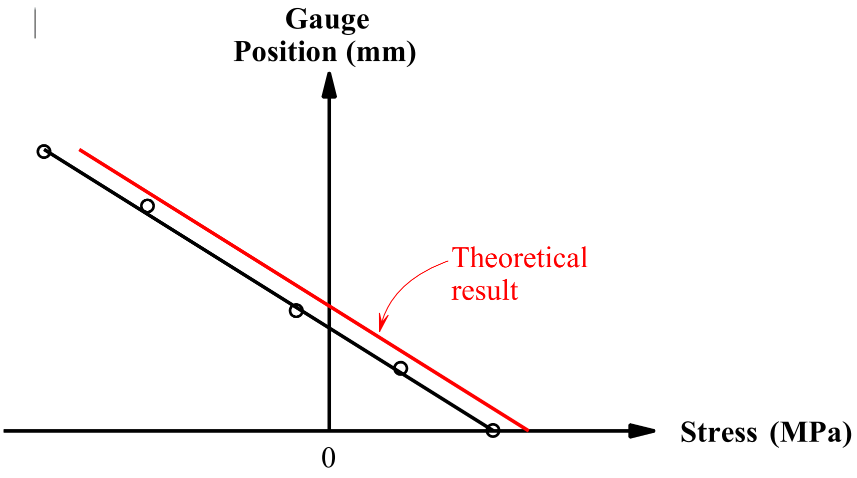


Figure 3 Sample Graph of Theoretical and Experimental Stress Results

For any gauge position, plot the average strain (x-axis) versus the bending moment (y-axis).

V.3. Comparison of Results

All graphs should be presented in the Results section with titles and axis

labels.

Compare the neutral axis location obtained from the graph and $\bar{y}$ presented in Table I.

Compare the theoretical and experimental stress graphs. Obtain a linear curve fit of the data points. The equation of a linear curve fit has the form $y = mx + b$ which can be displayed on the graph. Make percent comparisons of the data for each load case. Put these results in a table and include it in the Results section. Raw data go in the Appendix.

Is the load-deformation relationship linear?

VI. SELECTED REFERENCES

Hibbeler, R.C., Mechanics of Materials, 9th edition, Pearson, 2013.

Ehrgott, R., AM317 Instruction Manual - Experiment 3 Stress Measurement in a T-Beam, CSUN, Northridge, CA, 2001.

Gere, J.M. & Timoshenko, S.P., Mechanics of Materials, 4th edition, CL Engineering, 1996.

Table I Beam Specifications

Position of Neutral Axis, $\bar{y}$ (mm)	
Moment of Inertia, I (mm^4)	
Length of the Beam, L (mm)	
Modulus of Elasticity, E (Gpa)	
Allowable Stress, σ (MPa)	

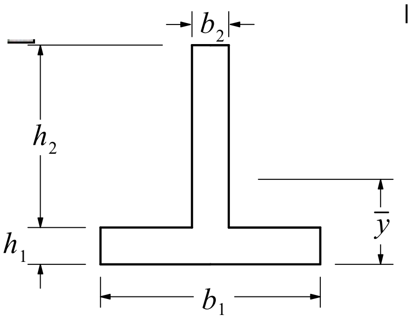
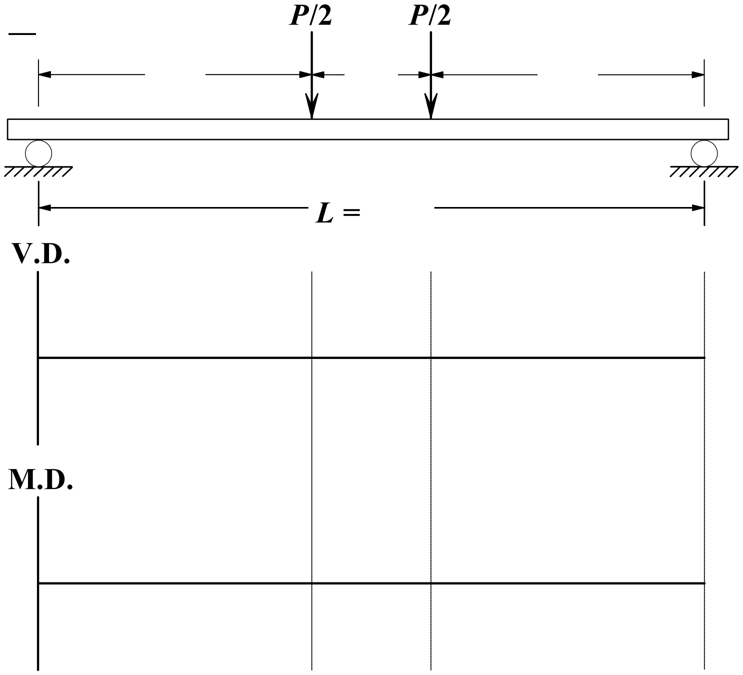


Figure 4 Dimensions of the Cross Section



Safe Load: $P_{\max}$ = ____________

Figure 5 Shear Force Diagram, Moment Diagram and Maximum Allowable Load

Table II Strain Gauge Locations

Gauge No.	Position of Gauge (mm) From Bottom of Beam
1	
2, 3	
4, 5	
6, 7	
8, 9	

Table III Calculated Stress and Strain for 100-N Load Case

Gauge No.	Bending Stress (MPa)	Strain (μ)
1		
2, 3		
4, 5		
6, 7		
8, 9		

Table IV Recorded Strain Values

Gauge No.	Load (N)					
	0	100	200	300	400	500
1						
2						
3						
4						
5						
6						
7						
8						
9						

Table V Zero-Adjusted Strain Data

Gauge No.	Bending Moment (N·m)				
1					
2					
3					
4					
5					
6					
7					
8					
9					

Table VI Averaged Strain Data

Gauge No.	Gauge Position (mm)	Bending Moment (N·m)				
1						
2, 3						
4, 5						
6, 7						
8, 9						