California State University, Long Beach

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Lab Report
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Title: FLEXURE TEST OF AN ALUMINUM CANTILEVER BEAM

Course Number: MAE 361
Section Number: Sec 03
Class Number: Eng 4 125

Instructor: Dr. Shamim Mirza

OBJECTIVE

The objective of this experiment is to observe flexural properties for engineering materials such as an aluminum beam or a concrete beam. The values analyzed will be the modulus of elasticity and Poisson's ratio. The material being observed for the experiment is an aluminum beam.

PROCEDURE and LIST OF APPARATUS

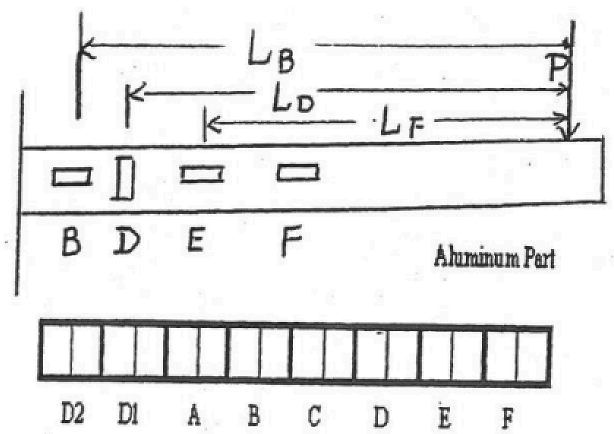

Figure 1: Drawing of Aluminum Beam with Different Strain Gage Connections

The first step of the experiment is to remove the wooden block. Strain gage B is then connected to the BLH type 20 Strain Indicator. The bridge selection should be pointed to "two arms". The two terminals of D1 are connected to points 0 and b of the bridge and the two terminals of B are connected to 0 and a. Knob A is then rotated until the needle on N reaches the black line. The needle is adjusted on the equilibrium line using the balancing knob. The value of C is read and added to the value of A to get the zero loading reading which is recorded. The weight at P is added in 1 lb increments where the load doesn't exceed 3 lbs. The needle on N is then brought back to the equilibrium position. The new C value is read and added to A again. The difference between the new value and the previous value is the value of strain at point B.

This process is repeated for gages D, E, and F. The distances from P to each strain gauge, the thickness, and the width of the beam are also recorded.

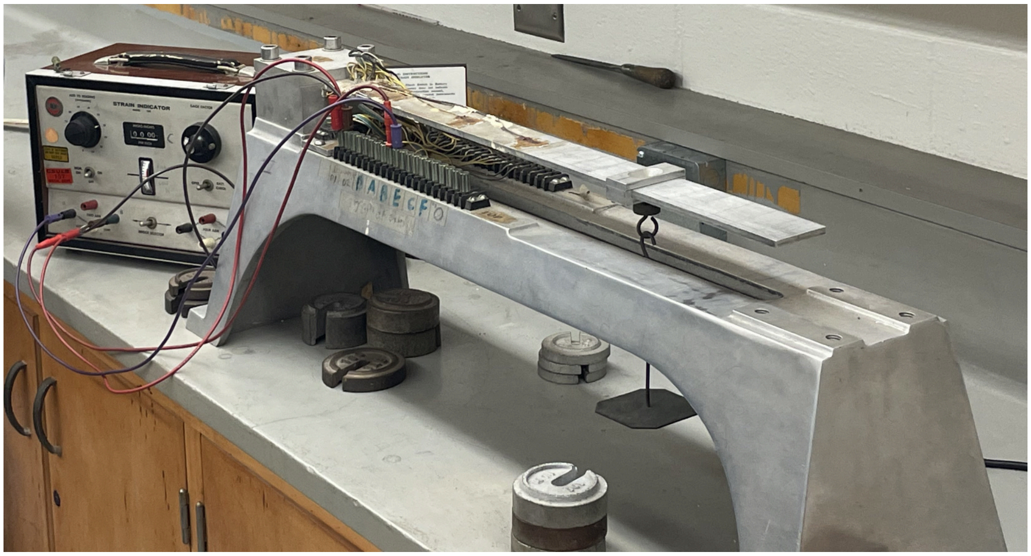

Figure 2: Full Flexure Test Experimental Set-Up

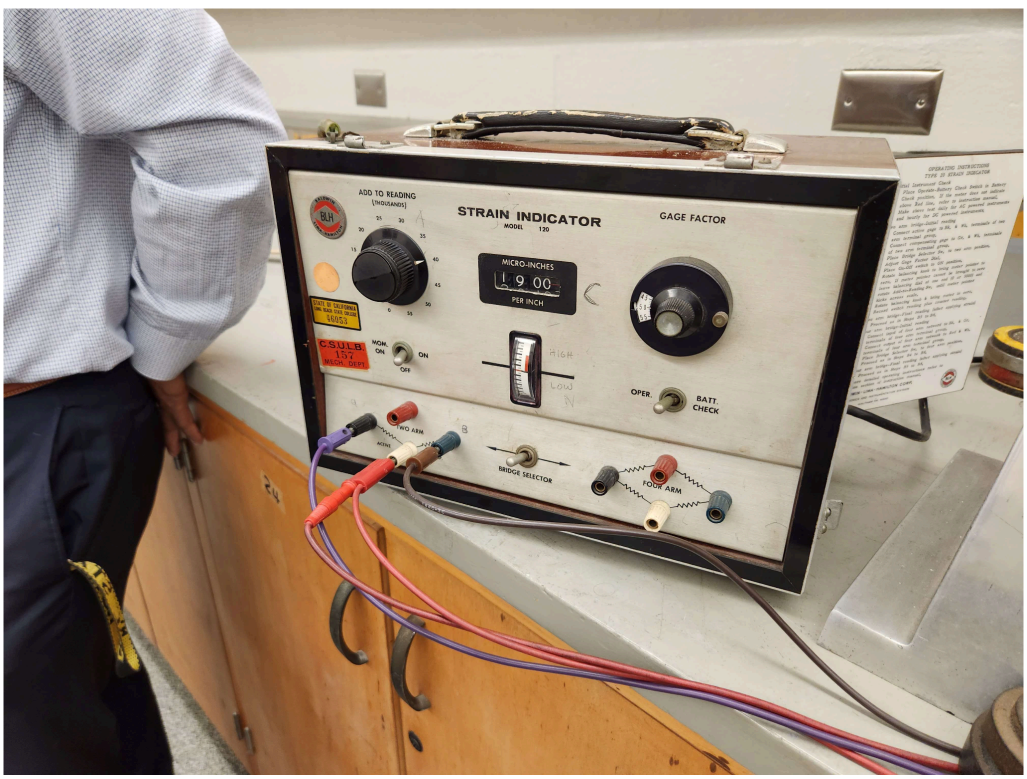

Figure 3: Baldwin Lima Hamilton Strain Indicator

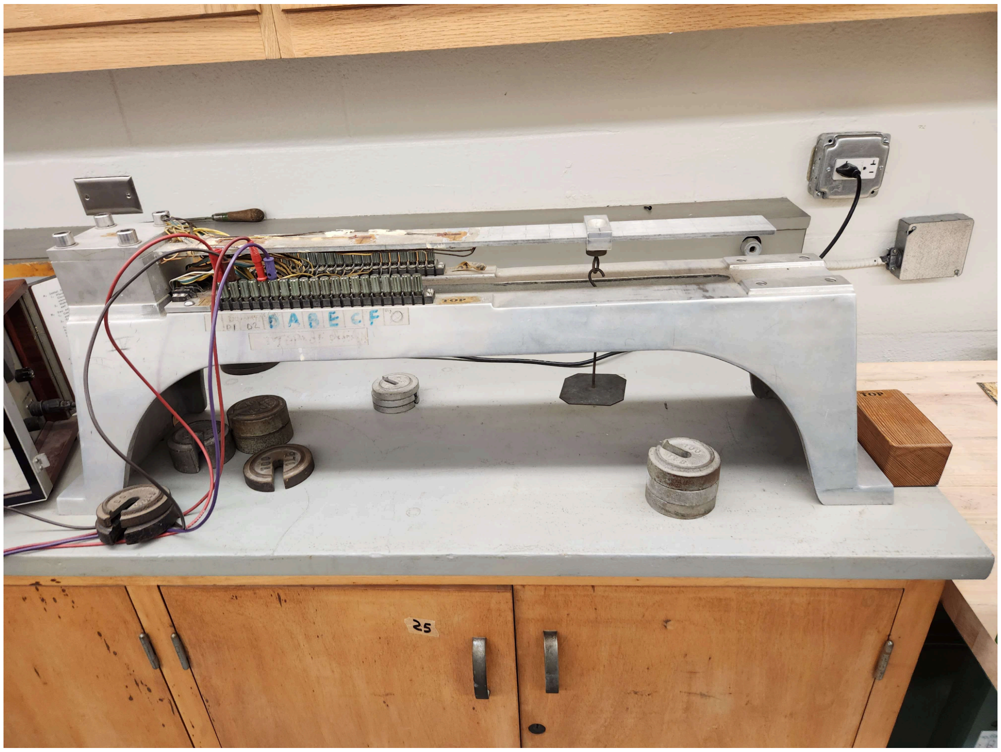

Figure 4: Aluminum Cantilever Beam with Sensors

DATA & RESULTS

	Diameter (Steel)	Diameter (Aluminum)	Locations Of sensors	Lengths in reference to loading (in)
	0.750	0.748	B	16.25
	0.750	0.746	E	10
	0.750	0.750	D	15
Average	0.750	0.748		

Table : Metal Post Measurements

Length (in)	19

Width (in)	2.007
Height (in)	0.275

Table : Calculated Values Sensor B

Load (lb)	ε_{BX} (μin/in)	Actual ε_{BX} (μin/in)	E_{exp} (10E+6 psi)	E_{st} (10E+6 psi)	% Error of E_{exp}	Theor ε_{BX} (μin/in)	% Error Of ε_{BX} (exp)
0	44690	0	0	0	100.00	0.00	
1	44770	80	8.03	10	19.703	64.24	19.70
2	44850	160	8.03	10	19.703	128.48	19.70
3	44940	250	7.71	10	22.914	192.71	22.91
2	44850	160	8.03	10	19.703	128.48	19.70
1	44760	70	9.18	10	8.231	64.24	8.23
0	44670	-20	0	10	100.00	0.00	

Table : Calculated Values Sensor E

Load (lb)	ε_{EX} (μin/in)	Actual ε_{EX} (μin/in)	E_{exp} (10E+6 psi)	E_{st} (10E+6 psi)	% Error of E_{exp}	Theor ε_{EX} (μin/in)	% Error Of ε_{EX} (exp)
0	30320	0	0	10	100.00	0.00	
1	30380	60	10.7	10	7.063	64.24	7.06
2	30450	130	9.88	10	1.172	128.48	1.17
3	30510	190	10.1	10	1.428	192.71	1.43
2	30450	130	9.88	10	1.172	128.48	1.17
1	30380	60	10.7	10	7.063	64.24	7.06
0	30320	0	0	10	100.00	0.00	

Table : Calculated Values Sensor D

Load (lb)	ε_{DY} (μin/in	Actual ε_{DY}	E_{exp} (10E+6	E_{st} (10+E	% Error	Theor ε_{DY}	% Error	γ_{exp} (neg,	γ_{theor}	% error γ

	)	(µin/in)	psi, neg, compres sion)	6 psi)	of E_{exp}	(µin/in)	Of ε_{DY} (exp)	compres sion)		
0	41900	0		10		0.00				
1	41870	-30	-8.70	10	13.011	64.24	314.13	-0.406	0.32	26.95
2	41840	-60	-4.35	10	56.506	128.48	314.13	-0.406	0.32	26.95
3	41820	-80	-2.78	10	72.164	192.71	340.89	-0.347	0.32	8.33
2	41850	-50	-4.35	10	56.506	128.48	356.95	-0.339	0.32	5.79
1	41880	-20	-9.94	10	0.584	64.24	421.19	-0.310	0.32	-3.27
0	41900	0		10		0.00				

SAMPLE CALCULATIONS For Sensor B

Safe Load = σ_{max}*I/Lc= 3500psi *(b*h^3/12)/(L*h/2)=3500psi *(2.007*0.275^3/12)/(19*0.275/2)= 4.66lb

Sensor B

Modulus of Elasticity (psi) = E_{exp} = P_{exp}*X_B*c /(ε_{BX}*I) = 1*16.25*(0.275/2)/(80x10^{-6}* (2.007*0.275^3/12))= 8.03x10^6 psi @ 1lb

E_{stand}= 10 x 10^6 psi

% Error = (E_{st} - E_{exp}) / E_{st} *100 = (10-8.03)/10*100= 19.70%

$\varepsilon_{BX,(\text{ theoretical})}$ = P_{exp}*X_B*c /(E_{stan}*I) = 1lb*16.25*(0.275/2)/((10x10^6)*(2.007*0.275^3/12))

Sensor D (same as B but change distances)

Modulus of Elasticity (psi) = E_{exp} = -ɣ*P_{exp}*X_D*c /(ε_{DY}*I) = 1*15*(0.275/2)/(-30x10^{-6}* (2.007*0.275^3/12))= -8.70x10^6 psi @ 1lb

E_{stand}= 10 x10^6 psi

% Error = (10-8.7)/10= 13.011%

Include Poisson's ratio:

$Ɣ_{exp} = (Ɛ_{DY}*X_B)/(Ɛ_{BX}*X_D)$= (-30*16.25)/(80*15)=-0.406

$Ɣ_{stand}$= 0.32

% error $Ɣ= (Ɣ_{exp}-Ɣ_{stan})/Ɣ_{stan}$= (0.406-0.32)/0.32= 26.95%

DISCUSSION

Using the data gathered at sensors B, D, and E, caused by the loading and unloading, from 0 lbs to 3 lbs and 3 lbs to 0 lbs, respectively, Young's Modulus and Poisson's ratio can be calculated. At sensor B for 1 lb, strain is measured to be 44770 µin/in, yielding a 80 µin/in strain and a modulus of 8.03e6 psi. All the sensors should have a theoretical modulus of 10e6 psi, this gives sensor B's modulus an error of 19.7%. The theoretical strain has a value of 64.24 µin/in, giving us an error of 19.7%. At sensor E, strain is measured to be 30380 µin/in, yielding a 10.7e6 psi modulus. This gives us an error of 7.063% for the modulus, and using a theoretical strain of 64.24 gives us an error of 7.06% for the strain. At sensor D, strain is measured to be 41870 µin/in, yielding a modulus of 8.70e6 psi. Poisson's ratio can be found to be -0.406. An error of 13% was found for the modulus, and using a theoretical Poission's ratio of 0.32, an error of 26.95% was found for this ratio. Taking a look at the error for Poisson's ratio in sensor D, the 1lb loading is 26.95% yet the same weight unloading is 3.27%. This could be due to human error, but it also could very well be due to the old age of the apparatus. During experimentation, even the slightest touch of the wires would mess up the results. A newer apparatus would very much decrease this discrepancy in the loading and unloading direction.

ANSWER TO INSTRUCTOR'S QUESTIONS

1. Account for the differences between the experimental strains and the theoretical strains. The theoretical strain is calculated by considering stress at each point and dividing it by reference value of Modulus of Elasticity. (2 points)

Experimental strain is found by testing a material. It can differ from theoretical strain because of unseen differences in the material such as grain structure and uniformity. The values for strain are found using strain gauge measurements while theoretical strain is calculated through assumed values and constants.

2. What does it mean by negative Poisson's ratio? Are there such materials? Show all the steps. (4 points)

A negative Poisson's ratio means a material is undergoing compressive deformation and expanding transversely under axial strain. There are such materials with a negative Poisson's ratio which include anti-rubber materials, dilational materials, and auxetic materials.

3. What are the safe loads at midspan and at the end of the cantilever beam? Given

the maximum allowable bending stress is 3500 psi. Show details of your calculations. (4 points)

Given:
σ_{max}= 3500 psi
L Mid= 9.5 in
L End= 19 in
b= 2.007 in
h= 0.275 in
c= h/2 = 0.1375 in
I=b*h^3/12 = ((2.007 in)*((0.275 in) ^3)/12 = 0.003478 in^4
Safe Load Mid= σ_{max}*I/(Lmid*c)
Safe Load End= σ_{max}*I/(Lend*c)

Safe Load Mid= ((3500 psi)*(0.003478 in^4))/((9.5 in)*(0.1375 in)) = 9.319 lb
Safe Load End= ((3500 psi)*(0.003478 in^4))/((19 in)*(0.1375 in)) = 4.660 lb

4. What is the contribution of Poisson's ratio in stress analysis and structural design? (2 points)

Poisson's ratio is useful in stress analysis and structural design since it helps determine the properties of a material relating to deformation such as how much it will expand or contract. Knowing the Poisson's ratio and properties helps determine which material is best for the application.

5. Besides this test, is there any other experiment to determine Young's modulus? Name three. (3 points)

Three other tests to find Young's modulus include the tension test, torsion test, and resonant frequency test.

RECOMMENDATIONS AND CONCLUSIONS

Through the experiment, we learned the flexure properties of an aluminum cantilever beam. We learned how to calculate properties such as the axial strain, stress, and modulus of elasticity. The concept of Poissson's ratio, a measure of deformation, and how to calculate it was also learned through the experiment. A recommendation to improve the experiment could be to make sure the strain indicator is calibrated properly to ensure that the data results are as accurate as they can be.

REFERENCES AND ACKNOWLEDGEMENT

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Names of negative Poisson's ratio materials: anti-rubber, auxetic, dilational (wisc.edu)

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