MECHANICS OF MATERIALS LABORATORY (CEN 200)

Experiment # 9

STRAIN GAGE TRAINING SYSTEM

Objective :

The training system offers a comprehensive introduction to the fundamentals of strain-gage technology, permitting investigation of simple mechanical situations as tension, bending and torsion.

Fundamentals:

With metallic strain gauges, a thin metal strip or metal wire is mechanically strained inducing a change in electrical resistance. The sensitivity, i.e. ratio of change in resistance to strain, is designated by k.

$$k = \frac{\Delta R/R}{\varepsilon}$$

Where R is the resistance and ε is the strain.
In order to provide high sensitivity, one or more strain gauges are combined in a Wheatstone bridge. The bridge is supplied with a regulated DC voltage. Strain is then applied, and the occurring voltage difference (U_A/U_E) is displayed in a differential amplifier.

Refer to the mechanics of materials textbook, R.C Hibbler, "*Mechanics of Materials*", 2nd edition, Section 3.1.

Materials :

The following material specifications shall be used in this experiment:

Table 1: Properties of materials used in this experiment.

Material	*Modulus of Elasticity, E (N/mm2)*	*Poisson's Ratio, μ*
Steel	210,000	0.28
Aluminum	191,000	0.305
Copper	123,000	0.33
Brass	88,000	0.33

PART 1 : TENSILE EXPERIMENT.

Set up :

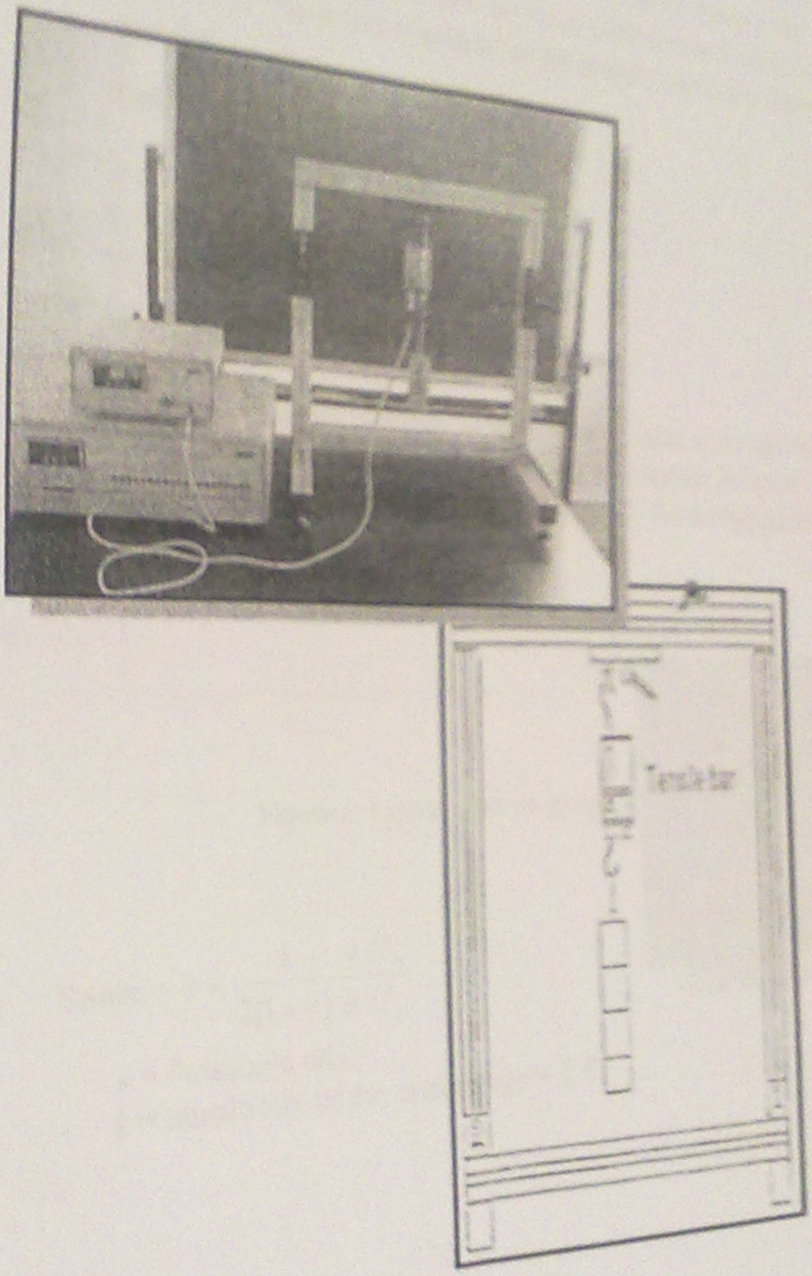


Figure 1: Sketch and photo of the setup for Group 1.

Procedure :

1. Fit the tension bar in the frame as shown in figure 1.
2. Connect up, switch, and adjust the measuring instrument
3. Load the bar in tension and measure the output signal to the feed voltage ratio.
4. U_a/U_e = output signal to the feed voltage ratio = reading in mV/V 10^{-3}

Lets Get TECHNICAL

Basics

:

Theoretically;

Under tensile loads, stresses and strains are constant through the cross-section. Tensile stress is the ratio of the applied tensile force to the cross sectional area. The strain is related to the stress according to Hooke's law:

- $\sigma = E.\varepsilon$
- $\text{Stress} = \sigma = \dfrac{F}{A}$
- σ in N/mm^2
- F = applied load in N
- A = Cross section of the bar in mm^2

Experimentally;

Two strain gauges are attached to the opposite sides of the specimen in both longitudinal and transverse directions – as shown in figure 2. The strain gauges form the bridge shown in figure 3. Such configuration gives the following:

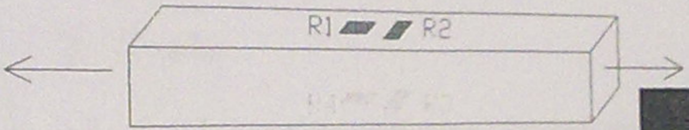
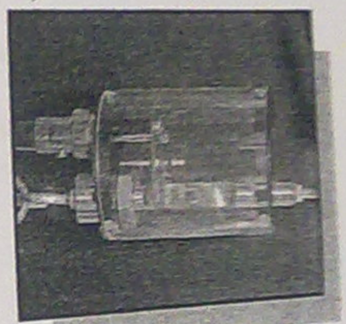


Figure 2: Layout of strain gauges.



$$\text{Strain} = \varepsilon = \frac{1}{2(1+\nu)} \frac{4}{k} \frac{U_a}{U_e}$$

- ν = Poisson's ratio
- k = Sensitivity of the strain gage = 2.05

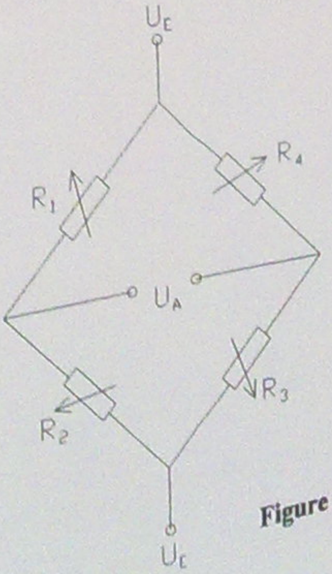


Figure 3: Bridge configuration for tensile test.

Reference :

R.C Hibbler, "*Mechanics of Materials*", 2nd edition, **Section 3.2 and Section 3.4**

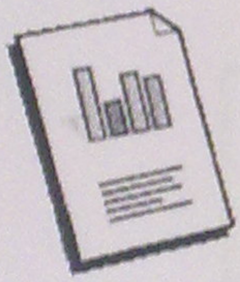
Keywords :

Axial load, Hooke's law.

Report :

1. *Discussion Questions*:

   ✓ What is the Poisson's ratio? (physical properties)
   ✓ Comment on the slopes of σ versus ε plots of different materials. Refer to graph 2 and graph 3.



2. *Graphs*:

   ✓ Graph 1: σ and ε versus load for steel beam, experimental and theoretical.
   ✓ Graph 2: σ versus ε for the four bars, experimental
   ✓ Graph 3: σ and ε (10^5) versus material, column chart, experimental, under 50N load.
   ✓ Comment on Hooke's law.

PART 2 : **BENDING TEST.**

Set up :

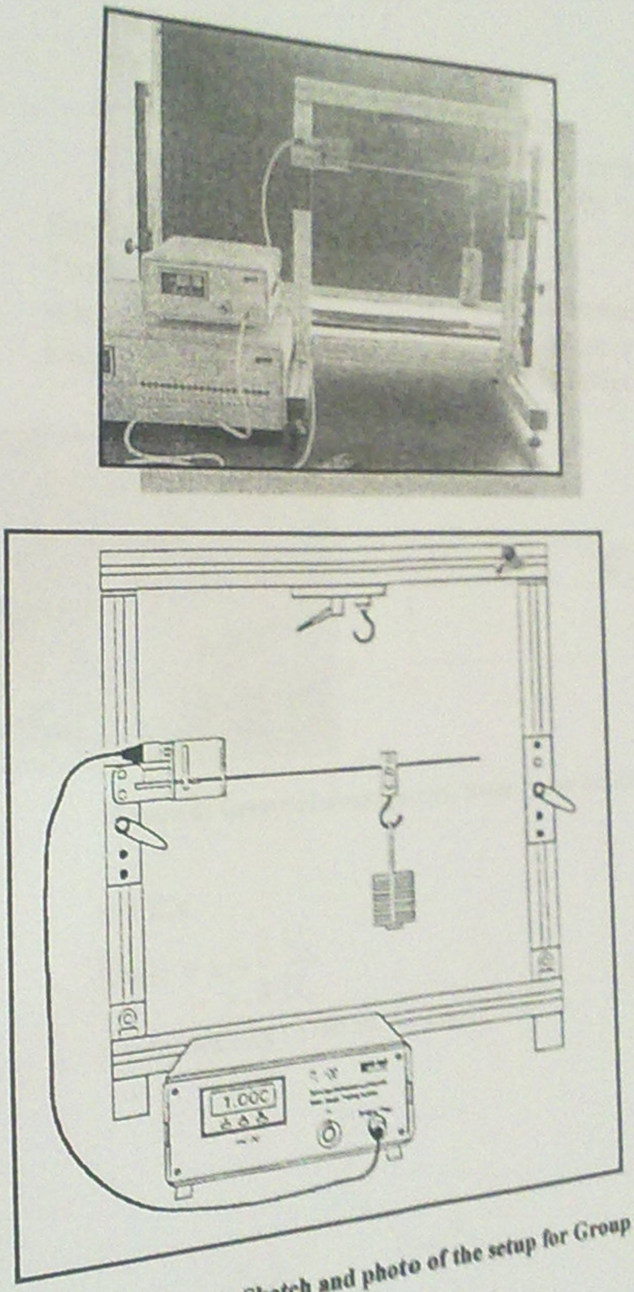


Figure 4: Sketch and photo of the setup for Group 2.

Procedure :

1. Fit the tension bar in the frame, connect up, switch, and adjust the measuring instrument
2. Load the bar in bending and measure the output signal to the feed voltage ratio.
3. U_a/U_e = output signal to the feed voltage ratio = reading in mV/V 10^{-3}

Lets Get TECHNICAL

Basics

Theoretically:

Under bending, the beam exhibits maximum stresses at the surface.

- Maximum stress = $\sigma = \frac{Mc}{I}$
- σ in N/mm^2
- M = Moment due to applied load in N.mm
- I = Moment of inertia of the Cross section of the bar in mm^4
- c = Largest distance from the neutral axis to the surface

Experimentally:

Two strain gauges are provided on each of the tension and compression sides. Unlike the tension test, the four strain gauges are arranged in the longitudinal direction – figure 5. The resulting bridge is shown in figure 6.

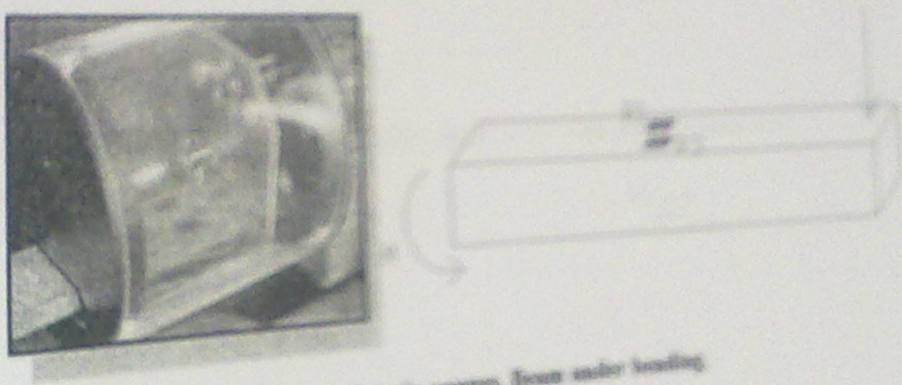
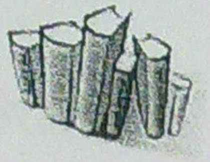


Figure 5: Layout of strain gauges, Beam under bending.

- $\sigma = E.\varepsilon$
- Strain = $\varepsilon = \frac{1}{k}\frac{U_a}{U_e}$
- k = Sensitivity of the strain gage = 2.05

Figure 6: Bridge configuration for bending test.

Reference :



R.C Hibbler, "*Mechanics of Materials*", 2nd edition, from **Section 6.3 & Section 6.4**.

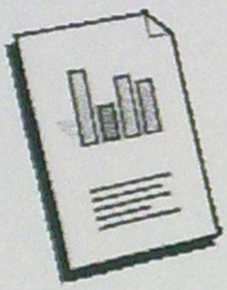
Keywords :

Bending, Neutral axis, Flexure formula.

Report :

1. *Discussion Questions*:

✓ What are c and I in the stress expression? Explain.
✓ Analyze the effect of load position on stress.

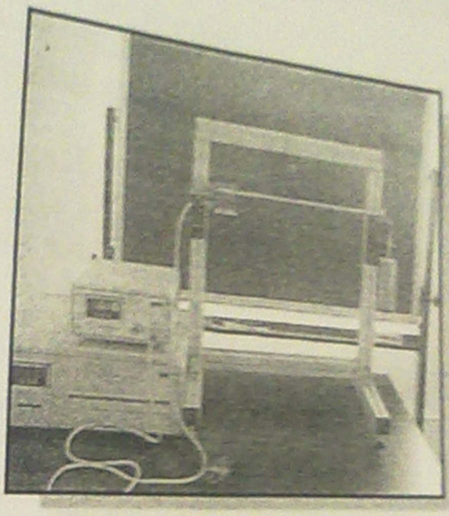


2. *Graph*:

✓ σ versus x for steel beam, under 20N load, experimental and theoretical.

PART 3 : TORSION TEST.

Set up :



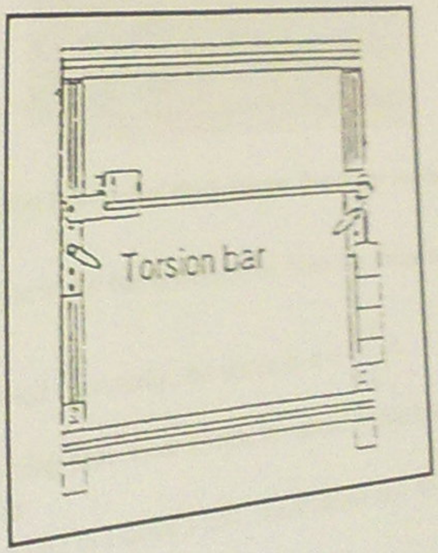


Figure 7: Sketch and photo of the setup for Group 3.

Procedure :

1. Load the bar in torsion and measure the output signal to the feed voltage ratio.
2. U_a/U_e = output signal to the feed voltage ratio = reading in mV/V 10^{-3}

Basics

:

Theoretically;

The torsional moment is the product of the applied force and the torsional arm.

- $M_t = F \times arm$ (in N.mm)
- F = Applied load (N)
- Arm = torsional arm (mm)

Experimentally;

The torsion bar is provided with four strain gauges located along the direction of the principal normal stresses, i.e. at 45° with the neutral axis.

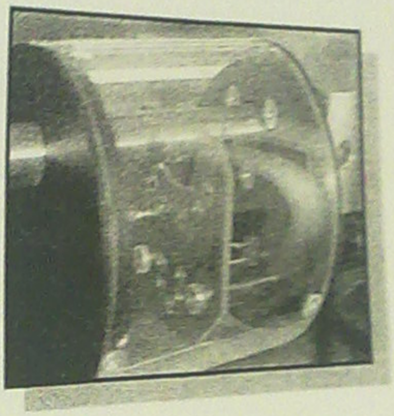


Figure 8: Layout of strain gauges. Bar under torsion.

The torque in the bar is calculated from the shear stress measured as follows:

- As noted previously, the strain is $\varepsilon = \frac{1}{k}\frac{U_a}{U_e}$
- Assuming pure shear stress, the shear strain is twice the normal strain: $\gamma = 2\varepsilon$
- According to Hooke's law, shear stress and shear strain are related as follows: $\tau = G.\gamma$

  Thus $\tau = G.2\varepsilon$
- Torsional Moment (Torque) = $M_t = \tau.W_p$

  Therefore $M_t = G\frac{2}{k} \times \frac{U_a}{U_e} \times W_p$

- k = Sensitivity of the strain gage = 2.05
- G = Shear modulus of steel = 80,000 N/mm²
- W_p = Section modulus of torsion for the circular cross section

  $= \frac{d^3\pi}{16}$

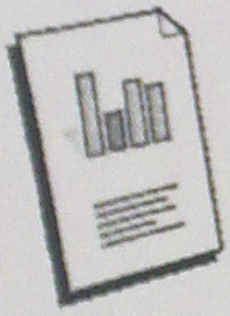
Reference :

R.C Hibbler, "*Mechanics of Materials*", 2nd edition, from Section 5.1 & **Section 5.2**.

Keywords :

Torque, Shear stress, Shear strain, Shear modulus, Section Modulus The torsion formula.

Report :



1. *Discussion Questions*:

✓ Experimentally, how the load (F) affects the torsional moment (M_t). Assess with the theory.

2. *Graph*:

✓ M_t versus F for steel beam, experimental and theoretical.