EXPERIMENTAL STUDY ON STRESS-STRAIN PROPERTY OF TWO DIFFERENT WIRES

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Abstract : ***The relationship between loads and deformation in a structure is a difficult concept, physics students often must master with little prior exposure to materials science concepts such as Hooke's law for elastic modulus Verma(1992). Two hands on experiments have been designed to help demonstrate for diploma students in an introductory strength of materials course the concept of structural stiffness and to help differentiate between the structural stiffness and the modulus of elasticity Begg et.al.(1977)for a material under applied axial load and the modulus of elasticity Mollenhauer (1987)gives for a material under applied shear loading.***

Index Terms -stress, strain, modulus of elasticity, young's modulus.

I.INTRODUCTION

Strength of materials is a second course in solid mechanics building on the first course, statics. The fundamental assumption underlying the static analysis of structures is that all structures and structural elements are rigid and hence the geometry of the structures is unchanged by applied loads Kesling (1987). In a diploma we have applied physics course we introduce students to the science of deformable bodies. It is easy to convince students that real structures are not in fact rigid but instead that every structure has an inherent deformation response or stiffness in the presence of applied loads. We then go on to teach students fundamental constitutive laws for linear elastic isotropic material behavior Ware et.al.(1975). At this juncture it is important to clearly demonstrate for the students the difference between structural stiffness and the material properties, modulus of elasticity and modulus of rigidity (Hazel et.al.1984). This paper will describe the setup and conduct of two hands-on experiments designed to help teach these important concepts as part of an applied science course. Both experiments have been designed to be highly interactive, requiring the students to become intimately familiar with each apparatus as well as receive training with some basic engineering instrumentation. The analysis in each case is designed to reinforce fundamental principles of mechanics.

Theoretical framework

The Young's modulus directly Measures the stiffness of the Solid material. It defines the relationship between stress (force per unit area) and strain (proportional deformation) in a material. Young's modulus is a measure of the ability of a material to withstand changes in length when under length wise tension or compression Kusy (1997). It predicts how much a material sample extends under tension or shortens under compression. Young's modulus is also used in order to predict the deflection that will occur in a statically determinate beam when a load is applied at a point in between the beam's supports (Acharya et.al.2005). Young's modulus or Modulus of Elasticity which is material Constant Value Khanna (1998). Thus modulus of elasticity always seems to be an important parameter in any field of engineering.

Elasticity is a property of a material which allows it to return to its original shape or length after being distorted. Some materials are not at all elastic - they are brittle and will snap before they bend or stretch. Others, like rubber, for example, will stretch a long way without significant warping or cracking Tidy(1989). This is because the materials contain long chain molecules that are wrapped up in a bundle and can straighten out when stretched (Vanderet.al.1975). Hooke's Law states that within the limit of elasticity, stress applied is directly proportional to the strain produced.

Methodology:

In the first experiment two different size wires of the same material are loaded in tension. As the applied load is increased the students record the load and the corresponding deflection of the wires. Using elementary mechanics the students can compute the stiffness of each system from a plot of load versus elongation. Then by applying the fundamental definitions of both stress and strain the data can be recast in the form of a stress-strain diagram (Hazel et.al.1984) for the material and the students can compute the modulus of elasticity for the material of the two wires.

Teaching Modulus of Elasticity

The experiment involves axial loading of different diameter wires. In this experiment the students will derive Hooke's law for uniaxial tension, Y and determine the modulus of elasticity from the measured deformation response of the test wire under applied load. From three different test cases they will be able to see that while the structural stiffness varies on a case by case basis the modulus of elasticity, Y is independent of the structural geometry and hence is only a property of the material used in the test wire. A schematic of the loading apparatus and test wire is shown in Figure 1. The loading apparatus is comprised of vertical tower welded to a heavy metal base, attached to the vertical tower is the support arm to which the test wire is attached. At the opposite end of the test wire, the lever arm is hinged to the vertical tower and fixed to the test wire. Load is applied to the test wire using dead weights suspended in a cradle from the lever arm. Deflection of the test wire is measured using a dial extensometer suspended from the support arm in parallel to the test wire. Three different apparatus are used in this experiment; the first apparatus uses a thin copper wire nominally 0.040" in diameter, the second apparatus uses a Steel wire nominally 0.065" in diameter, uses a length of thin wire in combination with a length of thick wire in parallel so that the applied load is shared by the two wires. The test wire in each case is copper with a modulus of elasticity, E = 6.28 $x10^{11}(N/m^2)$, assuming the wires have each been properly annealed they should all exhibit the same material properties. Small diameter copper wire is used because with only modest loads the entire linear elastic response of the material can be explored, that and it is of course readily available. As background for this experiment it is good to review what the students have already learned in

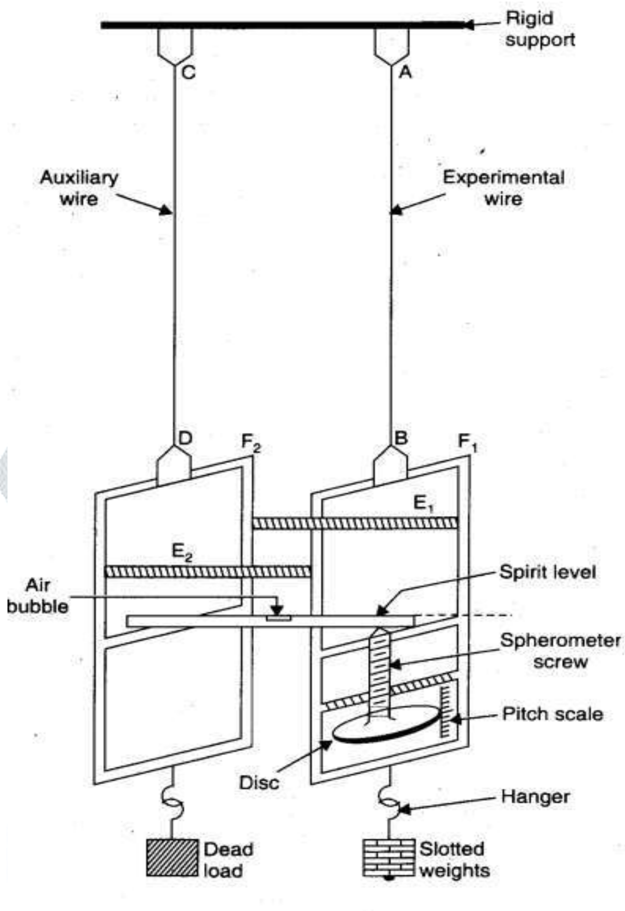

Fig. Searle's apparatus.

Table:1

Observations and Calculations:-

Given: 1) Material of wire = Steel

2)Area of the wire = 3.35 $x10^{-4}m^2$

3) LC of spherometer = 0.001cm.

Sr.no.	**Weight(N)**	**Sperometer reading**	**Elongation $x10^{-2}$m**	**Stress $x10^4$ (N/m^2)**	**Strainx 10^{-2}**
1	4.91	1.308	0.008	1.465	0.004
2	9.81	1.477	0.094	2.92	0.047
3	14.72	1.503	0.127	4.39	0.0639
4	19.62	1.615	0.246	5.85	0.123
5	24.53	1.662	0.262	7.32	0.131

Mean of Young's modulus (Y) =5.48 x $10^{11}(N/m^2)$

Table:2

Given: 1) Material of wire = Copper

2)Area of the wire = 4.50 $x10^{-4}$ m^2

Sr.no.	**Weight(N)**	**Sperometer reading**	**Elongation $x10^{-2}$m**	**Stress $x10^4$ (N/m^2)**	**Strain $x10^{-2}$**
1	4.91	1.509	0.015	1.09	0.0075
2	9.81	1.659	0.104	2.18	0.052

3	14.72	1.675	0.11	3.27	0.055
4	19.62	1.800	0.223	4.36	0.115
5	24.53	1.920	0.336	5.45	0.168

Mean of Young’s modulus (Y) =6.28 $x10^{11}$(N/m^2)

IV. RESULTS AND DISCUSSION

Summary

Two hands-on experiments have been designed and demonstrated to augment the conventional lecture only teaching of the concept of structural stiffness and to help differentiate between the structural stiffness and the modulus of elasticity for a material under applied axial load and the modulus of rigidity for a material under applied shear loading. Details of both apparatus and the methodology for each of these experiments have been described in full. .Both experiments serve to demonstrate that while the structural stiffness varies with the geometry of the structural element, both the modulus of elasticity and the modulus of rigidity are independent of geometry and thus material properties (Witting et.al.1992). This can be a challenging concept for students taking an introductory mechanics course, particularly when mechanics of materials precedes any sort of materials science course. Through hands-on experimentation and deliberate data manipulation the students acquire a better understanding of the difference between structural properties such as stiffness and material properties such as modulus of elasticity and modulus of rigidity.

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