TRIBHUVAN UNIVERSITY

INSTITUTE OF ENGINEERING

(DEPARTMENT OF MECHANICAL ENGINEERING)

LABORATORY MANUAL

ON

STRENGTH OF MATERIALS
(EG504ME)

FOR

B.E. in Mechanical Engineering Program
(Second year, Mechanical Engineering Students)

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1) Simply Supported beam.
2) Strut
3) Torsion test.
4) Tin Walled Slinder.

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Experiment No : 1

Title: Tension Test Of Metals.

Objectives:

1. To make familiar with the operation of SM100 Universal Materials Testing Machine.
2. To study the stress-strain relation of ductile and brittle materials under tensile force.

Introduction:

A stress-strain graph can be drawn for a specimen under the action of tensile force. It is found that upto certain point of P, the stress-strain graph is linear (fig. 1.a & 1.b) and point P is known as proportionality limit. Further increment on load beyond P and upto point E no permanent strain remains after unloading. The point E is known as elastic limit. After the elastic limit, at certain point Y, the strain increases without further increment of load and it is known as yield point. In ductile materials (fig. 1a), there are more than one yield points and the lower yield point is generally used for design purposes. The stress corresponding to yield point is known as yield stress or yield strength of the materials.

Many materials, especially brittle materials such as heat-treated steels and some non-ferrous metals, do not exhibit a pronounced yield front and in such cases a proof stress should be specified. The proof stress is the stress at which a non-proportional elongation equal to a specified percentage of the original gauge length occur (fig. 1c).

Beyond the yield point, the linear elastic region is followed by a non-linear plastic region. In this region, the load required to cause further deformation increases with increasing strain and this phenomenon is known as work hardening and strain hardening. The slop of the stress-strain decreases as the elongation increases. It becomes zero at certain maximum load and the engineering stress corresponding to it is called the ultimate tensile strength of the material. Beyond this point, the elongation continuous with even some decrement in load and the specimen break into two pines. For the brittle materials, the specimen may fracture at ultimate tensile strength value.

Ductility:

Ductility also can be measured from tensile test, as it is the ability of a material to withstand plastic deformation without fracturing. Ductility can be measured in following two ways.

(a) $$\% \text{ elongation} = \frac{L_F - L_0}{L_0} \times 100\%$$

Where, L_F = Final length of specimen
L_0 = Gauge " " "

(b) $$\% \text{ reduction in area} = \frac{A_0 - A_F}{A_0} \times 100\%$$

Where, A_0 = Initial cross-sectional area of specimen
A_F = Final cross-sectional area of specimen

Laboratory Set up:
Equipment:

The equipment used in this experiment are SM100 Universal Materials Testing Machine, SM100d specimen mounted extensometer and SM100k handoperated pump. The Universal Material Testing Machine is a hydraulically operated unit providing facilities for tensile and compression tests at loads upto 100KN to give load to the UMTS and extensometers (SM100d) is used to measure the elongation.

Safety Precautions:

1. Remove the extensometer well before the fracture of the specimen not to let extensometer damaged.

Procedure:

1) The space below the loading platform is used for tensile tests. Install the specimen into chucks which screw into two ball joints; one under the loading platform, the other in the frame base plate connect the hydraulic pump and to extensometer to the hydraulic ram of the Universal Materials Testing Machine. Remember to remove the extensometer locking pin.
[Always determine the values of yield and tensile strength of test specimen from manufacturer's data before testing. This is to allow removal of the extensometer before fracture].

2) Load the specimen slowly and as uniformly as possible. The wedge chucks take some time to grip the specimen fully. Keep tightening the locking discs initially to prevent the specimen slipping. Record the extension at load increments of at least every 5 KN in the elastic region. (At the yield point it is suggested that extra readings are made: for a metal exhibiting on upper and lower yield point take readings at increments of 0.2 KN, otherwise recordings every 0.5 KN is sufficient. During the period of considerable yielding tighten the extensometer clamps onto the specimen.

3) Continue loading and recording extensions at 0.5 KN increments upto a safe value below the forecast fracture load. Remove the extensometer before fracture, this is most important as damage to extensometer will occur if it is in place during fracture. Replace the locking pin in the extensometer. Set the E102 (Digital) 10 a me. to 'Peak Hold'. Increase the load, slowly and uniformly, and fracture the specimen. Record the fracture load.

4) Fit the two pieces together and measure the final length between the extensometer marks and the diameter in the neck using a vernier.

5) Calculate values for stress and strain and plot against each other.

6) Determine value for Young's Modulus (E) from graph.

7) Calculate values for percentage reduction in area and elongation.

8) Repeat for 75A (drawn) specimen).

Observation:

Specimen: 75 AN (normalised mild steel), cross-sectional area(a) = 75 mm^2

Stress							
Strain							

Specimen: 75 A (drawn mild steel), cross-sectional area(a) = 75 mm^2

Stress				
Strain				

Compare the difference in properties between above two specimens preparing table as follows:

Measured Mechanical Properties	As Drawn	As Normalised
Upper Yielding Stress (MN/ m^2) Lower " Tensile strength (MN/ m^2) Young's Modulus " Percentage Reduction in Area Percentage Elongation		

1.Sketch the given specimen.

2.Plot the stress-strain graph both for the specimens 75 AN and 75 A.Specify elastic region, transition region and plastic strain-strgthening region.Determine which material is brittle and which one is ductile.

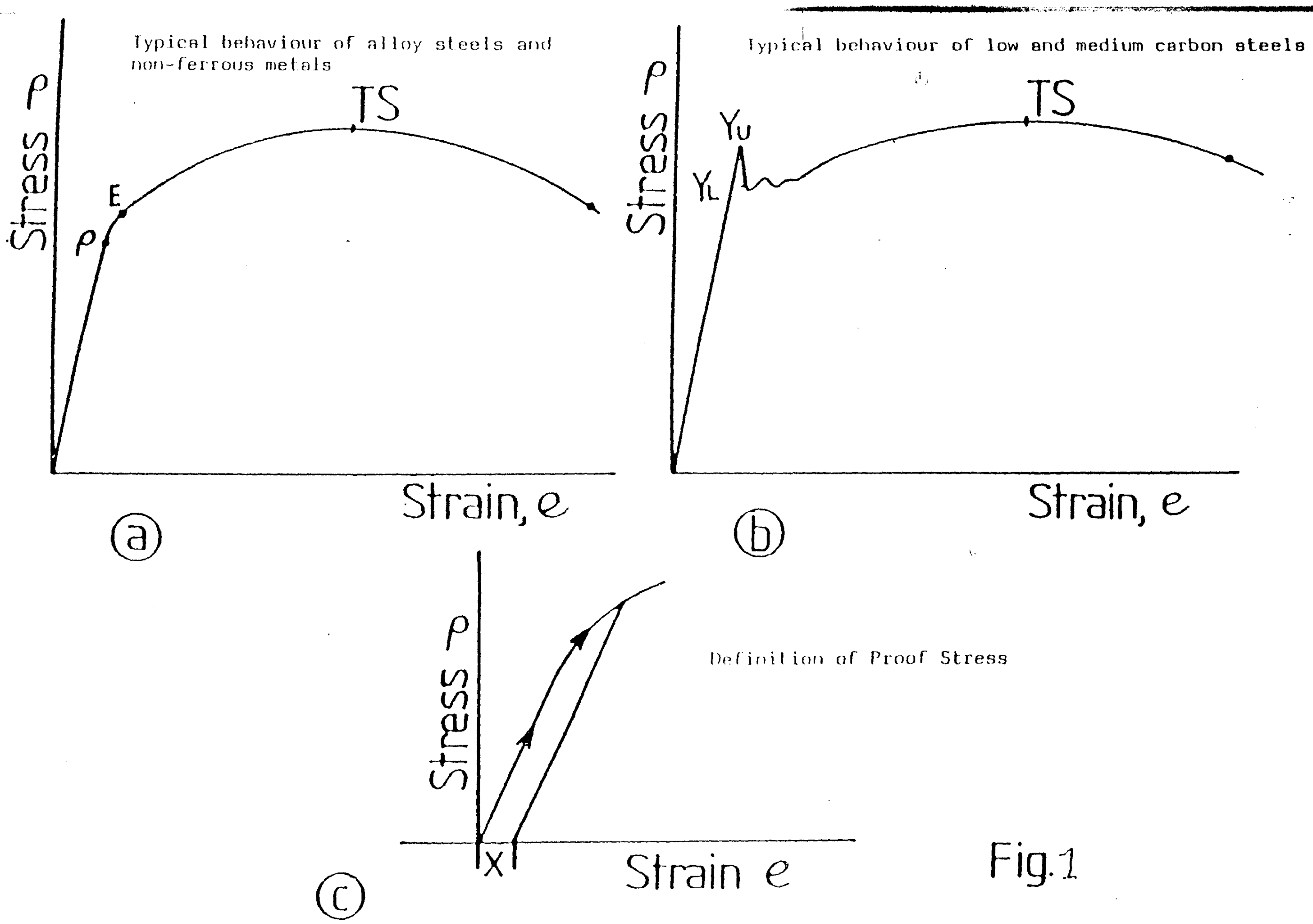

Typical behaviour of alloy steels and non-ferrous metals
Stress ρ
TS
E
ρ
Strain, e
(a)
Typical behaviour of low and medium carbon steels
Stress ρ
TS
Yu
YL
Strain, e
(b)
Definition of Proof Stress
Stress ρ
X
Strain e
(c)

Fig.1

Experiment No: 2

Title:-

Variation of Deflection of a simply supported beam with different load, beam thickness and material conditions.

Objective:-

1) **To verify the theory of pure bending.**
2) **To study the variation in deflection of a simply supported beam with different load, beam thickness and material conditions.**

Introduction:-

The theory of pure bending of a beam shows that when a beam is loaded in such away that it bends only in the plane of the applied moment, the stress distribution and curvature of the beam are related by

$$\frac{M}{I} = \frac{\sigma}{y} = \frac{E}{R} \qquad \text{.........................} \qquad (1)$$

Where ,

M is the bending moment.
I is the moment of inertia of the beam cross-section.
E is the modulus of elasticity .
R is the radius of curvature.
σ is the bending stress at distance y from the neutral axis.
y is the distance from the neutral axis (considering a beam of cross-section having two axes).

It can also be shown that the curvature of a beam (i.e. 1/R), to a close approximation, by the second derivative of the deflection. If z is the deflection of the beam at distance x from a chosen origin then:

$$\frac{d^2z}{dx^2} = \frac{1}{R} = \frac{M}{EI} \qquad \text{.............................} \qquad (2)$$

Using equation 2 it can be shown that the deflection of a beam subjected to direct loading can always be expressed in the form.

$$z = \frac{aWL^3}{EI} \qquad \text{.......................................} \qquad (3)$$

Where z is the deflection.

a is a constant whose value depends upon the type of loading and supports.
W is the load acting on the beam.
L is the span.

According to the above equation 3, the study of the variation of deflection of a beam with different load, beam thickness and material is performed.

Laboratory set up:-

Equipment:-

The equipment SM104 MK III Beam Apparatus has many features which extend the range of experiments to cover all coursework requirements relating to the bending of beams. The basic unit provides facilities for mounting beams on simple or sinking supports and also for clamping one end of the beam. Three load cells are supplied with the basic unit. These together with the clamping unit, provide for up to four points and three dial gauges allow simultaneous measurement of the deflections at three points. Transeversing a dial gauge along the upper cross-member allows measurement of deflection along the whole length of the beam. Five beams of 19 mm wide and 1350 mm long are supplied. Three of the beams are mild steel, one each of thikness 3mm, 4.5mm and 6mm; the fourthand fifth beams are of brass and aluminium with 6mm thickness.

Safety Precautions:-

1) The beam bending is done within elastic range. So, small weights should be used for thin beams with low value of modulus of elasticity.

2) Do not let the load hangers touch the ground.

Laboratory Procedure:-

1. Choose a suitable reading on the upper scale of the apparatus for the mid-span of the beam.

2. Set up one of the load cells so that it is 1/4 span to the left of the marker chosen in step 1.
   (Do not forget to take account of any offset in the position cursor).

3. Set up the second load cell 1/4 span to the right of mid-span reading. Lock the knife edge.

4. Place the beam in position with 1/4 - span overhang at either side.

5. Place the hanger at mid span so that the loading point is on the center-line of the beam.

6. Place a dial gauge in position on the upper cross member so that the ball end rests on the center-line of the beam immediately above the left-hand support. Check that the stem is vertical and the bottom O-ring has been moved down the stem. Adjust the dial gauge to read zero and then lock the bezel in position. Move the dial gauge to a position above the right-hand support, check that the beam is parallel to the cross-member then adjust the height of the knife edge so that the dial gauge reads zero.

7. Place the dial gauge at mid-span so that the ball end of the plunger rests on the center of the setscreen. Adjust the dial to read zero and lock the bezel.

8. Apply a load to the hanger and record the beam deflection on dial gauge.

9. Increase the load and record the new dial gauge reading (deflection) Do this at least five times.

10. Decrease the load by the same steps as in 9 and record the beam deflection at each step.

11. Repeat the experiment for all the beams.

12. For each beam plot a graph of deflection against load. Determine the gradient of each graph.

13. For the three steel beams plot a graph of the gradient obtained in step 12 against $1/d^3$ (d is the thickness of the beam)

14. Taking $E_s = 21 \times 10^{10}$ N/m², $E_B = 10.5 \times 10^{10}$ N/m², $E_A = 7.6 \times 10^{10}$ N/m² and using the values obtained for the 6 mm thick beams, plot a graph of the gradient obtained in step 12 against 1/E.

Observations:-

Load W (N)	Deflection z (mm.)			
	Steel 3 mm.	Steel 4.5 mm	Steel 6 mm	Brass 6 mm
5				
10				
15				
20				
25				
30				

Load W (N)	Deflection z (mm) Al 6 mm
2	
4	
6	
8	
10	

Plot the graphs of deflection vs. load for all five beams as stated in Laboratory Procedure section .

Experiment No: 3

Title: Deflection of a Cantilever

Objective:

1)To learn the effect of change in the lateral load on the deflection of a cantilever with given length and material.

Introduction:

A cantilever is a beam whose one end is fixed and the other end free. The deflection under the lateral load for a cantilever loaded at the free end is given by:

$$z = \frac{WL^3}{3EI} \qquad \text{.. (1)}$$

Where, W is the lateral load (N)
L is the span of the beam (m)
E is the Young's Modulus of Elasticity (N/m^2)
I is the moment of inertia of the cross-section of the beam (m^4)

If EI and L are maintained constant then.

$$z = K_1 w \qquad \text{............................ (2)}$$

Similarly if EI and W are maintained constant:

$$z = K_2 L^2 \qquad \text{............................ (3)}$$

Likewise $z = \frac{K_3}{E}$ and $z = \frac{K_4}{I}$ if E and I respectively are made the variables.

Where, K_1, K_2, K_3 and K_4 are constants.

So, experiments can be carried out showing the relationship between the deflection and varying each of the quantities E. I. L and W. But in the experiments below only L and W are varied.

Laboratory Set up:

Equipment:

The SM104 MKIII Beam Apparatus had many features which extend the range of experiments to cover virtually all coursework requirements relating to the bending of beams. The basic unit provides facilities for mounting both simple and cantilever beam. The beam apparatus is provided with clamped support, one load cell, one dial gauge and a beam.

Laboratory Procedure: (Refer to figure 3.1)

1. Set up a load cell at a convient position near to one side of the frame.
2. Set up the clamp to give a cantilever of conveniet length.
3. Pass one end of the beam through the clamp and rest the other end on the load cell. (It is convenient to lock the knife edge during assembly). Tighten the clamp and tie up the free end of the beam using a short piece of string.

4. Place the dial gauge near to the clamp and set the zero. Move the dial gauge to the free end of the cantilever, unlock the knife edge and adjust it so that the dial gauge returns to zero. Set the pointer of the load to zero.

5. Adjust the knife edge upwards to give convenient reading on the load cell. Record the load and the dial gauge reading.

6. Adjust the knife edge upwards to give a number of load increments recording loads and dial gauge reading.

7. Return the knife edge to its initial position, lock the knife edge, slacken the clamp and move it to new position(this is convenient than moving the load cell).

8.Repeat this experiment for several lengths of cantilever.

9. In order to vary E use the Aluminum, Brass and Steel beams 6 mm thick.

10. In order to vary I use the Steel beams 3 mm, 4.5 mm and 6 mm thick.

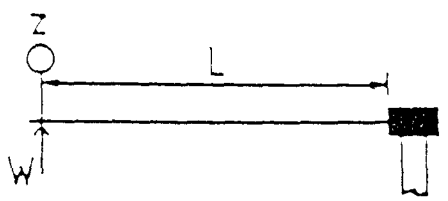


fig.3.1 Schematic diagram of experimental set-up

Note: Since the deflection of the cantilever due to self weight is large, the cantilever is made to deflect upwards by screwing the knife edge of a load cell upwards. For high accuracy the loading of the beam due to dial gauge should be taken into account.

Observation:

L(mm)	200	300	400	500	600
W(N)	z(mm)	z(mm)	z(mm)	z(mm)	z(mm)
2					
4					
6					
8					
10					

The graphs of z vs W verify equation 2 and the graph of z vs L^3 verifies equation 3 If the gradients of the graphs for z/W are obtained for each length and a graph of z/W vs L^3 is plotted, the gradient of the straight line obtained will give a measure of modulus of elasticity as follows:

$$z = \frac{WL^3}{3EI}$$

again, $\frac{z}{W} = k_2 L^3$

threfore, $E = \frac{1}{k_2\ 3\ I}$

Discuss and compare the results of the experiments with the theoretical aspect of the experiment.

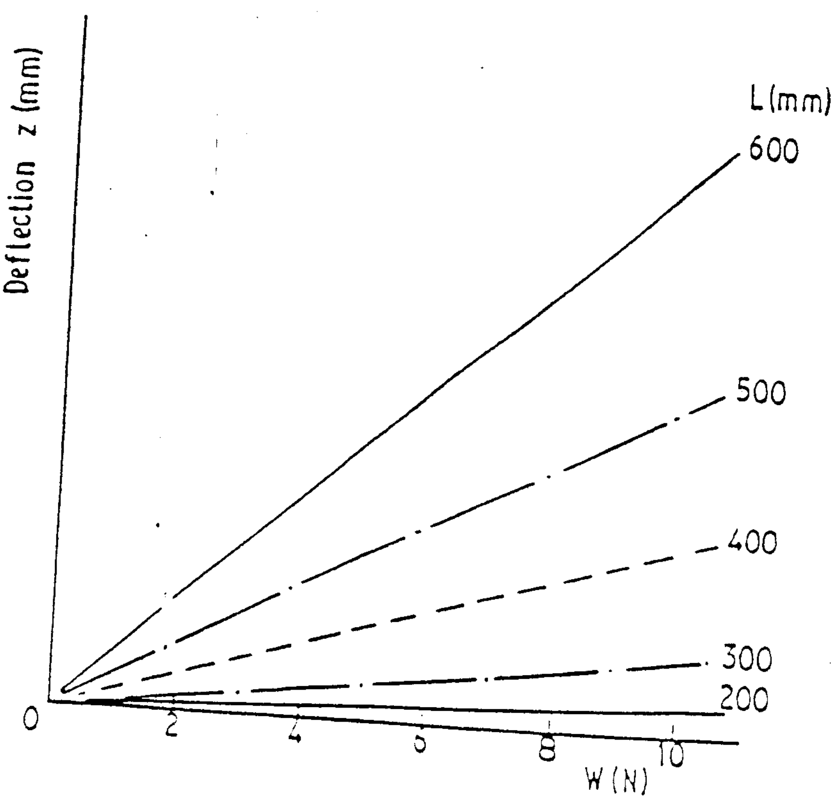


Fig 3.2 Graphs of z v W

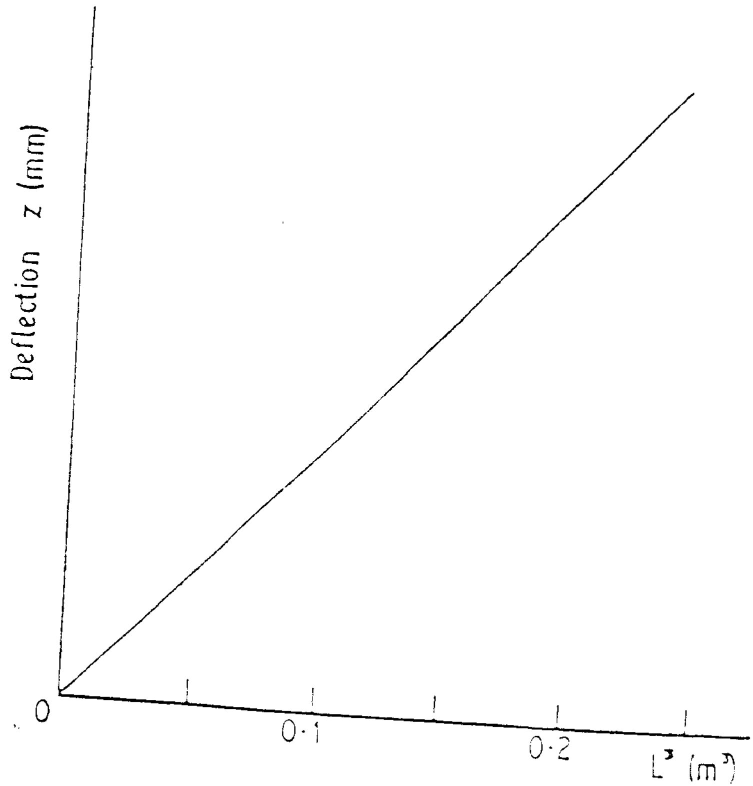


Fig 3·3 Graph of z v L³ for W = 10 N

EXPERIMENT NO: 4

TITLE: TORSION TEST OF A ROUND SOLID CIRCULAR BAR.

OBJECTIVE: To observe the shear stress- shear strain relation in a solid circular bar and to find the yield stress.

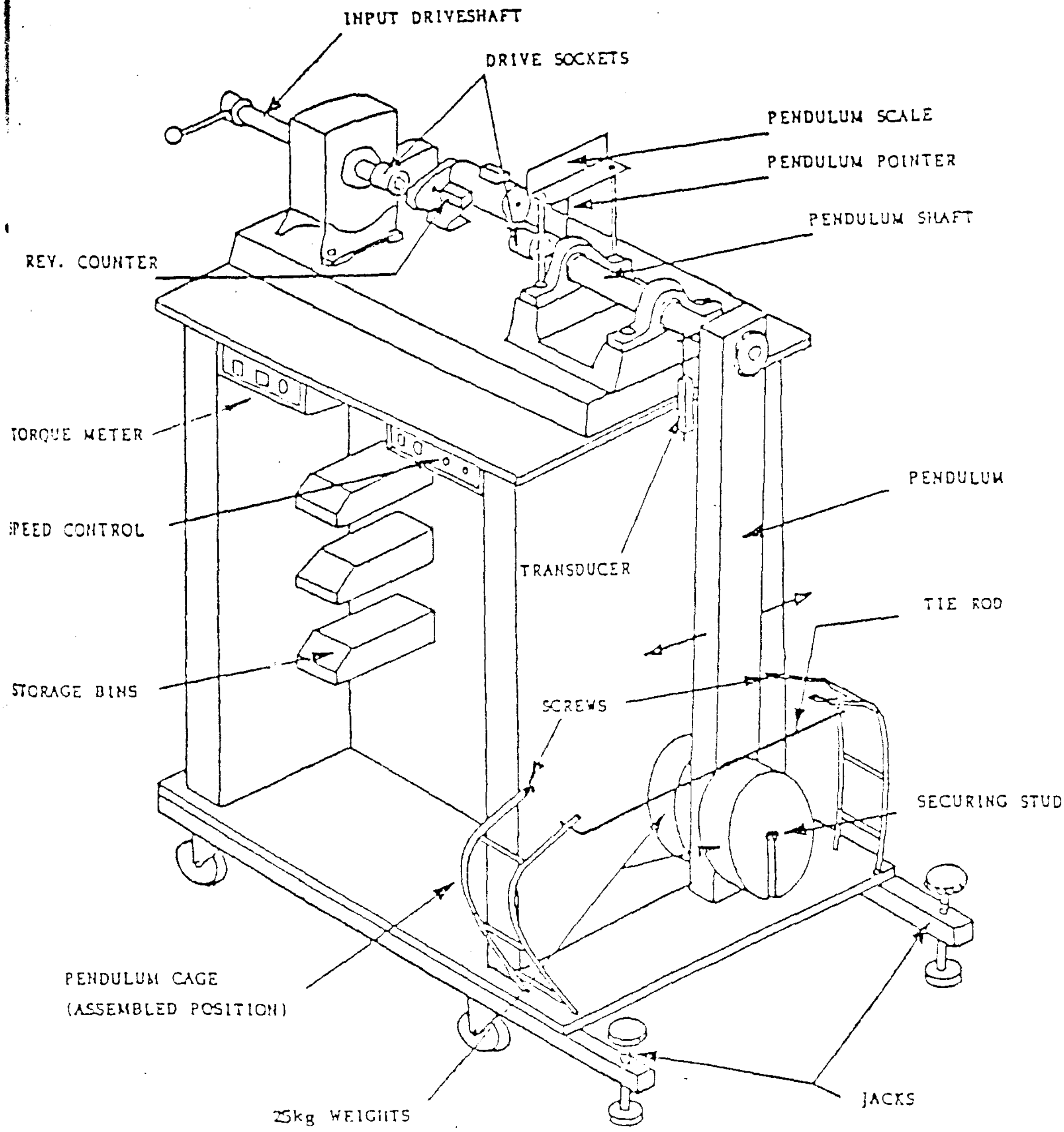


Figure .

INTRODUCTION

The SI 21 Advanced Torsion Testing Machine (as shown in Fig. 1) enables forward and reverse torsion tests on a range of sizes and lengths of specimens requiring test torques of up to 200 Nm. Load is applied by a variable speed electric motor driving through a 5:1 belt drive and a 1200:1 reduction gearbox. The torque reaction is provided by a pendulum whose movement is measured by a linear potentiometer connected to a digital meter giving a readout calibrated in torque units (N-m or lbf-in). Input rotation is measured by a digital counter, one unit being equal to 0.3^0 units of the input shaft rotation. The pendulum angle is measured by a scale and pointer. The twist of the specimen can be regarded as the difference between the angle of rotation of the input shaft and the pendulum angle. The test specimens are held at each end by sockets mounted on the input and pendulum shafts.

LABORATORY SETUP EQUIPMENTS

(Also refer the Appendix, General Notes, later in this manual.)

(a) Jack up the pendulum end of the rig using the two jacking screws in order to prevent movement of the rig due to any swinging of the pendulum during tests. (This should occur only when a specimen fractures.)

(b) Connect the speed control and torque meter modules to a single phase mains supply and switch on.

(c) Fit the appropriate sized sockets (and adaptors if required) to the input and pendulum shafts.

(d) With the pendulum steady, set the torque meter to zero using the "set zero" control at the rear of the meter unit and set the pointer to zero on the pendulum angle scale.

(e) Withdraw the input shaft through the gearbox and insert the specimen in one of the sockets. Run the motor using the speed control until the second socket will slide onto the other end of the specimen. Ensure that the input shaft is pushed inwards as far as it will go before applying any load. (Note: Select "forward" when first starting the motor.)

(f) Slowly inch the motor until the torque meter reading just begins to change, then set the input revolution counter to zero by pressing the trip lever on the left.

NOTE: NO ATTEMPT SHOULD BE MADE TO REMOVE A SPECIMEN WHEN UNDER LOAD.

EXPERIMENTAL PROCEDURE

(a) Use the motor to rotate the input shaft in increments of say 1.5^0 (i.e 5 revs to the counter). At each value record the counter reading, the torque value and the pendulum angle. This can be carried out incrementally or continuously (constant strain rate).

(b) Continue until the specimen has yielded, then increase the interval between reading to, say 6^0 (20 revs) and later to 15^0 (50revs) or more if testing relatively ductile specimens.

(c) If it is required to remove a strained specimen before fracture (for example for heat treatment), reverse the motor and run it until the pendulum angle falls to zero, and sockets become loose on the specimen. Then withdraw the sliding input shaft and remove the specimen.

NOTE: ALWAYS USE PROTECTION GLASS BEFORE ROTATING THE INPUT SHAFT.

OBSERVATION, AND CALCULATION

In torsion testing the observed readings are those of torque and twist. The results of interest are of shear-stress and shear-strain in particular the shear-stress vs shear-strain characteristics of the material. This is due to our interest in stress analysis for design purposes. If we merely require the torsional strength of a shaft we can apply torque to that shaft and measure the deflection over its length. In the case of the torsion of a solid circular shaft the stress varies directly as the radius; it is not a simple matter to convert from torque to shear-stress. For purposes of comparison what is usually done is to plot the NOMINAL Shear stress (τ) vs Shear strain (γ) curve. Use the following table to plot τ - γ.

speed counter reading (I)	Input shaft rotation = (I) x 0.3^0 (II)	Pendulum angle (III)	Total twist (θ) = [(II)-(III)] x $\pi/180$ rad	Applied torque T (N.m)	$\tau = \frac{16 \times T}{\pi d^3}$ (N/m^2)	$\gamma = \frac{d \times \theta}{2 L}$

Where, T = torque (Nm)

d = diameter of the specimen (m)

θ = twist of the specimen (rad)

L = gauge length of the specimen (m)

τ = Nominal shear stress (N/m^2)

γ = Nominal shear strain.

Fluctuation of results :- It may be noticed during continuous straining in the plastic region that the readings on the torque meter fluctuate. This is due to the shearing action taking place within the specimen and is also evident on observing the very slight oscillation of the pendulum of the machine because of vibration.

CONCLUSION:

If we merely require the torsional strength of a shaft we can apply torque to that shaft and measure the deflection over its length. In carrying out a tension test the assumption that the stress is uniform over the cross-section is usually accurate and, therefore, it is a simple matter to convert from force to stress. In the case of the torsion of a solid circular shaft the stress varies directly as the radius; it is not a simple matter to convert from torque to shear-stress.

(a) Speed Control: - the relays in this unit are wired in such a way that when the unit is first switched on, the motor will start only in the forward direction. Therefore FOWARD must always be selected when starting. REVERSE can be selected, after the motor had run forward, by stopping the motor with the speed control then selecting reverse direction.

(b) Sockets - four hexagon sizes are supplied, three being 1/2" drive for which adaptors are provided. The sockets are intended for use with the particular type of specimens.

(c) Torque Meter Calibration- the torque meter is calibrated before leaving the factory and can be checked using the values stated on the label. Setting zero at zero pendulum angle and checking values at ±10 gives a reasonable check on calibration but there may be small zeroing errors. A more accurate check can be carried out by setting zero at -10 and checking that the value at +10 is double the value state on the label.

(d) SM21 CALIBRATION PROCEDURE

To calibrate the E101 the weight hanger and weight should be used with the calibration arm.

Place the calibration arm on the square drive of the pendulum shaft (see Fig. 1). Zero the pendulum pointer by releasing the thumbscrew. Slide the E101out of its mounting bracket , switch to SI (on the front panel) and zero the reading using the knob on the rear.

Place the weight hanger on the calibration arm. The weight hanger is 2.5 Kg. Add weight to the hanger to give a total W Kg (e.g .40Kg), and note the pendulum angle. The active length of the calibration arm is 0.5m. Therefore the applied moment is:

$$M = W\, l \cos\alpha \quad \text{Kg.m}$$

$$M = Wg\, l \cos\alpha \quad \text{Nm}$$

e.g, $M = 40 \times 9.807 \times 0.5 \times \cos 20 = 184.37$ Nm

Adjust the display on the E101 to show this value, using the SI calibration trimmer on the rear of the unit. Replace the E101 in its bracket.

Experiment No. 5

Title:

FORCES IN A TRUSS (SECTIONS)

Objective:

1.To compare the forces in the members of a "right" jointed truss with the theoretical values obtained by applying the method of sections or joints to pin-jointed mathematical model.

Introduction:

External load is applied to the free end of the model through a joint plate and hanger and to measure the internal forces in the members two clamp-on strain transducers are employed in conjunction with a two channel force indicator. One transducer and meter channel has been calibrated in tension and the other in compression to read force in Newtons on a 500 N scale. Thus observed valued of forces are then compared with the theoretical values obtained from calculation either by joint method or by section method assuming pin joint condition. (Refer "Details of Theory for Calculation" later in this lab manual).

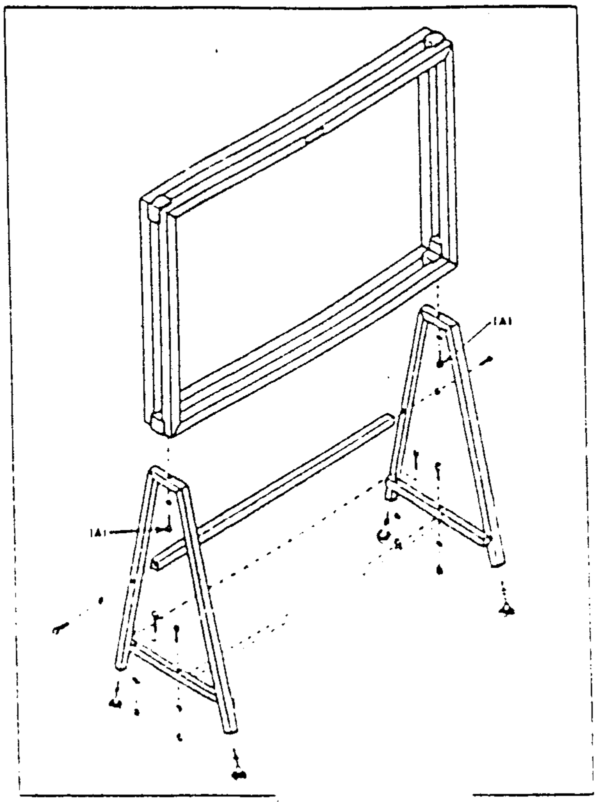
Laboratory Setup

Equipments

Universal HST. 1 Test Frame, Loading attachment, steady bar assembly, pair of Springs. Set of 9 joint plates, Set of 18 members (various lengths), Assembly Kit (3 Allen keys, 22 spanners nuts and washers), Load indicator with tension and 1 x 10 N). The experimental equipment provides for the construction of three regular plane trusses cantilevered from two wall springiness by using a selection of members as in the following lists ((Students have to perform experiment on any one set only).

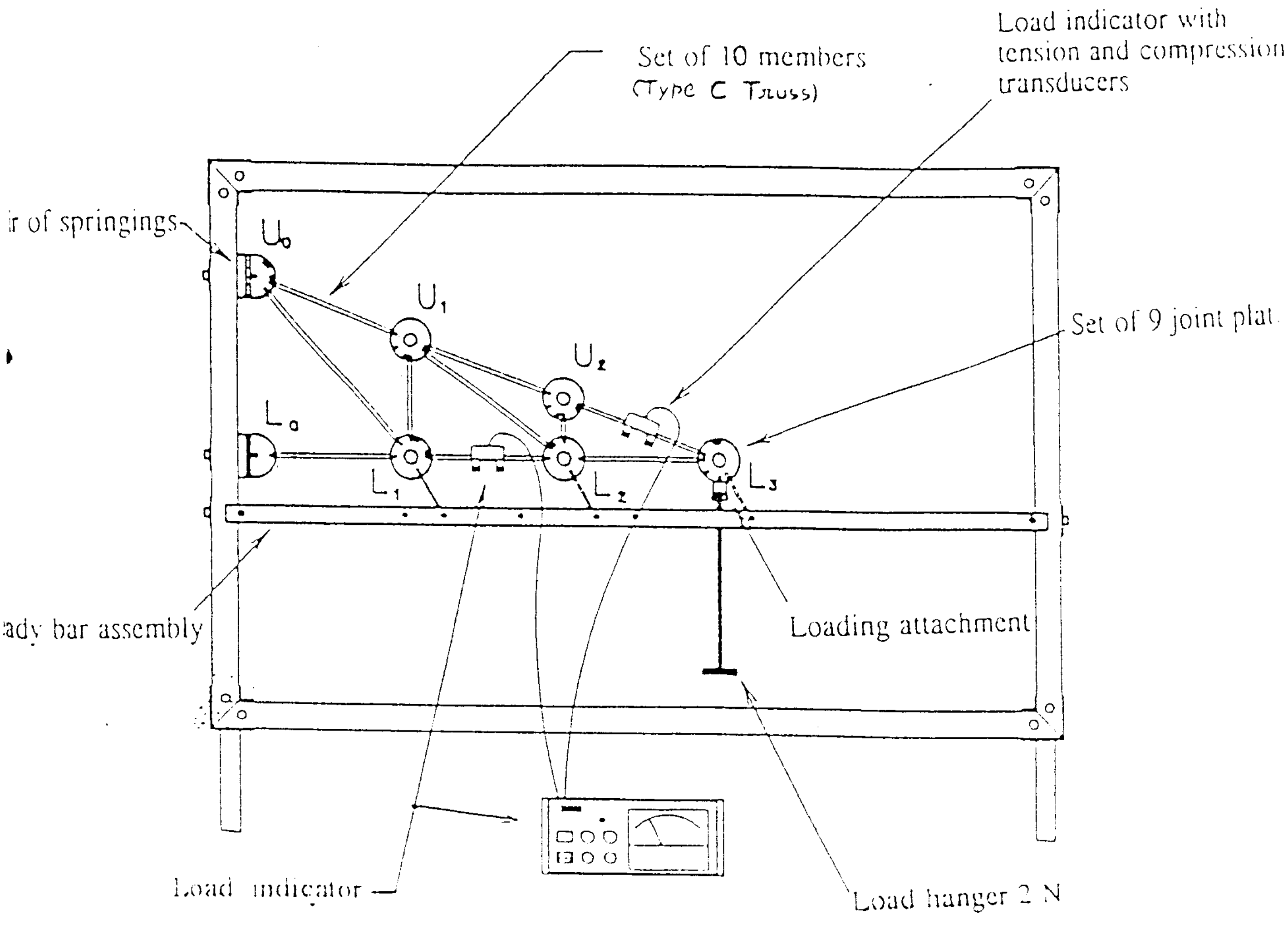
Truss Joint Centers (mm)	Actual Overall Length of Member (mm)	Quantity	Numbers used on truss type		
			A	B	C
361.3	319.3	1	-	-	1
300	258	3	3	3	1
256.3	214.3	3	-	-	3
240	198	5	5	2	3
180	138	5	2	5	1
90	48	1	-	-	1

HI-PLAN UNIVERSAL FRAME AND STAND



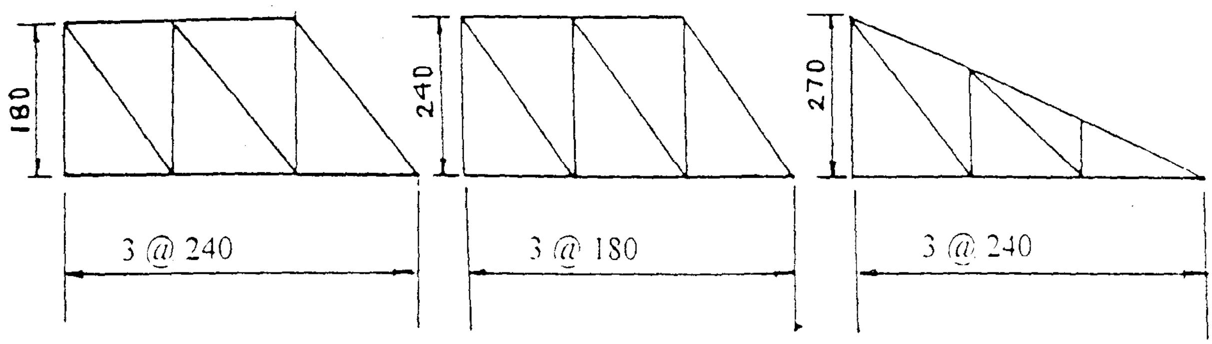
DO NOT OVER-TIGHTEN THE BOLTS (A)

FORCES IN A TRUSS (SECTIONS)



The members are made of steel and have a cross sectional area of 20 mm^2. Trusses A and B are based on a 3:44:5 triangle while C has a top member inclined at 20.5° as shown below.
The kit of parts supplied is for making up one of three "pin-jointed" trusses (A, B, C). (Note:Overall length of members is 40 mm less than truss joint centres).

Type A truss — Type B Truss — Type C Truss



Procure:

1 A pane truss is constructed in one of the three forms sketched above. To achieve close approximation to pin-jointed theory, at each joint plate one member is rigidly attached while the rest are free to rotate.

2 The joints along the top or upper boom of the truss are designated U_0 (Springing), U_1 & U_2 and the bottom or lower boo L_0 (Springing), L_1 & L_3 (U_0 and L_0 being clamped on the universal frame).

3 Check that the load hanger is attached at L_3 and that the steady bar forks restrain the lower joint plates from moving transversely (sideways) to the plane of the truss to prevent buckling failure.

4 It is recommended tat the transducers are connected to ehe meter and switched on at the earliest opportunity in order that temperature stability is acheved before the transducers are clamped on to members.

Part 1: Linearity test

5.1 Preparation: Clamp the compression transducers onto member L_0L_1 and the tension one onto U_0U_1. P1639582*1g the leads into the appropriate channel of the meter, switch on the power and set the zero at each channel temporarily. There will be some zero drift as the equipment warms up. Place a 120 re-set the zeros on each channel when the load is removed.

5.2 Take a series of force readings in the two members as the load is increased from 0 to 100 N by 10N increments. For each new load check the zero by lifting the load just clear of the hanger and then applying it to obtain either a tension or a compression force reading. Enter the results in Table 1.

Table 1 (For Linearity Test)

S. N.	Load L_3 (N)	Force in U_0U_1 (N)	Force in L_0L_1 (N)	Remarks
01	0			
02	10			
03	20			
04	30			
05	40			
06	50			
07	60			
08	70			
09	80			
10	90			
11	100			

Theoretical values for 100 N load at L_3 , U_0U_1 = 267 N, L_0L_1 = 400 N

Part 2. Forces in remaining members

6 Without switching off the power to the meter, move the force transducers to another pair of members. Places a 20N load permanently on the load hanger and zero each channel. Record the reading for 100N added to the 20 N already on the hanger. Repeat each reading, adjusting the zeros as necessary, three times so tat an averaged value can be obtained. Enter the results in Table 2

Table 2 (Forces in members due to 100N at L_3)

S.N.	Member	Force in member (N)					
		(a)	(b)	(c)	Average	Theory	Type
01	$U_1 U_2$					133	Tension(t)
02	$L_1 L_2$					267	Compression (c)
03	$U_0 L_1$					167	T
04	$U_1 L_1$					100	C
05	$U_1 L_2$					167	T
06	$U_2 L_1$					100	C
07	$U_2 L_3$					167	T
08	$L_2 L_3$					133	C

Note: Students should carefully read the detailed stepwise procedure for Attaching or Transferring the force Transducer given in this lab manual.

OBSERVATION, CALCULATION, TABLE and RESULTS

Note down the observation in the above table and plot the graph for part 1 using the x-axis for applied load as shown in the standard sample results of different type of trusses later in this manual. Draw the best fit straight lines through each set of points. Add the theoretical lines for the two members. In each case show details of theoretical calculation by section or joint method assuming pin-jointed truss.
Giving similar details, calculate the theoretical forces in all other members of the truss for entry into Table 2.

CONCLUSIONS/ SISCUSSIONS / SUGGESTIONS

Compare the experimental and theoretical values of the force in each member tested.
Comment on the three types of experimental error which appear in the results, using headings

(a) Random differences of individual readings.
(b) Differences in the gradient off the experimental and theoretical straight lines.
(c) Zero errors of the readings. DISCUSSION DO the results justify the use of the simplified theory,
based on a pin jointed frame, for analyzing the model truss?

DETAILS OF THEORY FOR CALCULATION (APPENDIX)

The use of the method of sections for finding the forces in truss members is most relevant when the force in a particular member is required. The technique is to cut the truss and then consider the equilibrium of the left or right hand part. (e.g., see the figure below)

Section 1: Three unknowns. To find any one take moments about the intersection of the lines of action of the other two forces. Assume all unknowns are tensile in which case a negative answer means that force is compressive.

Force in L_1L_2. Moments about U_1

$R_A \cdot l - F_4 \cdot p_4 = 0$ .... i.e., $F_4 = R_A \cdot l / p_4$ (tensile)

Force in U_1U_2. Moments about L_2

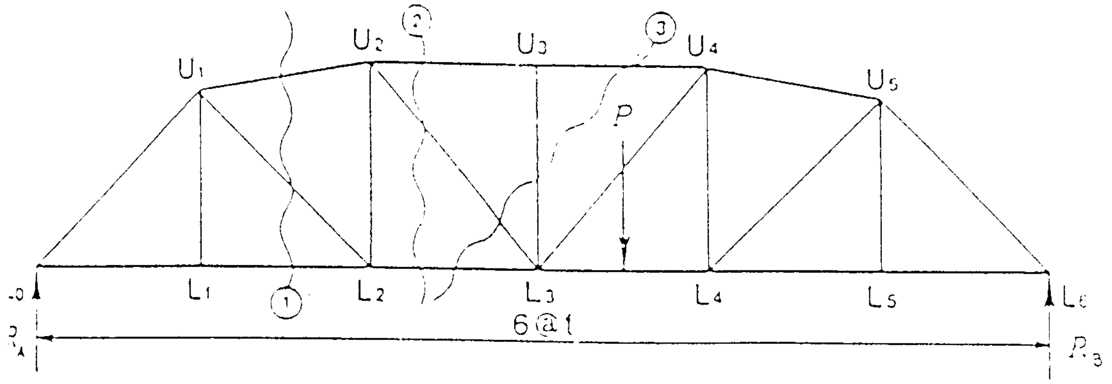
$R_A \cdot 2l + F_6 \cdot p_6 = 0$ .... i.e., $F_6 = -2 R_A \cdot l / p_6$ (compressive)

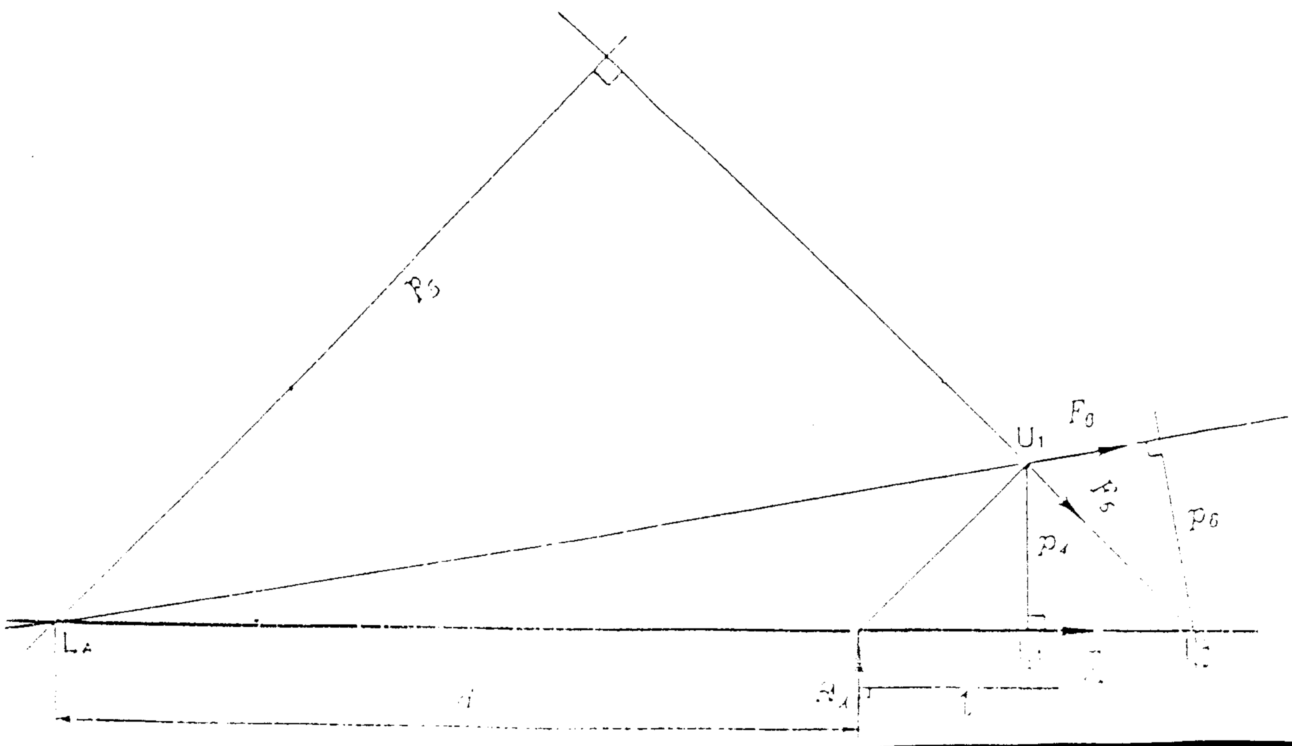
Force in U_1L_2. Moments about L_A

$-R_A \cdot d - F_5 \cdot p_5 = 0$ .... i.e., $F_5 = R_A \cdot d / p_5$ (tensile)

Section 2: Three unknowns. Moments about U_2 for force in L_2L_3 and L_3 for force in U_2U_3. Because top and bottom members are parallel and horizontal, find the force in U_2L_3 using the condition of vertical equilibrium.

The member U_3L_3 is a problem. A section such as 3 cuts four members and it might be necessary to use section 2 first to determine the unknown force in the member U_2L_3. However this is a secial case where one would use resolution at the joint U_3, because the only possibility of U_3L_3 having a force would be if an external load acted at U_3.





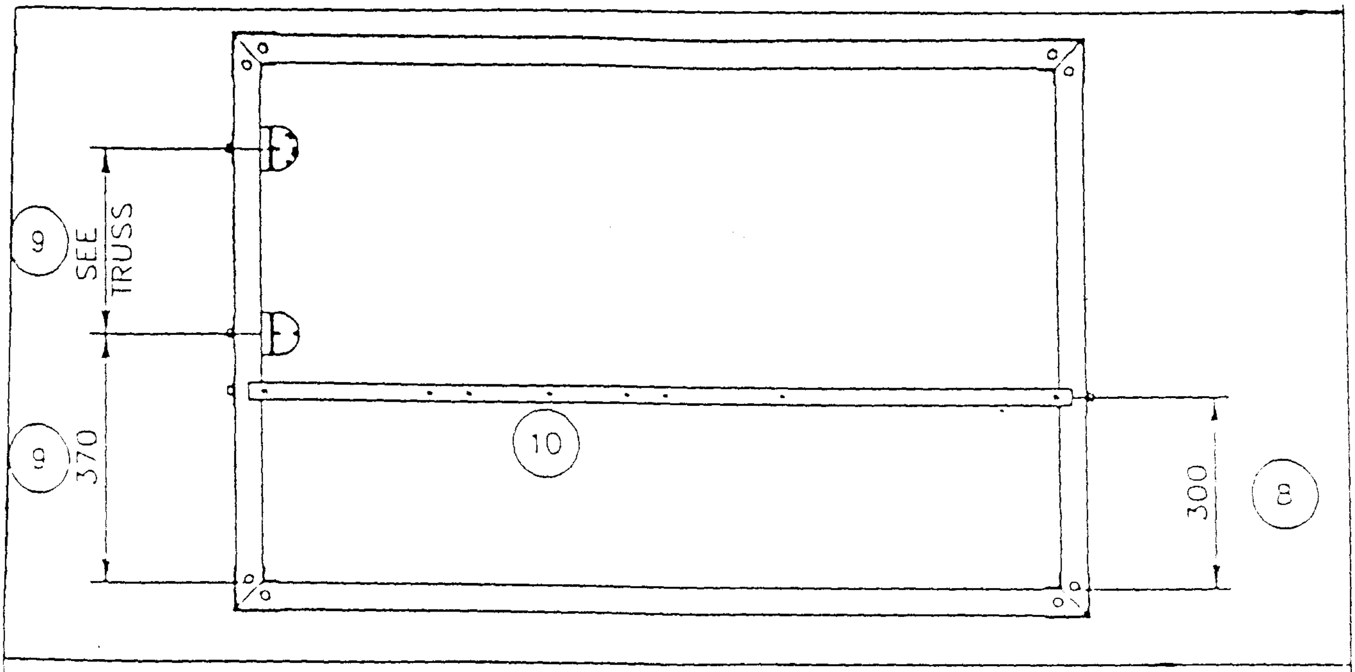
CONSTRUCTION APPENDIX

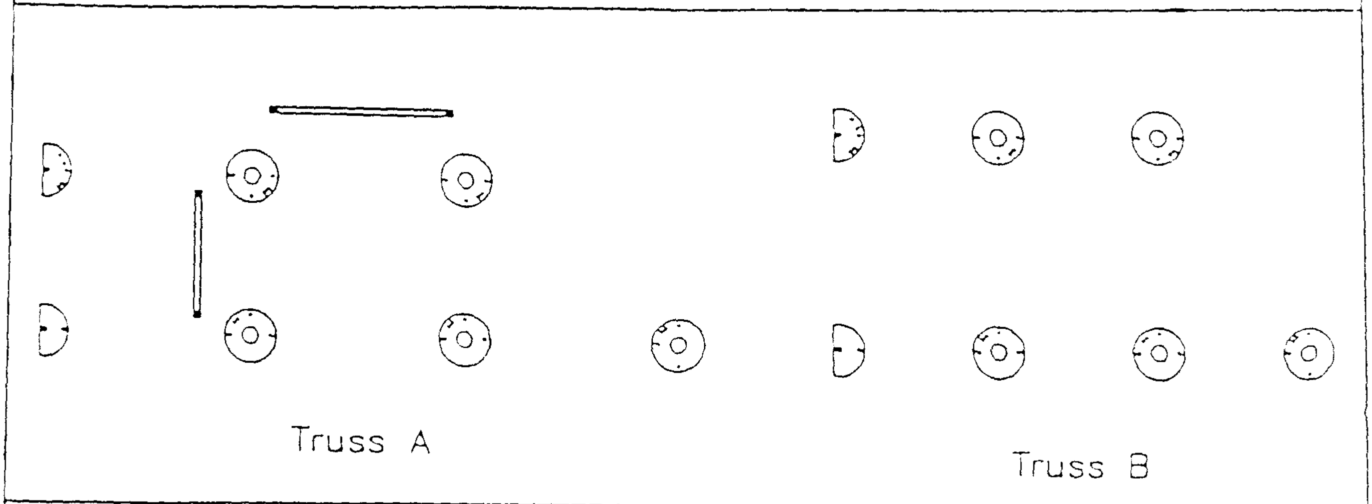
The trusses are to be built off the left hand side of the HST.1 frame. They should be assembled on a flat bench as described below and fixed to the frame after the steady bar has been attached.

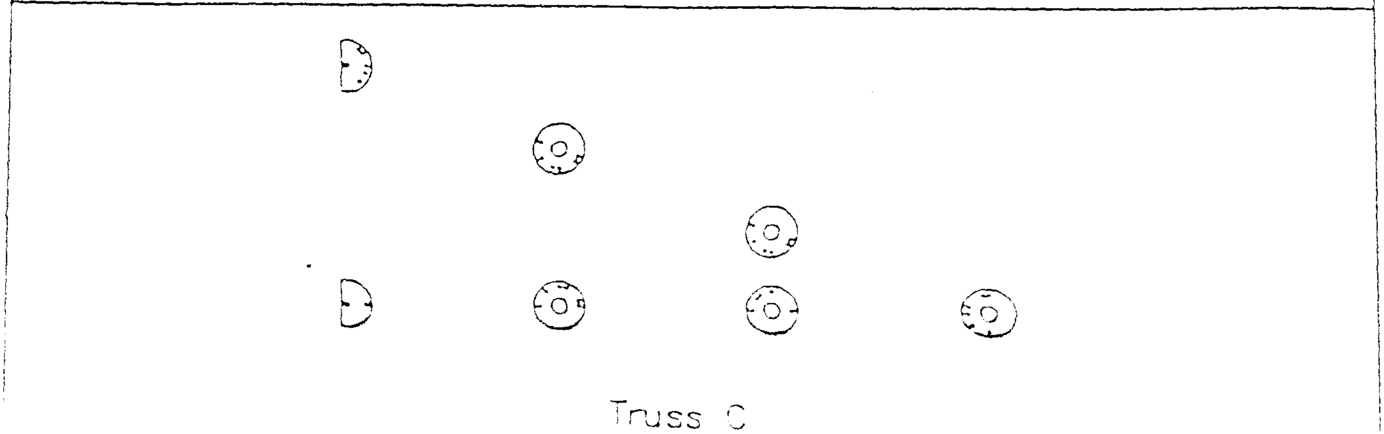
Assembling a truss

1. The joints along the top or upper boom of the truss are designated U_0 (springing), U_1 and U_2; along the bottom or lower boom the joints are L_0 (springing), L_1, L_2 and L_3. This identifies the position and direction of any member - for example the member U_0L_1 is a diagonal downward from the top springing.
2. Lay out the two springing and five joint plates on the bench in approximately the correct places. Note that L_3 is different from the other four plates.

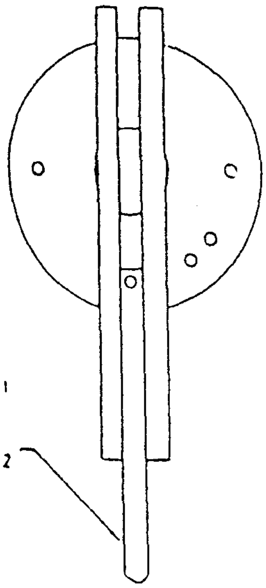
   Align the studs to suit the truss selected. Pick the required members and lay them by the sides of their positions.







3. Firstly, attach the vertical members to their top and bottom joint plates. To align them use two spare members laid each side to register with the central hole. The two vertical members MUST BE RIGIDLY BOLTED to the joint plates.



4 Secondly, attach the horizontal member to the L_1 joint plate, align it as above and BOLT IT RIGIDLY to the joint plate

5 Now assemble the other members between the joint plates and springings LOOSELY so the members are free to rotate. Make sure that the axes of the members align with the centres of the joint plates. This will simulate the pinned joint assumed in the theory

6 Next attach the load hanger stirrup loosely to L_1

7 If not already assembled, add the brackets behind the springing plates using the M6 socket headed screws

8 The steady bar should be fixed on the rear face of the HST 1 frame at 300 mm above the base. Check the forks are in line with each other and with the horizontal centre line of the frame. The adjustable forks should be turned downwards to allow the truss to be fixed

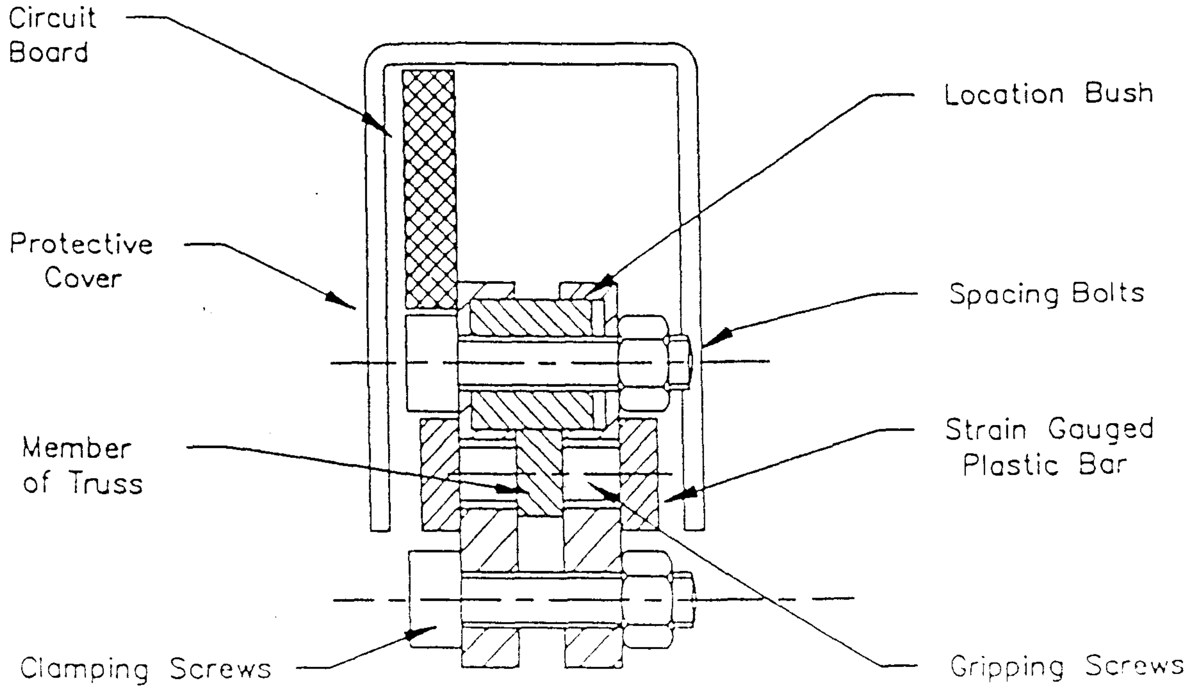
9 The whole assembled truss can finally be lifted into the HST 1 frame and fixed roughly in position (upper springing anchored first). Then anchor the lower springing at the correct height of 370 mm above the base of the frame and fix the upper springing at the appropriate centres distance for the chosen truss.

10 For the best results it is essential that the truss and its springings are in a vertical plane coinciding with the centre line / plane of the HST 1 frame. It may be necessary to put cardboard shims between the frame and the springings so that the springing plates are exactly in line with the vertical plane.

11 The adjustable forks on the steady bar can now be set in positions so that the horizontal compression booms and joints are restrained from moving sideways. This is essential to prevent a buckling failure of the whole bottom boom

11.1 The 2N load hanger is suspended from the loading stirrup.

Attaching or transferring a force transducer.



12. A cross section through one end clamp of a force transducer shows the basic principle of the clamp. To fit the transducer onto a member the clamping bolts must be removed.
13. Loosen the spacing bolts and with the clamping bolts removed drop the transducer over the member so that the member is up against the location bushes.
14. With an Allen key in the socket head of the screw tighten the nuts on the spacing bolts finger tight.
15. Insert the clamping screws, add the washers and put the nuts on. With the Allen key and ring spanner tighten the clamping bolts firmly.
16. Check that the spacing bolts are now firmly fixed by using the Allen key and spanner.
17. To remove a transducer loosen and remove both clamping bolts before loosening the spacing bolts.
18. Always plug in both transducers before switching on the power supply to the meter, and leave the power on while transferring the transducers from one member to another. This will minimise zero drift of the meter.

Experiment No: 6

Title:-

Determination of axial load-transverse deflection curves and buckling Load of columns with various end conditions.

Objectives:-

1) To study the effect of various end conditions on buckling load of a column.

Introduction:-

A compression member where length is considerably greater than the least radius of gyration of the cross-section is called a strut or column.
In practical contest a strut may bend under the action of a lateral loading due to its lack of straightness, lack of homogeneity of materials, the eccentricity of load applied etc. Even though a strut does not possess above three factors i.e. in ideal condition, strut has tendency to go through bending above a certain critical value, i. e. crippling load. Euler's theory is based on the ideal condition of a strut.
Euler's formula is used for calculating the critical load for a column or strut, and is as follows:

$$P_{euler} = \frac{\pi^2 E I}{l_e^2}$$

Where, P = Critical load
E = Modulus of elasticity
I = Least moment of inertia of section of the column
l_e = Equivalent length of the strut

A column of given length, cross-section and material will have different values of crippling loads for different end conditions. the various value of equivalent length of the strut varies with the end conditions and influence the crippling load for all given conditions. The different cases for end-conditions are as follows:

Case I : When both ends are hinged:

$$l_e = l$$

Case II: When one end is fixed, and other is free:

$$l_e = 2l$$

Case III: When one end is fixed and other is hinged:

$$l_e = \frac{l}{\sqrt{2}}$$

Case IV: When both ends are fixed:

$$l_e = \frac{l}{2}$$

Where, l = length of the strut between the joints.

Laboratory Set Up:-
Equipment:-

The equipment used in this experiment is SM1O5 strut apparatus. It is supplied with a set of strut of rectangular cross-section and provision of different end-conditions. The basic difference between the theoretical and experimental approach to the testing of struts lies in the fact that in the theoretical approach the natural concern is with the stresses induced in the strut when subjected to load, whilst in the experimental approach it is to observe and measure deflection.

The above difference is further complicated because, theoretically, a strut will remain straight until the Euler crippling load is reached. In practice the strut invariably deflects during loading and one has to use the fact that at some point the deflection becomes large as the load reaches a certain constant value. But if the strut is to be re-useable the yield stress must not be exceeded. In this case the maximum experimental load must always be less than the Euler crippling load.

Safety Precautions:-

1) In the experiments, it is necessary to avoid plastic deformation of the struts and it is therefore wise to limit the lateral deflection of the struts. It is advised that this limit be set at 150 dial gauge divisions for the steel struts supplied.

2) Do not apply load beyond the red mark indicated in the load meter

Laboratory Procedure:-

1) Ensure that the clamps of the specimen holders are tightened.

2) Select the required strut and adjust the rear specimen beam to the correct position and insert the dowel pins.

3) Turn the dowel gauge so that the stem does not impede the insertion of the strut.

4) Examine the strut and carefully straighten it if necessary. Insert the strut with its ends in the vee grooves of the specimen holders. The edge of the strut will rest against the stops at the bottom of the holders. It may be necessary to unscrew the loading knob to reduce the load to zero after the strut is inserted.

5) Adjust the position of the central cross-member so that dial gauge foot (ball end) rests on the center-line of the strut at mid-span.

6) Apply a load to the strut and ensure that the deflection is away from the dial gauge. If deflection is towards the dial gauge remove the load, turn the strut over and reload to give a central deflection of about 100 divisions.
7) Reduce the load to zero and adjust the bezel of the dial gauge to indicate zero. Tap the dial gauge stem gently and check the zeros.
8) Apply load by increments tapping the dial gauge stem very gently whilst applying the load and record the load and dial gauge reading for each increment of load.
9) Repeat the above procedure for the various end conditions required.
10) Plot graphs of load vs.deflection and extrapolate the curves to obtain the experimental crippling load. (as in fig6.1)

11) Compare the experimental crippling loads with those predicted by the Euler equation Determine the relationship between the experimental crippling loads for the various end conditions.

Observations and Exercises :-

Test no.1. Pinned Ends,

Load (N)	Deflection (div.)

Test No. 2. Pinned- Clamped

Load (N)	Deflection (div.)

Test No. 3 Clamped Ends

Load (N)	Deflection (div.)

1 div =0.1mm

1.Plot the graph for crippling load vs. deflection showing the curves for different end-conditions .

2.Draw the figure of the given specimen

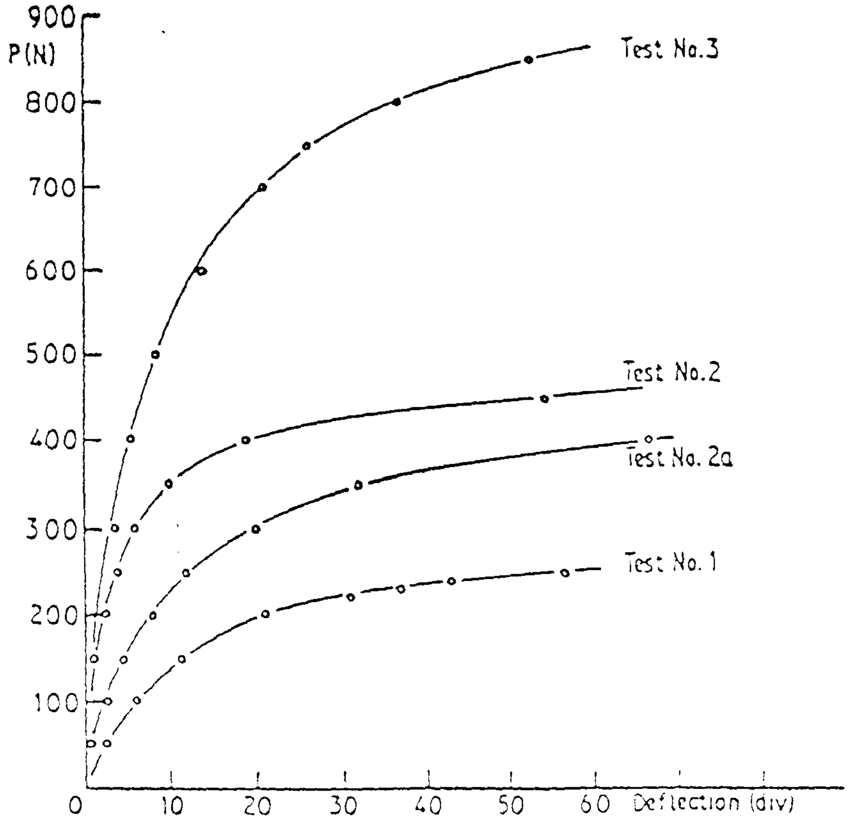


Figure 6·1. Load v deflection curves for struts.

Experiment No: 7

Title:-

STRESS AND STRAIN IN THIN WALL CYLINDERS.

Objectives:-

1) **To learn the effect of pressure on thin wall cylinders in developing principal strain and stresses for open ends condition and closed end conditions.**

2) **To calculate the value of Poisson's ratio and Young's Modulus for the cylinder material.**

Introduction:

In order to meet with several requirements, the fluids are stored under pressure in pressure vessels or shells and transported from one place to the other through pipes. Both spherical and cylindrical forms of vessels are used for storing fluids under pressure e.g. steam boilers, air compressors and tanks.

A cylindrical vessel may be thin or thick depending upon the thickness of the plate in relation to the internal diameter of the cylinder. The cylinder with its ratio (thickness to internal diameter) t/d less than 1/20 considered as thin wall cylinders. In thin wall cylinders, the stress may be assumed uniformly distributed over the wall thickness.

When thin cylinders are subjected to internal fluid pressures, following types of stresses are developed:

1. **Hoop or circumferential stresses** (σ_H) : These act in a tangential direction to the circumference of the vessel.

2. **Longitudinal stresses** (σ_L) : These act parallel to the longitudinal axis of the cylinder

3. **Radial stresses:** These act radially and are too small and can be neglected.

These three types of stresses are mutually perpendicular and are principal stresses. The value of hoop stress and longitudinal stress can be assumed constant over the area. From elementary theory, we know

$$\sigma_H = \frac{Pd}{2t} \quad \text{.......................(1)}$$

P = internal pressure in the cylinder(MPa)

$$\sigma_L = \frac{Pd}{4t} \quad \text{....................... (2)}$$

d = internal diameter of the cylinder(mm)

t = thickness of the cylinder(mm).

There are two possible conditions on which stress obtainable; i. e. with open-end condition and closed-ends condition.

a) Open Ends Condition:

The cylinder in this condition has no end constraints and therefore the longitudinal component of stress σ_L will be zero, but there will be some strain in this direction due to the Poisson effect. Considering an element of material :

σ_H will cause strains of :-

$$\varepsilon_{H'} = \frac{\sigma_H}{E} \qquad \text{.............................(3)}$$

$$\varepsilon_{L'} = \frac{-\mu\sigma_H}{E} \qquad \text{.............................(4)}$$

$\varepsilon_{H'}$ and $\varepsilon_{L'}$ are the two principal strains.

b) Closed Ends Condition:

By Constraining the ends, a longitudinal as well as circumferential stress will be imposed upon the cylinder considering an element of material

σ_H will cause strains of :-

$$\varepsilon_H = \frac{\sigma_H}{E} \qquad \text{..............(5)}$$

and

$$\varepsilon_L = \frac{-\mu\sigma_H}{E} \qquad \text{..............................(6)}$$

σ_L will cause strains of :-

$$\varepsilon_L = \frac{\sigma_L}{E} \qquad \text{..................(7)}$$

and

$$\varepsilon_H = \frac{-\mu\sigma_L}{E} \qquad \text{..................(8)}$$

The principal strains are a combination of these values, i.e.

$$\varepsilon_H = \frac{1}{E}(\sigma_H - \mu\sigma_L) \qquad \text{..................(9)}$$

$$\varepsilon_L = \frac{1}{E}(\sigma_L - \mu\sigma_H) \qquad \text{................(10)}$$

The principal strains may be evaluated and a mohr strain circle constructed for each test condition. From this circle the strain at any position relative to the principal axes may be determined.

c) Determination of Poisson's Ratio:-

Dividing equation 3 and 4 gives :-

$$\frac{\varepsilon_L'}{\varepsilon_H'} = -\mu \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (11)$$

This equation is only applicable to the open ends condition.

d) Determination of Young's modulus of elasticity.

$$E = \frac{\sigma_H}{\varepsilon_H}$$

Laboratory Setup :-
Equipment :-

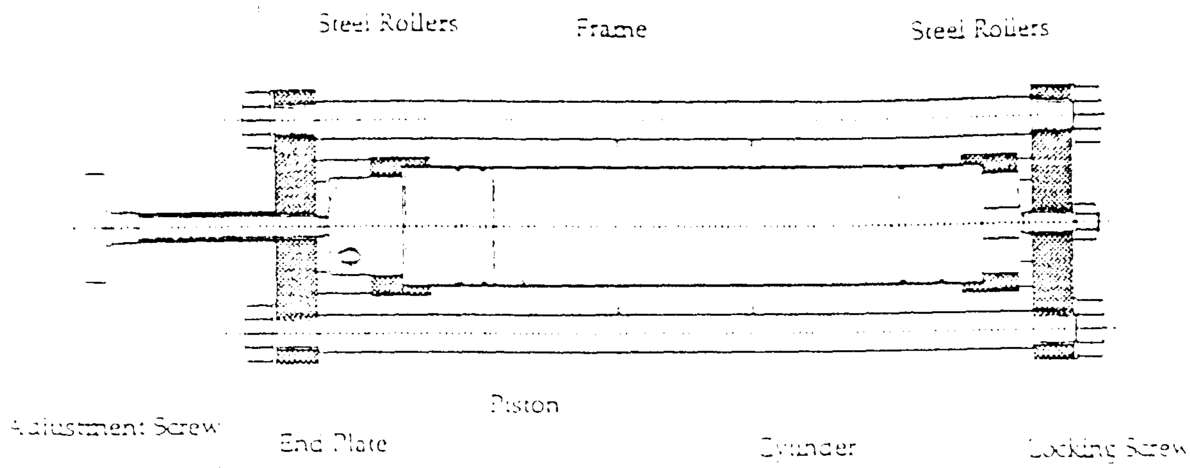


Figure - Sectional Plan of the Thin Cylinder

Above figure shows a thin-walled cylinder containing a freely supported piston. The piston can be moved in or out to alter end conditions by use of the adjustment screw. When the adjustment screw is screwed out; the cylinder is having closed end conditions and if the screw is screwed in it is in open end conditions.
Six active strain gauges are cemented onto the cylinder in the position show in figure below.

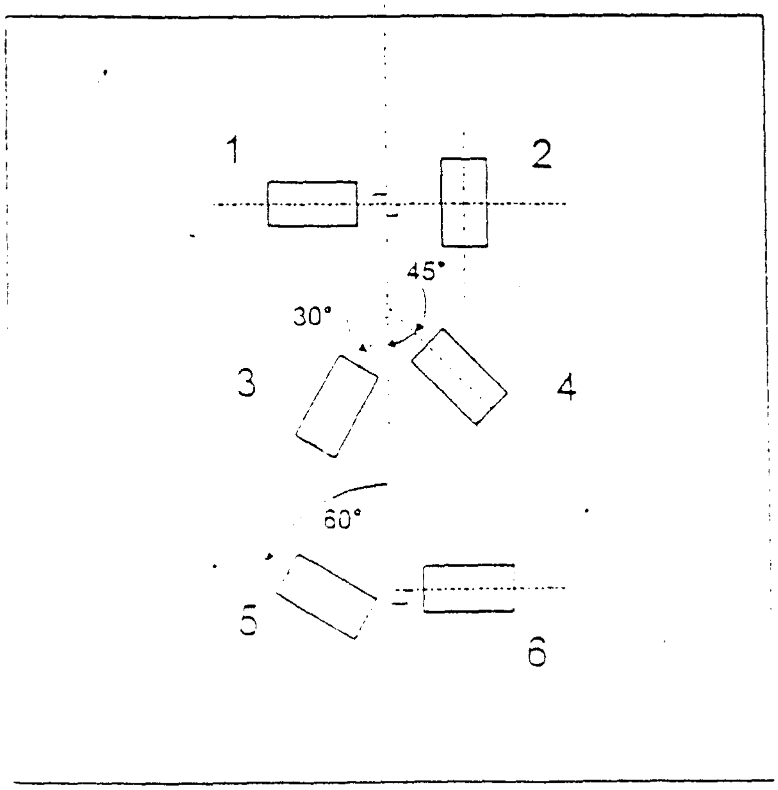


Figure . Positions of the active strain gauges on the wall of cylinder

With the aid of E10 / E18 interface, the strains measured by the strain gauges can be read out The self-contained hand pump unit applies pressure to the cylinder by closing the return valve, and operating the pump handle.

Safety Consideration:

1 Do not exceed the given pressure level.

Experimental Procedure:-

1. Connect the cables as in figure for connection requirements for E10 / E18 to SM107.

2. Before applying pressure balance each of the six strain gauges by balancing the respective balance controls.

3. (a) **To obtain the open ends condition:**
Unscrew the return valve fully. Screw in the adjustment screw until it reaches the stop. Now close the return valve and operate the hand pump to add pressure. The valve of Young's modulus for the cylinder material the valve for Poisson's ratio are determined in this condition.

(b) **To obtain the closed ends condition:**
Unscrew the return valve fully. Unscrew the adjustment screw and push the cross-piece to the left until it contacts the frame end plate. Now close the return valve and operate the hand pump increase the pressure.

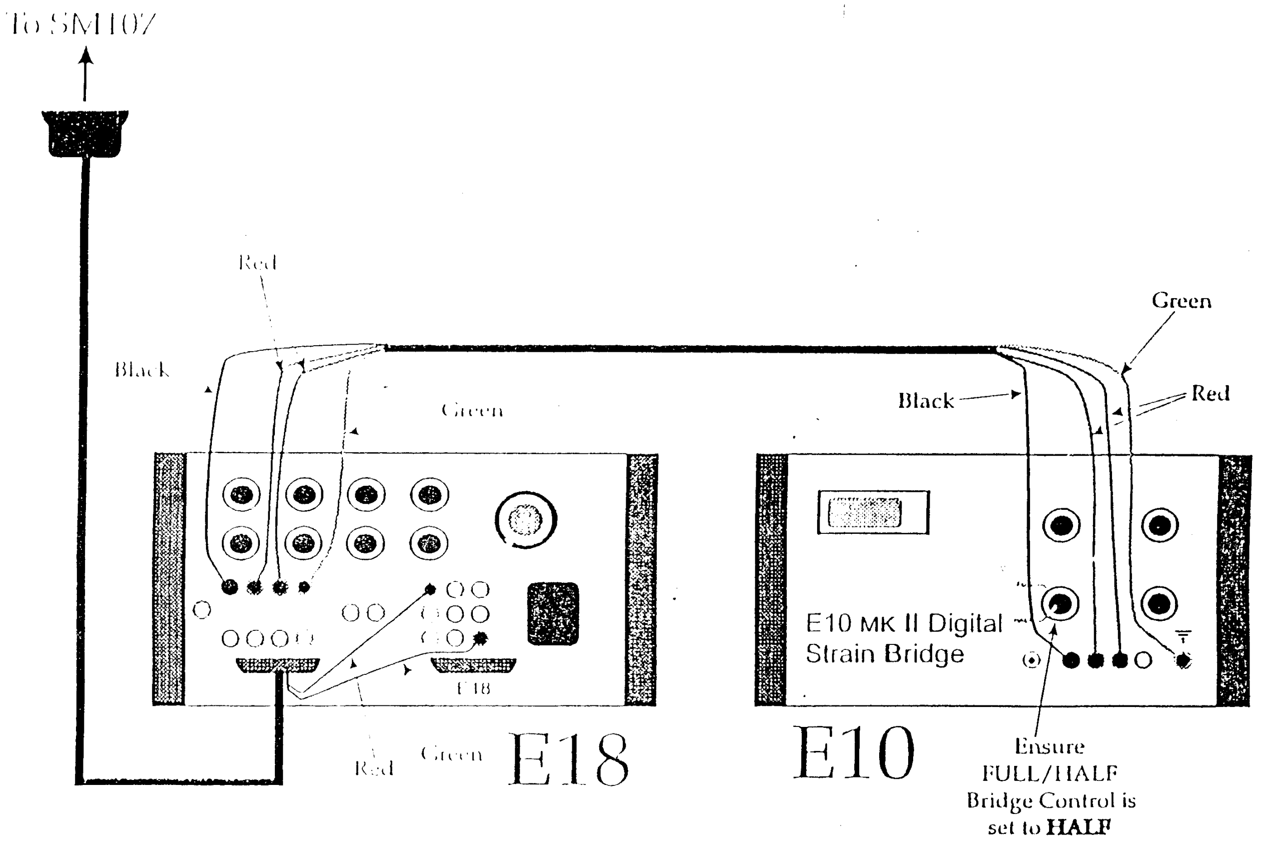


Figure ?Connection requirements for E10/E18 to SM107

Results and Calculations:

Given : $\frac{t}{d} = \frac{1}{24}$

Table 1: Determination of Young's Modulus (E) "OPEN ENDS CONDITION".

Cylinder Pressure (MN/m^2)	Hoop Stress σ_H (MN/m^2)	Measured Hoop Strain ε_H Gauge No. 1	Gauge No 6
0			
0.5			
1.0			
1.5			
2.0			
2.5			
3.0			

Value of E is obtained from the slope of the graph (stress-strain) for gauge 1 and for gauge 6 or from the formula,

$$E = \frac{\sigma_H}{\varepsilon_H}$$

Table 2 : 'OPEN ENDS CONDITION' at a cylinder pressure of 3 MN/m^2.

Gauge No.	Actual strain (micro ε)	Theoretical strain (micro ε)	Error
1		495.2	
2		-163.4	
3		1.3	
4		165.9	
5		330.6	
6		492.2	

Table 3 : 'CLOSE ENDS CONDITION' at a cylinder pressure of 3 MN/m^2

Gauge No.	Actual Strain (micro ε)	Theoretical strain (micro ε)	Error
1		413.5	
2		84.0	
3		166.4	
4		248.4	
5		331.1	
6		413.5	