



STRENGTH OF MATERIALS LAB MANUAL

B.Tech II Year – I SEM



NAME: _____

ROLL NO: _____

BRANCH: _____

DEPARTMENT OF
CIVIL ENGINEERING

Aurora's Technological & Research Institute
Parvathapur, Uppal, Hyderabad-98



STRENGTH OF MATERIALS LAB

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Evaluation of Laboratory Marks for II Year (Internal Exams)

1. The internal lab examination schedules will be given by the Examination Branch.
2. During a year there will be three lab exams and each exam will be evaluated for 25 marks.
3. Average of three lab exams will be the final internal lab exam marks.
4. First laboratory exam will be conducted on First 1/3 of the total number of experiments, Second Laboratory Exam will be conducted on the Second 1/3 of experiments and the Third Laboratory Exam will be conducted on the last 1/3 of experiments.

The evaluation is as follows

I.	Continuous evaluation	-	15 marks
II.	Internal Laboratory Exam	-	10 marks

I. Continuous Evaluation

- a) Day to day evaluation - 10 marks
Each experiment / program will be evaluated for 10 marks.
The splitting of marks is as follows
 - i) Attendance - 2 marks
The student should attend the lab regularly; if he/she is absent he/she will be losing 2 marks.
 - ii) Experiments / program and observation
The student should complete the program / experiment within the assigned time otherwise he / she will be losing 2 marks.
 - iii) Experiment result will carry 4 marks.
 - iv) Record 2 marks
Student must submit the record in the next lab session.
 - v) Average marks of the Half of the experiments will be considered for day to day evaluation for 10 marks separately for lab examination one and two.
- b) Lab knowledge Test (Quiz) 5 marks
 1. A quiz will be conducted along with the internal lab exam and schedule will be given separately.
 2. The quiz will be conducted for 20 minutes. The quiz contains 20 questions of type multiple choice. Each question carrying 0.25 marks.



- | | | |
|--|---|----------|
| II. Internal laboratory examination | - | 10 marks |
| a) Exam | - | 7 marks |
| The Splitting of marks as follows | | |
| i) Experiments / Program write up | - | 4 marks |
| ii) Result and Graphs | - | 3 marks |
| b) Viva Voce | - | 3 marks |
| 1. The internal lab examination duration | - | 2 hours |
| 2. Every student will be given programs / experiments in the internal lab exam.
In case the student wishes to change the programs / experiments 1 mark
will be deducted. A time slot of 45 minutes is given for write up of
programs / experiments. | | |
| 3. The student is expected to complete the assigned program / experiment within
1 hour and the remaining 15 minutes will be utilized for viva voce
examination. | | |
| 5. There shall be no supplementary exams in case the student fails to attend internal lab and
quiz exam as per schedule. | | |

**Evaluation of Laboratory Marks (End exams)**

1. The external lab examination schedules will be given by the Examination Branch.
2. Duration of External lab examinations - 3 Hours
3. Exam will be evaluated for 50 Marks

The Splitting of marks is as follows

- | | | | |
|------|--|---|----------|
| I. | Experiment write-up / Program with algorithm | - | 10 marks |
| II. | Experiment Setup / Program execution | - | 10 marks |
| III. | Result | - | 10 marks |
| IV. | Viva –Voce | - | 20 marks |
| | a) Written Viva | - | 10 marks |
| | b) Oral Viva | - | 10 marks |

Written Viva–Voce Exam will be consisting of 10 questions of short answer type and fill in the blanks. Each question will carry equal marks and allotted time is 15 minutes.

**LAB CODE**

1. Students should report to the labs concerned as per the timetable.
2. Students who turn up late to the labs will in no case be permitted to perform the experiment scheduled for the day.
3. After completion of the experiment, certification of the staff in-charge concerned in the observation book is necessary.
4. Students should bring a notebook of about 100 pages and should enter the readings/observations/results into the notebook while performing the experiment.
5. The record of observations along with the detailed experimental procedure of the experiment performed in the immediate previous session should be submitted and certified by the staff member in-charge.
6. Not more than three students in a group are permitted to perform the experiment on a set up.
7. The group-wise division made in the beginning should be adhered to, and no mix up of student among different groups will be permitted later.
8. The components required pertaining to the experiment should be collected from Lab- in-charge after duly filling in the requisition form.
9. When the experiment is completed, students should disconnect the setup made by them, and should return all the components/instruments taken for the purpose.
10. Any damage of the equipment or burnout of components will be viewed seriously either by putting penalty or by dismissing the total group of students from the lab for the semester/year.
11. Students should be present in the labs for the total scheduled duration.
12. Students are expected to prepare thoroughly to perform the experiment before coming to Laboratory.
13. Procedure sheets/data sheets provided to the students' groups should be maintained neatly and are to be returned after the experiment.
14. **DRESS CODE:**
Boys - Formal white shirt neatly tucked in, and white trousers, white / black / brown / tan shoes and belt, I-cards worn round neck
Girls - Formal white Salwar Kameez, white / black / brown / tan shoes, I-cards worn round neck

INTRODUCTION

Materials which we come across may be classified into elastic, plastic and rigid materials. An elastic material undergoes a deformation when subjected to an external loading such that the deformation disappears on the removal of loading. A plastic material undergoes a continuous deformation during the period of loading and the deformation is permanent and the material does not regain its original dimensions on the removal of the loading. A rigid material does not undergo any deformation when subjected to an external loading.

In practice no material is absolutely elastic nor plastic nor rigid. We attribute these properties when the deformations are within certain limits. Generally we handle a member in its elastic range. Structural members are all generally designed so as to remain in the elastic condition under the action of the working loads.

A material when subjected to an external load system undergoes a deformation. It becomes necessary to study the deformations in order to determine the conditions under which failure may occur. The ability of a part or element of a structure to resist failure by virtue of its strength. The ability to resist deformation is called stiffness. The material will have the ability to offer the necessary resistance when the deformation is within a certain limit. A loaded member remains in equilibrium when the resistance offered by the member against the deformation and the applied load are in equilibrium. When the member is incapable of offering the necessary resistance against the external forces, the deformation will continue leading to the failure of the member.

Because of the complexity involved certain simplifying assumptions are made in strength calculations:

1. The material of the body has a solid continuous structure.
2. Within the limits of the part of the body the material is homogeneous and isotropic i.e., it has identical properties in all directions at all points
3. There are no internal forces in a body prior to loading
4. The effect of the system of forces acting on a body is equal to the sum of the effects of these same forces applied in succession and in any order. This is the principle of super imposition.
5. At points in a body sufficiently away from the points of application of loads, internal forces are independent of the manner in which the loads are applied. This is known as Saint Venant Principle. Theoretical investigations show that points more than 1.5-2 times the greatest linear dimension of the area of load transmission from the region of loading a distributed load can be replaced by a concentrated load. Thus the principle enables a distributed load replaced by a point load over a small area.

1. ROCKWELL HARDNESS TEST

I. AIM: To determine the Rockwell Hardness of a given test specimen

II. APPARATUS: Rockwell Hardness testing machine, Test specimen.

III. THEORY:

HARDNESS-It is defined as the resistance of a metal to plastic deformation against Indentation, scratching, abrasion or cutting.

The hardness of a material by this Rockwell hardness test method is measured by the depth of Penetration of the indenter. The depth of Penetration is inversely proportional to the hardness. Both ball or diamond cone types of indenters are used in this test. There are three scales on the machine for taking hardness readings. Scale "A" with load 60 kgf or 588.4 N and diamond indenter is used for performing tests on thin steel and shallow case hardened steel. Scale "B" with load 100 kgf or 980.7 N and 1.588 mm dia ball indenter is used for performing tests on soft steel, malleable iron, copper and aluminum alloys.

First minor load is applied to overcome the film thickness on the metal surface. Minor load also eliminates errors in the depth of measurements due to spring of the machine frame or setting down of the specimen and table attachments.

The Rockwell hardness is derived from the measurement of the depth of the impression

E_p = Depth of penetration due to Minor load of 98.07 N.

E_a = Increase in depth of penetration due to Major load.

E = Permanent increase of depth of indentation under minor load at 98.07 N even after removal of Major load.

This method of test is suitable for finished or machined parts of simple shapes.

**IV. PROCEDURE:**

1. Select the load by rotating the Knob and fix the suitable indenter.
2. Clean the test-piece and place n the special anvil or work table of the machine.
3. Turn the capstan wheel to elevate the test specimen into contact with the indenter point.
4. Further turn the wheel for three rotations forcing the test specimen against the indenter. This will ensure that the Minor load of 98.07 N has been applied
5. Set the pointer on the Scale dial at the appropriate position.
6. Push the lever to apply the Major load. A Dash Pot provided in the loading mechanism to ensure that the load is applied gradually.
7. As soon as the pointer comes to rest pull the handle in the reverse direction slowly. This releases the Major, but not Minor load. The pointer will now rotate in the reverse direction.
8. The Rockwell hardness can be read off the scale dial, on the appropriate scale, after the pointer comes to rest.

V. OBSERVATIONS:

Material of test piece =

Thickness of test piece =

Hardness Scale used =

Minor Load =

Major Load =

Test No.	1	2	3	4
Hard ness value				

VI. PRECAUTIONS:

1. For testing cylindrical test specimen, use V-type platform.
2. Calibrate the machine occasionally using standard test blocks.



3. For thin metal pieces place another sufficiently thick metal piece between the test specimen and the platform to avoid any damage which may likely occur to the platform.
4. After applying Major load, wait for sometime to allow the needle to come to rest. The waiting time vary from 2 to 8 seconds.
5. The surface of the test piece should be smooth and even and free from oxide scale and foreign matter.
6. Test specimen should not be subjected to any heating or cold working.
7. The thickness of test piece or of the layer under test should be at least 8 times the permanent increase of depth of "E".
8. The distance between the centers of two adjacent indentation should be at least 4 indentation to the edge of the test piece should be at least 2.5 times the diameter of the indentation.

VII. VIVA QUESTIONS:

3. Define Hardness.
4. Applications of Rockwell Hardness A – Scale, B-Scale, C-Scale.
5. Type of Indentor used in the Three Different Scales of Rockwell Hardness Test.
6. Different Types of Hardness Testing Methods.
7. Size of the Ball to be used in Ball Indentor of Rockwell Hardness Test.
8. Diameters of the different Balls used in Brinell Hardness Test.
9. Selection of Load in Brinell Hardness Test.
10. Selection of Load in Rockwell Hardness Test.

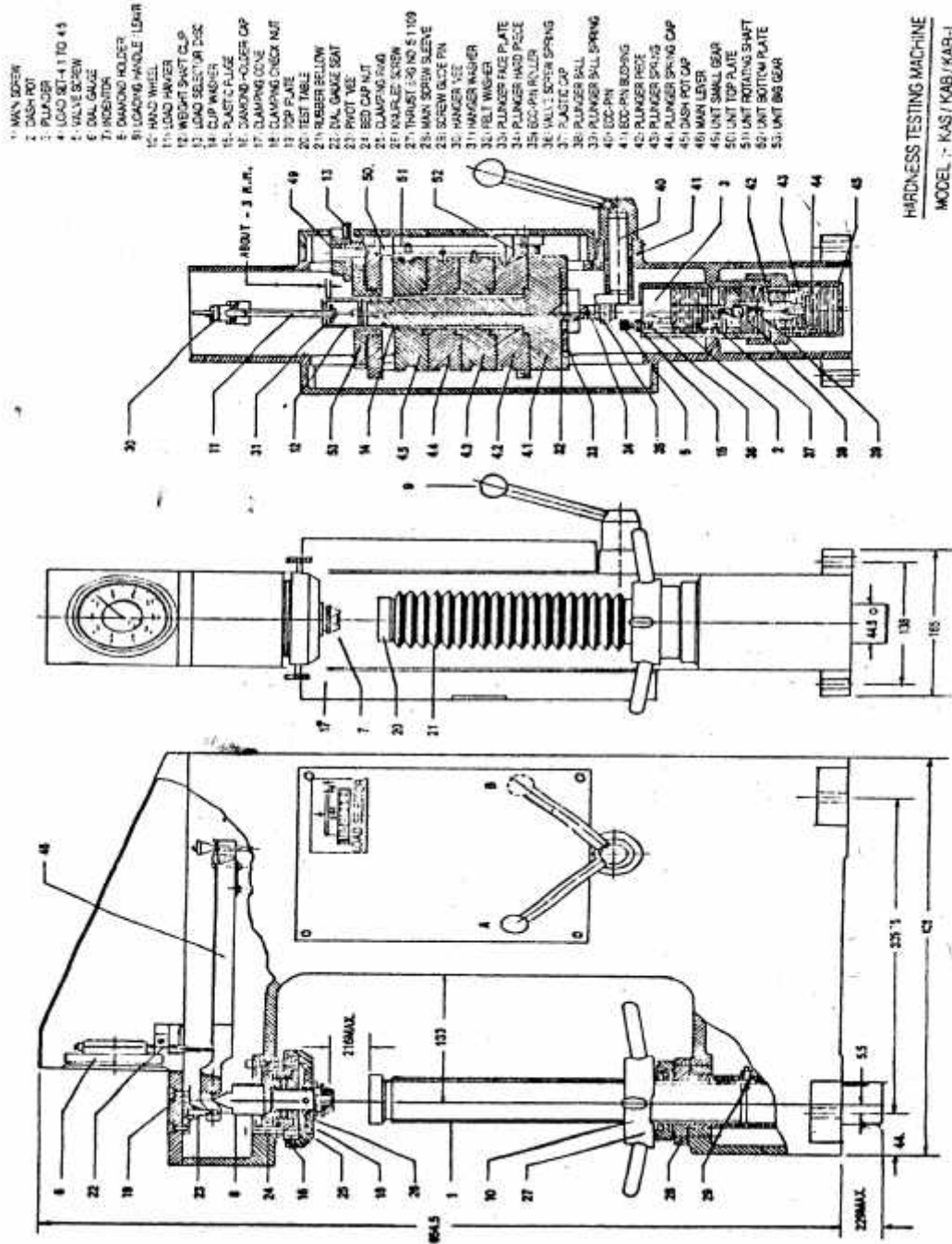


Figure: Hardness Testing Machine

BRINELL HARDNESS TEST

I. AIM: To determine the Brinell hardness of the given test specimen.

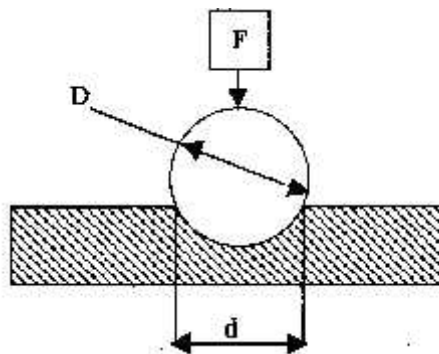
II. APPARATUS: Brinell hardness machine, test specimen. Brinell Microscope

III. THEORY:

INDENTATION HARDNESS-A number related to the area or to the depth of the impression made by an indenter or fixed geometry under a known fixed load.

This method consists of indenting the surface of the metal by a hardened steel ball of specified diameter D mm under a given load F (kgf) and measuring the average diameter d mm of the impression with the help of Brinell microscope fitted with a scale. The Brinell hardness HB is defined, as the quotient of the applied force F divided by the spherical area of the impression

$HB = \text{Test load in kgf/surface area of indentation}$



$$= \frac{2F}{\pi D(D - \sqrt{D^2 - d^2})} \text{ kg/mm}^2$$

IV. PROCEDURE:

1. Select the proper size of the ball and load to suit the material under test
2. Clean the test specimen to be free from any dirt and defects or blemishes.
3. Mount the test piece surface at right angles to the axis of the ball indenter plunger.
4. Turn the platform so that the ball is lifted up.
5. By shifting the lever apply the load and wait for some time.
6. Release the load by shifting the lever.
7. Take out the specimen and measure the diameter of indentation by means of the Brinell microscope.
8. Repeat the experiment at other positions of the test piece.
9. Calculate the value of HB.

V. OBSERVATIONS:

Test Piece Material =
 Diameter of Ball "D" =
 Load selection F/D² =
 Test Load F =
 Load application time =
 Least count of Brinell Microscope =

$$HB = \frac{2F}{fD(D - \sqrt{D^2 - d^2})} \text{ kg/mm}^2$$

Sl.No.	Impression Diameter			F in kG	T in sec	D in mm	HB Kg/mm ²
	d ₁	d ₂	$\frac{d_1 + d_2}{2}$				

Average value of HB =

VI. PRECAUTIONS:

1. The surface of the test piece should be clean.
2. The testing machine should be protected throughout the test from shock or vibration.
3. The test should be carried out at room temperature.
4. The distance of the center of the indentation from the edge of the test piece should be at least 2.5 times the diameter of the indentation and the distance between the center of two adjacent indentations should be at least 4 times the diameter of the indentation.
5. The diameter of each indentation should be measured in two directions at right angles and the mean value of the two readings used for the purpose of determining the hardness number.

LIST OF PARTS

- | | |
|------------------------|----------------------|
| 1. MAIN LEVER | 2. HANGER |
| 3. HANGER VEE (FEMALE) | 4. HANGER VEE (MALE) |
| 5. WEIGHT HANGER | 6. WEIGHT |
| 7. BOTTOM WEIGHT | 8. COVER |
| 9. FRAME | 10. OPERATING LEVER |
| 11. SPINDLE SPRING | 12. SPINDLE SHAFT |
| 13. MAIN KNIFE EDGE | 14. PIVOT VEE |
| 15. PIVOT KNIFE EDGE | 16. SPINDLE BUSHING |
| 17. SPINDLE | 18. BALL HOLDER |
| 19. FLAT ANVIL | 20. ADAPTOR |
| 21. ELEVATING SCREW | 22. ADAPTOR |
| 23. HAND WHEEL | 24. METERING VALVE |

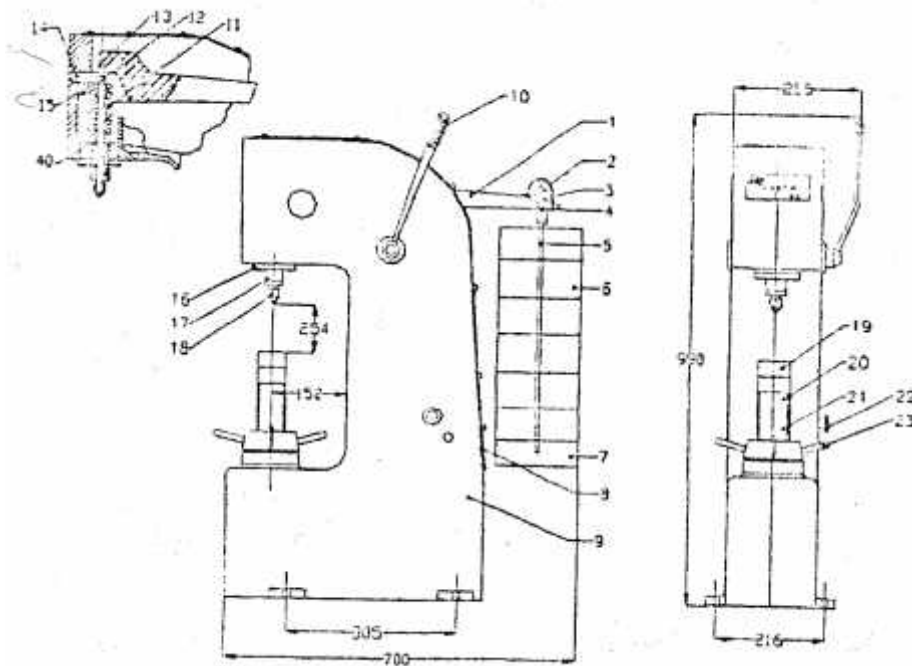


FIGURE: BRINELL HARDNESS TESTING MACHINE

2. IZOD IMPACT TEST

- I. AIM:** To perform the Izod Impact test on Metals.
- II. APPARATUS:** Izod impact testing machine, test specimen, verniar caliper, steel rule
- III. THEORY:**

IMPACT STRENGTH: The high resistance of material to fracture under suddenly applied loads.

The types of test pieces are used for this test as given.

- i. Square cross-section ii. Round cross-section

The specimens may have single, two or three notches. The testing machine should have the following specifications. Angle between top fce of grips and face holding the specimen vertical = 90° Angle of tip of hammer = $75^{\circ} \pm 1^{\circ}$

Angle between normal to the specimen and the underside face of the

Hammer at striking point	=	$10^{\circ} \pm 1^{\circ}$
Speed of hammer at impact	=	3.99 m/sec
Striking energy	=	168 N-M or Joules.
Angle of drop of pendulum	=	90°
Effective weight of pendulum	=	21.79 kg.
Minimum value of scale graduation	=	2 Joules.
Permissible total friction loss of corresponding energy	=	0.50%
Distance from axis of rotation of distance between base of specimen notch and the point of specimen hit by the hammer	=	22 mm \pm 0.5 mm.

The longitudinal Axis of the test piece shall lie in the plane of swing of the center of gravity of the hammer. The notch shall be positioned so that it is in the plane of the hammer. The notch shall be positioned so that its plane of symmetry coincides with the top face of the grips. For setting the specimen. The notch impact strength I is calculated according to the following relation.

$$I=K/A$$

Where I = Impact Strength in Joules/m²

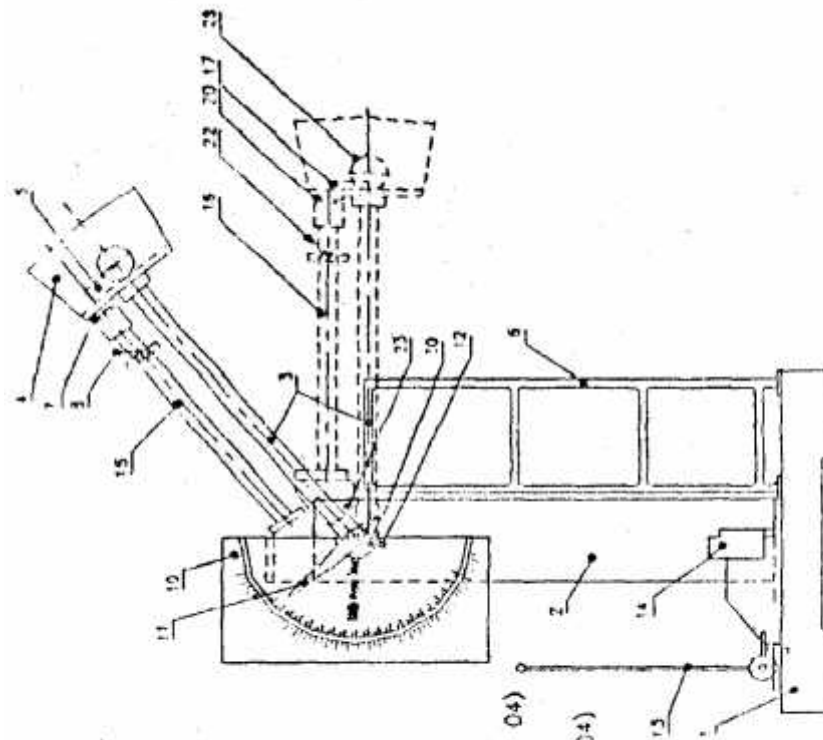
IV. PROCEDURE:

1. For conducting Izod test, a proper striker is to be fitted firmly to the bottom of the hammer with the help clamping piece.
2. The latching take for Izod test is to be firmly fitted to the bearing housing at the side of the columns.
3. Adjust reading pointer along with pointer carrier on 168 J reading on the dial when the pendulum is hinging free vertically.
4. The frictional loss of the machine can be determined by free fall test. Raise the hammer by hands and latch in. Release the hammer by operating liver, the pointer will then indicate the energy loss due to friction. From this reading confirm that the friction loss is not exceeding 0.5% of the initial potential energy. Otherwise friction loss has to be added to the final reading.
5. Now raise the pendulum by hands and latch in with latch
6. The specimen for Izod test is firmly fitted in the specimen support with the help of clamping screw and élan key. Care is to be taken that the notch on the specimen should face to pendulum striker.
7. After ascertaining that there is no person in the range of swinging pendulum. Release the pendulum to smash the specimen.
8. Carefully operate the pendulum brake when returning after one swing to stop the oscillations.
9. Read off position of reading pointer on dial and not indicated value.
10. Remove the broken specimen by loosening the clamping screw.

The notch impact strength depends largely on the shape of the specimen and the notch. The values determined with other specimens therefore may not be compared with each other.

V. OBSERVATION TABLE:

Sl.No.	A Area of Cross-section of Specimen	K Impact Energy Absorbed	I Impact Strength



3. LIST OF PARTS OF THE MACHINE.

1. Base with specimen support fitted.
2. Column.
3. Pendulum Pipe.
4. Pendulum Hammer.
5. Striker for Charpy Test. (Ref. Dwg. 03)
6. Guard.
7. Latch for Charpy Test.
8. Lever to release the Pendulum.
9. C.S.I.
10. C.I.
11. Reading Pointer.
12. Pointer Carrier.
13. Break for Pendulum.
14. Specimen Support. (Ref. Dwg. 03 & 04)
15. Latching tube for Charpy Test.
16. Latching tube for Izod Test.
17. Striker for Izod Test.
18. Clamping Screw for Izod Specimen. (Ref. Dwg. 04)
19. Izod Specimen. (Ref. Dwg. 04)
20. Latch for Izod Test.
21. Latching Gauge for Izod Specimen. (Ref. Dwg. 04)
22. Lever to release the pendulum.
23. Bearing Housing.
24. Setting gauge for Charpy specimen.
25. Pendulum shaft.

FIGURE : IZOD & CHARPY IMPACT TEST

3. BENDING TEST ON A SIMPLY SUPPORTED BEAM

III. AIM:

- This experiment is to demonstrate the effect of span of a simply supported beam on deflection of the beam.
- The effect of young's modulus of the material of the beam using different materials bars.
- The effect of type of cross section on the deflection because of the effect of moment of inertia of the beam.
- Determine the bending stress

III. THEORY:

A beam with a span L and is supported at both ends by knife edges. Let the moment of inertia of the Beam is ' I ' about it's neutral axis and the Young's Modulus be ' E '.

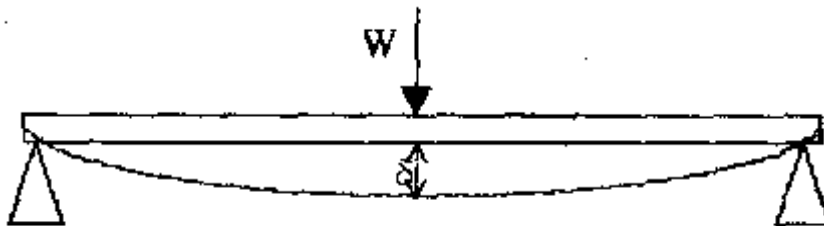


Figure:

$$\text{Moment of Inertia about the neutral axis } I = \frac{bh^3}{12}$$

Deflection at the center of span where the load is acting = δ




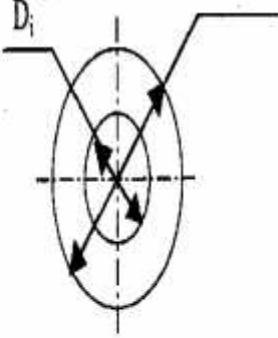
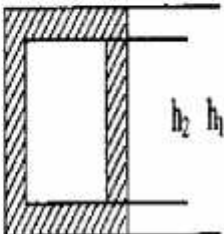
The deflection at the center (Max deflection) δ is related to the load ' W '. Span ' L ' moment of Inertia ' I ', and Young's Modulus ' E ' through the equation.

$$\delta = \frac{WL^3}{48EI}$$

We can observe that

- i. If load is doubled deflection will also be doubled
- ii. If span is doubled deflection increases by 8 times.

- iii. If Young's Modulus of material is more, then deflection will be less.
- iv. If Moment of Inertia is increased the deflection will reduced.
- The relations for Moment of Inertia area as follows.

Sl.No.	Cross Section	Moment of Inertia
1.	Rectangular 	$\frac{bh^3}{12}$
2.	Rectangular 	$\frac{hb^3}{12}$
3.	Circular 	$\frac{\pi d^4}{64}$
4.	Hollow Circular 	$\frac{\pi(D_o^4 - D_i^4)}{64}$
5.	Box 	$\frac{(h_1^4 - h_2^4)}{12}$

Cases of Hollow sections with same cross sectional area of solid sections.

- i. Hollow Circular Section: Let $D_o = 2 D_i$

$$\begin{aligned} \text{Cross Section Area} &= \frac{f(D_o^2 - D_i^2)}{4} = \frac{f[(2D_i^2 - D_i^2)]}{4} \\ &= \frac{f(4D_i^2 - D_i^2)}{4} = \frac{f(3D_i^2)}{4} \end{aligned}$$

- ii. Solid Circular Section: Let 'd' be the diameter of solid circular section with the same cross-sectional area.

$$\frac{fxd^2}{4} = \frac{f(3D_i^2)}{4}$$

$$d^2 = 3D_i^2 \text{ or } d = \sqrt{3} D_i$$

Moment of Inertia for Hollow Section

$$\begin{aligned} I_{\text{hollow}} &= \frac{f(D_0^4 - D_i^4)}{64} = \frac{f[(2D_i^2 - D_i^2)]}{64} \\ &= \frac{f(16D_i^4 - D_i^4)}{64} = \frac{f(15D_i^4)}{64} \end{aligned}$$

Moment of Inertia for Solid Section

$$I_{\text{solid}} = \frac{f(d^4)}{64} = \frac{f[\sqrt{3}D_i]^4}{64} = \frac{f[9D_i^4]}{64}$$

m Hollow section has more 'I' than solid section with same cross-sectional area.

Some comments on sections of Beams & Materials.

- i. Hollow section with same cross sectional area of a solid section; will have more load carrying capacity and hence more stiffness.
- ii. Beams area used with depth longer than width because of more Moment of Inertia for the same cross-sectional area.
- iii. Mild Steel is stiffer than Aluminum because the Young's Modulus of the former material is bigger.

Concept of stiffness of Beam's in Bending (K_b)

Stiffness of component in bending is defined as the ration of load required for unit deflection in bending.

$$\text{Bending stiffness } K_b = W/\delta$$

In the case of Simply supported Beam with control loading the Stiffness

$$K_b = \frac{48EI}{L^3}$$

Hence

- i. If E is doubled Stiffness will be doubled.
- ii. If Moment of Inertia is doubled Stiffness will be doubled.
- iii. If the Distance of load is doubled the Stiffness reduced by 1/8 times.
- iv. Higher the Stiffness lesser will be the deflection of beam for the same load applied.

Bending stress in beam at the extreme fiber at the cross section located at center of the beam (f) = (3/2) * (WL/BD²)

IV. EXPERIMENTAL SET-UP: The set-up contains the following

1. Two knife edges and supporting stands for beam.
2. Beams of different section
3. Loading arrangement along with different weights
4. Dial gauge with magnetic stand.
5. Measuring tape or Steel Scale.

XIII. PROCEDURE:

- i. Set the beam horizontally on the two knife edges.
- ii. Measure the span of Beam L (distance from clamp end to loading point)
- iii. Fix the dial gauge under the beam at the loading point middle of the span to Read down-ward moment and set to zero.
- iv. Hang the loading Pan at the mid point of the beam span.
- v. Load the Beam with different loads(W) and note the dial gauge readings (δ).
- vi. Change the span of beam for two more different lengths repeat the experiment.
- vii. Change the position of Beam and repeat the experiment for the other value of I for rectangular cross-section.

XIV. PRECAUTIONS :

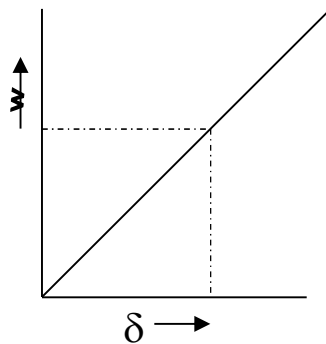
- i. Beam should be positioned Horizontally
- ii. The span of the Beam should be measured properly
- iii. The dial gauge spindle knob should always
- iv. Loading hanger should be placed at center of the Beam length.
- v. All the errors should be eliminated while taking readings.
- vi. Elastic limit of the Beam should not exceeded.

XV. OBSERVATIONS:

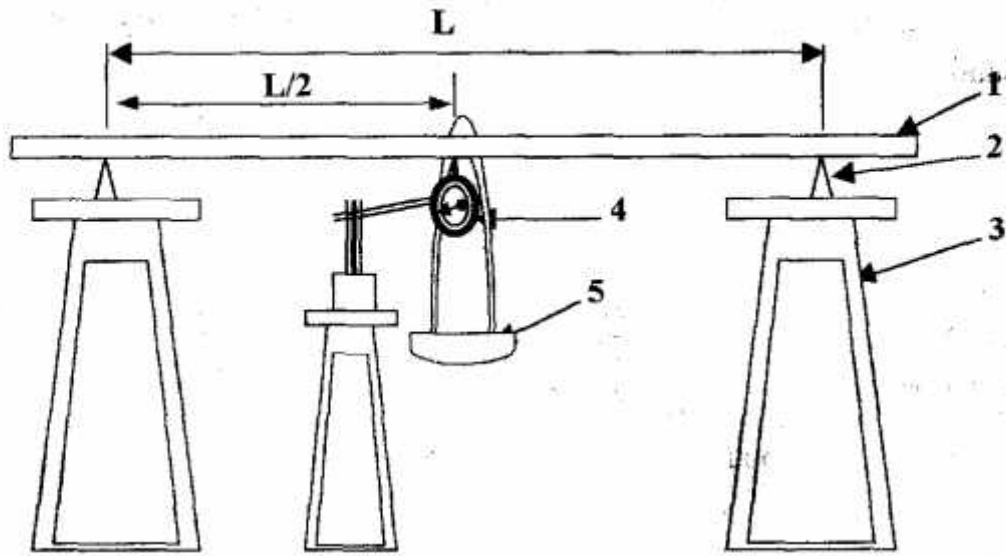
- a) Independent Variables:
1. Load
 2. Span
 3. Moment of Inertia (By choosing different sections)
 4. Young's Modulus (By choosing different Materials)

Sl. No.	Beam Material	Cross Section	Y.M. E N/mm ²	M.I. I mm ⁴	Span L mm	Load W in N	Deflection δ in mm	Bending Stiffness N/mm

Bending stress =

XVI. GRAPHS:Deflection Vs W , L , I and E Stiffness Vs W , L , I and E **XVIII. VIVA QUESTIONS:**

1. Give Equation for maximum Deflection, Maximum Bending Moment, Maximum Slope in the case of Cantilever, Simply Supported Beam, Fixed Beam and a Continuous Beam with Three Supports.
2. For the same cross sectional area and span give in the increasing order the values of i) Square Section, ii) Rectangular Section with ' h ' > ' b ' and ' h ' < ' b ', iii) Hollow Square Section, iv) Circular Section.
3. Define Point of Contraflexure, Stiffness, Shear Force and Shear Stress in Beams in Bending.



- 1. Beam for test
- 2. Knife Edge
- 3. M.S. Stand
- 4. Dial Gauge
- 5. Loading Pan

Fig 4. 1

DEFLECTION TEST ON A SIMPLY SUPPORTED BEAM

4. BENDING TEST ON CANTILEVER BEAM

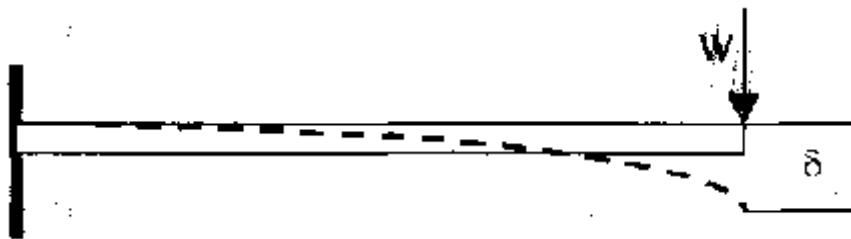
I. AIM:

- This experiment is to demonstrate the effect of distance at which the load acting from the fixed end on deflection of the beam
- The effects of young's modulus of the material of the beam using different materials bars.
- The effect of type of cross section on the deflection because of the effect of moment of inertia of the beam.
- Determine the bending stress

II. THEORY:

A Cantilever is a Beam one end of which is clamped and other end is free.

A beam with a length L and is fixed at one end and the other end is free. Let the moment of inertia of the Beam is ' I ' about it's neutral axis and the Young's Modulus be ' E '.



Moment of inertia about the neutral axis $I = \frac{bh^3}{12}$


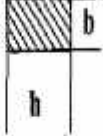
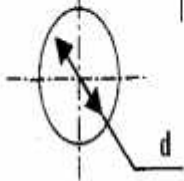
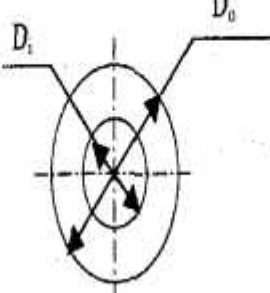
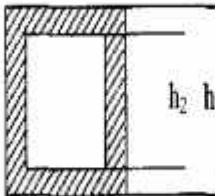
Deflection at the end where point load is acting = δ

The deflection at the end (Max deflection) δ is related to the load ' W ', length ' L ' moment of Inertia ' I ' and Young's Modulus ' E ' through the equation.

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

We can observe that

- i. If load is doubled deflection will also be doubled
- ii. If span is doubled deflection increases y 8 times.
- iii. If Young's Modulus of material is more, then deflection will be less.
- iv. If Moment of Inertia is increased the deflection will reduced.

Sl.No.	Cross Section	Moment of Inertia
1.	Rectangular 	$bh^3/12$
2.	Rectangular 	$hb^3/12$
3.	Circular 	$\pi d^4/64$
4.	Hollow Circular 	$\frac{\pi(D_o^4 - D_i^4)}{64}$
5.	Box 	$\frac{(h_1^4 - h_2^4)}{12}$

Cases of Hollow sections with same cross sectional area of solid sections.

i. Hollow Circular Section: Let $D_o = 2 D_i$

$$\begin{aligned} \text{Cross Section Area} &= \frac{f(D_o^2 - D_i^2)}{4} = \frac{f[(2D_i^2 - D_i^2)]}{4} \\ &= \frac{f(4D_i^2 - D_i^2)}{4} = \frac{f(3D_i^2)}{4} \end{aligned}$$

ii. Solid Circular Section: Let 'd' be the diameter of solid circular section with the same cross-sectional area.

$$\frac{fd^2}{4} = \frac{f(3D_i^2)}{4}$$

$$d^2 = 3D_i^2 \text{ or } d = \sqrt{3} D_i$$

Moment of Inertia for Hollow Section

$$\begin{aligned}
 I_{\text{hollow}} &= \frac{f(D_0^4 - D_i^4)}{64} = \frac{f[(2D_i)^4 - D_i^4]}{64} \\
 &= \frac{f(16D_i^4 - D_i^4)}{64} = \frac{f(15D_i^4)}{64}
 \end{aligned}$$

Moment of Inertia for Solid Section

$$I_{\text{solid}} = \frac{f(d^4)}{64} = \frac{f[\sqrt{3}D_i]^4}{64} = \frac{f[9D_i^4]}{64}$$

m Hollow section has more 'I' than solid section with same cross-sectional area.

Some comments on sections of Beams & Materials.

- i. Hollow section with same cross sectional area of a solid section; will have more load carrying capacity and hence more stiffness.
- ii. Beams area used with depth longer than width because of more Moment of Inertia for the same cross-sectional area.
- iii. Mild Steel is stiffer than Aluminum because the Young's Modulus of the former material is bigger.

Concept of stiffness of Beam's in Bending (K_b)

Stiffness of component in bending is defined as the ration of load required for unit deflection in bending.

Bending stiffness $K_b = W/\delta$

In the case of Simply supported Beam with control loading the Stiffness

$$K_b = \frac{3EI}{L^3}$$

Hence

- i. If E is doubled Stiffness will be doubled.
- ii. If Moment of Inertia is doubled Stiffness will be doubled.
- iii. If the Distance of load is doubled the Stiffness reduced by 1/8 times.
- iv. Higher the Stiffness lesser will be the deflection of beam for the same load applied.

Maximum Bending stress $f = 6WL/BD^2$

IV. EXPERIMENTAL SET-UP: The set-up contains the following

- iii. One rigid clamping support for fixing one end of the beam.
- iv. Beams of different section
- v. Loading arrangement along with different weights.
- vi. Dial gauge with magnetic stand.
- vii. Measuring tape or Steel Scale

V. PROCEDURE:

- i. Clamp the Beam horizontally on the clamping support at one end.
- ii. Measure the length of cantilever L (distance from clamp end to loading point)
- iii. Fix the dial gauge under the beam at the loading point to Read down-ward moment and set to zero.
- iv. Hang the loading Pan at the free end of the cantilever.
- v. Load the cantilever with different loads (W) and note the dial gauge readings (δ)
- vi. Change the length of cantilever for two more different lengths repeat the experiment.
- vii. Change the position of cantilever and repeat the experiment for the other value of I for rectangular cross-section.

VI. PRECAUTIONS:

- i. Beam should be positioned Horizontally
- ii. The length of the cantilever should be measured properly
- iii. The dial gauge spindle knob should always touch the beam at the bottom of loading point.
- iv. Loading hanger should be placed at known distance of cantilever length.
- v. All the errors should be eliminated while taking readings.
- vi. Elastic limit of the Bema should not exceeded.

VII. OBSERVATIONS:

- a) Independent Variables:
 - 1. Load
 - 2. Span
 - 3. Moment of Inertia (By choosing different sections)
 - 4. Young's Modulus (By choosing different Materials)
- b) Dependant Variable: Bending Deflection δ
- c) Derived Variable: Bending Stiffness

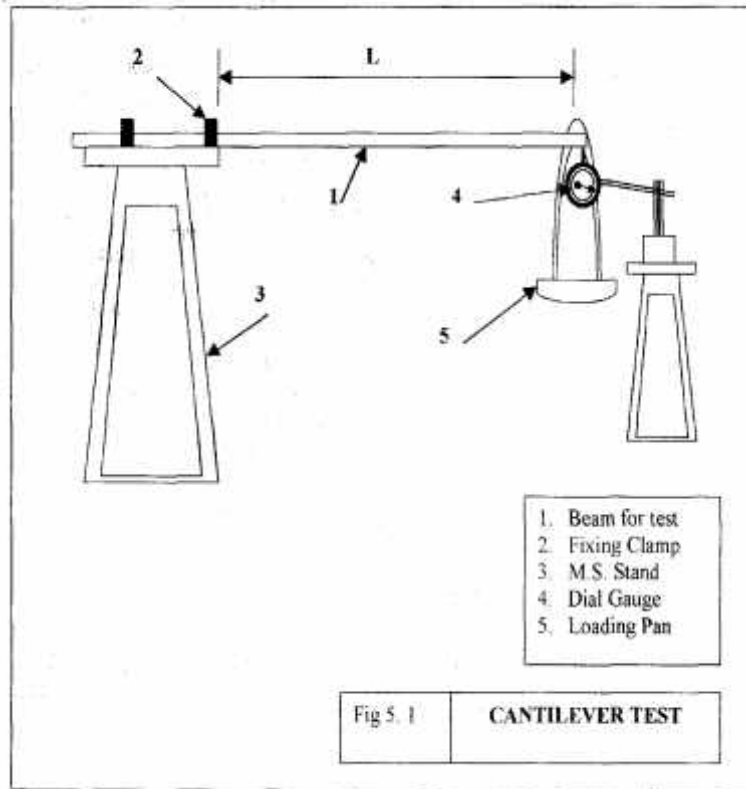
Sl.No.	Beam Material	Cross Section	Y.M.E N/mm ²	M.I.I.Mm ⁴	Span L mm	Load W in N	Deflection δ in mm	Bending Stiffness N/mm

Bending stress f =

VIII. GRAPHS:

Deflection Vs W, L, I and E
 Stiffness Vs W, L, I and E

XII. CONCLUSION:



5. SPRING TEST

I. AIM: To determine the stiffness of the Spring and Modulus of Rigidity of the Spring Wire.

II. MATERIAL AND EQUIPMENT:

- i) Spring testing machine
- ii) Springs for testing
- iii) Micrometer
- iv) Vernier Caliper.

III. THEORY: Springs are elastic members which distort under load and regain their original shape when load is removed. They are used in railway carriages, Motor Cars, Scooters, Motor Cycles, Rickshaws, Governors etc.

Types of Springs:

1. Close-coiled helical springs & Tension helical springs with circular cross-section
2. Open-coiled springs & Compression helical springs with square cross-section
3. Full-elliptical leaf springs.
4. Semi-elliptical laminated springs.
5. Cantilever leaf springs
6. Circular Springs.

According to their uses, the springs perform the following function:

- i. To absorb shock or impact loading as in carriage springs.
- ii. To store energy as in clock springs.
- iii. To supply forces to and to control motions as in brakes and clutches.
- iv. To measure forces as in spring balances.
- v. To absorb the vibrations, characteristic of a member as in flexible mounting of motors.

The springs are usually made of either high carbon steel (0.7% to 1.0%) or Medium carbon alloy steels. Phosphor bronze, Brass and 18/8 Stain less steel. Other metal alloys are used for corrosion resistance.

Analysis of Close-Coiled Helical Springs: (Circular Section wire)

W	Axial load applied (N)
R_m	Mean radius of the Coil(mm)
D_o	Outer Diameter of Coil (mm)
D_m	(D_o-d) Mean diameter of the Coil (mm)
d	Diameter of the wire of the Coil (mm)
δ	Deflection of coil (m) under the load 'W'
C	Modulus of rigidity (N/mm ²)
n	Number of coils or turns.
L	Lenth of wire = $2\pi R_m n$ (mm)
t	Shear stress (N/mm ²)
T	Torque (N-mm)
I_P	Polar Moment of Inertia of wire = $\pi d^4/32$ (mm ⁴)

Spring index = D_m/d

Torsion Equation: $\frac{T}{I_p} = \frac{C_\theta}{L} = \frac{\tau}{r}$

a) For circular section of spring with dia = d

$$T = \frac{\tau I_p}{r} = \frac{\tau f d^4}{32} \times \frac{2}{d} = \frac{\tau f d^3}{16} \text{ Nmm}$$

$$\tau = \frac{16T}{r} = \frac{16WR_m}{f d^3} = \frac{8WD_m}{f d^3} \text{ (where } T=WR_m \text{ \& } R_m = D_m/2\text{)}$$

We have $\frac{T}{I_p} = \frac{C_\theta}{L}$

$$\theta = \frac{TL}{CI_p} = \frac{WR_m 2R_m n 32}{C f d^4} = \frac{64WR_m^2 n}{C d^4} \text{ (Radians)}$$

Deflection $\delta = R_m \theta$ (mm)

$$\delta = \frac{64WR_m^3 n}{C d^4} = \frac{8WD_m^3 n}{C d^4} \text{ (mm)}$$

or Modulus of Rigidity $C = \frac{8WD_m^3 n}{\delta d^4} \text{ (N/mm}^2\text{)}$

b) For Rectangular Cross-section wire (Width = b and Thickness = h)

$$C = \frac{7fWR_m^3 n}{u} \left[\frac{b^2 + h^2}{b^3 h^3} \right] \text{ N/mm}^2$$

c) For Square cross-section wire when 'b' is the side of square

$$C = \frac{14fWR_m^3 n}{u b^4} \text{ (N/mm}^2\text{)}$$

d) For Open coiled helical spring with circular cross-section wire, With the angle of Helix = α ,

Deflection of spring (α) due to axial load

$$\delta = \frac{64WR_m^3 n \cdot \sec \alpha}{d^4} \left[\frac{\cos^2 \alpha}{C} + \frac{2 \sin^2 \alpha}{E} \right]$$

Stiffness of spring = W/δ

IV. PROCEDURE:

1. By using micrometer measure the diameter of the wire of spring (d)
2. By using the vernier caliper measure the outer diameter of spring coil (D_o),
3. Count the number of turns (n),
4. Insert the spring in the spring testing machine and load spring by a suitable weight and note the corresponding axial deflection in tension or compression.
5. Increase the load and take the corresponding axial deflection readings.
6. Plot a curve between load and deflection, shape of the curve gives the stiffness of the spring.
7. Calculate modulus of rigidity C in N/mm^2 from the readings obtained within the elastic limit.

V. OBSERVATIONS AND CALCULATIONS:

Sl.No.	Outer dia D_o	Wire dia d .	No. of Turns 'n'	Mean dia D_m	Load W (N)	Deflection δ (mm)	Stiffness W/δ	Modulus of Rigidity $C(N/mm^2)$

VI. GRAPHS & RESULTS:

Load Vs Deflection
Stiffness Estimation

VII. VIVA QUESTIONS:

1. Types of Springs.
2. State Different Functions of Springs.

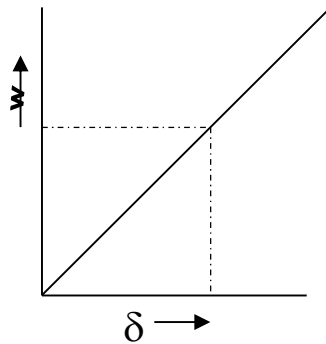
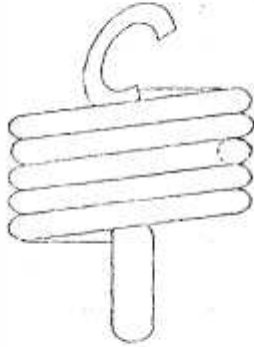
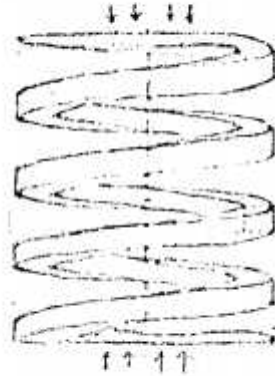


Fig. 5.1 TYPES OF SPRINGS

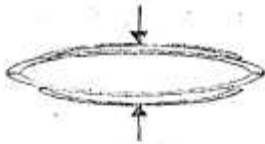
a) Close-coiled Helical Spring & Tension Helical Spring with Circular cross-section.



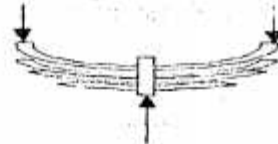
b) Open-coiled Helical Spring & Compression Helical Spring With Square cross-section.



3. Full-Elliptical Leaf Spring



4. Semi-Elliptical Laminated Spring



5. Cantilever Leaf Springs



6. Circular Springs



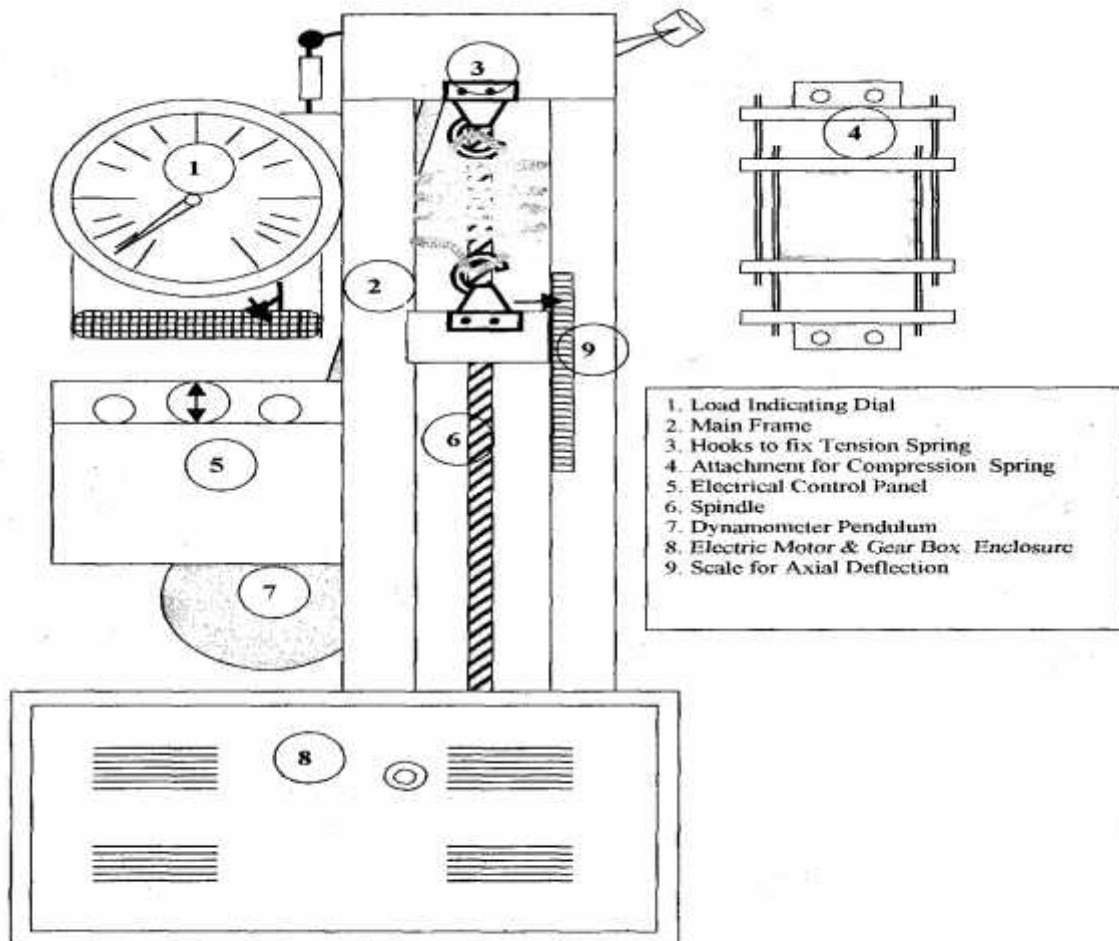


Fig 6.2 **SPRING TESTING MACHINE**

6. TORSION TEST

I. AIM: To conduct torsion on mild steel or cast iron specimens to find out Modulus of Rigidity or to find angle of twist of the materials which are subjected to Torsion

II. MATERIAL AND EQUIPMENT:

4. A Torsion testing machine along with angle of twist measuring attachment
5. Standard specimen of mild steel or cast iron.
6. A steel rule.
7. Vernier caliper or Micrometer.

III. THEORY: For transmitting power through a rotating shaft it is necessary to apply a turning force. The force is applied tangentially and in the plane of transverse cross-section. The torque or twisting moment may be calculated by multiplying two opposite turning moments, it is said to be in pure torsion and it will exhibit the tendency of shearing off at every cross-section which is perpendicular to longitudinal axis.

Torsion Equation:

If T = Maximum Twisting Torque (Nmm)

$$= \frac{P \times 60}{2fN} \times 10^6 \quad \text{where Power (P) Transmitted by shaft in kW}$$

and N is Revolutions per minute of shaft.

D = Diameter of a solid shaft (mm)

D_o = Outer diameter of hollow shaft (mm)

D_i = Inner diameter of hollow shaft (mm)

I_p = Polar Moment of Inertia (mm^4)

For Solid shafts $I_p = \frac{\pi D^4}{32}$ (mm^4)

For Hollow shafts $I_p = \frac{\pi (D_o^4 - D_i^4)}{32}$ (mm^4)

τ = Shear Stress (N/mm^2)

C = Modulus of Rigidity (N/mm^2)

θ = The angle of twist in radians

L = Length of shaft under Torsion (mm)

Torsion Equation is $\frac{T}{I_p} = \frac{\tau}{R} = \frac{C \theta}{L}$ Where $R = D/2$ in mm for Solid shaft

$R = D_o/2$ in mm for Hollow shaft

Torque applied $T = WR/2$ (Nmm) Where W is tangential load applied.

The value of Modulus of Rigidity can be found by $C = \frac{TL}{I_p \theta}$ in N/mm^2

Or Angle of Twist per unit Length $\frac{\theta}{L} = \frac{T}{I_p C}$ (Radian/mm Length)

Assumptions made for getting Torsion Equation

1. The material of the shaft is uniform throughout
2. The shaft, circular in section remain circular after loading.

3. Plane sections of shaft normal to its axis before loading remain plane after the torque have been applied.
4. The twist along the length of shaft is uniform throughout.
5. The distance between any two normal – sections remains the same after the applications of torque.
6. Maximum Shear Stress induced in the shaft due to application of Torque does not exceed its Elastic Limit.

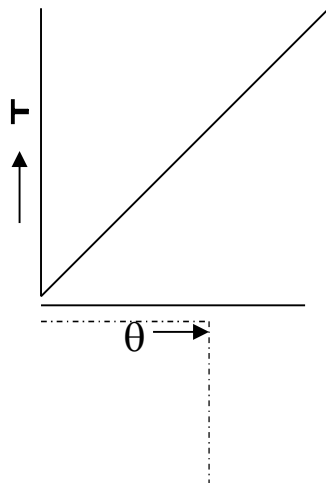
IV. PROCEDURE:

1. Select suitable grips to suit the size of the Specimen and clamp it in the machine by adjusting sliding Jaw.
2. Measure the diameter at about three places and take average value.
3. Choose the appropriate loading range depending upon specimen.
4. Set the maximum load pointer to zero.
5. Carry out straining by rotating the hand wheel or by switching on the motor.
6. Load the member in suitable increments, observe and record strain readings.
7. Continue till failure of specimen.
8. Calculate the value of Modulus of Rigidity C by using $C = TL/I_p\theta$ taking values of T & θ within Elastic Limit.
9. Plot a Torque – Twist graph (T Vs θ).
10. For known value of C, θ per unit length $\theta/L = T/I_pC$

V. OBSERVATIONS:

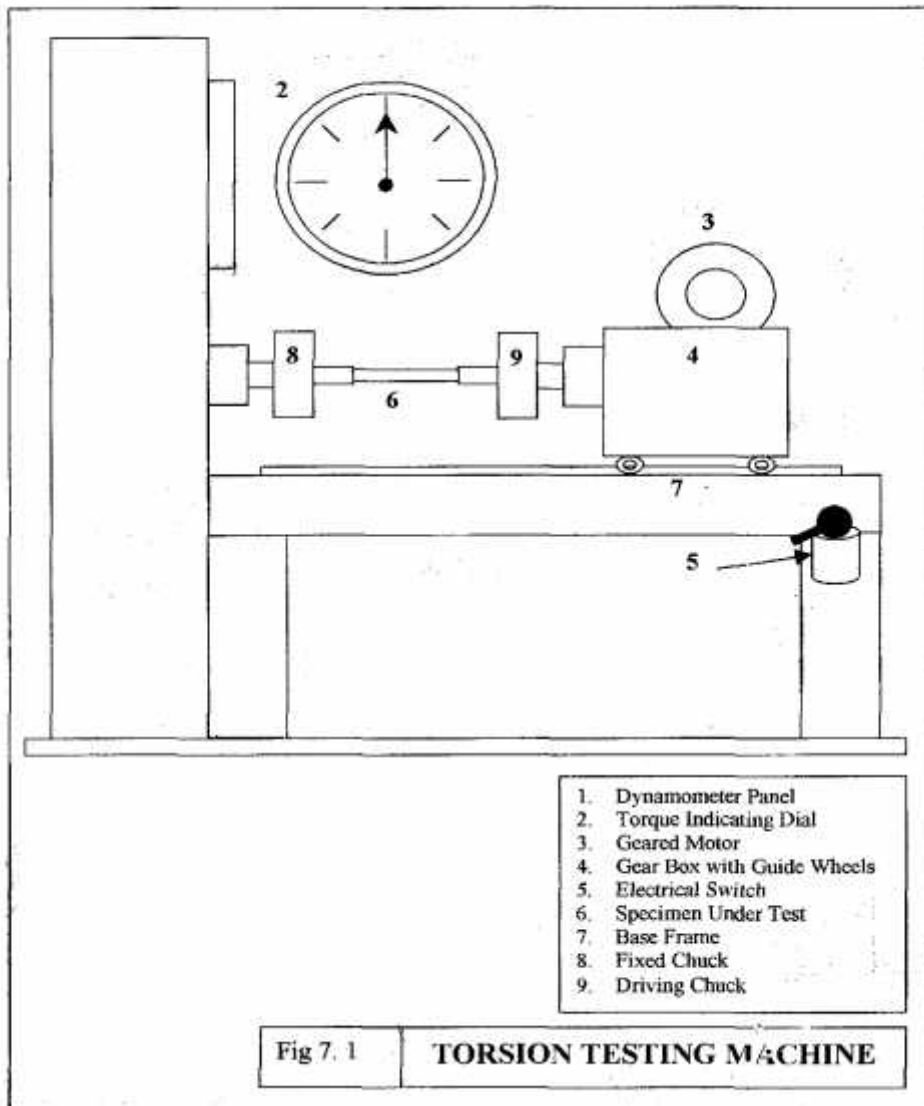
- Gauge length (L) = mm.
- Diameter of the Specimen (D) = mm.
- Weight (W) = Newtons,
- Torque (T) = $WD/2$ N-mm.
- Angle of twist (θ) = θ^0 in degrees.
- (θ) = $\theta^0 \times \pi/180$ in radians.
- Polar Moment of Inertia I_p = $\pi D^4/32$ mm⁴,
- Modulus of Rigidity C = $TL/I_p \theta$ N/mm²

Sl. No.	L (mm)	D (mm)	W (N)	T (N-mm)	θ		I_p (mm ⁴)	C (N/mm ²)
					Degrees	Radians		



VI. CONCLUSIONS:

- i. Modulus of Rigidity calculated will be a constant for given material, irrespective of L, D, W & T. The differences must be explained for.
- ii. Angle of twist per unit length can be calculated for known values of Torque, Diameter of specimen and Modulus of Rigidity.



7. TENSILE TEST USING UTM

I. AIM: To conduct tensile test on a mild steel specimen and determine the following:

- | | |
|----------------------------------|---------------------------------------|
| i) Limit of proportionality | ii) Upper yield point |
| iii) Ultimate strength | iv) Lower yield point |
| v) Ultimate strength | vi) Fracture Strength |
| vii) Young's modulus | viii) Percentage elongation |
| ix) Percentage reduction in area | x) Ductility |
| xi) Toughness | xii) True-Stress & true-strain values |
| xiii) Malleability | |

II. MATERIAL & EQUIPMENT:

- | | |
|----------------------------|---------------------|
| i) Tensile testing machine | ii) Specimen |
| iii) Steel rule | iv) Vernier caliper |
| v) Micrometer | |

III. THEORY:

The tensile test is not applied one of all mechanical tests. In this test, a test specimen is fixed into grips connected to a Straining device and to a load-measuring device. (one end in stationary grips and the other in movable grips). If the applied load is small enough, the deformation of any solid body is entirely elastic. An elastically deformed solid will return to its original form as soon as load is removed. However if the load is too large, the material can be deformed permanently. The initial part of the tension curve, which represents the manner in which solid undergoes plastic deformation is termed plastic. The stress below which the deformation is essentially entirely elastic is known as the elastic limit of material. In some materials like mild steel the onset of plastic deformation is denoted by a sudden drop in load indicating both an upper and lower yield point. However some materials do not exhibit a sharp yield point. During plastic deformation, at larger extensions, strain hardening cannot compensate for the decrease in section and thus the load passes through a maximum and then begins to decrease. At this stage the **ULTIMATE STRENGTH** which is defined as the ratio of the load on the specimen to original cross-sectional area, reaches a maximum value. Until this point the deformation is uniform at all sections of the specimen. Further loading will eventually

Usually a tension test is conducted at room temperature. And the tensile load is applied slowly. During this test either round or flat specimens may be used. The load on the specimen is applied mechanically or hydraulically depending on the type of testing machine.

3.1) **Nominal/Engg. Stress and Nominal/Engg Strain:**

Original C/S area = A_0 (mm^2)	Nominal Stress = P/A_0 (N/mm^2)
Original gauge length = L_0 (mm)	Nominal Strain = $\delta L_0/L_0$

3.2 Limit of Proportionality (Point A in Fig 9)

Stress is proportional to strain upto this point.

$$\text{Nominal Stress} = P_A/A_0$$

$$\text{Nominal Strain} = (\delta L_0)_A/L_0$$

3.3 Elastic Limit (Point B in Fig.9)

When the load is removed at "B", the specimen will go back to original dimension i.e. L_0 and δA_0

$$\text{Nominal Stress} = P_0/A_0$$

3.4 Upper Yield (point C in Fig.9)

$$\text{Nominal Stress} = P_0/A_0$$

$$\text{Nominal Strain} = (\delta L_0)_c/L_0$$

3.5 Lower Yield point (Point D in Fig.9)

$$\text{Nominal Stress} = P_D/A_0$$

$$\text{Nominal Strain} = (\delta L_0)_D/L_0$$

3.6 Ultimate Load or Maximum Load Point (Point E in Fig.9)

$$\text{Nominal Ultimate Stress} = P_E/A_0$$

$$\text{Nominal Strain} = (\delta L_0)_E/L_0$$

3.7 Fracture Load Point F (Point F in Fig.9)

$$\text{Nominal Fracture stress} = P_F/A_0$$

$$\text{Nominal Strain at fracture} = (\delta L_0)_F/L_0$$

3.8 Young's Modulus (E)

$$\text{Young Modulus (E)} = \text{Stress} / \text{strain}$$

(in the elastic region limit of Proportionality
= Nominal Stress at A/Nominal Strain at A

3.9 Modulus of Resilience = (Nominal stress at elastic limit)²/2E
(Area under Engg. Stress-Strain diagram upto elastic limit)**3.10 Resilience = Modulus of Resilience X Volume of specimen undergoing tensile stress.****3.11 Yield Point Elongation**

Elongation taking place in the specimen from C to D'. This is taking place without increase in stress.

3.12 Modulus of toughness

Area under Engineering stress-strain diagram upto fracture.

3.13 Toughness = Modulus of toughness x Volume of specimen

This indicates the amount of energy absorbed by the specimen before fracture takes place.

3.13 Malleability:

It is the ability of the material to undergo plastic deformation prior fracture under Compressive Loading conditions. In a tensile test it is approximated as percentage reduction in cross sectional area of the specimen.

$$\text{Malleability} = (A_0 - A_f)/A_0 \times 100$$

4. True Stress – True strain diagram

Engineering stress is calculated based on original cross sectional area (A_0) but not on the actual cross sectional area at load 'P'.

$$\text{True stress} = P/A = P/A_0 \times A_0/A$$

Since volume remains constant during plastic deformation we have $A_0L_0 = A_L$

$$\text{True Stress} = P/A_0 \times L/L_0$$

$$= P/A_0 \times (L_0 + \delta L_0) / L_0$$

$$= P/A_0 \times (1 + \delta L_0) / L_0 = p(1 + e)$$

$$= \text{Normal stress} (1 + \text{Nominal strain})$$

$$\text{True Strain} = \epsilon = \ln(1 + e)$$

These relations are valid upto ultimate load i.e. upto which the strain is uniform all along the gauge length.

4.1 True Stress at Upper Yield Point

= Nominal stress at upper yield point $(1 + e_c)$

$$\text{True strain } C = \ln(1 + e_c)$$

4.2 True Stress at Ultimate Load (Point E_l)

= Nominal ultimate stress $(1 + e_E)$

$$\text{True strain at ultimate load} = \ln(1 + e_E)$$

4.3 True Stress at Fracture (At point F_l)

True stress at fracture = P_f/A_f

Where A_f is the area of cross section at fracture can be measured.

$$\text{True strain at Fracture} = \ln(A_0/A_f)$$

Area relation is taken instead of lengths because the strains are localized in the region between ultimate load point and Fracture point.

4.4 Strain Hardening

From lower yield point onwards increase in load is required for increase in strain. Thus the stress required for further deformation is more. This phenomenon is called strain hardening.

4.5 True-Stress-True Strain Curve in log-log co-ordinates

When the True – stress and True strain are plotted on log-log co-ordinates the curve looks as in Fig.2 i.e. Straight line.

4.6 Ductile and Brittle Materials

If a material fails without much plastic deformation it can be called brittle. If the percentage elongation at fracture is less than 2.5 the material is classified as brittle. Ex Grey Cast Iron

- Usually the metals with F.C.C and C.P.H structures are highly ductile. Ex Al, Cu, Ag, Au etc.

IV. PROCEDURE:

1. Measure the original gauge length and diameter of the specimen.

2. Insert the specimen into grips of the test machine
3. Begin the load application and record load versus elongation data
4. Take readings more frequently as yield point is approached
5. Measure elongation values
6. Continue the test till fracture occurs.
7. By joining the two broken halves of the specimen together measure the final length and diameter of specimen at fracture.

V. RESULTS & DISCUSSIONS

a) Plot the Engg. Stress strain curve and determine the following

- i) Limit of proportionality = (N/mm^2)
- ii) Yield strength = (N/mm^2)
- iii) Ultimate Strength = (N/mm^2)
- iv) Young's modulus = (N/mm^2)
- v) Percentage Elongation = %
(Ductility)
- vi) Percentage reduction in area = %
- vii) Fracture Strength = (Nominal / Engg)
- viii) Toughness = area under Stress-Strain curve up to fracture
- ix) Malleability

b) Plot True-Stress, True-strain curve after calculating true-Stress and True-strain values at various points.

- Estimate
- i) Strength coefficient
 - ii) Strain hardening coefficient

c) Determine whether the material is Ductile or Brittle?

d) Comment on the results.

VI. PRECAUTIONS:

When the UTM is in operation stay away from the machine jaws

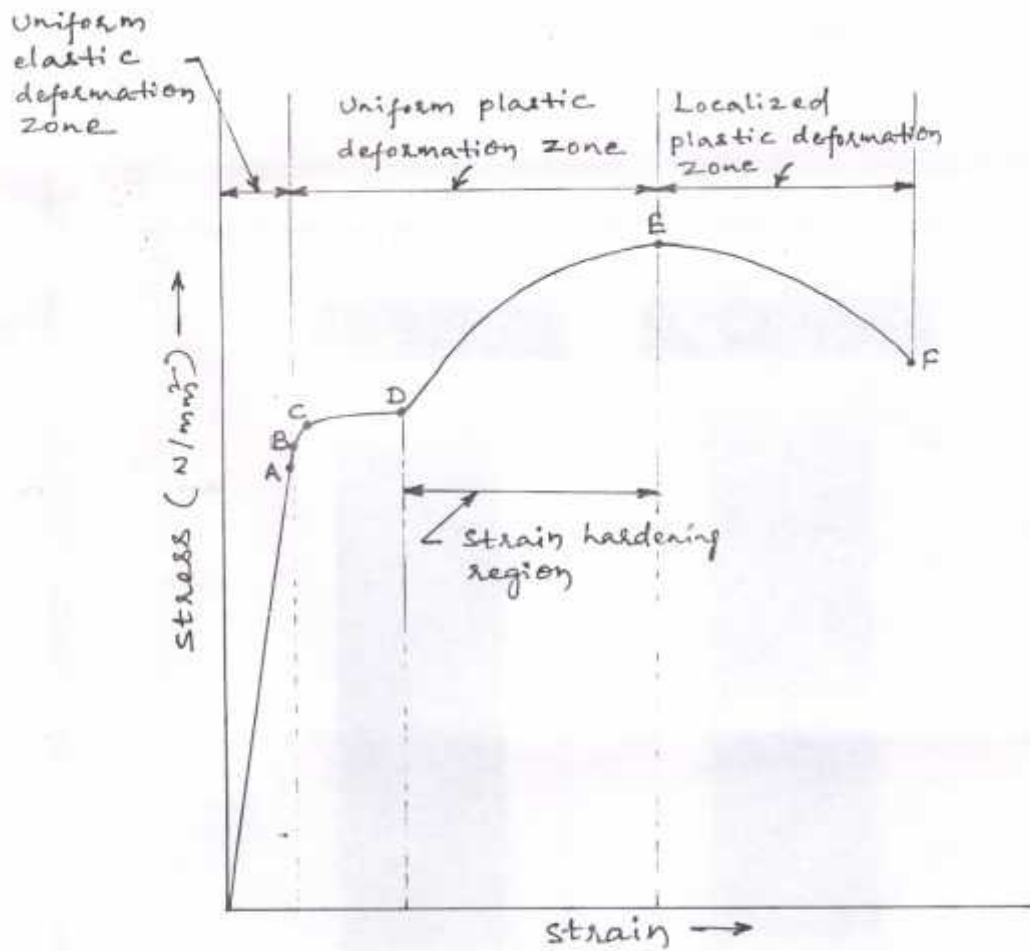
VII. VIVA QUESTIONS:

Define the following terms

1. Elasticity.
2. Plasticity
3. Rigidity
4. Ductility
5. Toughness
6. Brittleness
7. Stress.
8. Strain
9. Tensile Stress
10. Shear Stress
11. Limit of Proportionality
12. Elastic Limit
13. Yield Point
14. Upper Yield Point



15. Lower Yield Point
16. Strain Hardening.
17. Proof Stress.
18. Modulus of Resilience.
19. Resilience.
20. Percentage Elongation
21. Percentage Reduction in Area
22. True Stress
23. True Strain
24. Ultimate Strength
25. Breaking Strength
26. Elastic Constants
27. Young's Modulus
28. Shear Modulus or Modulus of Rigidity
29. Bulk Modulus
30. Poissons/Ratio
31. Modulus of Elasticity for Mild Steel, Copper, Aluminum, Cast Iron etc.
32. Examples for Ductile Materials
33. Examples for Brittle Materials
34. Examples for Malleable Materials .
35. Failure of Ductile Material under Tension
36. Failure of Brittle Material under Tension.



- A: Proportional limit
- B: Elastic limit
- C: Yield point
- E: Ultimate stress point
- F: Breaking point

STRESS-STRAIN DIAGRAM FOR MILDSTEEL

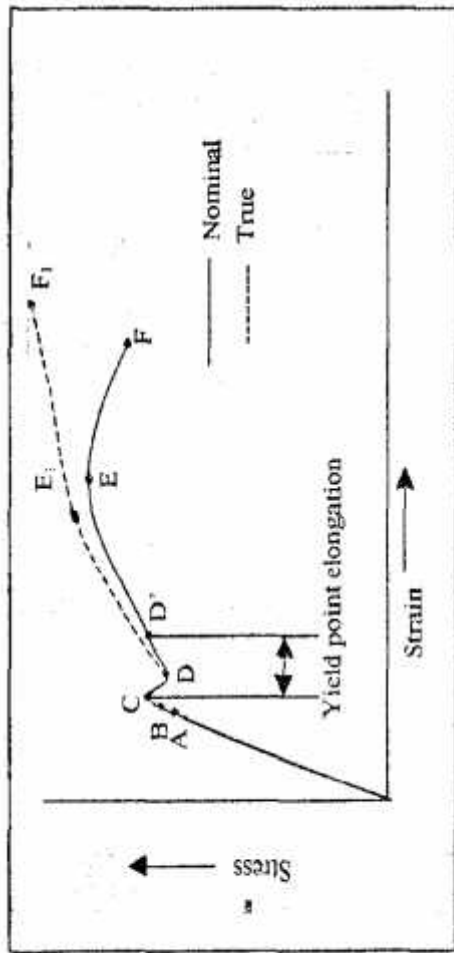


Fig. 9 Stress-Strain curve

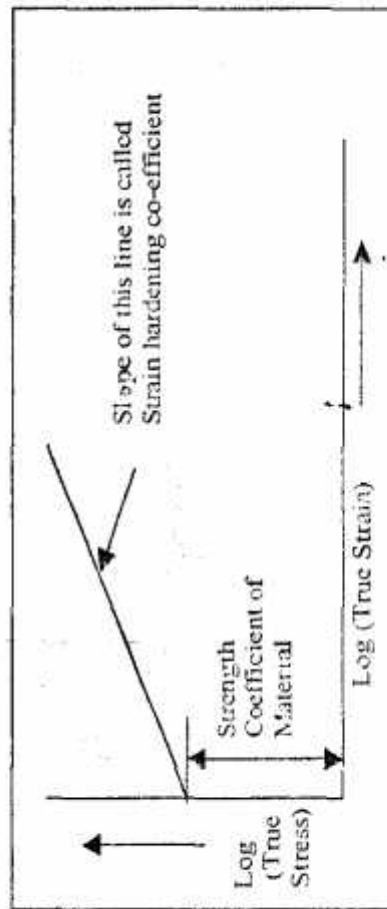
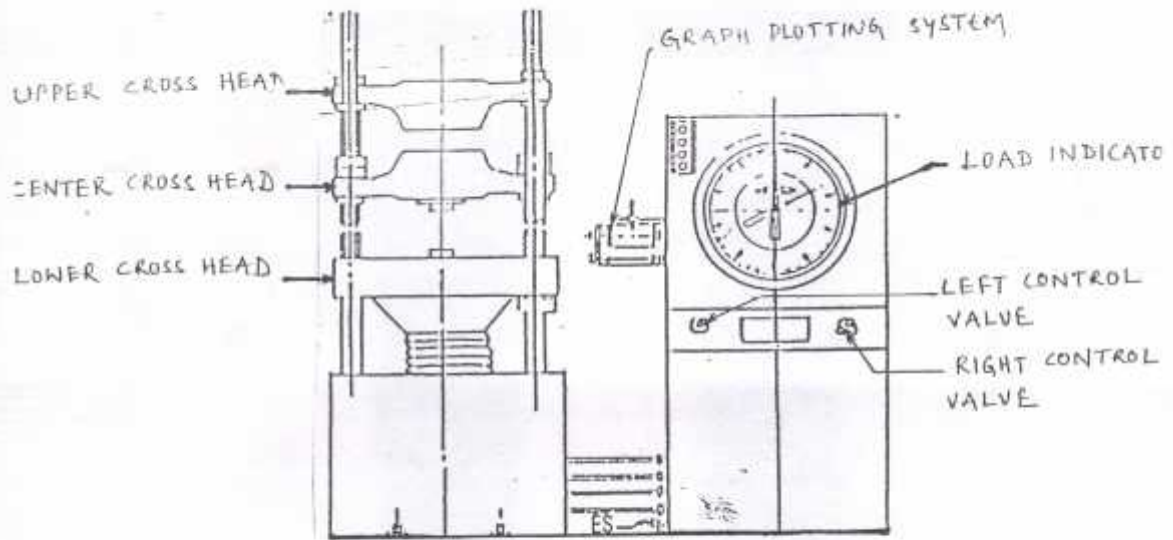


Fig. 10 True Stress-True Strain in log-log co-ordinates



UNIVERSAL TESTING MACHINE

8. SHEAR TEST

Aim:

To find the shear stress of the given specimen

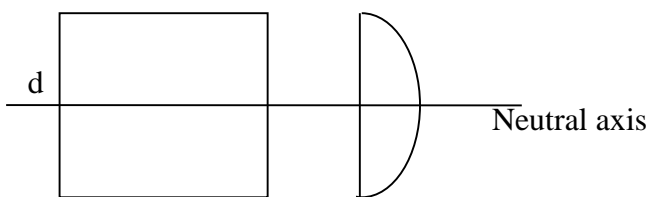
Apparatus:

UTM, specimen, shear test attachment

Theory:

When the material is subjected to a certain amount of shear force, shear stress develops in the body, these stresses developed vary in a parabolic form at the cross section with maximum shear stress at the neutral axis of the material element and when these stresses exceed the maximum shear resistance capacity of the material, the material will shear.

b



The variation of shear stress along the rectangular cross section

The total shear force applied at any rectangular cross section is given by

$$= (3F)(d^2-4a^2)/(2bd^3)$$

Where F is the amount of force applied

a is the distance in the cross-section measured from neutral axis

b is the breadth of the beam

d is the depth of the beam

The maximum shear stress when a=0 at centre, is given by $\tau_{max} = (3F)/(2bd)$

The average shear stress $\tau_{avg} = F/bd$

Procedure:

Place the specimen in the shear attachment of the UTM and apply the force increasing it in increments till the specimen shears.

Note down the load where the specimen is subjected to maximum shear force.

If the test specimen shears at two points then the total force applied is equally shared at two cross sections.

Result:

The value of shear force at failure =

Maximum Shear stress at centre is =

Average shear stress is =

9. COMPRESSION TEST ON CONCRETE

Aim:

To determine the 7 day and 28 day compressive strength of concrete specimen of size 150 mm cube using compression testing machine

Apparatus/material required:

Cement, coarse aggregate of size 20 mm, fine aggregate, water, casting cube, trowel, standard bowl, tray, hand gloves, weigh balance, oil, water

Theory:

The method of concrete mix design consists of selection of optimum combination of cement, coarse aggregate and fine aggregate and water to produce concrete specimen of desired properties. The concrete is graded according to its compressive strength as per Indian Standards 456-2000. The design of mix shall involve determination of water, cement, fine aggregate and coarse aggregate so that the concrete of specified properties can be obtained economically.

Steps to mix the aggregate:

- Weigh the aggregate in the following proportions:

Aggregate for each specimen of 150 mm cube	Weight in Kilograms (except water)	Measure using
Cement	1.0164	Weighing machine
Coarse aggregate	1.655	
Fine aggregate	3.406	
Water	0.613 ltr (density = 1gm/cc)	Measuring flask
Total weight	6.75 approximately	

- Take a clean bowl and place the coarse aggregate and fine aggregate and cement in the order and thoroughly mix the aggregate and add water and mix till the aggregate mix attains consistency.
- Take two numbers standard 150mm cube test moulds and apply oil on all inner sides.
- Pour the aggregate mix into this mould ensure that the cast is continuous and no voids are observed.
- Remove any excess material and allow the mould to set for 24 hours.
- After 24 hours, the following day after when the material is set demould the material and cure the specimen thoroughly for seven days and twenty eight days.
- Thorough curing operation need to done.
- After seven days, one of the specimens is tested using a compressive testing machine for crushing strength.



- After twenty eight days, the second specimen is tested using a Compressive testing machine for crushing strength.

Result:

1. Water cement ratio used =
2. 7-day crushing strength =
3. 28 day crushing strength =

10. VERIFICATION OF MAXWELLS RECIPROCAL THEOREM ON BEAMS

Aim:

To verify the Maxwells reciprocal theorem on beams

Apparatus required:

Simply supported beam set up, cantilever beam set up, dial gauges, weights

Theory:

Consider a Cantilever ACB of length L with fixed end 'A' and point 'C' at a distance 'a' from fixed end. Let the free end be 'B'. The distance measured from point C to point B = L-a

Apply the load W at free end B and the deflection at C = $\delta_C = (Wa^2/2EI) * (L-(a/3))$

Apply the load W at point C and the deflection at B = $\delta_B = (Wa^2/2EI) * (L-(a/3))$

Note that $\delta_C = \delta_B$

Cantilever Beam



Procedure:

1. Choose two points A, B on a beam. At constant temperature and unyielding supports, consider a beam subjected to a load W at point A. Let δ_B be the deflection produced at point B by load W in Y direction pointing south.
2. If the load at point a is removed and applied at point B in Y direction pointing south, the deflection measured at A will also be equal to δ_B .

The work done when the load W is acting at A and deflection is measured at B = $W_A * \delta_B$

The work done when the load W is acting at B and deflection is measured at A = $W_B * \delta_A$

Here $W_A = W_B$ and hence $\delta_A = \delta_B$

This is known as the Clark Maxwell's reciprocal theorem.

3. Repeat the steps 1 & 2 above with different set of loads and tabulate the results.
4. Repeat the above steps for both cantilever and simply supported beam setup



Observations:

Simply supported Beam/Cantilever Beam	
Load in KG at Point A	Deflection at point B

Simply supported beam/Cantilever Beam	
Load in KG at Point B	Deflection at point A

Result:

Deflection at point A when load is at point B = Deflection at point B when load is at point A

Maxwells reciprocal theorem is proved.

11. CONTINUOUS BEAM - DEFLECTION TEST

Aim:

To conduct the deflection test on continuous beam

Apparatus :

Continuous beam set up, dial gauges, weights

Theory:

Consider the continuous beam having three supports as shown below:



The left support A is hinged with two roller supports at B and C. The length of the span AB is equal to the length of the span BC which is equal to L each.

The distance between AD=DE=EB=BG=GH=HC = L/3

The symmetrical loading W is applied at each one third points (D, G) in each span and deflections are measured using dial gauges at the other one third points in each span (E, and H) as shown in the diagram. Compare the observed values with the theoretical deflection values at E and H.

Using the slope deflection method, the reactions are found as follows:

$$R_A = 14W/27, R_B = 26W/27, R_C = 14W/27$$

$$\text{Slope at left end A is } i_A = WL^2 / 27EI$$

Consider any section XX in span DB at a distance of x from left end A.

$$\text{Use the relation } EI \frac{d^2y}{dx^2} = M_{xx}$$

Use Macaulays method to find the moment M_{xx} , and Integrating it twice to obtain the deflection equation.

$$EI \frac{d^2y}{dx^2} = R_A x - W (x - (L/3))$$

The two conditions used to find constants of integration C_1 and C_2 are the slope and deflection at point B are zero (symmetrical loading on both the spans and support at B)

$$C_1 = - 0.09259259 WL^2$$

$$C_2 = 6.1722 \times 10^{-3} WL^3$$

Compute the theoretical values of deflection using the following expression

The deflection at any point x in span DB is given by

$$Y = R_A (x^3/6) - W(x^3/6) + WL (x^2/6) + C_1x + C_2$$

A Sample calculation for deflection at point E for the sample data is given below:

Take,

$$W = 10 \text{ N}$$

$$L = 1000 \text{ mm}$$

$$X = 2/3 \text{ m} = 666.66 \text{ mm}$$

$$E = 2 \times 10^5 \text{ N/mm}^2$$

$$\text{Breadth } b = 30 \text{ mm}$$

$$\text{Depth } d = 5 \text{ mm}$$

$$I = bd^3/12 = 312.5 \text{ mm}^4$$

$$EI = 625 \times 10^5 \text{ Nmm}^2$$

$$C_1 = - 0.09259259 * 10 * 1000 * 1000$$

$$C_2 = 6.1722 \times 10^{-3} * 10 * 1000^3$$

$$EIY \text{ (at } x = 666.66 \text{ mm)} = (140/27) (666.66^3/6) - 10(666.66^3/6) + 10.1000 (666.66^2/6) + 666.66 * (- 0.09259259 * 10 * 1000 * 1000) + 6.1722 \times 10^{-3} * 10 * 1000^3$$

$$Y = 0.841 \text{ mm in the downward direction}$$

Observations:

LOAD		Observed Deflection at E	Observed Deflection at H	Calculated deflection at E	Calculated deflection at H
AT D	AT G				

Result:

Deflection calculated =

The observed values of deflection match with the theoretical values.

12. EFFECT OF LOADING AND UNLOADING BEYOND ELASTIC LIMIT

Aim:

The aim of the experiment is to understand the behavior of the material when loading and unloading is continued beyond elastic limit

Appartus:

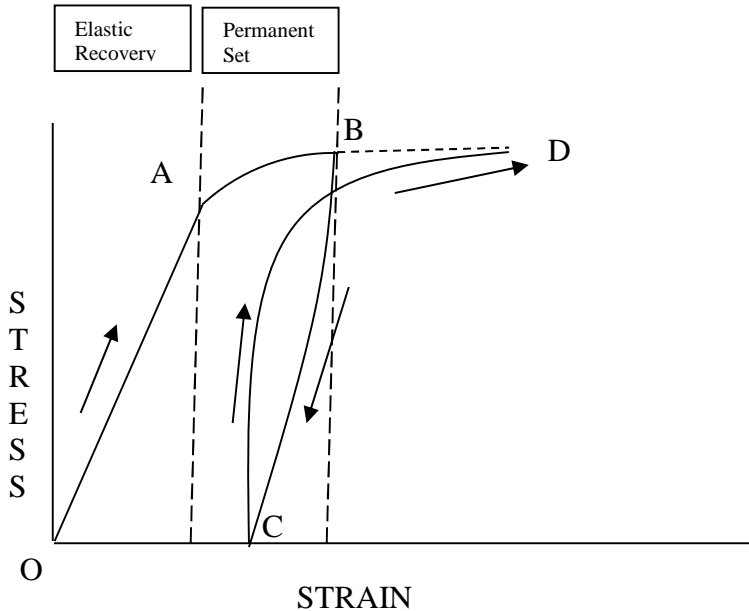
UTM, test specimen, dial gauge reading, vernier calipers

Theory:

After being loaded when a member is unloading beyond elastic limit, the elastic strain recovers and the plastic strain remains as a permanent set in the member. The behavior is illustrated in the stress strain diagram given below.

The slope of the unloading line BC is same as that of loading line OA. If the material is reloaded, it follows the unloading curve CB till the yielding commences and then joins the curve which the material would have followed had there been no unloading. The limit of proportionality increases when the material is reloaded as shown.

In most of the elastic materials the elastic recovery is not immediate on unloading. Some portion of elastic deformation remains and disappears only after some time with the result that the unloading curve is not a straight line. When the material is reloaded immediately, it does not follow unloading curve and forms a narrow loop with the unloading curve as shown in the diagram. This loop is known as hysteresis loop. The area of this loop represents the energy lost in a cycle of unloading and reloading and is usually small.



OA – loading

BC – Unloading

CB – Reloading

BD – continued loading

Procedure:

1. Mark two points on the specimen and measure the length of specimen between the two points. Mount the specimen in the UTM apply the loading on the test specimen incrementally, note down the loading and the corresponding dial gauge readings, once after the material crosses the elastic limit and enters the yielding zone stop the loading and slowly unload till zero. Unmount the specimen and note down the increase in length.
2. Again mount the test specimen in the UTM and apply the loading incrementally, note down the loading and the corresponding dial gauge readings. Once after the reloading crosses the last loading point and material starts further yielding stop the loading and gradually unload till zero. Note down the loading and any changes in the dial gauge readings. Unmount the specimen and note down the change in length between the same marked points.
3. Repeat step two till the ultimate stress point is attained.
4. Plot the stress strain curve with loading, unloading, reloading and continued loading phases and with the corresponding strain on x-axis

Tabulate your results:

Load in KN	Dial gauge reading	Phase/cycle	Length of the specimen

Result:

Cycle 1 maximum Loading is
Permanent Set =

Cycle 2 maximum loading
Permanent set =

Cycle 3 maximum loading
Permanent set =

The behavior of the material under loading and unloading and reloading phases is graphed and hysteresis loop is observed.