



# **Laboratory Manual of Mechanics of Solid**

**Department of Civil Engineering**

**Academic year: - 2020-21 Sem (I/II)**

**Class: - S.Y.B.Tech / S.E.**

### List of Experiments

Sr. No.	Name of Experiment	Date of Completion	Sign	Remark
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## EXPERIMENT – 01

### TENSILE TEST ON MILD STEEL

#### Aim

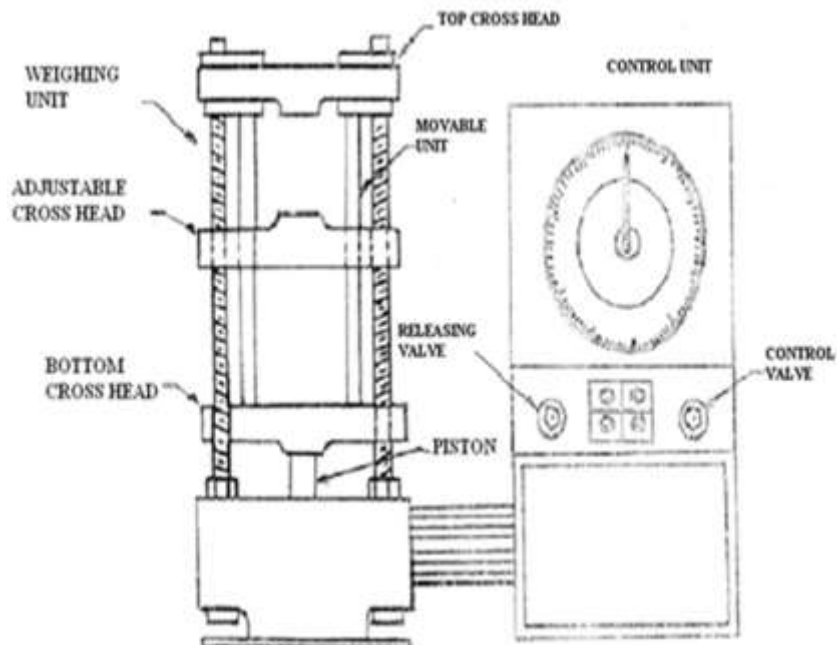
To conduct tensile test on mild steel specimen and determine the following.

1. Yield stress
2. Ultimate stress
3. Breaking stress
4. Percentage elongation
5. Percentage reduction in area

**Reference** IS 1608 Method for tensile testing of steel products.

#### Apparatus

Universal testing machine, test specimen, steel rule, vernier calipers, micrometer-graph.



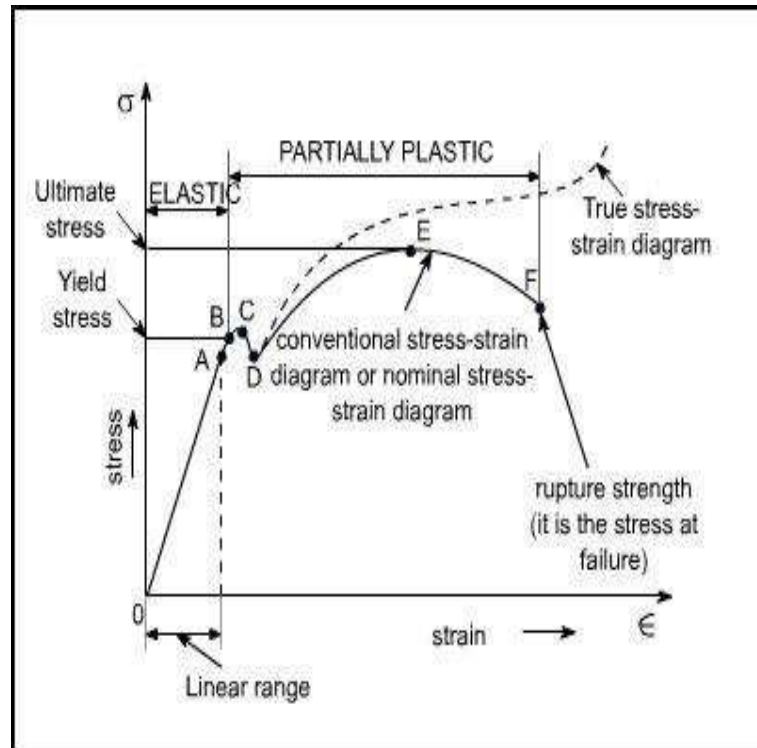
**Tension test Apparatus on mild steel**

## System description

The machine consists of a weighing unit and control unit connected with each other by means of hydraulic pipes. In the weighing unit there are three cross heads (namely top, bottom and adjustable cross heads). Adjustable cross head can be adjusted in between top and bottom cross heads. The bottom cross head and top cross head are one unit and it is connected with the piston, which moves up and down inside the cylinder.

## Theory

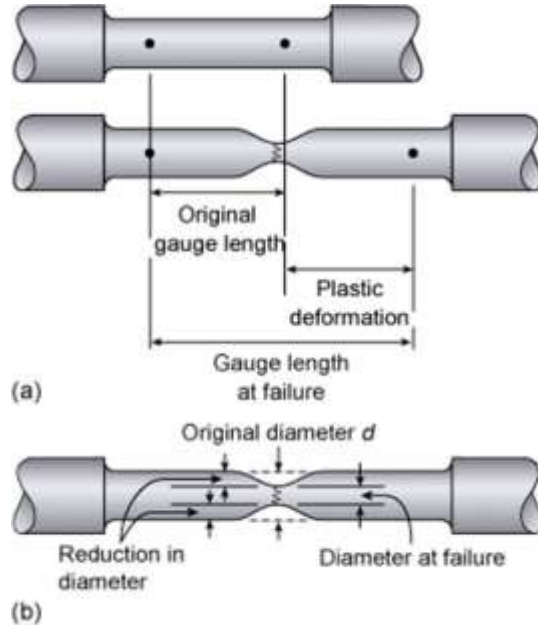
A tensile test is generally conducted on a test specimen to obtain the relationship between the stress and the strain which is an important characteristic of a ductile material. In the test, the uniaxial load is applied to the specimen and increased gradually. The corresponding deformations are recorded throughout the loading. Stress-strain diagrams of materials vary widely depending upon whether the material is ductile or brittle in nature. If the material undergoes a large deformation before failure, it is referred to as ductile material or else brittle material.



### Schematic showing typical tensile responses of a mild steel bar under tensile loading

The stress-strain diagram for a mild steel specimen is shown in figure. The diagram begins with a straight line O to A, in which stress is directly proportional to strain. Point A marks the limit of proportionality beyond which the curve becomes slightly curved, until point B, the elastic limit of the material. If the load is increased further, yielding takes place. Point C is the point of sudden large extension, known as yield point. After the yield point stress is reached, the ductile extensions take place, the strains increasing at an accelerating rate as represented by C and D. The material becomes perfectly plastic in this region (C to D), which means that it can deform without an increase in the applied load. If the load is further

increased, the steel begins to strain harden. During strain hardening, the material appears to regain some of its strength and offers more resistance, thus requiring increased tensile load for further deformation. The point E is the maximum load or ultimate load up to which the bar extends uniformly over its parallel length, but if straining is continued, a local deformation (neck formation) starts at E and after considerable local extension, the specimen breaks at F called breaking stress.



**Schematic showing the *necking* behavior in a metal**

**Formulae**

A measure of the *ductility* of a material is the magnitude of the plastic strain at fracture. Ductility can be specified in terms of either % elongation (% EL) or % reduction in area (% RA)

$$\% \text{ EL} = \left[ \frac{(l_f - l_o)}{l_o} \right] \times 100 \quad [4]$$

$$\% \text{ RA} = \left[ \frac{(A_o - A_f)}{A_o} \right] \times 100 \quad [5]$$

$$\left[ \frac{\quad}{A_o} \right]$$

Where  $l_o$  and  $l_f$  refer to the initial and final specimen lengths, respectively and  $A_o$  and  $A_f$  refer to the initial and final cross-sectional areas of the specimen.

$$\text{Yield strength} = \frac{\text{Yield Load}}{\text{original cross sectional area}} \dots\dots\dots N/mm^2$$

$$\text{Ultimate strength} = \frac{\text{Maximum tensile Load}}{\text{original cross sectional area}} \dots\dots\dots$$

$$\text{Breaking strength} = \frac{\text{Breaking Load}}{\text{original cross sectional area}} \dots\dots\dots N/mm^2$$

Young's modulus= Slope of the stress –strain curve

$$E = \frac{d_y}{d_x} \dots\dots\dots N/mm^2$$

$$\text{Percentage of elongation} = \frac{\text{Final length(at fracture)} - \text{Original length}}{\text{original length}}$$

$$\% \text{ of elongation} = \frac{L_f - L}{L} \dots\dots\dots \%$$

$$\text{Percentage of reduction in area} = \frac{\text{Original area} - \text{Area at fracture}}{\text{original area}}$$

$$\% \text{ of reduction in area} = \frac{A - a}{A} \dots\dots\dots \%$$

$$\text{Cross sectional area of neck (a)} = \frac{\pi}{4} x d^2 \dots\dots\dots mm^2$$

$$\text{Original area of the rod (A)} = \frac{\pi}{4} x D^2 \dots\dots\dots mm^2$$

Where

d –Neck diameter of the mild steel rod in millimeters

D-original diameter of the rod in millimeters

## Procedure

1. Clean the M.S rod and measure the original length (L) and diameter (d) of the specimen. The length may either be length of gauge section which is marked in the specimen with a preset punch or the total length of the specimen.
2. Mark the gauge length to determine the elongation by marking punch marks at 2.5times diameter distance on the specimen.
3. Fix the extensometer at the center of the specimen and adjust the extensometer reading to zero position. Also set the Vernier scale on the vertical column on machine on zero position to take reading in the plastic range.
4. Apply the load gradually and note down the value of load for every five division of increase in the extensometer reading.
5. Remove the extensometer after 70% of the yield load is applied .Yield load may be calculated by product of projected yield stress ( $250 \text{ N/mm}^2$  in case of steel) and the area of cross section.
6. Note down the load at yield i.e., the short deviation of time when the pointer remains stationary.
7. Increase the load and note down the ultimate load. At the ultimate load the red pointer will be left in position and the black point which indicates the instantaneous applied load will move in to reverse direction.
8. Note down the break point load at which the specimen fails.
9. Measure the distance between the two points A and B. This distance is known as final gauge length of the specimen.
10. Draw a graph between stress Vs strain by taking stress along Y axis and strain along X axis.
11. Take the slope of straight line portion of the curve which gives Young's Modulus of the material.

**Tabulation**

**Table**

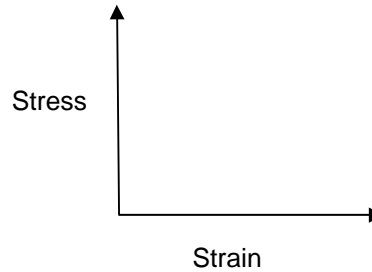
Sl. No	Load (P) kN	Elongation in divisions	Elongation in mm	Stress ( $\sigma$ ) N/mm <sup>2</sup>	Strain ( $\epsilon$ )	Young's Modulus (E) N/mm <sup>2</sup>
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
11						
12						
13						
14						
15						



## Graph

The following graph is drawn by taking **strain** along X-axis and **stress** along Y - axis.

- Stress Vs Strain



## Observation

1. Material of the specimen =.....
2. Original gauge length of the specimen = .....
3. Original diameter of the specimen =.....
4. Neck diameter of the specimen =.....
5. Initial gauge length of the specimen =.....
6. Final length of the specimen =.....
7. Yield Point load =.....
8. Ultimate load =.....
9. Breaking load =.....

## Precaution

1. If the strain measuring device is an extensometer it should be removed before necking begins.
2. Measure deflection on scale accurately & carefully

**Result** Tension test for given specimen was conducted and the results are as follows

1. Yield stress = .....N/mm<sup>2</sup>
2. Ultimate stress = ..... N/mm<sup>2</sup>
3. Breaking stress = .....N/mm<sup>2</sup>
4. Percentage elongation = .....
5. Percentage reduction in area = .....

### **Inference**

### **Significance of the test**

The stress characteristics of mild steel and for steel can be found with help of this test. The yield stress of steel is important in design of flexural members. As per IS, the yield stress for mild steel is 250 N/mm<sup>2</sup>.

**Space for Calculations**

**Graph paper to be added**

## EXPERIMENT - 2

### DEFLECTION TEST ON A SIMPLY SUPPORTED BEAM

#### **Aim**

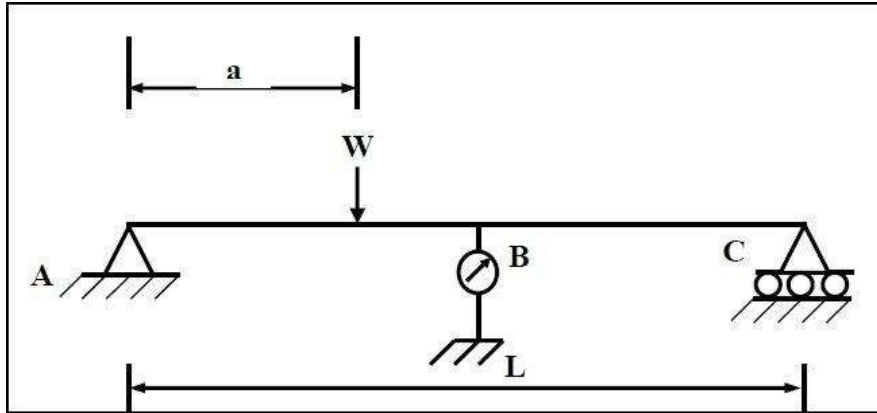
To conduct deflection test on a simply supported beam carrying a point load at a distance 'a' from left support.

#### **Apparatus required**

1. Deflection beam apparatus
2. Weights
3. Dial gauge
4. Magnetic dial stand
5. Vernier calipers
6. Scale/Steel tape

#### **Theory**

When the beam is subjected to load, the beam is deflected from its original position. The deflection of a member should always be within the specified limits. We can determine the deflection of beams subject to any type of loading by using standard deflection formulae. The actual deflection of the member is directly proportional to the load and cube of span (if subjected to point load) and is inversely proportional to flexural rigidity (EI). Actual deflection so calculated should be less than the permissible deflection.



**Deflection apparatus beam set up**

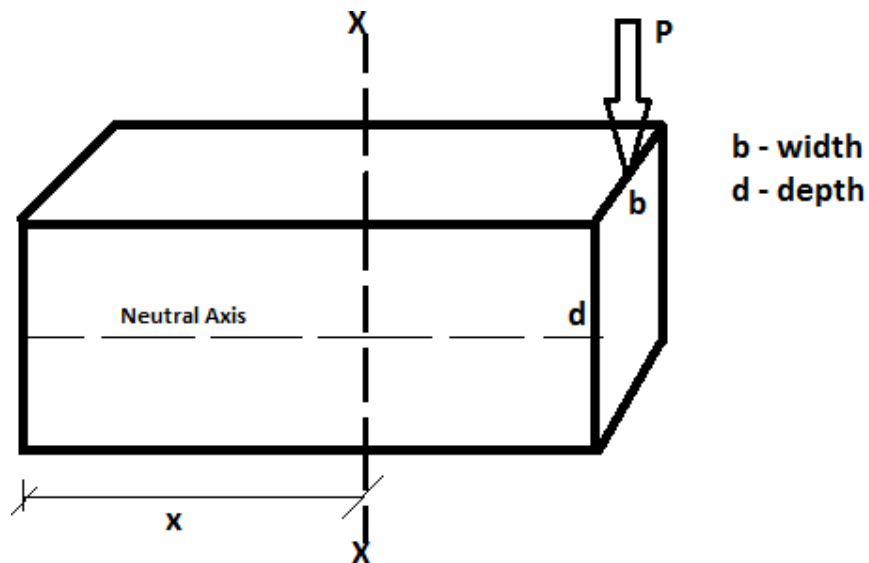
Where,

L-Span of the beam

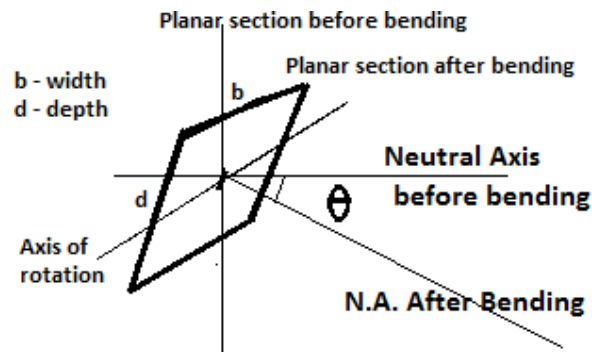
W-Load applied

a-The distance of the load from left support

As the loading applied is transverse loading as shown in the Fig. 2(a)-2 which is perpendicular to the plane containing the neutral axis, and hence the member is a beam.



**Beam carrying the Transverse loading**



### The cross section at XX

Moment of Inertia is calculated about the axis of rotation =  $I = \frac{bd^3}{12}$

### Formulae

The general formula for deflection at mid span when load is applied at a distance 'a' is given by

$$\frac{Wa(3L^2 - 4a^2)}{48EI}$$

If load at 'a'=L/4 from left support and substituting in above equation,

$$\text{Modulus of Elasticity, } E = \frac{11WL^3}{768 I_{\text{central}}} \text{ N/mm}^2$$

(Deflection at the centre of the beam, span L is in 'mm' and W in N)

$$\frac{11L^3}{768I}$$

Modulus of Elasticity from graph,  $E = slope \times X = \dots\dots\dots N/mm^2$

**Procedure**

1. Note the initial reading of the Vernier Scale.
2. Measure the breadth and depth of the given beam using Vernier Caliper.
3. Adjust cast iron blocks along the bed so that they are symmetrical with respect to the length of the bed.
4. Place the beam on the knife edges on the blocks so as to project equally beyond each knife edge. See that the load is applied at the centre of the beam.
5. Set the dial gauge below the center of the beam and note down the reference point from the dial gauge.
6. Measure the effective length of the beam by using scale or steel tape
7. Place the load frame at exact position on the specimen and note down the corresponding deflection from the corresponding deflection from the dial gauge
8. Similarly note down the dial gauge readings by placing different weights on the load frame.
9. Remove the load gradually and record the dial gauge readings while unloading.

**Observations & Tables**

**Calculation of width of the beam**

S.No.	Main scale reading (M.S.R.) in mm	Vernier scale coincidence (V.C.) div	Width=M.S.R+L.C.xV.C.
1			
2			
3			

Average width in mm=

### Calculation of depth of the beam

S.No.	Main scale reading (M.S.R.) in mm	Vernier scale coincidence (V.C.) div	Depth=M.S.R+L.C.xV.C.
1			
2			
3			

Average depth in mm=

1. Least count of Dial gauge= .....
2. Least count of vernier calipers=.....
3. Material of the beam =.....
4. Length of beam = .....mm
5. Breadth of beam =.....mm
6. Depth of beam =.....mm
7. Moment of Inertia of the beam= .....mm<sup>4</sup>

Sl. No	Load		Deflection				Young's modulus
	W		Loading ( $\delta_1$ )	Unloading ( $\delta_2$ )	Avg. ( $\delta$ )		E
Units	Kg	N	mm	mm	mm	m	N/mm <sup>2</sup>
1							
2							
3							
4							
5							
6							
7							
8							



**Precautions**

1. Make sure that the beam and load are placed at desired positions.
2. Measure the dimensions of the beam carefully.

**Graph**

The following graph is drawn by taking **load** along Y-axis and **deflection** along X-axis.

- Load Vs Deflection



**Result**

The deflection test on given simply supported beam is conducted.

The Young's modulus of the given beam from calculation = ..... N/mm<sup>2</sup>.

The Young's modulus of the given beam from graph = ..... N/mm<sup>2</sup>

**Significance of the test**

If the Young's Modulus of the material of the specimen is equal to the standard value specified for the material, the deflection found to be correct.

**Inference**

**Space for Calculations**

**Graph paper to be added**

## EXPERIMENT-03

### TORSION TEST

#### Aim

To find the Modulus of Rigidity of the given test specimen.

#### Material and Equipment

Torsion testing machine, Standard specimen of mild steel or cast iron, steel rule, and Vernier calipers (or) Micrometer.

#### Theory

Torsion test is quite instrumental in determining the value of modulus of Rigidity (ratio of shear stress to shear strain) of a metallic specimen. The value of modulus of rigidity can be found out through observations made during the experiment by using the torsion equation.

$$\frac{T}{I_p} = \frac{C}{l} \theta$$

Where, T = Torque applied

C = Modulus of

rigidity l = length of

the shaft

q = shear stress

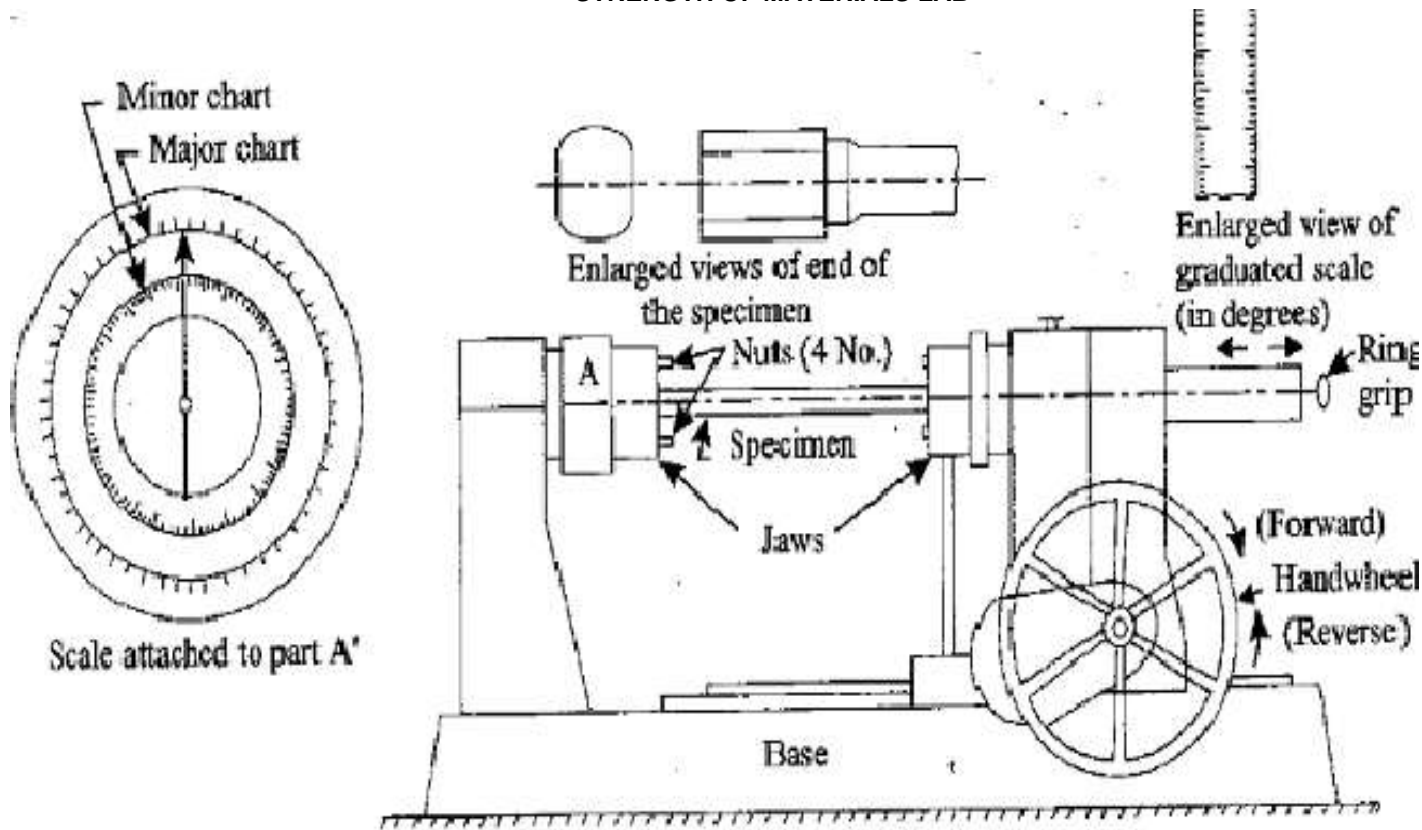
r = distance of element from centre of shaft

$\theta$  = Angle of twist (radians)

$I_p$  = Polar moment of inertia.

In the torque equipment (refer figure shown in the next page), one end of the specimen is held by a fixed support and the other end to a pulley. The pulley provides the necessary torque to twist the rod by addition of weights (w). The twist meter attached to the rod gives the angle of twist.

**STRENGTH OF MATERIALS LAB**



**Torsion Testing Machine**

### Procedure

1. Measure the diameter at about three places and find the average value.
2. Select suitable grips to suite the size of the specimen and clamp it in the machine by adjusting the sliding jaw.
3. Choose the appropriate loading range depending upon specimen.
4. Set maximum load pointer to zero.
5. Continue till failure of the specimen.
6. Calculate the value of modules of rigidity  $C$  by using Torsion equation.
7. Plot a torque – Twist graph ( $T$  V/s  $\theta$ ).

### Observation

Diameter of the Specimen,  $d = \dots\dots\dots$ mm

Gauge length of the Specimen,  $l = \dots\dots\dots$  mm

Polar Moment of Inertia,  $\frac{d^4}{32} = \dots\dots\dots \text{mm}^4$

**Tabulation**

**Torsion test observations**

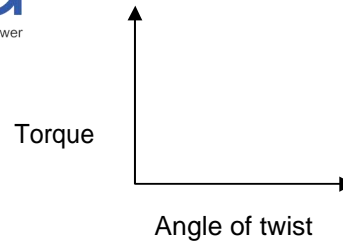
S.No.	Angle of Twist (Deg.)	Angle of Twist (Radians)	Torque		Modulus of Rigidity (N/ mm <sup>2</sup> )	Shear stress (N/ mm <sup>2</sup> )
			N-m	N-mm		
1						
2						
3						
4						
5						
6						
7						
8						
9						





**Graph**

1. Torque vs. Angle of Twist.



**Result**

Thus the torsion test on given mild steel specimen is done and the value of modulus of rigidity is calculated.

Rigidity modulus of the specimen calculated= .....N/mm<sup>2</sup>

Rigidity modulus of the specimen from graph= ..... N/mm<sup>2</sup>

**Inference**

**Reference**

IS 1717: 2012 Metallic Materials — Wire — Simple Torsion Test

**Significance of the test**

When a shaft is subjected to torsion, pure shear stresses are developed in the shaft material. Hence Modulus of rigidity of the material can be determined.

**Space for calculations**

**Graph paper to be added**

## EXPERIMENT -04

### BRINELL HARDNESS TEST

#### **Aim**

To find the Brinell Hardness number for the given metal specimen.

#### **Apparatus**

Brinell hardness machine, test specimen and Brinell microscope.

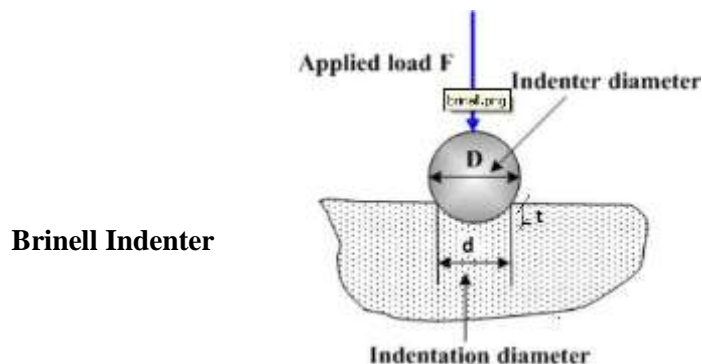
#### **Theory**

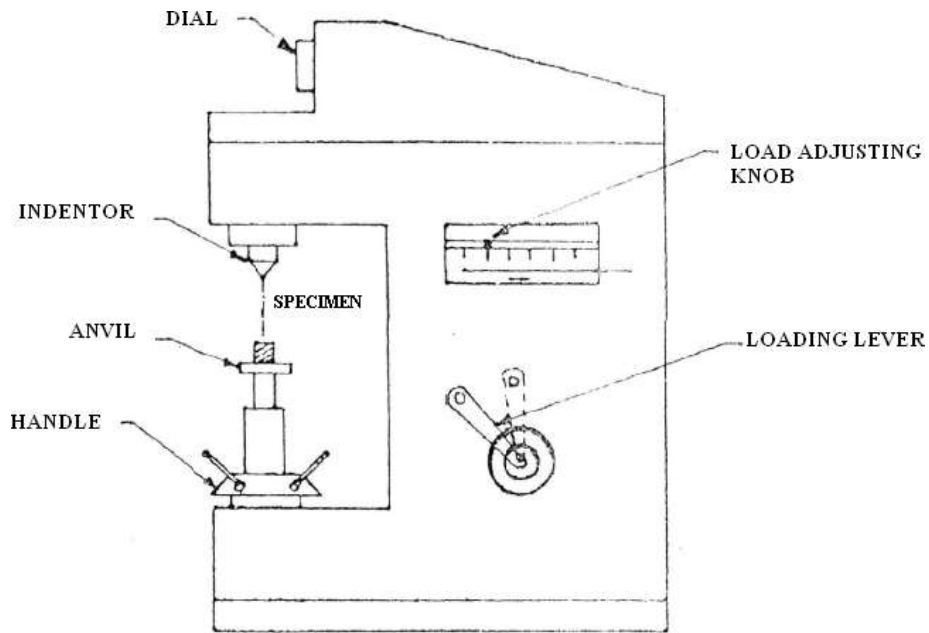
Hardness represents the resistance of material surface to abrasion, scratching and indentation. In all hardness tests, a definite force is mechanically applied on the test piece for about 15 seconds. The indenter, which transmits the load to the test piece, varies in size and shape for different tests. Common indenters are made of hardened steel or diamond.

In Brinell hardness testing, steel balls are used as indenter. Diameter of the indenter and the applied force depend upon the thickness of the test specimen. For accurate results, depth of indentation should be less than  $1/8^{\text{th}}$  of the thickness of the test pieces.

#### **System description**

The machine consists of a lever of a dial indicator an elevating screw, a hand wheel, load changing lever, load lever, hanging weights, etc. there are two scales on the dial B scale marked in red color and C scale marked in black color. Each scale is graduated with hundred divisions. Zero reading in C scale is opposite to 30 numbers in B scale, so that there is a difference between C and B scales at any point. There are flat and V shape anvils available and they can be used for plane and cylindrical surface respectively. Anvil is placed on the elevating screw so that the specimen can be placed. Indenter can be hold in the indenter holder which is just above the elevating screw.





**Brinell Hardness Testing Machine**

**Formulae**

The depth of indentation,  $t = \frac{D}{2} - \sqrt{\left(\frac{D^2}{4} - \frac{d^2}{4}\right)}$

The surface area of indentation =  $nDt$

Brinell hardness number = Test load / Surface area of indentation

$$\text{BHN} = \frac{2P}{nD[D - \sqrt{D^2 - d^2}]}$$

D – Diameter of indenter in millimeters

d – Diameter of indentation in millimeters

P – Applied test load

**Observations and calculations**

1. Test piece material
2. Diameter of Ball
3. Load application time
4. Least count of Brinell Microscope

**Tabulation**

S. No.	Material of specimen	Load (P) Kg	Ball dia (D) in mm	Load applied 'P' in Kgf.	Trial No	Dia of Indentation 'D <sub>i</sub> or d' (mm)	Brinell Hardness Number	Mean Brinell Hardness Number
1	Mild steel				1			
					2			
					3			
2	Al				1			
					2			
					3			
3	High Carbon Steel				1			
					2			
					3			

### Procedure

1. Select the proper size of ball and insert ball of dia “D” in the ball holder of the m/c
2. Make the test specimen surface clean by removing dust, dirt, oil and grease etc.
3. Mount the test specimen surface at right angles to the axis of the ball indenter plunger.
4. Make contact between the specimen surface and the ball by rotating the jack adjusting wheel.
5. Apply the load by shifting the “load-lever” and wait for minimum 15 seconds. The load will be applied gradually.
6. Release the load by shifting the “load-lever”.
7. Remove the specimen from support table and mark the indentation so made.
8. View the indentation through microscope and measure the diameter ‘d’ by micrometer fitted on microscope.
9. Repeat the entire operation, three times at other positions of test piece.
10. Calculate the value of BHN.

### Precautions

1. The surface of the test specimen should be clean.
2. The testing machine should be protected throughout the test from shock and vibration.
3. The test should be carried out at room temperature.
4. The diameter of each indentation should be measured in two directions at right angles and mean of the diameter should be taken for calculation.

**Result** The given materials were tested and their Brinell hardness numbers are

1. Mild steel = .....BHN
2. High carbon steel = .....BHN
3. Brass = .....BHN
4. Copper = ..... BHN
5. Aluminum = ..... BHN

### Inference

### **Significance of the test**

Brinell hardness test is best for measuring hardness of grey iron castings consisting of soft flake graphite, iron and hard iron carbide. Brinell hardness tests are conducted on structural steel, other rolled sections, steel cast iron, and aluminum castings and in most of forgings.

### **Reference**

IS 1789-1961 Method for Brinell Hardness test for grey cast iron.

IS 3054-1965 Method for Brinell Hardness test for Copper and Copper

alloys. IS 15002005 method for Brinell hardness test for metallic materials





## EXPERIMENT – 04 (b)

### ROCKWELL HARDNESS TEST

#### Aim

To determine the Rockwell hardness number of the given specimen.

#### Apparatus

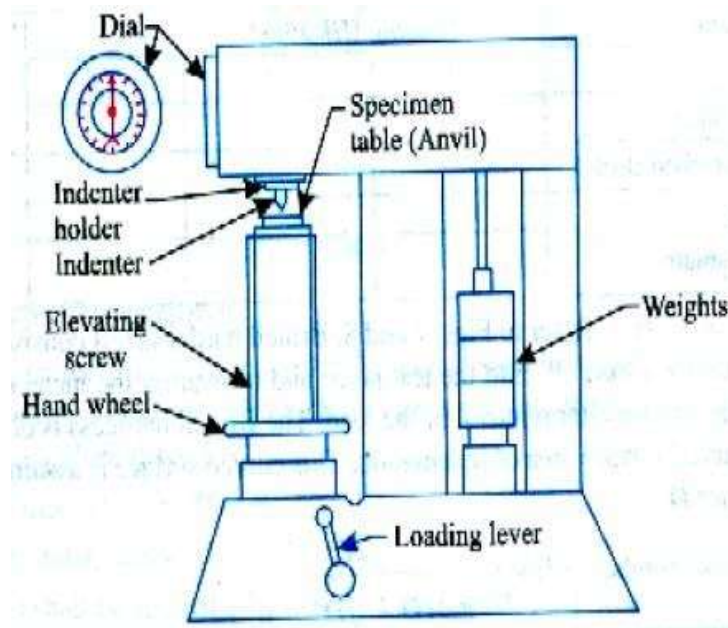
Rockwell hardness testing machine, penetrator and test specimen.

#### Theory

The hardness of a material is resistance to penetration under a localized pressure or resistance to abrasion. The general method of judging the hardness is measuring the resistance of a material to indentation. Hardened steel, sintered tungsten carbide or diamond indenters are generally used for indentation. In this tests, a load is applied by pressing the indenter at right angles to the surface being tested. The hardness of the material depends on the resistance which it exerts during a small amount of yielding or deformation. The resistance depends on friction, elasticity, viscosity and the intensity and distribution of plastic strain produced by a given tool during indentation. Various scales in Rockwell hardness test are given below-

**Table**

Scale	Type of indenter (Dimensions)	Color	Initial load (Kgf)	Major load (Kgf).	Pointer position on dial.	Kind of material.
A	Cone, 120 <sup>0</sup>	Black	10	50	0	Much harder such as carburized steels, cemented carbides.
B	Ball, 1.588 mm	Red	10	90	30	Soft steels, copper, brass, grey cast iron.
C	Cone, 120 <sup>0</sup>	Black	10	140	0	Hard steels, Ti, W, Va, etc.



### Rockwell Hardness Testing Machine

#### Procedure

1. Select the proper size of ball and insert ball of diameter "D" in the ball holder of the m/c
2. Make the test specimen surface clean by removing dust, dirt, oil and grease etc.
3. Mount the test specimen surface at right angles to the axis of the ball indenter plunger.
4. Place the specimen on platform of a machine. Using the elevating screw raise the platform and bring the specimen just in contact with the ball. Apply an initial load until the small pointer shows red mark.
5. Release the operating valve to apply additional load. Immediately after the additional load applied, bring back operating valve to its position.
6. Read the position of the pointer on the relevant scale of graduation, which gives the Rockwell hardness number.
7. Repeat the procedure three times on the specimen selecting different points for indentation.

#### Precautions

1. Indentation should not be made nearer to the edge of a specimen to avoid unnecessary concentration of stresses. In such case distance from the edge to the center of indentation should be greater than 2.5 times diameter of indentation.
2. Rapid rate of applying load should be avoided. Load applied on the ball may rise a little because of its sudden action. Also rapidly applied load will restrict plastic flow of a material, which produces effect on size of indentation.
3. After applying major load, wait for some time to allow the needle to come to rest.
4. Test specimen should not be subjected to any heating or cold working.
5. Thickness of the specimen should not be less than 8 times the depth of indentation to avoid the deformation to be extended to the opposite surface of a specimen.

#### Tabulation

#### Table

Sl No.	Material	Load in Kgf	Indenter Scale	Trial Number			Rockwell Hardness Number (HRC)
				1	2	3	
1							
2							
3							

### Observations

1. Material of test piece
2. Hardness of scale used
3. Minor load
4. Major load

### Result

Rockwell Hardness number of the specimen was found for the given material as

- follows 1. Copper .....= HRC  
 2. Brass = .....HRC  
 3. Aluminum = ..... HRC

### Inference

### Significance of the test

The Rockwell test is rapid and simple in operation and may be used on thinner specimens, and very soft to very hard materials. It is essentially used to determine the hardness of finished parts (bearings, valves, nuts, bolts, gears, etc.) cutting tools and forming tools, small castings and forging, sheet metal, large diameter wire, electrical contacts, plastic sheets or parts and case hardened parts etc.

### Reference

IS 5652-1 (1993) Rockwell (A scale) hardness test for Hard Metals.

IS 1586-2000 Method for Rockwell Hardness Test for Metallic material (Scales A,B,C,D,E,F,G,H,K scales).

### **Viva-voce Questions**

- 1) What is Hardness?
- 2) State the difference between Rockwell and Brinell Hardness tests. Can they be related to any other property of the material?

**Space for calculations**

## **EXPERIMENT- 05**

### **COMPRESSION TEST**

#### **Aim**

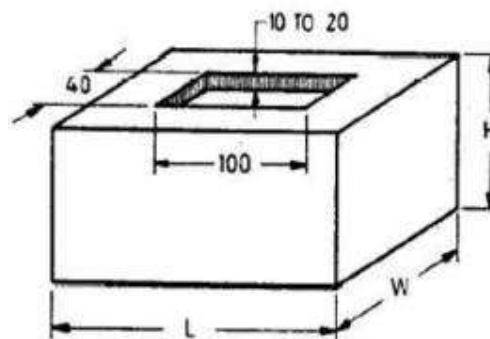
To determine the compressive strength of a given brick.

#### **Apparatus**

Vernier calipers Scale, Compression testing machine.

#### **Theory**

Bricks are used in construction of either load bearing walls or in partition walls of framed structure as shown in the Fig.6-1. In load bearing walls total weight from slab and upper floor comes directly through brick wall and then it is transferred to the foundation. In this case the bricks are loaded with compressive nature of force on other hand in framed structure bricks are used only for construction of partition walls, in which layer comes directly on the lower layers of wall. However in any case the bricks in actual practice are to be tested for their compressive strength.



**Burnt clay brick**

## Procedure

### A. Preparation of test specimen

- 1) Remove unevenness observed in the bed faces to provide two smooth and parallel faces by grinding.
- 2) Immerse in water at room temperature for 24 hours.
- 3) Remove the specimen and drain out any surplus moisture at room temperature.
- 4) Fill the frog (if provided) and all voids in the bed face with cement mortar (1 cement, 1 clean course sand of grade 3mm and down).
- 5) Store under the damp jute bags for 24 hours followed by immersion in clean water for 3 days.
- 6) Remove, and wipe out any traces of moisture.

### B. Test Procedure

- 1) Measure the length and breadth of the specimen at the center of the brick.
- 2) Place the specimen with flat faces horizontal, and mortar filled face facing upwards between two 3-plywood sheets each of 3mm thickness and carefully centered between plates of the testing machine.
- 3) Apply load axially at a uniform rate of 14 N/mm<sup>2</sup> (140kgf/cm<sup>2</sup>) per minute till failure occurs and note the maximum load at failure.
- 4) The load at failure shall be maximum load at which the specimen fails to produce any further increase in the indicator reading on the testing machine.
- 5) Calculate the compressive strength.
- 6) Repeat the test procedure for minimum of 3 bricks and report the average.

### Formula

$$\text{Compressive Strength} = \frac{\text{Max.Load at failure}}{\text{Loaded Area of brick}}$$



## Tabulation

S.N	Identification Mark	Area A=L X B	Height (H)	Load (N) (P)	Compressive Strength (stress) P/A (N/mm <sup>2</sup> )	Average Compressive Strength N/mm <sup>2</sup>
1						
2						
3						

## Precautions

1. Measure the dimensions of Brick accurately. .
2. The range of the gauge fitted on the machine should not be more than double the breaking load of specimen for reliable results.

## Result

The average compressive strength of brick sample is found to be.....

## Inference

## Reference

IS 3495 Method of tests of burnt clay building

bricks Part I – Determination of compressive

strength **Significance of the test**

For load bearing walls, compressive strength of brick is the criterion to decide the thickness of the wall.

**Space for calculation**

**EXPERIMENT – 06 (a)**  
**IZOD IMPACT TEST**

**Aim**

To determine the Impact toughness (strain energy) of a given specimen through Izod Impact test.

**Apparatus**

Izod impact testing machine, test specimen of mild steel, Aluminum, Vernier calipers, steel rule and specimen setting fixture.

**Theory**

In manufacturing locomotive wheels, connecting rods etc. the components are subjected to impact (shock) loads. These loads are applied suddenly. The stress induced in these components is more than stress produced due to gradually applied loads. Therefore, impact tests are performed to assess shock absorbing capacity of materials subjected to suddenly applied loads. These capabilities are expressed as (i) rupture energy (ii) Modulus of rupture (iii) Notch impact strength.

Two types of notch impact tests are used

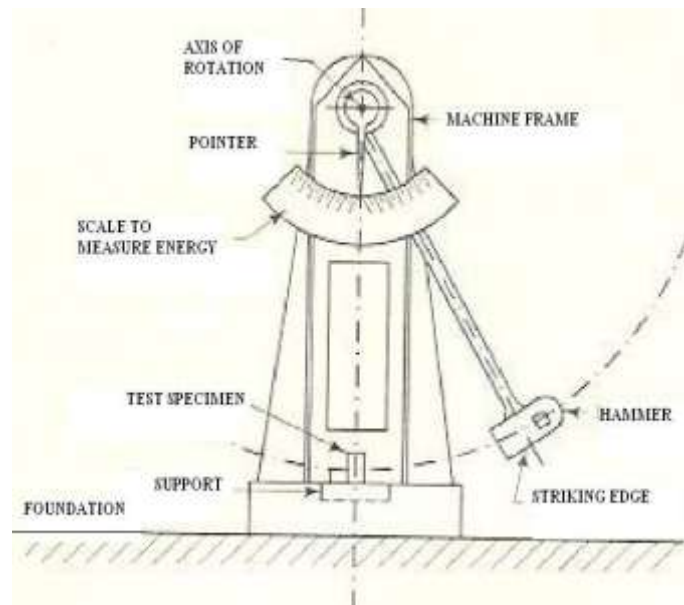
1. Charpy test
2. Izod test

In Charpy test, the specimen is placed as 'cantilever beam'. The specimens have V-shaped notch of  $45^\circ$  or a U-shaped notch. The notch is located on tension side of specimen during impact loading. Depth of notch is generally taken as  $t/5$  to  $t/3$ , where 't' is thickness of the specimen.

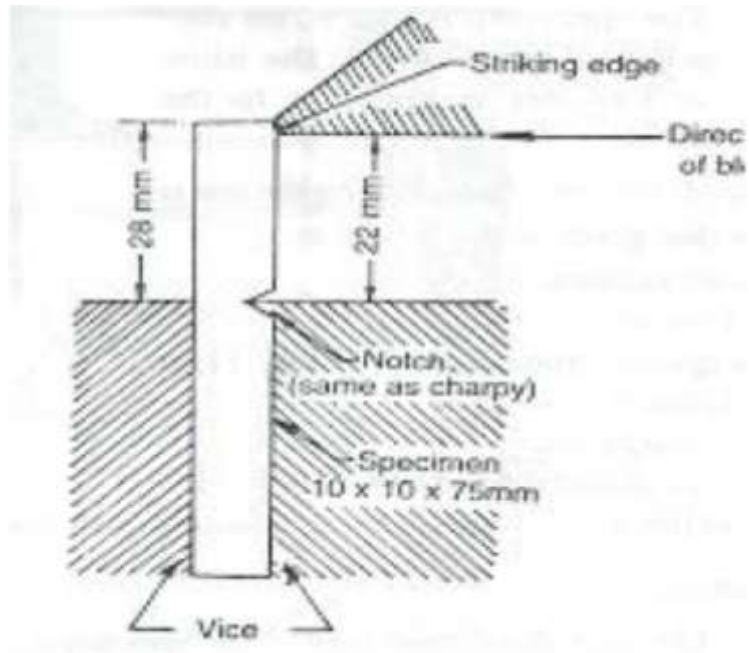
Impact Strength The resistance of material to fracture under suddenly applied loads is known as Impact Strength.

### Specification of M/c and Specimen detail

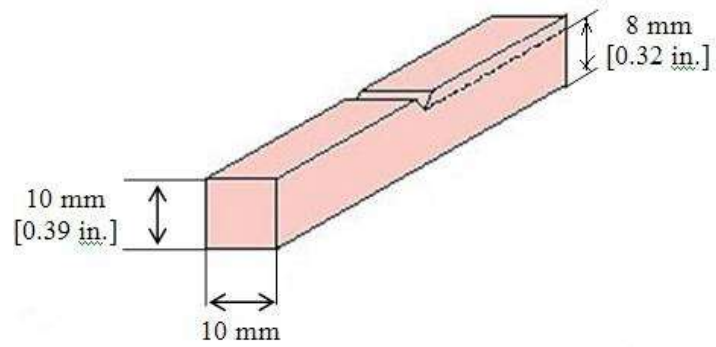
- Impact capacity 300joule
- Least count of capacity (dial) scale = 2 joule
- Weight of striking hammer = 18.7 kg
- Swing diameter of hammer = 1600mm
- Angle of hammer before striking =  $90^{\circ}/135^{\circ}$
- Distance between supports = 40mm.
- Striking velocity of hammer = 5.6m/sec.
- Specimen size = 75 X10 X 10 mm
- Type of notch = V-notch
- Angle of notch =  $45^{\circ}$
- Depth of notch = 2mm.



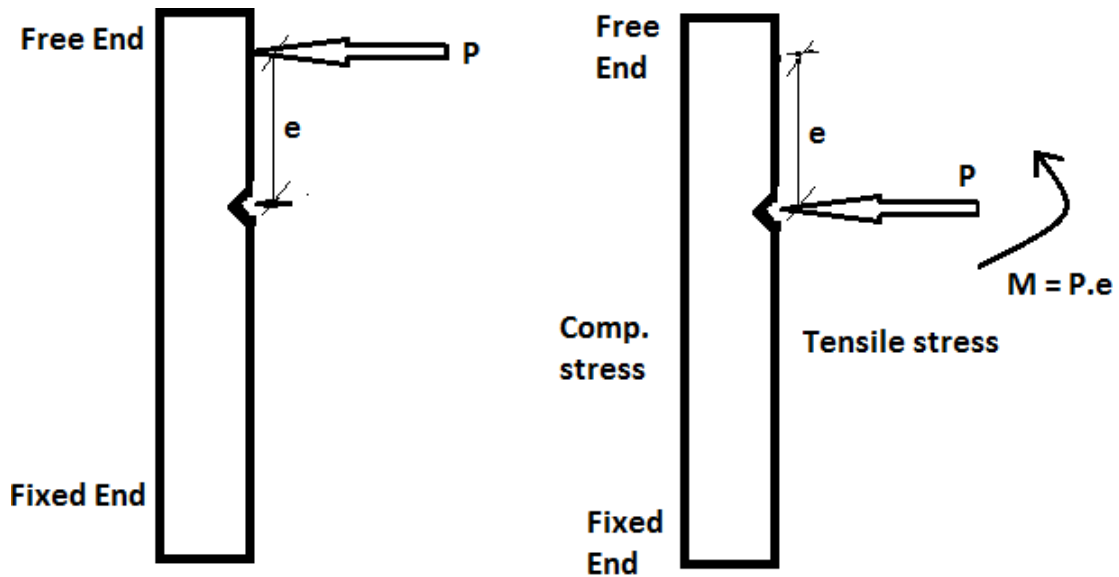
**Izod Impact testing machine**



**Specimen position in Izod Impact testing**



**Specimen dimensions in Izod Impact testing**



**Figure showing the specimen with the equivalent load (P) accompanied by the moment (M)**

#### Specimen showing the equivalent load in Izod Impact testing

The accompanying moment as shown in the Fig. 7(a)-4 will produce bending stress. Tensile stress on the striking face and compressive stress on the non-striking face.

#### Procedure

1. With the striking hammer (pendulum) in safe test position, place the test specimen in impact testing machine's anvil in such a way that the notch face the hammer and is half inside and half above the top surface of the anvil. The notch is on the tension face. For a standard test, the energy is set to 168 J.
2. Bring the striking hammer to position of Initial energy, and lock it at this position.
3. Note down the initial energy.
4. Release the hammer by trigger, it will fall due to gravity and break the specimen through its momentum, the total energy is not absorbed by the specimen. Then it continues to swing. At its topmost height after breaking the specimen, the indicator stops moving, while the pendulum falls back. Note the indicator reading at the top most final position.
5. Again bring back the hammer to its initial position and lock it.
6. Remove the broken specimen by loosening the clamping screw.

#### Tabulation

Area of cross- section of specimen (A) \_\_\_\_\_

S.No.	Material	Initial Energy (E <sub>1</sub> ) In Joule	Absorbed Energy (E <sub>2</sub> ) In Joule	Residual Energy E <sub>3</sub> =(E <sub>1</sub> -E <sub>2</sub> ) in Joule	Impact Energy I = E <sub>2</sub> /A In Joule/mm <sup>2</sup>

### Calculations

1. Modulus of rupture = Rupture/Effective volume of specimen
2. Notch impact strength = Absorbed energy/ Effective cross section area.

### Precaution

1. **Do not stand in front of the swinging hammer or releasing hammer.**
2. The specimen should be prepared in standard dimensions.
3. Bring the loose pointer in contact with the fixed pointer after setting the pendulum.
4. Hold the specimen (Izod test) firmly.

### Result

S.No.	Material	Energy Absorbed J/mm <sup>2</sup>

### Inference

The test is conducted using different material specimens. The softer materials undergo large deformation and hence work done is more. As a result, the energy absorbed is higher for soft materials than other materials.

### Significance of the test

Impact test is very useful in testing materials, which have not been properly heat-

treated. Heat treatment gives poor impact or Izod values. Wrought iron has very high impact value.

**Reference**

IS 1598 Method for Izod Impact test (V – Notch) for steel.



## EXPERIMENT – 06 (b)

### CHARPY IMPACT TEST

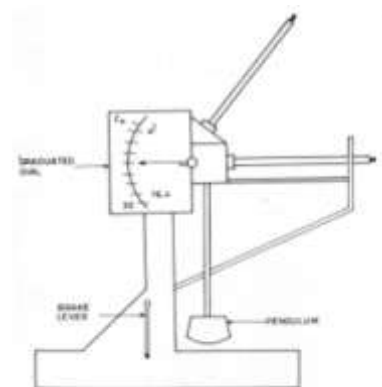
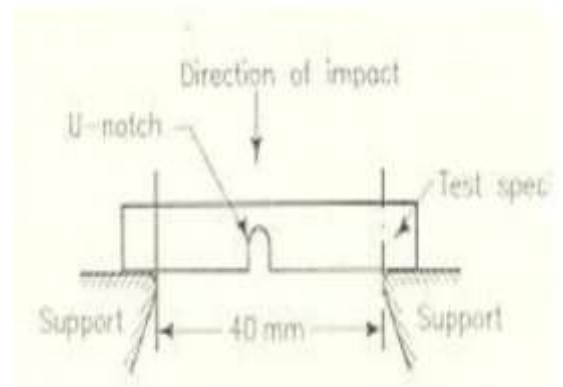
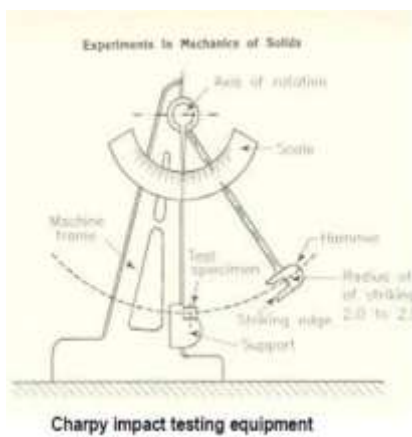
#### **Aim**

To study the Impact testing M/c, and perform the Charpy impact test.

**Apparatus** Impact testing M/c, Charpy test specimens of mild steel, Aluminum, Vernier calipers, specimen setting fixture.

#### **Mounting of specimen**

Specimen is tested as a beam supported at each end. Hammer is allowed to hit then specimen at the opposite face behind the notch.



**Izod / Charpy testing machine**

**Procedure**

1. Lift the hammer to an appropriate knife edge position and note the energy stored in the hammer. For the standard charpy test the energy stored should be 300J
2. Place the test specimen on the m/c supports. The notch is on the tension face.
3. Release the hammer. The hammer will break the piece and shoot up the other side of the specimen.
4. Note the energy indicated on the scale by the hammer.
5. Impact strength of the test specimen is the difference of the initial energy stored in hammer and the residual energy.

**Tabulation**

Area of cross- section of specimen (A) \_\_\_\_\_

S.No.	Material	Initial Energy (E <sub>1</sub> ) In Joule	Absorbed Energy (E <sub>2</sub> ) In Joule	Residual Energy E <sub>3</sub> =(E <sub>1</sub> -E <sub>2</sub> ) in Joule	Impact Energy I = E <sub>2</sub> /A In Joule/mm <sup>2</sup>

**Calculations**

1. Modulus of rupture = Rupture/Effective volume of specimen
2. Notch impact strength = Absorbed energy/ Effective cross section area.

**Precautions**

1. Do not stand in front of swinging hammer or releasing hammer.
2. The specimen should be prepared in standard dimensions.
3. Make the loose pointer in contact with the fixed pointer after setting the pendulum.
4. Place the specimen in proper position.

## Result

S.No.	Material	Energy Absorbed J/mm <sup>2</sup>

## Inference

The test is conducted using different material specimens. The softer materials undergo large deformation and hence work done is more. As a result, the energy absorbed is higher for soft materials than other materials.

## Significance of the test

Impact test is very useful in testing materials, which have not been properly heat-treated. Heat treatment gives poor impact or Izod values. Wrought iron has very high impact value.

## Reference

IS 1499 Method for Charpy Impact test (U – Notch) for steel.

IS 1757 Method for Charpy impact test (V notch) for metallic material

## **EXPERIMENT - 07**

### **SHEAR TEST**

#### **Aim**

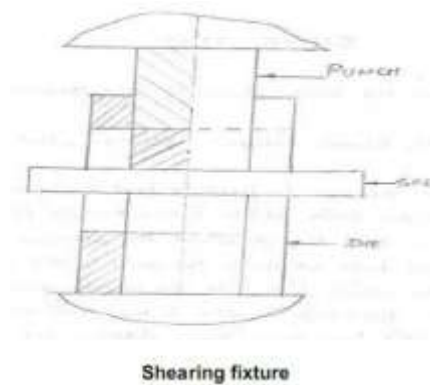
To conduct shear test under double shear action and to determine the shear strength of the given specimen by using universal testing machine

#### **Apparatus**

1. Universal Testing Machine.
2. Shear test attachment.
3. Specimen.
4. Vernier caliper

#### **Theory**

Place the shear test attachment on the lower table, this attachment consists of cutter. The specimen is inserted in shear test attachment & lift the lower table so that the zero is adjusted, then apply the load such that the specimen breaks in two or three pieces. If the specimen breaks in two pieces then it will be in single shear & if it breaks in three pieces then it will be in double shear.



**Shear fixture**

## Formulae

$$\text{Shear strength} = \frac{\text{Maximum shear force}}{\text{Cross sectional area}} \dots\dots\dots N / mm^2$$

$$\tau = \frac{P_s}{A} \dots\dots\dots N / mm^2$$

$$\text{Cross sectional area in double shear } (A) = 2x \frac{\pi}{4} x d^2 \dots\dots\dots mm^2$$

Where

B – Breadth of the Specimen in millimeters

D – Depth of the Specimen in millimeters

## Procedure

1. The dimensions of the specimen are to be measured.
2. The middle bush is placed in the shearing tool, and it is aligned with the holes in the U-shaped portion of the shear tool attachment.
3. The specimen (or rod) is then inserted and the side bushes are placed.
4. It may be noted that the bushes are placed on both sides, since it is double shear test.
5. The shearing tool assembly is then placed in the Universal testing machine.
6. The load is increased gradually and the ultimate load at failure is noted and the ultimate shear strength is then calculated.

## Observation

Diameter of the Rod, d = ..... mm

Cross-section area of the Rod (in double shear) =  $2x (\pi/4) x d^2 = \dots\dots\dots mm^2$

Load taken by the Specimen at the time of failure,  $P_s = \dots\dots\dots N$

Strength of rod against Shearing =  $P_s / \{2x (\pi/4) x d^2\} = \dots\dots\dots N/mm^2$

## Precaution

1. The measuring range should not be changed at any stage during the test.
2. The inner diameter of the hole in the shear stress attachment should be slightly greater than that of the specimen.
3. Measure the diameter of the specimen accurately.

**Result**

The Shear strength of mild steel specimen is found to be =.....N/mm<sup>2</sup>

**Inference**

**Significance of the test**

When a member is subjected to a stress parallel to a given plane it is subjected to shear stress. This test shows the behavior of specimen under double shear.

**Space for calculations**

## EXPERIMENT - 08

### USE OF ELECTRICAL RESISTANCE STRAIN GAUGE

#### **Aim**

To learn about the use of the resistance strain gauges and Wheatstone bridges. To learn to use a static strain indicator

To determine the modulus of elasticity for the given material of the cantilever beam using electrical resistivity strain gauge

#### **Apparatus**

Electrical Resistivity strain gauge set up, Vernier calipers, scale

#### **Introduction**

Strain gauges are used as sensors in many systems to measure forces, moments, and the deformations of structures and materials. The experiment deals with measuring the strain in the cantilever beam through the use of resistance strain gauges.

The digital Strain Indicator is a field programmable indicator specially designed to be used with strain gauge based transducers to measure strain. It can take full, half & quarter bridge of 120 ohms configuration. The resistance strain gauge consists of grid of fine conducting wire directly bonded to an insulated backing material which is directly bonded to the machine surface by a thin layer of epoxy resin. The deformation of the machine surface is transferred to the bonded strain gauge causing its electrical resistance to change. The strain gauge is found by measuring the change in the electrical resistance of the strain gauge. The strain gauges are instruments that measure the stretch/squeeze of the fibres. They are connected to strain gauge boxes through a data acquisition system that allow us to record the amount of stretching the fibres undergo when a beam is loaded.

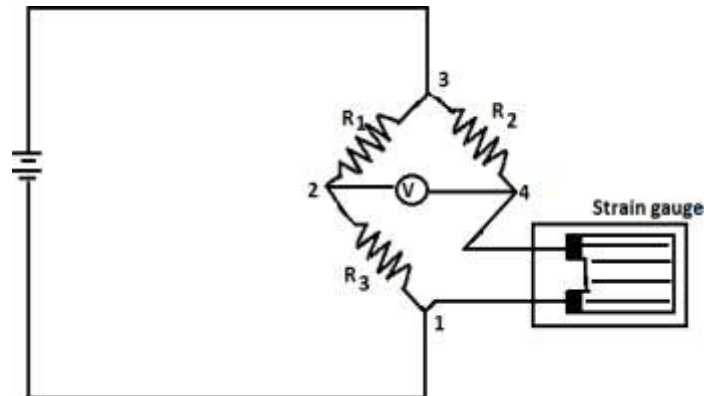
#### **Bridge Configuration**

The full, half & quarter bridge configuration can be measured by the strain indicator. The bridge can be connected to the banana operator provided on the switching unit of the multi-channel strain indicator. There are four connectors. 1. Red 2. Green 3. Black & 4. Yellow. Red is input +ve Black is input -ve. Green is output +ve and Yellow is output -ve.

When the quarter bridge has to be measured, connect the two wires from the strain gauge to the front side as specified i.e.,. The power supply should be made available with a proper earthing within two meters of the indicator. Connect the instrument to AC mains through the

connector provided at the rear of the indicator. Strain indicator connection has to be connected to the switching unit. The calibration is done by setting the gauge factor.

### The Quarter bridge strain gauge circuit



### Principle of Strain gauge

The normal strain  $s = \frac{dl}{L}$ , where  $dl$  = change in the length and  $L$  is the original length. Since the electrical resistance is proportional to  $\frac{dR}{R}$ , where  $dR$  is the change in resistance and  $R$  is the original resistance. Thus,  $\frac{dR}{R} \propto s$ . The proportionality constant of the strain gauge is precisely measured by the gauge manufacturer and is supplied as gauge factor (GF). Thus,

$$s = \frac{dR}{R \cdot GF} \quad (1)$$



For a MM Type WA-06-250WT-120 the gauge factor is 2.10 and the resistance is 120 ohms  $\pm 0.4\%$ .

### Mechanics of a Cantilever beam

The experiment deals with the measuring the strain in a cantilever beam through the use of resistance strain gauges. The strain gauge is parallel to the length of the beam. The strain measured is the axial strain parallel to the length. A static load will be incremented at different locations along the beam to produce measurable strains. The theoretical strain can be found using the theory of simple bending relation

$$\frac{f}{y} = \frac{M}{I}$$

where,

‘f’ is the stress produced

‘y’ is the distance of the most distant fibre from the neutral axis

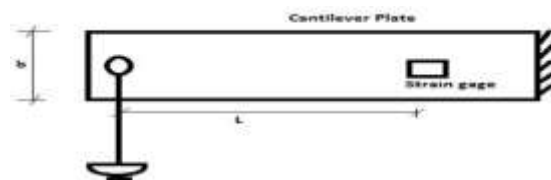
‘M’ is the bending moment

‘I’ is the moment of inertia of the cross section about the axis of rotation

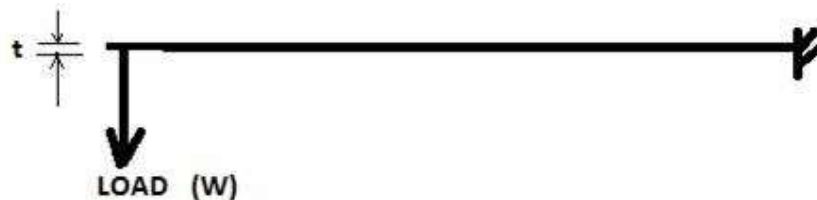
Moment of Inertia is equal to  $I = bt^3/12$

where ‘b’ is the width of the section, measured parallel to the axis of the rotation

‘t’ is the thickness



The cantilever plate and the strain gauge



### **The cantilever plate carrying the load**

As shown in the Fig.11-2a and Fig.11-2b the load (W) in kg is a gradually applied load at a distance of L = 150 mm from the strain gauge. The load is applied gradually in steps of 1kg and the maximum load carrying capacity is equal to 5kg. The bending moment  $M = W \cdot 150$  kg-mm.

The distance from the neutral axis to the most distant fibre,  $y = t/2$

The stress produced at the section where strain gauge is provided can be calculated using the theory of simple bending. The strain reading is taken from the micro strain gauge indicator.

Using Hooke's law, the ratio of the stress to strain is taken as equal to the modulus of the elasticity of the material of the cantilever beam.

$$\text{Modulus of Elasticity (E)} = \frac{\text{stress (f)}}{\text{strain (s)}}$$

#### **Procedure**

1. Switch on the indicator connected to AC Mains.
2. Determine the cross-sectional dimensions (b, t) of the cantilever using Vernier calipers
3. Measure the distance from the point of application of the load to the section where strain gauge is used as L.
4. Connect the red and white wire to channel 5.

5. Tare the micro strain indicator to zero.
6. Apply the loading in increments of 1 kg each and note down the corresponding micro strain
7. Calculate the value of stress for each load increment
8. Calculate the modulus of elasticity (E) for each load increment and average the 'E' values
9. Draw the graph with stress v/s strain and determine the modulus of elasticity

**Observations**

Measure the width (b) of the cantilever beam

S.No.	Main Scale Reading	VC	MSR + VC*LC

The width (b) of the cross section is \_\_\_\_\_mm

Measure the thickness (t) of the cantilever beam

S.No.	Main Scale Reading	VC	MSR + VC*LC

The thickness (t) of the cross section is \_\_\_\_\_mm

The distance from the neutral axis to the most distant fibre  $y = t/2 =$  \_\_\_\_\_mm

The Moment of Inertia,  $I =$  \_\_\_\_\_ mm<sup>4</sup>

Observations for the gradually applied load and the micro strain to calculate the Modulus of Elasticity of the material (E)

S. No.	Load Applied (W in kg)	Load Applied (W in N)	Distance from the point of load to the strain gauge (L)	Bending Moment (M = W*L) in N-mm	Stress (f) in MPa	Micro Strain (s)	Modulus of the elasticity (E) in MPa
1							
2							
3							
4							
5							

## **Calculations**

## **Precautions**

1. The strain gauge is a sensitive instrument and the measurements should be taken carefully.
2. The wires connecting the strain gauge are delicate and should not be touched.

## **Result**

The electrical resistance using strain gauge test is conducted.

The average value of the modulus of elasticity of the material of the cantilever beam is

\_\_\_\_\_

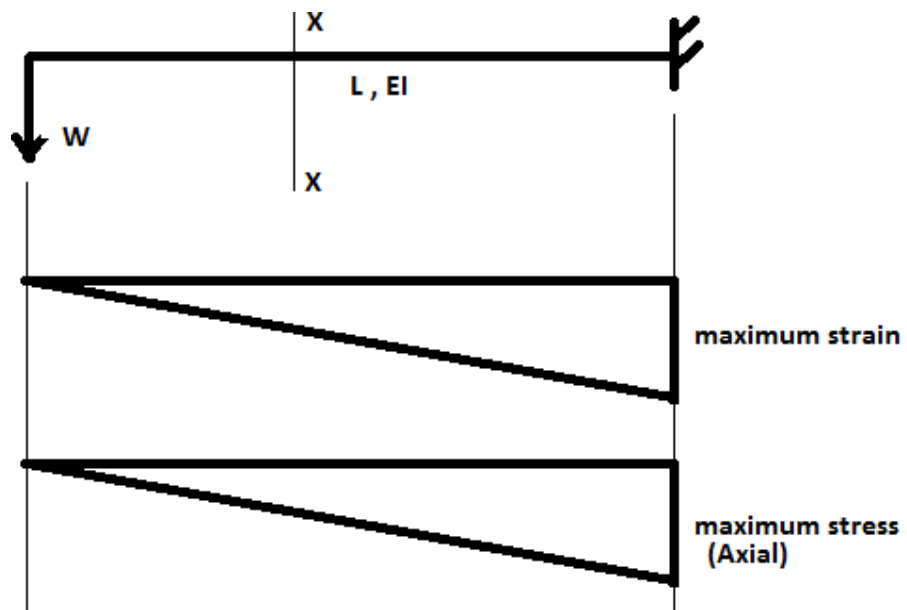
The Youngs modulus of elasticity of the material of the cantilever beam from graph is

\_\_\_\_\_

## **Inference**

## **Significance**

1. The modulus of the elasticity can be useful to measure the stresses produced at any section XX anywhere in the beam as shown in the Fig. 11-3.



**The variation of strain and stress for a cantilever carrying the load**

2. To determine the distribution of the stress at any cross section  $XX$

## EXPERIMENT – 08

### Compressive Strength of Concrete

**Aim:** To determine the compressive strength of a given sample of cement.

**Theory** :

The compressive strength of hardened cement is the most important of all the properties. Therefore, it is not surprising that the cement is always tested for its strength at the laboratory before the cement is used in important works. Strength tests are not made on neat cement paste because of difficulties of excessive shrinkage and subsequent cracking of neat cement.

**Apparatus** :

The standard sand to be used in the test shall conform to IS : 650-1966, Vibration Machine, Poking Rod, Cube Mould of 70.6 mm size conforming to IS : 10080-1982, Balance, Gauging Trowel, Stop Watch, Graduated Glass Cylinders, etc.

**Procedure** :

1. Preparation of test specimens - Clean appliances shall be used for mixing and the temperature of water and that of the test room at the time when the above operations are being performed shall be  $27 \pm 2^{\circ}\text{C}$ . Potable/distilled water shall be used in preparing the cubes.
2. The material for each cube shall be mixed separately and the quantity of cement, standard sand and water shall be as follows:

Cement 200 g and Standard Sand 600 g

Water  $\frac{P}{4} \times 0.3$  percent of combined mass of cement and sand, where P is the percentage of water

required to produce a paste of standard consistency determined as described in IS : 4031 (Part 4)-1988 or Experiment No.1(a).

3. Place on a nonporous plate, a mixture of cement and standard sand. Mix it dry with a trowel for one minute and then with water until the mixture is of uniform colour. The quantity of water to be used shall be as specified in step 2. The time of mixing shall in any event be not less than 3 min and should the time taken to obtain a uniform colour exceed 4 min, the mixture shall be rejected and the operation repeated with a fresh quantity of cement, sand and water.
4. Moulding Specimens - In assembling the moulds ready for use, treat the interior faces of the mould with a thin coating of mould oil.
5. Place the assembled mould on the table of the vibration machine and hold it firmly in position by means of a suitable clamp. Attach a hopper of suitable size and shape securely at the top of the mould to facilitate filling and this hopper shall not be removed until the completion of the vibration period.
6. Immediately after mixing the mortar in accordance with step 1 & 2, place the mortar in the cube mould and prod with the rod. Place the mortar in the hopper of the cube mould and prod again as specified for the first layer and then compact the mortar by vibration.
7. The period of vibration shall be two minutes at the specified speed of  $12\ 000 \pm 400$  vibration per minute.
8. At the end of vibration, remove the mould together with the base plate from the machine and finish the top surface of the cube in the mould by smoothing the surface with the blade of a trowel.
9. Curing Specimens - keep the filled moulds in moist closet or moist room for  $24 \pm 1$  hour after completion of vibration. At the end of that period, remove them from the moulds and immediately submerge in clean fresh water and keep there until taken out just prior to breaking.
10. The water in which the cubes are submerged shall be renewed every 7 days and shall be maintained at a temperature of  $27 \pm 2^\circ\text{C}$ . After they have been taken out and until they are broken, the cubes shall not be allowed to become dry.
11. Test three cubes for compressive strength for each period of curing mentioned under the relevant specifications (i.e. 3 days, 7 days, 28 days)
12. The cubes shall be tested on their sides without any packing between the cube and the steel plattens of the testing machine. One of the plattens shall be carried on a base and shall be self-adjusting, and the load shall be steadily and uniformly applied, starting from zero at a rate of  $35\ \text{N/mm}^2/\text{min}$ .



**Figure**



**Observation** :

Sr. No.	Age of Cube	Weight of Cement Cube (gms)	Cross-Sectional area (mm <sup>2</sup> )	Load (N)	Compressive strength (N/mm <sup>2</sup> )	Average Compressive strength (MPa)
1	7 Days					
2						
3						
4	28 Days					
5						
6						

**Calculation** :

The measured compressive strength of the cubes shall be calculated by dividing the maximum load applied to the cubes during the test by the cross-sectional area, calculated from the mean dimensions of the section and shall be expressed to the nearest 0.5 N/mm<sup>2</sup>. In determining the compressive strength, do not consider specimens that are manifestly faulty, or that give strengths differing by more than 10 percent from the average value of all the test specimens.

**Conclusion / Result** :

- i) The average 3 Days Compressive Strength of given cement sample is found to be .....
- ii) The average 7 Days Compressive Strength of given cement sample is found to be .....
- iii) The average 28 Days Compressive Strength of given cement sample is found to be .....























