

# **BASIC MATERIALS TESTING LABORATORY**

## **INSTRUCTION MANUAL**

for

**III Semester B.E. Civil Engineering**

**Testing of Metals, Wood and Burnt Clay Products for their  
Physical and Mechanical Properties**

*Compiled and Edited*

*by*

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**1<sup>st</sup> Edition – 2008**

**2<sup>nd</sup> Edition – 2009**

**3<sup>rd</sup> Edition – 2011**

**4<sup>th</sup> Edition – 2013**

**5<sup>th</sup> Edition – 2016**



## ***Department of Civil Engineering***

*Sri Jayachamarajendra College of Engineering, Mysuru- 570 006*

### **Vision and Mission of the Department of Civil Engineering**

#### **VISION**

- “To produce engineers having professional and leadership qualities with capacity to take up research and professional assignments in Civil Engineering and allied fields with focus on interdisciplinary and innovative approach and to compete in civil engineering profession at the global level”.

#### **MISSION**

- To impart quality and real time education to contribute to the field of Civil Engineering.
- To impart soft skills, leadership qualities and professional ethics among the graduates to handle projects independently.
- To develop graduates to compete at the global level.
- To deal with the contemporary issues and to cater to the societal needs.

### **Programme Educational Objectives (PEOs)**

PEO1	To impart quality education and knowledge in contemporary science and technology to meet the challenges in the field of Civil Engineering and to serve the society.
PEO2	To impart the knowledge of analysis and design using the codes of practice and software packages.
PEO3	To inculcate the sense of ethics, morality, creativity, leadership, professionalism, self-confidence and independent thinking.
PEO4	To motivate the students to take up higher studies and innovative research projects.

### **Programme Specific Outcomes (PSOs)**

PSO1	The student has the ability to apply the knowledge of Physics, Chemistry, Mathematics, Programming Skills and Soft Skills to solve Civil Engineering problems.
PSO2	The student has the proficiency in streams of Civil Engineering to visualise and execute the systems for sustainable living.
PSO3	The student has the practical knowledge and experimental skills to tackle Civil Engineering problems using technical and management skills, exhibiting professional ethics to meet the societal needs.
PSO4	The programme enables the faculty to develop academic proficiency by involving in research & innovation, interaction with industry and professional bodies through technical advice and Continuing Education Programs (CEP) to meet the needs of the user system.

	<p style="text-align: center;"><b>Department of Civil Engineering</b>  <i>Sri Jayachamarajendra College of Engineering, Mysuru- 570 006</i></p>
<b>PROGRAMME OUTCOMES (POs)</b>	
<b>Engineering Graduates will be able to:</b>	
P01	Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems – <b>(Engineering knowledge)</b>
P02	Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences – <b>(Problem analysis)</b>
P03	Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations – <b>(Design/development of solutions)</b>
P04	Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions – <b>(Conduct investigations of complex problems)</b>
P05	Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations – <b>(Modern tool usage)</b>
P06	Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice – <b>(The engineer and society)</b>
P07	Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development – <b>(Environment and sustainability)</b>
P08	Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice – <b>(Ethics)</b>
P09	Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings – <b>(Individual and team work)</b>
P10	Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions – <b>(Communication)</b>
P11	Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments – <b>(Project management and finance)</b>
P12	Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change – <b>(Life-long learning)</b>

## FOREWORD

The Basic Materials Testing Laboratory intends to train the students in the field of testing of common materials of construction to study their behaviour when subjected to external loading and to obtain their mechanical properties, which are used directly or indirectly in the design of structural elements.

This instruction manual guides the students to conduct the test as per standard procedures. The students shall follow the guidelines indicated for conducting the tests more effectively and for better understanding & for logically interpreting the results.

- Before conducting any test, students shall come prepared with theoretical background of the corresponding test (indicated under the section 'theory' in each test).
- Students shall make sure to have the knowledge of measuring instruments like slide calipers, screw gauge and other gauges.
- Students shall give importance to accuracy and precision while conducting the test and interpreting the results.
- Students shall acquaint themselves with the safe and correct usage of instruments / equipments under the guidance of teaching / supporting staff of the laboratory.

It is hoped that this instruction manual will serve to orient the students in the right direction of material testing. The authors thank Mr. Naveen Kumar H.V. for his excellent efforts in typesetting and in bringing out this instruction manual in the present format.

K. Prakash  
V. Madhava Rao



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## 1. TENSION TEST ON MILD STEEL

**Aim:** To study the stress-strain behaviour of mild steel test specimen under a gradually increasing tensile load and to determine the Young's modulus of elasticity, yield stress, tensile strength, percentage elongation & percentage reduction in cross sectional area.

**Theory:** Definitions: Stress, Strain; Statement of Hooke's law; Definitions: Ductility, Brittleness, Young's modulus of elasticity, Limit of proportionality, Elastic limit, Yield stress, Proof stress, Ultimate strength, Breaking stress, Gauge length, Percentage elongation, Percentage reduction in area; Typical stress-strain diagrams for mild steel and cast iron under axial tension with explanation.

### Test Set Up:

- Universal Testing Machine (UTM)

The machine is so called as it can be used to conduct various tests like tension test, compression test, bending test, shear test etc. The loading is done hydraulically. Three ranges of loading are available (i) 0 to 4 tonnes (ii) 0 to 20 tonnes (iii) 0 to 40 tonnes. UTM is equipped with a provision for getting load – deformation diagram automatically.

The loading unit of UTM consists of (i) Lower cross head (ii) Middle cross head (iii) Upper cross head and (iv) Linear scale. Lower and upper cross heads are connected rigidly with each other and with the hydraulic piston. During loading condition, middle cross head is fixed and the remaining two cross heads move as one unit. However, during no load condition, the position of the middle cross head is adjustable.

The control unit of UTM consists of ON and OFF switches, load indicating dial with live and dummy needles, switches to position the middle cross head and also a graph plotter.

- Extensometer:

This is a device which is used to measure the elongation of the test specimen over certain length. It consists of two dials. The average of their readings is taken as the extensometer reading.

- Slide Calipers and Scale

**Procedure:**

- Observe the specimen. Measure the total length and parallel length of the specimen. Also measure the diameter of the specimen. Calculate the gauge length. Mark the gauge length on the central portion of the specimen.
- Fix the specimen in-between the upper and middle cross heads using the gripping devices. Take precautions to fix the test specimen in such a way as to ensure that the load is applied axially.
- Fix the extensometer in its position over the gauge points. Adjust the extensometer and the linear scale to read zero initially.
- Select proper range of loading (i.e. 0 to 40 tonnes).
- Switch on the machine. Apply the axial tensile load on the specimen gradually. Record the extensometer readings at a constant load increment of 400 kg.
- The yield point can be observed either:
  - by the kickback of the live needle of the load indicating dial.

**OR**

- by the rapid movement of extensometer dial needle at constant load reading.
- Record the yield load(s), and remove the extensometer.
- Continue the axial loading.
- At one stage, the live needle begins to return, leaving the dummy needle there itself. Note down the load at that point as the ultimate load. Also, observe the neck formation on the specimen.
- Note down the load at the point of failure of the specimen.
- Switch off the machine; Remove the failed specimen; Observe the type of fracture.
- Measure the final gauge length on the tested specimen, if the failure has occurred within the gauge length portion and also, the diameter at the neck.

**Note:**

- a) The above procedure is valid for steel bar of diameter equal to or greater than 4 mm, or of thickness equal to or greater than 3 mm.
- b) For test pieces of rectangular section, a ratio of width to thickness of 8 : 1 should not be exceeded.
- c) The gauge length can be calculated from the equation

$$L_0 = 5.65 \sqrt{A} \approx 5D$$

where  $A$  is the initial cross sectional area of the test specimen. It is rounded off to nearest multiple of 5 mm. However, test pieces with other gauge lengths may be used, for technical or economical reasons.

- d) Some specimens exhibit both upper and lower yield points, and some specimens exhibit only one yield point.
- e) Some materials may not exhibit any yield point at all. For such materials, 0.2% proof stress is to be determined.
- f) If the failure occurs outside the gauge length, the value of the percentage of elongation can not be calculated.

#### Observations and Calculations before the test:

1. Material of the specimen : \_\_\_\_\_
2. Initial diameter of the specimen =  $D =$  \_\_\_\_\_ cm.
3. Total length =  $L_t =$  \_\_\_\_\_ cm.
4. Parallel length =  $L_P =$  \_\_\_\_\_ cm.
5. Initial gauge length =  $L_0 =$  \_\_\_\_\_ cm.
6. Initial cross sectional area of the specimen =  $A =$  \_\_\_\_\_  $\text{cm}^2$
7. Least count of the extensometer = \_\_\_\_\_ cm
8. Capacity of the extensometer = \_\_\_\_\_ cm
9. Range of gauge length allowed in the extensometer = \_\_\_\_\_

#### Data Sheet for Tension Test:

Load $P$ , kg	Stress = $\sigma = P/A$ , $\text{kg/cm}^2$	Extensometer readings			Deformation $dl$ , cm	Strain $e = dl/L_0$	Remarks
		Left, div.	Right, div.	Average, div.			

**Observations and Calculations after the test:**

1. Type of fracture : \_\_\_\_\_
  2. Diameter of the specimen at the neck after failure =  $d =$  \_\_\_\_\_ cm
  3. Final parallel length =  $L_f =$  \_\_\_\_\_ cm
  4. Final gauge length =  $L_U =$  \_\_\_\_\_ cm
  5. Final cross sectional area of the specimen at the neck =  $a =$  \_\_\_\_\_  $\text{cm}^2$
  6. Percentage elongation =  $(L_U - L_0) \times 100 / L_0 =$  \_\_\_\_\_
  7. Percentage reduction in cross sectional area =  $(A - a) \times 100 / A =$  \_\_\_\_\_
  8. Young's modulus of elasticity of Mild Steel in tension = Slope of the straight line portion of the stress vs. strain curve =  $E_t =$  \_\_\_\_\_  $\text{kg/cm}^2$   
 $=$  \_\_\_\_\_ GPa
  9. (a) Upper yield stress =  $\sigma_{yu} = \frac{\text{load at upper yield point}}{A} =$  \_\_\_\_\_  $\text{kg/cm}^2$   
 $=$  \_\_\_\_\_ MPa
  - (b) Lower yield stress =  $\sigma_{yl} = \frac{\text{load at lower yield point}}{A} =$  \_\_\_\_\_  $\text{kg/cm}^2$   
 $=$  \_\_\_\_\_ MPa
- OR**
- Yield stress =  $\sigma_y = \frac{\text{load at yield point}}{A} =$  \_\_\_\_\_  $\text{kg/cm}^2$ .  
 $=$  \_\_\_\_\_ MPa
10. Tensile strength (Ultimate strength) =  $\sigma_{ult} = \frac{\text{Ultimate load}}{A} =$  \_\_\_\_\_  $\text{kg/cm}^2$ .  
 $=$  \_\_\_\_\_ MPa
  11. Failure or breaking stress =  $\sigma_f = \frac{\text{Load at failure}}{A} =$  \_\_\_\_\_  $\text{kg/cm}^2$ .  
 $=$  \_\_\_\_\_ MPa

**Results and conclusions:****Relevant IS Codes:**

IS: 1608 (1972), Method for tensile testing of steel products (First Revision), BIS, New Delhi.

## 2. TENSION TEST ON HIGH STRENGTH DEFORMED STEEL

**Aim:** To study the stress-strain behaviour of High Strength Deformed (HSD) Steel (i.e., hot-rolled steel without subsequent treatment or hot-rolled steel with controlled cooling & tempering or cold worked steel) under a gradually increasing tensile load, and to determine the Young's modulus of elasticity of the material, 0.2% proof stress, tensile strength & percentage elongation:

**Theory:** High strength deformed steel bars: Thermo Mechanically Treated bars (TMT) and Cold Twisted Deformed bars (CTD); Proof stress and its determination.

### Test set up:

- Universal Testing Machine (UTM).
- Extensometer to measure the axial extension of the specimen.
- Weighing balance, slide calipers, scale etc.

### Procedure:

- Take the given steel bar of length not less than 0.5 m, and determine its mass (m) and length accurately.
- Calculate the gross cross sectional area and the nominal diameter of the bar.
- Calculate the gauge length, and mark it on the test piece.
- Fix the specimen in its position on UTM between the middle and top cross heads, and fix the extensometer on the specimen over the gauge points. Adjust the extensometer to read 'zero'.
- Select proper range of loading (i.e., 0 to 40 tonnes)
- Switch on the machine. Apply the axial tensile load on the specimen gradually. Record the extensometer readings at a constant load increment of 400 kg.
- The material of the bar may or may not exhibit yield point. If the material exhibits the yield point, it can be observed either:
  - a) by the kickback of the live needle of the load indicating dial.

**OR**

- b) by the rapid movement of extensometer dial needle at constant load reading.
- Record the yield load(s), and remove the extensometer.

- If the material of the bar does not exhibit such definite yield point (s), then proof stress shall be calculated. In such cases remove the extensometer immediately after the material is observed to have entered the plastic range of deformation.
- Continue the axial loading.
- At one stage, the live needle begins to return, leaving the dummy needle there itself. Note down the load at that point as the ultimate load. Also, observe the neck formation on the specimen, if any.
- Note down the load at the point of failure of the specimen.
- Switch off the machine; Remove the failed specimen; Observe the type of fracture.
- Measure the final gauge length on the tested specimen, if the failure has occurred within the gauge length portion.

#### Observations and Calculations before the test:

1. Material of the specimen : \_\_\_\_\_
2. Total length of the specimen =  $L =$  \_\_\_\_\_ cm
3. Mass of the specimen =  $m =$  \_\_\_\_\_ kg.
4. Gross cross sectional area =  $A = \frac{m}{0.00785L} =$  \_\_\_\_\_  $\text{mm}^2$   
= \_\_\_\_\_  $\text{cm}^2$

where m is the mass in kg and L is the total initial length in meter.

5. Nominal diameter =  $D = \sqrt{\frac{4A}{\pi}} =$  \_\_\_\_\_ mm = \_\_\_\_\_ cm
6. Initial gauge length =  $L_0 \approx 5D =$  \_\_\_\_\_ cm.
7. Least count of the extensometer = \_\_\_\_\_ cm
8. Capacity of the extensometer = \_\_\_\_\_ cm
9. Range of gauge length allowed in the extensometer = \_\_\_\_\_

#### Data sheet for the tension test on HSD bar

Load P, kg	Stress = $\sigma = P/A$ , kg/cm <sup>2</sup>	Extensometer readings			Deformation dl, cm	Strain $e = dl/L_0$	Remarks
		Left, div.	Right, div.	Average, div.			

**Observations and Calculations after the test:**

1. Type of fracture : \_\_\_\_\_
2. Final gauge length =  $L_U$  = \_\_\_\_\_ cm
3. Percentage elongation =  $\left( \frac{L_U - L_0}{L_0} \right) 100 =$  \_\_\_\_\_
4. Young's modulus of elasticity of the given high strength deformed steel = slope of the straight line portion of the stress-strain curve =  $E_t =$  \_\_\_\_\_ kg/cm<sup>2</sup>  
= \_\_\_\_\_ GPa

$$5. \text{ (a) Upper yield stress } = \sigma_{yu} = \frac{\text{load at upper yield point}}{A} = \text{_____ kg/cm}^2$$

$$= \text{_____ MPa}$$

$$\text{ (b) Lower yield stress } = \sigma_{yl} = \frac{\text{load at lower yield point}}{A} = \text{_____ kg/cm}^2.$$

$$= \text{_____ MPa}$$

**OR**

$$\text{Yield stress } = \sigma_y = \frac{\text{load at yield point}}{A} = \text{_____ kg/cm}^2.$$

$$= \text{_____ MPa}$$

**OR**

$$0.2\% \text{ proof stress} = \sigma_{P0.2} = \text{_____ kg/cm}^2$$

$$= \text{_____ MPa}$$

$$6. \text{ Tensile strength (Ultimate strength) } = \sigma_{ult} = \frac{\text{Ultimate load}}{A} = \text{_____ kg/cm}^2$$

$$= \text{_____ MPa}$$

$$7. \text{ Failure or breaking stress } = \sigma_f = \frac{\text{Load at failure}}{A} = \text{_____ kg/cm}^2$$

$$= \text{_____ MPa}$$

**Results and Conclusions:****Relevant IS Codes:**

IS: 1608 (1972), Method for tensile testing of steel products (First Revision), BIS, New Delhi.

IS: 1786 (2008), Specification for high strength deformed steel bars and wires for concrete reinforcement (Fourth Revision), BIS, New Delhi.

## Annexure

Table 1: Nominal Cross-Sectional Area and Mass (Clause 6.2)

Sl. No.	Nominal Size, mm	Cross Sectional Area, mm <sup>2</sup>	Mass per Meter, kg
1.	4	12.6	0.099
2.	5	19.6	0.154
3.	6	28.3	0.222
4.	8	50.3	0.395
5.	10	78.6	0.617
6.	12	113.1	0.888
7.	16	201.2	1.580
8.	20	314.3	2.470
9.	25	491.1	3.850
10.	28	615.8	4.830
11.	32	804.6	6.310
12.	36	1018.3	7.990
13.	40	1257.2	9.860

Table 2: Mechanical Properties of High Strength Deformed bars and Wires (Clause 8.1)

SL. No.	Property	Fe 415	Fe 415D	Fe 500	Fe 500D	Fe 550	Fe 550D	Fe 600
1.	0.2 % proof stress / yield stress, Min, N/mm <sup>2</sup>	415.0	415.0	500.0	500.0	550.0	550.0	600.0
2.	Elongation, percent, Min. on gauge length $5.65 \sqrt{A}$ , where A is the cross sectional area of the test piece	14.5	18.0	12.0	16.0	10.0	14.5	10.0
3.	Tensile strength, Min.	10 percent more than the actual 0.2 % proof stress / yield stress; but not less than 485.0 N/mm <sup>2</sup>	12 percent more than the actual 0.2 % proof stress / yield stress; but not less than 500.0 N/mm <sup>2</sup>	8 percent more than the actual 0.2 % proof stress / yield stress; but not less than 545.0 N/mm <sup>2</sup>	10 percent more than the actual 0.2 % proof stress / yield stress; but not less than 565.0 N/mm <sup>2</sup>	6 percent more than the actual 0.2 % proof stress / yield stress; but not less than 585.0 N/mm <sup>2</sup>	8 percent more than the actual 0.2 % proof stress / yield stress; but not less than 600.0 N/mm <sup>2</sup>	6 percent more than the actual 0.2 % proof stress / yield stress; but not less than 660.0 N/mm <sup>2</sup>
4.	Total elongation at maximum force, percent, Min. on gauge length $5.65 \sqrt{A}$ , where A is the cross sectional area of the test piece	—	5	—	5	—	5	—



### 3. COMPRESSION TEST ON MILD STEEL

**Aim:** To study the stress-strain behaviour of the given mild steel specimen under a gradually increasing axial compressive load and to determine the compressive strength characteristics of the given material.

**Theory:** Definitions: Ductility, Malleability; Stress-strain diagram of mild steel specimen under axial compressive load with explanation.

**Test Set Up:**

- Universal Testing Machine (UTM)
- Dial gauge to measure the axial compression of the specimen.
- Slide calipers / Micrometer, Scale.

**Procedure:**

- Observe the specimen. Measure its diameter and length.
- Place the specimen in between the middle and lower cross heads of the UTM.
- Fix the dial gauge in its proper position. Adjust the dial reading to zero initially or note down the dial gauge reading corresponding to zero load.
- Select proper range of loading (i.e. 0 to 40 tonnes).
- Switch on the machine. Apply the axial compressive load on the specimen gradually. Note down the dial gauge readings at a constant load increment of 400 kg.
- The yield point can be observed either
  - by the kickback of the live needle of the load indicating dial

**OR**

- by the rapid movement of dial gauge needle at constant load reading.

Record the yield load(s), and remove the dial gauge.

- Loading is continued and can be stopped at any stage after this. The specimen will not fail under compression in the case of highly ductile materials.
- Release the load. Switch off the machine. Remove the tested specimen and observe its shape.

**Note:**

1. It is preferable to have a length to diameter ratio of 2 to 3 for the compression test specimen of either ductile or brittle material.
2. Utmost care should be taken to apply the load axially.

**Observations and calculations before the test:**

1. Material of the specimen : \_\_\_\_\_
2. Diameter of the specimen = D = \_\_\_\_\_ cm
3. Length of the specimen = L = \_\_\_\_\_ cm
4. Initial Cross sectional area of the specimen = A = \_\_\_\_\_ cm<sup>2</sup>
5. Least count of the dial gauge = \_\_\_\_\_ cm
6. Capacity of the dial gauge = \_\_\_\_\_ cm

**Data Sheet for Compression Test:**

Load P, kg	Stress = $\sigma =$ P/A, kg/cm <sup>2</sup>	Dial gauge reading, div.	Deformation dl, cm	Strain e = dl/L	Remarks

**Observations and calculations after the test:**

1. Nature of the specimen after the test : \_\_\_\_\_
2. Young's modulus of Elasticity of Mild Steel under compression = slope of the straight line portion of the stress vs. strain curve =  $E_c =$  \_\_\_\_\_  $\text{kg/cm}^2$   
 $=$  \_\_\_\_\_ GPa
3. (a) Upper yield stress =  $\sigma_{yu} = \frac{\text{load at upper yield point}}{A} =$  \_\_\_\_\_  $\text{kg/cm}^2$ .  
 $=$  \_\_\_\_\_ MPa
- (b) Lower yield stress =  $\sigma_{yl} = \frac{\text{load at lower yield point}}{A} =$  \_\_\_\_\_  $\text{kg/cm}^2$ .  
 $=$  \_\_\_\_\_ MPa

**OR**

$$\text{Yield stress} = \sigma_y = \frac{\text{load at yield point}}{A} = \text{_____ } \text{kg/cm}^2.$$

$$= \text{_____ } \text{MPa}$$

**Results and conclusions:**



## 4. COMPRESSION TEST ON CAST IRON

**Aim:** To study the stress-strain behaviour of the given Cast Iron specimen under a gradually increasing axial compressive load and to determine the compressive strength characteristics of the given material.

**Theory:** Definitions: Brittleness; Stress-strain diagram of Cast Iron specimen under axial compressive load with explanation.

### Test Set Up:

- Universal Testing Machine (UTM)
- Dial gauge to measure the axial compression of the specimen
- Slide calipers / Micrometer, Scale.

### Procedure:

- Observe the specimen. Measure its diameter and length.
- Place the specimen in between the middle and lower cross heads of the UTM.
- Fix the dial gauge in its proper position. Adjust the dial reading to zero initially or note down the dial gauge reading corresponding to zero load.
- Select proper range of loading (i.e. 0 to 40 tonnes).
- Switch on the machine. Apply the axial compressive load on the specimen gradually. Take the dial gauge readings at a constant load increment of 400 kg.
- In the case of brittle materials like cast iron, no yield point can be observed. Continue the loading up to failure of the specimen. Take precaution to remove the dial gauge before the failure occurs. Note down the ultimate load and the load at failure.
- Switch off the machine. Remove the tested specimen and observe the type of fracture.

### Note:

- a) It is preferable to have a length to diameter ratio of 2 to 3 for the compression test specimen of either ductile or brittle material.
- b) Utmost care should be taken to apply the load axially.

**Observations and calculations before the test:**

1. Material of the specimen : \_\_\_\_\_
2. Diameter of the specimen = D = \_\_\_\_\_ cm
3. Length of the specimen = L = \_\_\_\_\_ cm
4. Initial cross sectional area of the specimen = A = \_\_\_\_\_ cm<sup>2</sup>
5. Least count of the dial gauge = \_\_\_\_\_ cm
6. Capacity of the dial gauge = \_\_\_\_\_ cm

### Data Sheet for Compression Test:

Load P, kg	Stress = $\sigma$ = P/A, kg/cm <sup>2</sup>	Dial gauge reading, div.	Deformation dl, cm	Strain e = dl/L	Remarks

### Observations and calculations after the test:

1. Type of fracture : \_\_\_\_\_
2. Young's modulus of Elasticity of Cast Iron in compression = slope of the straight line portion of the stress vs. strain curve =  $E_c =$  \_\_\_\_\_ kg/cm<sup>2</sup>  
= \_\_\_\_\_ GPa
3. Compressive strength =  $\sigma_c = \frac{\text{Ultimate load}}{A} =$  \_\_\_\_\_ kg/cm<sup>2</sup>.  
= \_\_\_\_\_ MPa
4. Breaking stress =  $\sigma_f = \frac{\text{load at failure}}{A} =$  \_\_\_\_\_ kg/cm<sup>2</sup>.  
= \_\_\_\_\_ MPa.

### Results and conclusions:

## 5. DOUBLE SHEAR TEST ON MILD STEEL

**Aim:** To determine the average and maximum shear strengths of the given mild steel specimen when subjected to double shear:

**Theory:** Definition of shear force; Difference between single and double shear; Relationship between maximum and average shear stresses for different cross sections.

### Test set up:

- Universal testing machine (UTM)
- Double shear box: This consists of
  - (a) a load centraliser
  - (b) a central bush
  - (c) two end bushes
  - (d) two end screws
  - (e) a main block to house the above elements
- Slide calipers/Micrometer.

### Procedure:

- Observe the specimen. Measure its diameter.
- Place the load centraliser along with the central bush, inside the main block.
- Insert the specimen inside the block such that it passes through the central bush.
- Place the end bushes in their positions such that their grooved surfaces face outwards.
- Tighten the end screws moderately.
- Place the whole assembly on the lower cross head of UTM such that the compression plate of the middle cross head touches the load centraliser.
- Select a proper load range (i.e. 0 to 20 tonnes)
- Apply the axial compressive load gradually on the load centraliser which transforms the axial load into shear load along two parallel planes.
- Record the load at which the specimen fails.
- Switch off the machine; Remove the tested specimen and observe the nature of failure.

### Observations and calculations:

1. Material of the specimen : \_\_\_\_\_
2. Diameter of the specimen =  $D$  = \_\_\_\_\_ cm
3. Initial cross sectional area  
of the specimen =  $A$  = \_\_\_\_\_  $\text{cm}^2$

4. Load at failure =  $P_f$  = \_\_\_\_\_ kg
5. Type of failure : \_\_\_\_\_
6. Average shear stress at failure =  $\tau_{av.} = \frac{P_f}{2A} =$  \_\_\_\_\_ kg/cm<sup>2</sup>.  
= \_\_\_\_\_ MPa.
7. Maximum shear stress at failure =  $\tau_{max.} = \frac{4}{3} \tau_{av.} =$  \_\_\_\_\_ kg/cm<sup>2</sup>.  
= \_\_\_\_\_ MPa.

**Results and Conclusions:**



## 6. TORSION TEST ON MILD STEEL

**Aim:** To study the behaviour of Mild steel when subjected to a gradually increasing torque and to determine the rigidity modulus & modulus of rupture (torsion):

**Theory:** Definitions: Shear stress, Shear strain, Rigidity modulus; Torsion, Torsion equation; Modulus of rupture (torsion).

### Test set up:

- Torsion machine

It has the following parts:

- Arrangement to twist the specimen – It consists of end blocks, specimen holder, a worm gear arrangement and a heavy weight pendulum.
- A circular scale with a vernier to record the angle of twist.
- A calibrated scale mounted on a rack and pinion arrangement to record the torque in kg-m. The capacity of the machine is 50 kg-m.

The machine can be operated either manually by means of a crank or mechanically with the help of an electric motor.

- Slide calipers/micrometer, scale.

### Procedure:

- Observe the specimen. Measure its diameter and initial length.
- Mark a straight line parallel to the longitudinal axis of the specimen with a piece of chalk to observe the twisting of the specimen and to measure the percentage elongation.
- Place the two enlarged ends of the specimen inside the two end blocks and place the whole assembly in the specimen holder. See that the specimen is fixed with no slack.
- Adjust the circular scale and the torque scale to read zero. See that the screw provided in the torque scale arrangement is in contact with the main scale and that the vernier of the circular scale is in contact with the pendulum frame, initially.
- To begin with, operate the machine manually. Record the torque scale readings at regular intervals of  $1^\circ$  twist up to  $10^\circ$  and at every  $2^\circ$  intervals up to  $30^\circ$ .
- Now, remove the crank used for manual operation and connect the machine to an electric motor through a clutch arrangement.

- Note down the torque scale readings at 60° and afterwards at an interval of 60° up to the failure of the specimen.
- At the instant of failure, disengage the clutch. Record the angle of twist as well as the torque at the instant of failure.
- Remove the tested specimen. Observe the type of fracture.
- With the help of a thread, measure the length of the chalk mark on the specimen.

**Observations and calculations before the test:**

1. Material of the specimen : \_\_\_\_\_
2. Diameter of the specimen =  $D =$  \_\_\_\_\_ cm
3. Length of the specimen =  $L =$  \_\_\_\_\_ cm
4. Polar moment of inertia of the  
cross section of the specimen =  $I_P = \frac{\pi D^4}{32} =$  \_\_\_\_\_  $\text{cm}^4$
5. Least count of circular scale = \_\_\_\_\_
6. Least count of torque scale = \_\_\_\_\_ kg-m
7. Capacity of the torque scale = \_\_\_\_\_ kg-m

**Data Sheet for Torsion Test:**

Angle of twist $\theta^\circ$	Torque $T$ , kg-m	Remarks

**Observations and calculations after the test:**

1 Type of fracture : \_\_\_\_\_

2 Length of the chalk mark on the specimen =  $L' =$  \_\_\_\_\_ cm

3 Modulus of rigidity of the material of the specimen

$$= G = \left( \frac{dT}{d\theta} \right) \frac{L}{I_p} = \text{_____ kg/cm}^2 = \text{_____ GPa}$$

where,  $\left( \frac{dT}{d\theta} \right) =$  Slope of the initial straight line portion of Torque – angle of twist

curve (dT in kg-cm and dθ in radians).

$L =$  Length of the specimen in cm

$I_p =$  Polar moment of inertia in  $\text{cm}^4$

4 Modulus of rapture (Torsion)  $= \frac{16 T_{\max}}{\pi D^3} = \text{_____ kg/cm}^2$ .  
 $= \text{_____ MPa}$

5 Percentage elongation  $= \left( \frac{L' - L}{L} \right) 100 = \text{_____}$

**Results and Conclusions:**



## 7. IMPACT TESTS

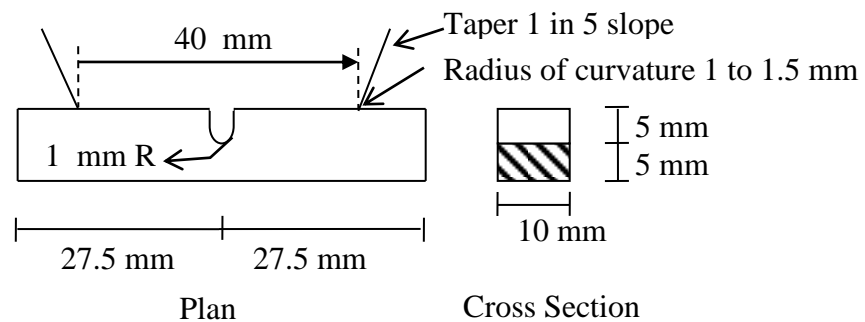
**Aim:** To determine the impact energy/Impact strength of a given test specimen by

- (a) Izod test                      (b) Charpy test

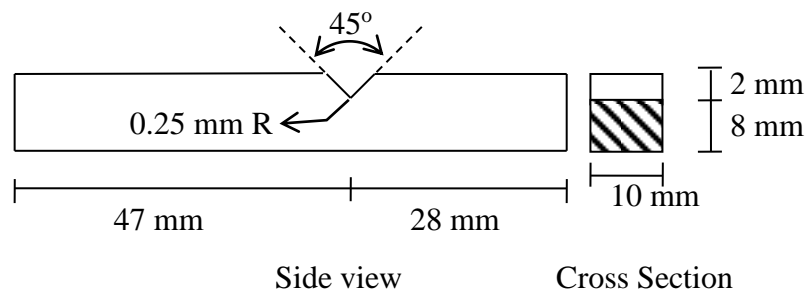
**Theory:** Definitions: Impact load, Impact energy, Impact strength, Toughness.

### Test Set Up:

- Pendulum type impact testing machine. The machine consists of:
  - A pendulum of mass 18.748 kg, length = 825 mm with an angle of swing of  $160^\circ$ .
  - Specimen holder (different for Izod and Charpy tests)
  - Striking edge (different for Izod and Charpy tests)
  - Lock lever and pendulum releaser.
  - Pendulum brake.
  - A calibrated dial to measure the Impact energy, with red and black indicators.
  - Slide Calipers and Scale
- Standard Specimen for Charpy test:



- Standard specimen for IZOD test



**Procedure:**

- Check the specimen for its standard dimensions.
- Depending upon the type of test, fix the corresponding striking edge to the hammer.
- To find the frictional loss:
  - Raise the pendulum to its highest position where it gets locked. At this position, the potential energy stored in the pendulum is 30 kg-m.
  - Set the dial to read 30 kg-m with the indicator showing black colour.
  - Press the lock lever first and then the pendulum releaser to release the pendulum.
  - Stop the oscillations of the pendulum using the damper plate / brake.
  - Record the reading on the dial which indicates the frictional loss directly.

**Note:** Read the black or red scale according as the indicator is black or red respectively.

- i) Fix the specimen in its holder.
  - a) For Izod Test: The specimen should be placed vertically as a cantilever with the shorter end of the specimen projecting above the holder and V-notch on the tension side.
  - b) For Charpy Test: The specimen should be placed horizontally as a simple beam and the U-notch on the tension side.

**Note:** Use the appropriate centraliser to keep the specimen in its proper position.

- ii) Raise the pendulum to its highest position where it gets locked. Set the dial to read 30 kg-m with the indicator showing black colour.
- iii) Release the pendulum by pressing down the lock lever first and then the pendulum releaser to strike the specimen.
- iv) Use the damper plate / brake to stop the oscillations of the pendulum.
- v) Record the dial reading on the red or black scale depending upon whether the indicator is red or black respectively.
- vi) Observe whether the specimen has broken completely or not.

**Note:**

1. Utmost care must be taken to see that no person is present in the line of oscillation of the pendulum.
2. During the test, if the test piece is not completely broken, the impact value obtained is indefinite. Then the test report should state that the test piece was unbroken by \_\_\_\_\_ joules, in case of Izod test, and the test report should state that the test piece was not broken by the striking energy of the testing machine, in case of Charpy test.

**Observations and Calculations:**

1. Material of the specimen : \_\_\_\_\_
2. Mass of the pendulum : 18.748 kg
3. Length of the pendulum : 825 mm
4. Angle of swing :  $160^\circ$
5. Frictional loss =  $U_f =$  \_\_\_\_\_ kg-m

**I. Izod Impact Test:**

Specimen No.	Specimen dimensions	Observed reading $U_0$ , kg-m	Impact energy OR Impact value $U_I = U_0 - U_f$		Remarks
			kg-m	joules	

**II. Charpy Impact Test**

Specimen No.	Specimen dimensions	Cross sectional dimensions of the specimen below the notch	Area of cross section below the notch, $A \text{ cm}^2$	Observed reading $U_0$ kg-m	Impact energy $U_I = U_0 - U_f$ kg-m	Impact strength $KU = U_I / A$ $\frac{\text{kg} - \text{m}}{\text{cm}^2}$	Remarks

**Results and Conclusions:**

**Relevant IS Codes:**

IS: 1499 (1977), Method for Charpy impact test (U-notch) for metals [1<sup>st</sup> Revision, with amendment No. 1 (reaffirmed 1987)], BIS, New Delhi.

IS: 1598 (1977), Method for Izod impact test of metals [1<sup>st</sup> Revision, reaffirmed 1987] , BIS, New Delhi.



## 8. BRINELL HARDNESS TEST

**Aim:** To determine the hardness number for a given metallic specimen by Brinell Test (HB).

**Theory:** Definitions: Hardness, Static Indentation, Dynamic Indentation.

### Test Set Up:

- Brinell Hardness Testing machine, hereafter called as HTM-1.
- Brinell and Vickers Hardness Testing Machine, hereafter called as HTM-2.
- Indenters. Steel ball indenters of diameters 5 mm and 2.5 mm.
- Test specimens of different materials: Mild steel, Cast iron, Brass, Gun metal and Aluminum.
- Travelling microscope.

### Some Important Tables:

#### *Load range for Brinell hardness test:*

The load to be applied can be obtained by the formula

$$P = KD^2 \text{ kgf.}$$

where K = Constant for a given metal (listed in Table-1)

D = Diameter of the ball indenter in mm.

Table 1: Values of 'K' and range of hardness for different metals (for Brinell Hardness Test)

Sl. No.	Metal	Value of K	Range of Brinell hardness number (HB)
1.	Mild steel	30	67-500 kgf/mm <sup>2</sup>
2.	Cast Iron	30	67-500 kgf/mm <sup>2</sup>
3.	Brass	10	22-315 kgf/mm <sup>2</sup>
4.	Gun Metal	10	22-315 kgf/mm <sup>2</sup>
5.	Aluminum	5	11-158 kgf/mm <sup>2</sup>

### Example:

Material \ Ball Indenter diameter, mm	5	2.5
Mild steel	750 kgf	187.5 kgf
Cast Iron	750 kgf	187.5 kgf
Brass	250 kgf	62.5 kgf
Gun Metal	250 kgf	62.5 kgf
Aluminum	125 kgf	31.25 kgf

**Procedure:**

*I. For HTM-1*

- Clean the smooth surface of the specimen to be tested to remove dirt and oil, if any. Polish the test spot, which is flat, by Emory sheet. The top and bottom surfaces of the specimen should be parallel to each other.
- Fix the required ball indenter along with its holder to the thrust member or penetrator.
- Depending upon the material of the specimen and the indenter diameter, arrange the designed loads on the weight shaft (The combined weight of the lever, hanger bracket, weight shaft and the bottom weight is equivalent to 500 kg. Additional weights can be placed on the bottom weight using loose weights 250 kg each).
- Actuate the toggle switch.
- Actuate the hydraulic loading system by pressing the green button provided on the side of the machine.
- Switch on the indicator lamp.
- Place the standard specimen on the test table, and turn the main nut (hand wheel) in the clockwise direction until a sharp display of the surface of the specimen is obtained on the focusing screen of the measuring device.
- Apply the load by turning the load lever to the “Load” position.
- Wait for the red indicator present near the optical device at the top to activate.
- Release the load by turning the load lever to the “Unload” position. At the same instant, the objective (of magnification 14) comes just above the indentation, and a sharp image of the indentation is seen on the focusing screen.
- Measure the diameter of the indentation using the scale with micrometer present on the screen itself.

**Procedure for using the scale present on the screen for measuring the dimension of the indentation.**

The scales of the focusing screen and clear screen have long and short division marks. In addition, the focusing screen is equipped with a vernier scale. The long centre division mark on the clear screen (marked ‘O’) should be within the vernier scale. If it is not so, turn the micrometer to bring the long centre division mark within the vernier scale. The distance between a long and a short division mark of the scale is equal to 1 mm.

- The inner edge of the nearer long or short division mark on the left of the scale is made to coincide with the left outer edge of the impression of the indentation using the turning knob provided for that purpose.
- The inner edge of the nearer long or short division mark on the right side of the scale is made to coincide with the right outer edge of the impression of the indentation using the micrometer. If the long center division is not within the vernier scale, adjust the micrometer once again so that the outer edge of the impression contacts with another long or short mark.
- Count the number of divisions between the long and short marks enclosing the impression (exclude the small strip 0 – 0) to get the diameter of the indentation before the decimal point.
- Count the number of vernier scale divisions within the small strip 0 – 0. This indicates the 1<sup>st</sup> decimal value of the diameter of the indentation.
- Read the coinciding head scale division of micrometer, which is the value of the 2<sup>nd</sup> decimal place of the diameter of the indentation.
- Turn the screw through 90° and determine the diameter of the indentation once again. Consider the mean of the two values so determined as the diameter of the indentation.
- If no further tests are to be conducted, switch off the lamp indicator, hydraulic loading system (by pressing the red button provided on the side of the machine) and finally the main switch.

## *II. For HTM-2*

- Clean the smooth surface of the specimen to be tested to remove dirt and oil, if any. Polish the test spot, which is flat, by Emory sheet. The top and bottom surfaces of the specimen should be parallel to each other.
- Fix the required ball indenter along with its holder to the thrust member or penetrator.
- Depending upon the material of the specimen and the indenter diameter select the required load stage and adjust it through corresponding push button provided on the side of the machine.
- Actuate the switch to switch on the lamp of light source.
- Place the standard specimen on the test table, and turn the main nut (hand wheel) in the clockwise direction until a sharp display of the surface of the specimen is obtained on the focusing screen of the measuring device.

- Push the button provided at the front bottom of the instrument, and hold it until the hand lever moves upwards. Then, release the push button and wait until the hand lever stops. Further, wait for 10 seconds.
- Press down the hand lever without any jerks, which indicates the release of the load. At the same instant, the objective (of magnification 70) comes just above the indentation, and a sharp image of the indentation is seen on the focusing screen.
- Measured the diameter of the indentation using the scale with micrometer present on the screen itself.

**Procedure for using the scale present on the screen for measuring the dimension of the indentation.**

The scales of the focusing screen and clear screen have long and short division marks. In addition, the focusing screen is equipped with a vernier scale. The long centre division mark on the clear screen (marked 'O') should be within the vernier scale. If it is not so turn the micrometer to bring the long centre division mark within the vernier scale. The distance between a long and a short division mark of the scale is equal to 0.1 mm.

- The inner edge of the nearer long or short division mark on the left of the scale is made to coincide with the left outer edge of the impression of the indentation using the turning knob provided for that purpose.
- The inner edge of the nearer long or short division mark on the right side of the scale is made to coincide with the right outer edge of the impression of the indentation using the micrometer. If the long center division is not within the vernier scale, adjust the micrometer once again so that the outer edge of the impression contacts with another long or short mark.
- Count the number of divisions between the long and short marks enclosing the impression (exclude the small strip 0 – 0). Multiply that by 0.1 to get the diameter of the indentation up to first decimal value.
- Count the number of vernier scale divisions within the small strip 0 – 0. This indicates the 2<sup>nd</sup> decimal value of the diameter of the indentation.
- Read the coinciding head scale division of micrometer, which is the value of the 3<sup>rd</sup> decimal place of the diameter of the indentation.
- Turn the screw through 90° and determine the diameter of the indentation once again. Consider the mean of the two values so determined as the diameter of the indentation.
- If no further tests are to be conducted, switch off the machine.

**Note:**

1. The thickness of the test piece should not be less than 10 times the depth of indentation.
2. The distance of the centre of the indentation from the edge of the test piece are from the circumference of the adjacent indentation should not be less than 3 times the diameter of the indentation.
3. The Brinell hardness number is calculated using the formula

$$HB = \frac{2P}{\pi D (D - \sqrt{D^2 - d^2})} \quad \text{kgf/mm}^2$$

where P is the applied load in kg, D is the diameter of the indenter in mm and d is the diameter of the indentation in mm.

4. The Brinell hardness number is expressed as:  
(value in kg/mm<sup>2</sup>) HB (D in mm) / (P in kg.f) / (time in s).

**Observations and Calculations:***I. H.T.M.-1*

Material of the specimen	Diameter of the indenter D, mm	Load P, kgf	Diameter of the indentation			Brinell hardness value
			d <sub>1</sub> , mm	d <sub>2</sub> , mm	d = (d <sub>1</sub> + d <sub>2</sub> )/2, mm	
Cast Iron						
Mild Steel						

*II. H.T.M.-2*

Material of the specimen	Diameter of the indenter D, mm	Load P, kgf	Diameter of the indentation			Brinell hardness value
			d <sub>1</sub> , mm	d <sub>2</sub> , mm	d = (d <sub>1</sub> + d <sub>2</sub> )/2, mm	
Brass						
Gun Metal						
Aluminum						

***Specimen calculation:***

For the given \_\_\_\_\_ specimen,

$$HB = \frac{2P}{\pi D (D - \sqrt{D^2 - d^2})} = \text{_____ kgf/mm}^2$$

**Results and Conclusions:**

**Relevant IS Codes:**

IS: 1500 (1983), Method of Brinell hardness test for metallic materials (2<sup>nd</sup> Revision), BIS, New Delhi.

## 9. VICKERS HARDNESS TEST

**Aim:** To determine the Vickers hardness number (HV) for a given metallic specimen.

### Test Set Up:

- Brinell and Vickers Hardness Testing Machine (i.e. HTM-2).
- Indenter: Pyramidal diamond indenter of square base, with a vertex angle of  $136^\circ$ .
- Specimens of different materials: Mild steel, Cast iron, Brass, Gun metal and Aluminum.

Table 1: Standard Loads for Vickers test

Sl. No.	Material	Load P, kgf
1.	Cast Iron	30
2.	Mild Steel	30
3.	Brass	10
4.	Gun Metal	10
5.	Aluminum	10

### Procedure:

- Clean the smooth surface of the specimen to be tested to remove dirt and oil, if any. Polish the test spot, which is flat, by Emory sheet. The top and bottom surfaces of the specimen should be parallel to each other.
- Fix the pyramidal diamond indenter along with its holder to the thrust member or penetrator.
- Depending upon the material of the specimen and the indenter diameter select the required load stage (Table 1) and adjust it through corresponding push button provided on the side of the machine.
- Actuate the switch to switch on the lamp of light source.
- Place the standard specimen on the test table, and turn the main nut (hand wheel) in the clockwise direction until a sharp display of the surface of the specimen is obtained on the focusing screen of the measuring device.
- Push the button provided at the front bottom of the instrument, and hold it until the hand lever moves upwards. Then, release the push button and wait until the hand lever stops. Further, wait for 30 seconds.

- Press down the hand lever without any jerks, which indicates the release of the load. At the same instant, the objective (of magnification 70) comes just above the indentation, and a sharp image of the indentation is seen on the focusing screen.
- Measure the diagonal of the square indentation using the scale with micrometer present on the screen itself.

**Procedure for using the scale present on the screen for measuring the dimension of the indentation.**

The scales of the focusing screen and clear screen have long and short division marks. In addition, the focusing screen is equipped with a vernier scale. The long centre division mark on the clear screen (marked 'O') should be within the vernier scale. If it is not so turn the micrometer to bring the long centre division mark within the vernier scale. The distance between a long and a short division mark of the scale is equal to 0.1 mm.

- The inner edge of the nearer long or short division mark on the left of the scale is made to coincide with the left outer edge of the impression of the indentation using the turning knob provided for that purpose.
- The inner edge of the nearer long or short division mark on the right side of the scale is made to coincide with the right outer edge of the impression of the indentation using the micrometer. If the long center division is not within the vernier scale, adjust the micrometer once again so that the outer edge of the impression contacts with another long or short mark.
- Count the number of divisions between the long and short marks enclosing the impression (exclude the small strip 0 – 0). Multiply that by 0.1 to get the length of the diagonal indentation up to first decimal value.
- Count the number of vernier scale divisions within the small strip 0 – 0. This indicates the 2<sup>nd</sup> decimal value of the length of the diagonal indentation.
- Read the coinciding head scale division of micrometer, which is the value of the 3<sup>rd</sup> decimal place of the length of the diagonal indentation.
- Turn the screw through 90° and determine the length of the diagonal indentation once again. Consider the mean of the two values so determined as the length of the diagonal indentation.
- If no further tests are to be conducted, switch off the machine.



**Note:**

1. The thickness of the test piece should not be less than 1.5 times the length of the diagonal of the indentation.
2. The distance of the centre of the indentation from the edge of the test piece or from the circumference of the adjacent indentation should not be less than 3 times the length of the diagonal of the indentation.
3. The Vickers hardness number is calculated using the formula

$$HV = \frac{2P \sin (136/2)^{\circ}}{d^2} \quad \text{kgf/mm}^2.$$

where P is the applied load in kgf and d is the average length of the diagonal of the indentation in mm.

4. The Vickers hardness number should be rounded off to first decimal, if the value is below 25 OR it should be reported in integers, if the value exceeds 25.
5. The Vickers hardness number is expressed as:  
(value in kg/mm<sup>2</sup>) HV (load)

**Observations and Calculations:**

1. Type of the indenter: Pyramidal diamond of square base.
2. Vertex angle of the indenter =  $\theta = 136^{\circ}$ .

Material of the specimen	Load P, kgf	Length of the Diagonal of the Indentation			Vickers hardness value
		d <sub>1</sub> , mm	d <sub>2</sub> , mm	d = (d <sub>1</sub> + d <sub>2</sub> )/2, mm	
Cast Iron					
Mild Steel					
Brass					
Gun Metal					
Aluminum					

***Specimen calculation:***

For the given \_\_\_\_\_ specimen,

$$HV = \frac{2P \sin (136/2)^{\circ}}{d^2} = \text{_____ kg/mm}^2$$

**Results and Conclusions:**

**Relevant IS Codes:**

IS: 1501- Part – I (1984), Method for Vickers hardness test for metallic materials, HV 5 to HV 100 (Second Revision), BIS, New Delhi

IS: 1501- Part – II (1984), Method for Vickers hardness test for metallic materials, HV 0.2 to less than HV 5 (Second Revision), BIS, New Delhi

## 10. ROCKWELL HARDNESS TESTS

**Aim:** To determine the Rockwell hardness number on B and C scales for a given metallic specimen.

### Test Setup:

- Rockwell Hardness Testing Machine (i.e. HTM-3).
- Indenters:
  - i) For Rockwell – B Test: Steel ball indenter of diameter  $(1/16)^{\text{th}}$  inch.
  - ii) For Rockwell – C Test: Rockwell diamond cone of vertex angle  $120^{\circ}$  and tip radius 0.2 mm.

### Standard Loads:

Sl. No.	Material	For Rockwell – B Test Load, kgf	For Rockwell – C Test Load, kgf
1.	Cast Iron	–	150
2.	Mild Steel	–	150
3.	Brass	100	–
4.	Gun Metal	100	–
5.	Aluminum	100	–

### Procedure:

- Smoothen the surface of the specimen to be tested, and clean it to remove dirt and oil, if any.
- Fix the appropriate indenter to the thrust member or penetrator.
- Depending upon the material of the specimen and type of the indenter, select and set the required load stage, and see that the load lever is in position “A”.
- Place the standard specimen on the test table, and turn the main nut (hand wheel) in the clockwise direction to have contact between specimen and the penetrator. Continue turning until the small pointer of the dial gauge reaches the red spot and the long pointer comes to “0” mark on the dial gauge. This also indicates the application of a preload of 10 kg.
- Turn the load lever from position “A” to position “B” to apply the main load on the specimen.
- Wait for the long needle of the dial gauge to reach a steady position.

- Release the main load by bringing back the load lever from position “B” to position “A” slowly.
- Record the reading shown by the long pointer
  - on red scale for Rockwell – B Test
  - on black scale for Rockwell – C Test.
- Turn the main nut in the counter clock wise direction and remove the specimen.

**Note:**

- c) One division of Rockwell B or C scale is equal to a depth of indentation of 2 micron.
- d) Rockwell hardness should be designated by HR, preceded by the hardness value and supplemented by a letter indicating the scale.

Ex: 60 HRC indicates Rockwell hardness of 60 on C scale.

**Observations and Calculations:***I. Rockwell – B Test*

Type of indenter. Steel ball of diameter (1/16)<sup>th</sup> inch.

Specimen	Load P, kgf	Red scale reading ‘n’	Hardness value, n	Depth of indentation = (130-n) 2, microns
Brass				
Gun Metal				
Aluminum				

*II. Rockwell – C Test*

Type of indenter. Rockwall diamond of vertex angle 120°

Specimen	Load P, kgf	Black scale reading ‘n’	Hardness value, n	Depth of indentation (100-n) 2, microns
Cast Iron				
Mild Steel				

**Results and Conclusion:****Relevant IS Codes:**

IS: 1586 (2000), Method for Rockwell Hardness Test for Metallic Material (Scales A-B-C-D-E-F-G-H-K 15N, 30N, 45N, 15T, 30T and 45T) (Third Revision), BIS, New Delhi

## 11. COMPRESSION TEST ON WOOD

**Aim:** To study the stress-strain behaviour of the given wooden specimen under a gradually increasing axial compressive load and to determine the compressive strength characteristics of the given material.

**Theory:** Definitions: Isotropy and anisotropy; Stress-strain diagrams for wooden specimen under axial compressive load – when the load is applied parallel to the grains and when the load is applied normal to the grains with explanations.

### Test Set Up:

- Universal Testing Machine (UTM)
- Dial gauge to measure the axial compression of the specimen
- Slide calipers / Micrometer, Scale.

### Procedure:

- Observe the specimen. Measure its cross sectional dimensions and length.
- Place the specimen on the lower cross head of UTM. Observe the orientation of the grains with respect to the loading direction.
- Fix the dial gauge in its proper position. Adjust the dial reading to zero initially or note down the dial reading corresponding to zero load.
- Select proper range of loading (i.e. 0 to 20 tonnes).
- Switch on the machine. Take the dial gauge readings at a constant load increment of 400 kg when the grains are parallel to the direction of loading and 200 kg when the grains are normal to the direction of loading.
- Continue the loading up to failure. Take precautions to remove the dial gauge before failure occurs.
- Switch off the machine. Remove the tested specimen and observe the type of failure.

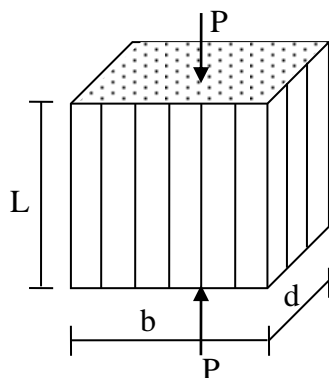


Fig. 1: Grains are parallel to the direction of loading

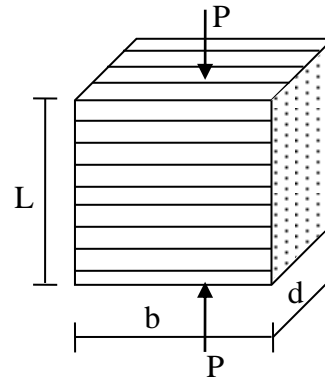


Fig. 2: Grains are normal to the direction of loading

**Observations and calculations before the test:**

1. Material of the specimen : \_\_\_\_\_
2. Orientation of the grains : \_\_\_\_\_
3. Length of the specimen = L = \_\_\_\_\_ cm
4. Cross sectional dimensions of the specimen = b x d = \_\_\_\_\_ cm x \_\_\_\_\_ cm
5. Initial cross sectional area of the specimen = A = b x d = \_\_\_\_\_ cm<sup>2</sup>
6. Least count of the dial gauge = \_\_\_\_\_ cm
7. Capacity of the dial gauge = \_\_\_\_\_ cm

**Data Sheet for Compression Test:**

Load P, kg	Stress = $\sigma$ = P/A, kg/cm <sup>2</sup>	Dial gauge reading, div.	Deformation dl, cm	Strain e = dl/L	Remarks

**Observations and calculations after the test:**

1. Type of failure : \_\_\_\_\_
2. Young's modulus of Elasticity of the given wood = slope of the straight line portion of the stress vs. strain curve = E = \_\_\_\_\_ kg/cm<sup>2</sup>  
= \_\_\_\_\_ GPa
12. Ultimate compressive strength =  $\sigma_{ult} = \frac{\text{Ultimate load}}{A} = \text{_____ kg/cm}^2$ .  
= \_\_\_\_\_ MPa
3. Breaking stress =  $\sigma_f = \frac{\text{load at failure}}{A} = \text{_____ kg/cm}^2$ .  
= \_\_\_\_\_ MPa

**Results and conclusions:**

Type of Wood	Direction of loading →	Parallel to the grains	Normal to the grains
	E  $\sigma_{ult}$  $\sigma_f$		

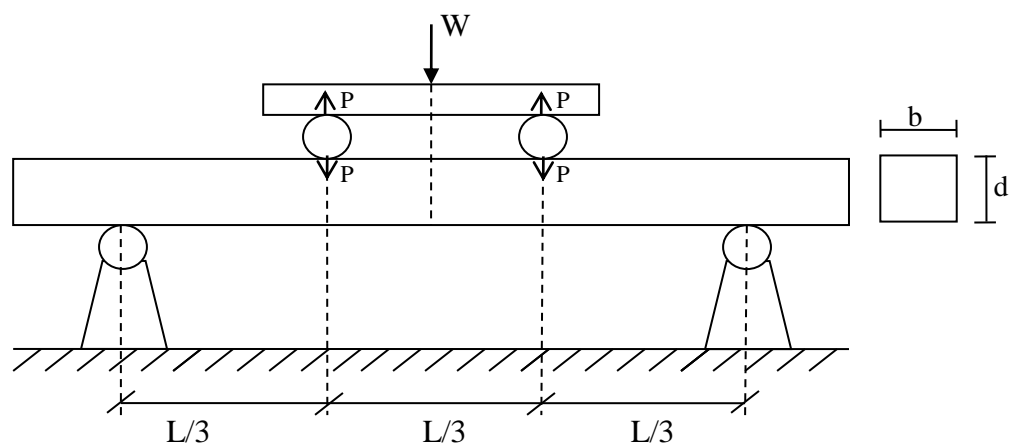
## 12. BENDING TEST ON WOOD

**Aim:** To study the behaviour of given specimen of wood subjected to pure bending and to determine the Young's modulus of elasticity and modulus of rupture (bending).

**Theory:** Definitions: Bending moment, Pure bending, Neutral axis, Bending equation, Section modulus, Modulus of rupture (bending).

**Test set up:**

- Universal Testing Machine (UTM)
- Roller supports mounted on a rigid base. The distance between the roller supports can be adjusted with the help of adjustable blocks.
- Dial gauge.
- Trisquare.
- Arrangements to apply two-point loading. This consists of two rollers, one M.S. Plate, and a loading element fixed to the middle cross head.
- Scale.



**Procedure:**

- Observe the specimen and measure its cross sectional dimensions.
- Select a suitable span.
- Mark the mid span point and two-point loading locations at  $1/3$  span distances. Mark the cross section lines at these locations.
- Select a proper range of loading (i.e. 0 to 4 tonnes).
- Move the adjustable blocks and fix them at positions corresponding to selected span.

- Place the specimen over the roller supports. Place two more rollers at two-point loading positions and M.S. plate over them.
- Move the middle cross head to suitable position close to M.S. plate.
- Move the lower cross head and establish a slight contact between M.S. plate and the loading element fixed to the middle cross head.
- Fix the dial gauge suitably to measure the central deflection (i.e. maximum deflection) of the wooden beam. Adjust the dial gauge to read zero.
- Start applying the load gradually. Note down the dial gauge readings at regular load intervals of 40 kg. Remove the dial gauge after about 10 readings.
- Continue loading up to failure and record the load at failure.
- Switch off the machine and release the load. Remove the specimen and observe the type of failure.

#### Observations and Calculations before the test:

1. Type of wood : \_\_\_\_\_
2. Cross sectional dimensions =  $b \times d$  = \_\_\_\_\_ cm x \_\_\_\_\_ cm.
3. Span =  $L$  = \_\_\_\_\_ cm.
4. Moment of inertia of the beam  
cross section about the neutral axis =  $I = \frac{bd^3}{12} =$  \_\_\_\_\_  $\text{cm}^4$ .
5. Section modulus =  $Z = \frac{bd^2}{6} =$  \_\_\_\_\_  $\text{cm}^3$ .
6. Least count of the dial gauge = \_\_\_\_\_ cm
7. Capacity of the dial gauge = \_\_\_\_\_ cm

#### Data Sheet for Bending Test:

Total Load $W$ , kg	Load $P = \frac{W}{2}$ , kg	Dial gauge readings, Divisions	Central deflection $\delta$ , cm	Remarks



**Observations and Calculations after the test:**

1. Type of failure : \_\_\_\_\_

2. Young's modulus of elasticity of given wood

$$= E = \frac{23}{648} \left( \frac{dP}{d\delta} \right) \frac{L^3}{I} = \text{_____ kg/cm}^2.$$

$$= \text{_____ GPa}.$$

where  $\left( \frac{dP}{d\delta} \right)$  is the slope of the straight line portion of load vs. deflection curve.

3. Maximum bending moment =  $M_f = \left( \frac{P_f L}{3} \right) = \text{_____ kg-cm}$

where  $P_f$  is the load at failure.

4. Modulus of rupture (bending) =  $\sigma_f = \frac{M_f}{Z} = \text{_____ kg/cm}^2.$

$$= \text{_____ MPa}.$$
**Results and conclusions:**



### 13. TESTING OF BURNT CLAY BUILDING BRICKS

**Aim:** To study the dimensional characteristics, to determine the water absorption and to determine the compressive strength of burnt clay building bricks.

**General Quality of Bricks:**

Bricks shall be hand moulded or machine moulded and shall be made from suitable soils. They shall be free from cracks, flaws and nodules of free line. Hand moulded bricks of 90 mm or 70 mm height shall be moulded with a frog 10 to 20 mm deep on one of its flat sides. The bricks shall have smooth rectangular faces with sharp corners and shall be uniform in colour.

The standard size of common building bricks:

Type of bricks	Length (L), mm	Width (W), mm	Height (H), mm
Modular bricks	190	90	90
	190	90	40
Non-modular bricks	230	110	70
	230	110	30

A) To study the dimensional characteristics of burnt clay building bricks:

**Procedure:**

Twenty bricks shall be selected at random from the sample. All blisters, loose particles of clay and small projections shall be removed. They shall then be arranged upon a level surface one by the side of other length wise, width wise and height wise. The overall length, overall width and overall height of the assembled bricks shall be measured with a steel tape to the nearest mm. The tolerances for the dimensions of bricks when measured as indicated above shall be within the following limits.

Type of bricks	Length (L), mm	Width (W), mm	Height (H), mm
Modular bricks	$3800 \pm 80$	$1800 \pm 40$	$1800 \pm 40$
	$3800 \pm 80$	$1800 \pm 40$	$800 \pm 40$
Non-modular bricks	$4600 \pm 80$	$2200 \pm 40$	$1400 \pm 40$
	$4600 \pm 80$	$2200 \pm 40$	$600 \pm 40$

**Observation:**

- Type of bricks:
- Identification mark on the bricks:

Sl. No. of brick	Length (L), mm	Width (W), mm	Height (H), mm
1			
2			
3			
4			
5			

**Conclusion:**

-----

B) To determine the water absorption of burnt clay building bricks.

**Apparatus:**

- A sensitive balance capable of weighing within 0.1% of the mass of the specimen.
- A ventilated, temperature controlled oven.

**Procedure:**

- Measure the dimensions of the bricks to the nearest 1 mm.
- Dry the specimen in a ventilated oven at a temperature of 105 to 115°C till it attains substantially constant mass.
- Cool the specimen to the room temperature and note down its mass ( $M_1$ ).
- Completely immerse the dried specimen in clean water at a temperature of  $27 \pm 2^\circ\text{C}$  for 24 hours.
- Take the specimen out of water and wipe out any traces of water with a damp cloth.
- Note down the mass of the specimen ( $M_2$ ), taking care to see that the process of measuring the mass takes not more than 3 minutes after the specimen is removed from water.
- Calculate the water absorption, percent by mass, after 24 hours of immersion in cold water using the formula.

$$\text{Water absorption} = [(M_2 - M_1) / M_1] \times 100$$

- The water absorption for burnt clay building bricks when tested after immersion in cold water for 24 hours shall not be more than 20% by mass upto class 12.5 and 15% by mass for higher classes (refer Table 1).

**Observation:**

- Type of bricks:
- Identification mark on the bricks:

Sl. No.	Dimensions, mm (L x W x H)	Mass of Bricks, g		Water absorption, %
		Oven dried mass, (M <sub>1</sub> )	Mass after 24 hours immersion in cold water, (M <sub>2</sub> )	
1.				
2.				
3.				
4.				
5.				

Average water absorption = \_\_\_\_\_

**Conclusion:**

-----  
C) To determine the compressive strength of burnt clay building bricks.

**Apparatus:**

- A compressive testing machine.

**Procedure:**

- Remove the unevenness observed on the bed faces of the specimen to provide too smooth & parallel faces by grinding and measure the dimensions of the specimen.
- Immerse the specimen in water at room temperature for 24 hours.
- Take the specimen out of water and drain out any surplus moisture at room temperature.
- Fill the frog (where provided) and all voids in the bed faces flush with cement mortar (one cement: 1 clean coarse of sand of grade 3 mm and down).
- Store the specimen under the damp jute bags for 24 hours followed by immersion in clean water for 3 days.
- Take the specimen out of water and wipe out any traces of moisture.
- Place the specimen with flat faces horizontal, and mortar filled face facing upwards between two 3 – ply plywood sheets each of 3 mm thickness and carefully center the specimen between the plates of the testing machine.
- Apply the load axially at an uniform rate of 14 N/mm<sup>2</sup> per minute till the failure occurs and note down the maximum load at failure.
- Calculate the compressive strength in N/mm<sup>2</sup> using the formula.  
Compressive strength = (Maximum load at failure) / Average area of the bed faces.
- Report the average of results and classify the sample of bricks tested (use Table 1 as reference)

**Table 1: Classes of Common Burnt Clay Bricks**

Class Designation	35	30	25	20	17.5	15	12.5	10	7.5	5	3.5
Average compressive strength (note less than), N/mm <sup>2</sup>	35.0	30.0	25.0	20.0	17.5	15.0	12.5	10.0	7.5	5.0	3.5

**Observation:**

- Type of bricks:
- Identification mark on the bricks:

Sl. No.	Dimensions of the brick, mm		Average cross sectional area, mm <sup>2</sup>	Maximum load at failure, N	Compressive strength, N/mm <sup>2</sup>	Remarks
	L	W				
1.						
2.						
3.						
4.						
5.						

- Average compressive strength = \_\_\_\_\_ N/mm<sup>2</sup>
- 80% of the minimum average compressive strength specified for the class of brick = \_\_\_\_\_ N/mm<sup>2</sup>

**Conclusions:**

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**Relevant IS Codes:**

IS: 1077 (1992), Indian Standard Common Burnt Clay Building Bricks - Specification, BIS, New Delhi

IS: 3495-Part 1 (1992), Indian Standard Methods of Tests of Burnt Clay Building Bricks: Determination of Compressive Strength, BIS, New Delhi

IS: 3495-Part 2 (1992), Indian Standard Methods of Tests of Burnt Clay Building Bricks: Determination of Water Absorption, BIS, New Delhi

IS: 5454 (1978-Reaffirmed 1995), Indian Standard Methods for Sampling of Clay Building Bricks, BIS, New Delhi

## 14. TESTING OF CLAY ROOFING TILES – MANGALORE PATTERN

**Aim:** To determine the water absorption and braking load for machine – pressed, clay interlocking roofing tiles of the ‘Mangalore Pattern’ and to classify the tiles.

### General Quality of Tiles:

- The roofing tiles shall be made of suitable clay of even texture and shall be well burnt. They shall be free from irregularities such as twists, bends, cracks and laminations.
- The roofing tile shall be free from impurities like particles of stone, lime or other foreign materials visible to the naked eye either on the surface or on the fractured face of the tile obtained by breaking the tile. However, occasional particles up to 2 mm in size may be permissible. When struck, the tile shall give a characteristic ringing sound and when broken, the fracture shall be clean and sharp at the edges. The Class AA tile shall be of uniform colour.
- When the roofing tile is placed on either face on a plane surface, the gap at the corners shall be not more than 6 mm.

The dimensions of the tiles:

Sl. No.	Overall Length (L), mm	Overall Width (W), mm
1	410	235
2	420	250
3	425	260

- The average weight of 6 tiles, when dried at 105 to 110° C to constant weight and weighed, shall be not less than 2 kg and not more than 3 kg. The weight of the tile shall be noted correct to the nearest 0.01 kg.

A) To determine the water absorption of tiles:

**Procedure:**

- Six tiles shall be used for this test.
- Dry the six tiles selected in an oven at a temperature of 105 to 110°C till they attain constant mass. Cool them and record their masses (A).
- Immerse the dry specimens completely in clean water at 24 to 30°C for 24 hours.
- Remove the tiles, wipe of the surface water carefully with a damp cloth and record their masses nearest to a gram (B) within 3 minutes after removing them from the tank.
- Calculate the percentage water absorption using the formula

$$\text{Percentage absorption} = [(B-A) / A] \times 100$$

- Report the average percentage average water absorption of the six tiles.

**Observation:**

- Identification mark on the tiles:

Sl. No.	Mass of the Tiles, g		Water absorption, %
	Oven dried mass, (A)	Mass after 24 hours immersion in clean water, (B)	
1.			
2.			
3.			
4.			
5.			
6.			

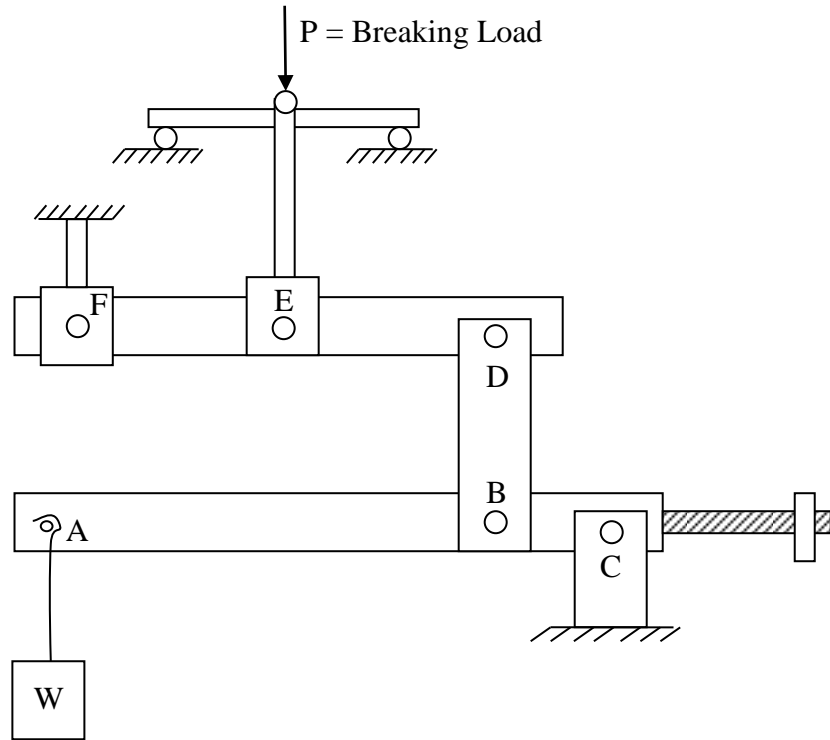
Average water absorption = \_\_\_\_\_



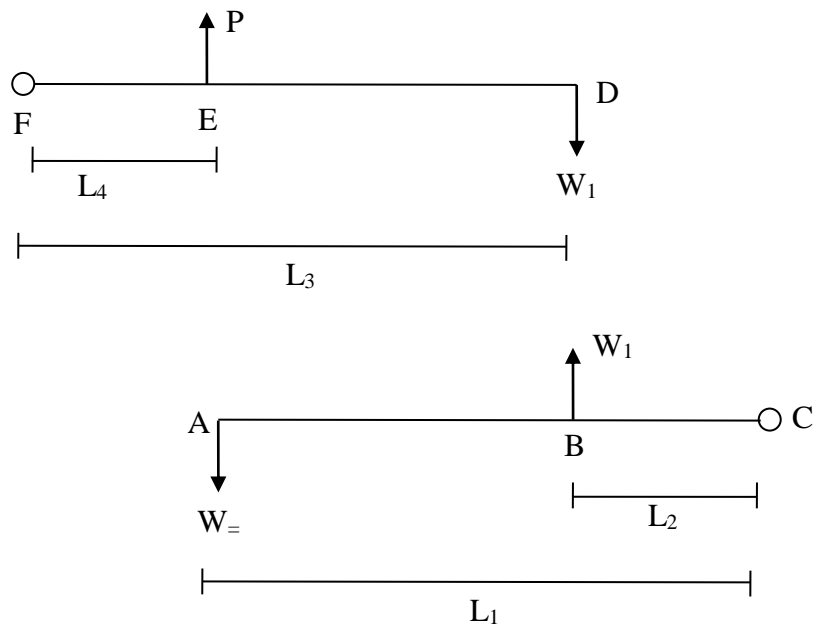
B) To determine the breaking load of tiles:

**Apparatus:**

- Tile testing machine.



**Determination of LAC**



$$LAC = (L_1 / L_2) \times (L_3 / L_4) = (300 / 75) \times (225 / 75) = 12$$

**Procedure:**

- Six tiles shall be used for this test.
- Six tiles shall be soaked in water at  $27 \pm 2^\circ\text{C}$  for 24 hours.
- Take the tiles out of water and test them in the wet condition only.
- Support the tiles evenly flat wise on the bearers set with a span of 25 cm and resting on the bottom surface.
- Apply the load with the direction of the load perpendicular to the span, at a uniform rate of 450 to 550 N/minute.
- Note down the load at failure for each of the six tiles separately.
- Report the average value calculated.

**Observation:**

- Identification mark on the tiles:
- Lever Arm Constant (LAC): 12

Sl. No.	Mass of the led shots in pan (M), kg	Breaking load (P), N	Average value of the breaking load, N
1			
2			
3			
4			
5			
6			

Breaking Load =  $P = M \times \text{LAC} \times 9.81 = \underline{\hspace{2cm}}$  N

**Results and Conclusions:**

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C) To classify the clay roofing tile, 'Mangalore Pattern':

**Procedure:**

- Classify the given Mangalore pattern clay roofing tile according to the specifications given in Table 1.

Sl. No.	Characteristic	Requirement	
		Class AA	Class A
1	Water absorption, % (Max)	18	20
2	Breaking load, kN (Min)		
	a) Average	1.0 (for 410 x 235 mm) 1.1 (for 420 x 250 mm) and (425 x 260 mm)	0.8 (for 410 x 235 mm) 0.9 (for 420 x 250 mm) and (425 x 260 mm)
	b) Individual	0.9 (for 410 x 235 mm) 1.0 (for 420 x 250 mm) and (425 x 260 mm)	0.68 (for 410 x 235 mm) 0.78 (for 420 x 250 mm) and (425 x 260 mm)

**Results:**

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**Relevant IS Codes:**

IS: 654 (1992), Indian standard clay roofing tiles, Mangalore pattern – specification, BIS, New Delhi

IS: 2248 (1991), Glossary of terms relating to structural clay products, BIS, New Delhi



## REBOUND HARDNESS TESTS

**Aim:** To measure the rebound hardness of a given metallic specimen using share scleroscope.

**Test Setup:**

- Place the specimen on a level surface. The surface of the specimen must be flat, smooth and clean.
- Place the scleroscope on the surface of the specimen.
- Release the hammer, and note the scale reading corresponding to top of the hammer on first rebound.
- Lift the hammer back ;into the position.
- Make five determinations on each specimen and consider the average and express it to the first decimal place the in 0.5 units.

**Note:**

- a) Do not allow the hammer to fall on the same spot.
- b) Perform the test at a place not less than 4 mm from the end surface of the specimen.
- c) The hardness shall be expressed by the numerical value followed by the symbol HAS.  
Ex. 25.5 HAS.
- d) When the difference between the maximum and minimum hardness measurements is 4 or more, the maximum end minimum value shall be given along with the mean hardness value. Ex. 70(67-73) HAS.

**Relevant IS Codes:** IS: 7096-1973.

**Standard Loads:**

Specimen	Trial No.	Height of first rebound	Average scleroscope hardness number

## HELICAL SPRING

**Aim:** To determine the spring constant and rigidity modulus of the material of the given open coiled helical spring.

**Theory:** Definitions of:- Spring constant, proof load, Differentiation between

- i) Open and close coiled helical springs.
- ii) Leaf and helical springs.

**Test Setup:**

- Universal Testing Machine (UTM)
- Slide caliper, scale.

**Procedure:**

- Measure the mean coil diameter and the wire diameter. Record the number of coils and determine the angle of helix.
- Place the spring on the bottom cross head, and see that the middle cross head is in contact with the top of the spring. Set the linear scale in the UTM to zero.
- Select a proper load range (0 to 4 t), apply a gradual compressive load on the spring. Record the axial compression at regular intervals of 20 kg.
- Take about ten readings, and then, release the load.
- Switch off the machine.

**Observations:**

2. Number of coils =  $n =$  \_\_\_\_\_
3. Mean coil diameter =  $D =$  \_\_\_\_\_ cm
4. Diameter of the wire =  $d =$  \_\_\_\_\_ cm
5. Mean pitch =  $P =$  \_\_\_\_\_ cm
6. Angle of helix =  $\alpha = \tan^{-1} (p/\pi D) =$  \_\_\_\_\_
7. Young's modulus of the material of the spring =  $E =$  \_\_\_\_\_  $2 \times 10^6 \text{ kg/cm}^2$ .

**Calculations:**

1. Spring constant = Slope of the straight line portion of the load compression graph =  $K =$  \_\_\_\_\_ kg/cm.
2. Modulus of rigidity of the material of the spring. 
$$\frac{\cos^2 \alpha}{\frac{d^4 \cos \alpha}{8 \pi D^3 K} - \frac{2 \sin^2 \alpha}{E}} =$$
 \_\_\_\_\_ kg/cm<sup>2</sup>.

**Results and Conclusion:**

Load – compression data sheet for compression test on open coiled helical spring:

Pin kg LOAD	Compression $\delta$ in cm

