University of Global Village (UGV), Barishal

Materials Testing I (Structural)

Content of Laboratory Course

Prepared By
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Program: B.Sc. in CE

BASIC COURSE INFORMATION

Course Title	Materials Testing I (Structural)
Course Code	CE 0732-2104
Credits	01
CIE Marks	30
SEE Marks	20
Exam Hours	2 hours (Semester Final Exam)
Level	4th Semester

Materials Testing I (Structural)

COURSE CODE: CE 0732-2206

CREDIT:01

TOTAL MARKS:50

CIE MARKS: 30

Semester End Exam Hours 2

SEE MARKS: 20

Course Learning Outcomes (CLOs): After completing this course successfully, the students will be able to-

CLO 1	**Explain the** mechanical properties of materials used in different applications.
CLO 2	**Solve** practical problems by evaluating the relationship between stress and strain
CLO 3	**Examine** the effect of load on structural members and machine parts
CLO 4	**Plan** effectively to work individually and in a group

SL	Content of Course	Hrs	CLOs
1	Compressive Strength Behavior of M20 Concrete	5	CLO1
2	Determination of Slump Value	5	CLO3
3	Tensile Strength Behavior of low strength (16mm) Steel	10	CLO2, CLO4
4	Flexural Strength Behavior of Beam	10	CLO1, CLO3
5	Tensile Splitting Test of Concrete	10	CLO1
6	Hardness Test of Metal Specimens	10	CLO3
7	Impact Test of Metal Specimen	10	CLO1
8	Direct Shear Test of Metal Specimens	10	CLO1
9	Compression Test of Timber Specimen	7	CLO3
10	Lab Test, Viva, Quiz, Overall Assessment, Skill Development Test (Competency)	8	CLO2, CLO4

Text Book:

1. Singer, F. L., & Pytel, A. (1980). *Strength of materials*. New York: Harper & Row.
2. Beer, F. P., E Russell Johnston, Dewolf, J. T., & Mazurek, D. F. (2015).
3. "Mechanics of Materials" by Ferdinand P. Beer, E. Russell Johnston Jr., John DeWolf, and David Mazurek
4. "Materials Science and Engineering: An Introduction" by William D. Callister Jr. and David G. Rethwisch
5. "Materials Testing Practice" by S.T. Mileiko and R.A. Ainsworth
6. "Non-Destructive Testing of Materials and Structures" by R.E. Green Jr.

ASSESSMENT PATTERN

CIE- Continuous Internal Evaluation (30 Marks)

SEE- Semester End Examination (20 Marks)

SEE- Semester End Examination (60 Marks) (should be converted in actual marks (20))

Bloom's Category	Tests
Remember	**05**
Understand	**07**
Apply	**08**
Analyze	**07**
Evaluate	**08**
Create	**05**

CIE- Continuous Internal Evaluation (60 Marks) (should be converted in actual marks (30))

Bloom's Category Marks (out of 60)	Lab Final (30)	Lab Report (10)	Continuous lab performance (10)	Presentation & Viva (10)	External Participation in Curricular/Co-Curricular Activities (10)
Remember	05			02	Attendance 10
Understand	05	05	02	03	
Apply	05		02		
Analyze	05		02		
Evaluate	05	05	02		
Create				05	

Couse plan specifying content, CLOs, teaching learning and assessment strategy mapped with CLOs

Week	Topic	Teaching-Learning Strategy	Assessment Strategy	Corresponding CLOs
1	Compressive Strength Behavior of M20 Concrete	Lecture, discussion, Experiment	Quiz, Lab Test	CLO1
2-3	Determination of Slump Value	Oral Presentation, Project Exhibition	Lab Report Assessment, viva	CLO3
4-5	Tensile Strength Behavior of low strength (16mm) Steel	Presentation, Field visit	Skill Development Test	CLO2, CLO4
6-7	Flexural Strength Behavior of Beam	Lecture, discussion, Experiment, Demonstration	Quiz, Lab Test	CLO1, CLO3
8-9	Tensile Splitting Test of Concrete	Oral Presentation, Project Exhibition	Lab Report Assessment, viva	CLO1
10-11	Hardness Test of Metal Specimens	Presentation, Field visit	Skill Development Test	CLO3
12-14	Impact Test of Metal Specimen	Lecture, discussion, Experiment	Quiz, Lab Test	CLO2, CLO4
15	Direct Shear Test of Metal Specimens	Presentation, Field visit	Skill Development Test	CLO3
16	Compression Test of Timber Specimen	Lecture, discussion, Experiment	Quiz, Lab Test	CLO2, CLO4
17	Lab Test, Viva, Quiz, Overall Assessment, Skill Development Test (Competency)	Presentation, Field visit	Skill Development Test	CLO3

Mechanics of Solids-I Sessional

CE 0732-2206

Department of Civil Engineering

University of Global Village (UGV), Barishal

Preface

The Mechanics of Solids Sessional Lab Manual describes the experiments in the Mechanics of Solids Sessional course. Each experiment is explained thoroughly along with related theory and background. The experiments are selected to apply some concepts from strength of materials such as analysis of material properties based on tension, compression, hardness, bending, buckling, direct shear, impact, torsion, behavior of spring etc. This is one of the vital laboratory courses in the curriculum of the Bachelor of Civil Engineering program. Students can learn variety of engineering and structural materials and their mechanical and engineering properties, different testing procedure and testing standards, testing equipment, materials stress-strain behavior and failure patterns, types of materials based on characterization, report writing process and evaluation of the experimental results and so on. In civil engineering profession, the use of structural behavior and understanding the quality of product will be discussed in this course. Some complementary topics are also presented such as using of measuring tools like digital slide calipers. The use of these tools will help the students to understand how to measure objects precisely, which is a crucial skill in lab. Experimental data analysis techniques and graph formation in MS Excel are also discussed to help the students to prepare graphs.

The authors are highly indebted to their colleagues for their constant support and guidance during the course of preparing this manual. In addition, concepts were taken solid mechanics books by Singer/Bansal and AUST manual, while the pictures were collected from the internet.

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The ACI Method of Mix Design

Example Problem:

Data Known:

Specified strength = 20 MPa

Required Slump = 50 mm

Maximum size of aggregate = 20 mm

FM of fine aggregate = 2.20

Grading of aggregate as satisfied by by ASTM C33

SSD specific gravity of fine and coarse aggregate = 2.65

Rodded bulk density of coarse aggregate = 1600 kg/cubic m

Absorption Capacity of coarse aggregate = 0.5 %

Absorption Capacity of fine aggregate = 0.7%

Moisture Content of fine and coarse aggregate = Zero

Exposure Conditions = Normal

Type of Construction	Range of slump mm
Reinforced foundation walls and footings	20-80
Plain footing, cassions and substructure wall	20-80
Beams and Reinforced Wall	20-100
Building Column	20-100
Pavement and Slabs	20-80
Mass Concrete	20-80

- Decide maximum size of aggregate to be used. Generally, **for RCC work 20 mm** and for **pre-stressed concrete 10 mm** size are used.

- **specific gravity, is the ratio of the density of a substance to the density of a given reference material.**

Type of soil	Specific gravity
Sand	2.65-2.67
Silty sand	2.67-2.70
Inorganic clay	2.70-2.80
Soil with mica or iron	2.75-3.00
Organic soil	1.00-2.60

SOLUTION:

Step 1: Specified Strength.

The first step is the determination of specific strength
In this case the specified strength is given as **20 MPa**

Step 2: Target Strength.

Design average strength = fcr = fc + 7.0
= 20 +7 = 27 MPa

where,

fc = Characteristic/Specified Strength of concrete.

fcr = Target strength of concrete.

Note:

Specified Strength is the result of the actual compression testing done of properly prepared, cured and tested samples.

Whereas, Target strength implies what it was supposed to be, according to its designers.

If previous statistical data is not given then, the required average strength is determined according to the ACI code as follows:

$fcr \geq fc + 7.0$ MPa for $fc \leq 21$ MPa

$fcr \geq fc + 8.5$ MPa for $fc = 21$ to 35 MPa

$fcr \geq 1.1fc + 5.0$ MPa for $fc > 35$ MPa

Step 3: Water/Cement Ratio.

Water/Cement ratio of the concrete mix will depend upon the target strength of concrete mix. The following table show the relationship between the two by proposed by ACI Code.

Average Compressive strength at 28 days (MPa)	Effective water/cement ratio by mass for Non-Air Entrained Concrete
45	0.38
40	0.43
35	0.48
30	**0.55**
25	**0.62**
20	0.70
15	0.80

As in our case the target strength is 27 MPa for which the required water/cement ratio is not given so we will find the required value using interpolation.

Strength	W/C ratio
30 MPa	0.55
27 MPa	?
25 MPa	0.62

W/C ratio = 0.55 + (0.62-0.55) / (30-25) = 0.59

Step 4: Water Content.

The water content of cement depends upon the slump value and the maximum aggregate size. The following table shows the relationship between them as proposed by the ACI code.

Workability (Slump)	Water Content of Concrete for Maximum Aggregate Size (mm) for Non-Air Entrained Concrete				
	10	**12.5**	**20**	**25**	**40**
30 – 50	205	200	185	180	160
80 – 100	225	215	200	195	175
150 – 180	240	230	210	205	185
Approximate Entrapped Air Content Percent	3	2.5	2.0	1.5	1.0
Recommended Avg. Air Content percent for **Mild Exposure** **Moderate Exposure** **Extreme Exposure**	 4.5 6.0 7.5	 4.0 5.5 7.0	 3.5 5.0 6.0	 3.0 4.5 6.0	 2.5 4.5 5.5

So as in our case the mixing water content for non-air entrained concrete with a slump of 50 mm and maximum aggregate of 20 mm is **185 kg/cubic m** (from table)

Step 5:

The approximate entrapped air content is **2%**.

Step 6:

Cement Content: Cement content can be calculated by the ratio between water content to W/C ratio.

Cement Content = Water Content / W/C Ratio

= 185/0.59

= 314 kg/cubic meter

Step 7: Mass of Coarse Aggregate.

It depends upon maximum size of aggregate and fineness modulus of fine aggregate.

The following table shows the relation as proposed by ACI.

Maximum Size of Aggregate	Dry bulk volume of Rodded Coarse Aggregate per unit volume of concrete for fineness modulus of sand of:							
	1.6	**1.8**	**2.0**	**2.2**	**2.4**	**2.6**	**2.8**	**3.0**
10	0.56	0.55	0.54	0.52	0.50	0.48	0.46	0.44
12.5	0.65	0.64	0.63	0.61	0.59	0.57	0.55	0.55
20	0.72	0.71	0.70	**0.68**	0.66	0.64	0.62	0.60
25	0.77	0.76	0.73	0.73	0.71	0.69	0.67	0.65
40	0.81	0.80	0.79	0.77	0.75	0.73	0.71	0.69
50	0.84	0.83	0.82	0.80	0.78	0.76	0.74	0.72
70	0.86	0.85	0.85	0.84	0.82	0.80	0.78	0.76
150	0.91	0.90	0.89	0.88	0.87	0.85	0.86	0.81

In this case as maximum size of aggregate is 20 mm and fineness modulus of fine aggregate is 2.20 So dry bulk volume of the aggregate per unit volume of concrete = **0.68**.

Volume of SSD coarse aggregate required = 0.68 cubic m/cubic m of concrete

Mass of coarse aggregate = 0.68 * 1600 (Rodded bulk density of Coarse aggregate)

Mass of coarse aggregate = **1088 kg/cubic m**

Step 8: Mass of fine aggregate.

Specific gravity of fine aggregate = Yf = 2.65

Water content = W = 185 kg/cubic m

Cement content = C = 314 kg/cubic m

Specific gravity of cement = Y = 3.15

Mass of coarse aggregate = Ac = 1088 kg/cubic m

Specific gravity of coarse aggregate = Yc = 2.65

Air content = 2 %

Mass of fine aggregate = Yf [1000- (W + C/Y + Ac/Yc + 10A)]

= 2.65 [1000- (185 + 314/3.15 + 1088/2.65 + 20)]

= 755 kg/cubic m

Step 9:

Extra water required for absorption of Aggregate = 0.005 * 1088 (Ac) + 0.007 * 755 (Af)

= 10.73 kg/cubic m

Total water content = 185 + 10.73 = 196 kg/cubic m

Note:

If excess water is present in the aggregate the required water is to be reduced accordingly.

Step 10:

The quantities of the mix of 1.0 cubic m are as under:

Cement	:	314 kg/cubic m
Fine aggregate	:	755 kg/cubic m
Coarse Aggregate	:	1088 kg/cubic m
Water	:	196 kg/cubic m

The mix ratio is as follows :

Cement : Fine Aggregate : Coarse Aggregate = 314 : 755 : 1088

= 1 : 2.40 : 3.46

Aggregate / Cement ratio = 5.87

W/C ratio = 0.59

Week 1

1.0 Introduction

The Concrete Cube Crushing Test is determined the Compressive Strength of hardening concrete. Via this test determined the specification of concrete fulfills required. Compressive Strength means the ability of the structure to carry the loads on its surface without any deflections or cracks. In here, under compression, the size of the structure is reduced.

❖ **The Formula of Compressive Strength of Hardening Concrete**

$$\textbf{Compressive Strength} = \frac{\textbf{\textit{Maximum Load}}}{\textbf{\textit{Cross} - \textit{Sectional Area}}}$$

After removing cubes the age of 3, 7, 14, 21 and 28 days in curing bath, the cube test can be done for the harden concrete cubes. Day by day, the compressive strength of concrete increased. Therefore, The compressive strength of concrete increases according to age. The 28 days concrete strength considered as the standard day for most of the concrete works. The temperature and moisture affect the increment rate of the concrete strength in the hardening process. The Grade 30 (M30) concrete mix is used in the Cube Test. Followings are the factors affecting the compressive strength of concrete.

- Water-Cement ratio
- Cement Strength
- Quality of concrete materials
- Quality control during production of concrete

2.0 Apparatus & Materials

➢ **Apparatus**

Figure 1 - Concrete Cube Test kit set (Anon., n.d.)

1. **Compression Testing Machine**

Figure 2 - Compression Testing Machine (Anon., n.d.)

➢ The Compression Strength Machine is used to test the Compressive Strength of hardening concrete.

2. **Steel Cube Mold**

Figure 3 - Steel Cube Molds (Anon., n.d.)

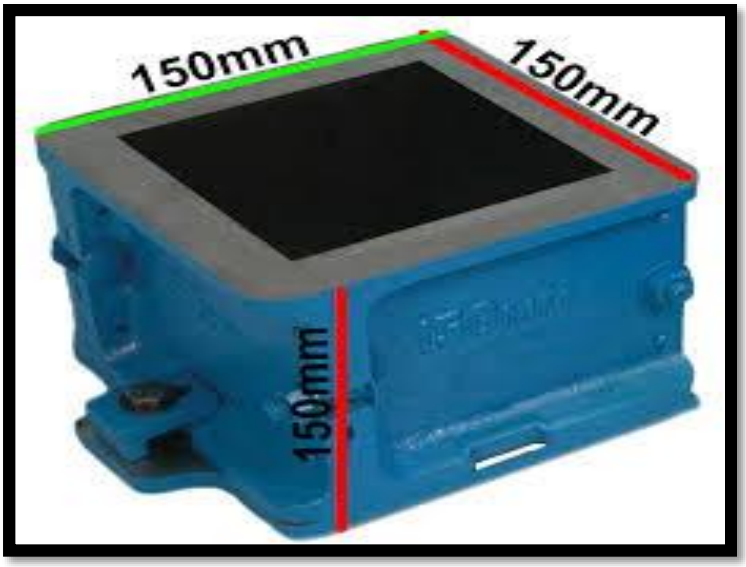


Figure 4 - Measurements of a Cube Mold (Anon., n.d.)

- The Steel Cube Molds is used to place the fresh concrete for the hardening process.

3. **Steel Rod**

- The Steel Rod is used to compact each concrete layer to remove the air voids and subsequent layers penetrate into the underlying layer.
- Height of Steel Rod – 60 cm
- Length of Steel Rod – 25 mm

- Width of Steel Rod – 25 mm

Figure 5 - Steel Rod (Anon., n.d.)

4. **Hand Float**

Figure 6 - Hand Float (Anon., n.d.)

- Hand Float is used to level (plate) the surface in the over concrete layer.

Materials

1. **Cement, Sand, Aggregates & Water**

Figure 7 - Materials of Concrete mix (Anon., n.d.)

Materials	Cement (kg)	Fine Aggregate (kg)	Coarse Aggregate (kg)	Water (kg or liters)
Quantities	3.465	1.87	6.105	15.62

Table 1 - Quantities of using materials of concrete mix

- Mix ratio of Cement : Fine Aggregate : Coarse Aggregate = 1 : 2 : 4

2. **Grease**

Figure 8 - Grease (Anon., n.d.)

- Grease oil is used to prevent the concrete from sticking to the cube mold.

3.0 Procedure

1. The mold that was used in the cube test must be cleaned internally using the wire brush. Because remove any residual particles from previous concrete tests.

2. The interior surface of the assembled mold was required to be thinly coated with grease oil to prevent adhesion of concrete.

3. The mixed concrete was poured with a certain mix proportion into the mold in 3 layers and each layer was must be tamped 35 times using the compacting steel rod. The mold was filled up until overflow and leveled the surface using the hand float.

Figure 9 - How the group members were filled the cubes and compacted each layer 35 times using the steel rod

4. The concrete mixture cube was left for 24 hours setting.

5. The above steps were should be repeated for another 2 more cubes with the same mix proportion.

6. The date of the mixture was recorded for every cube and all 3 cubes were submerged in the curing tank at the temperature of 18 degrees Celsius – 20 degrees Celsius. Tested on the 7th day.

7. After the 7th day, When the cube was fully matured it should be weighted and recorded.

Figure 10 - A harden concrete cube looks like after 7 days

Cube No.	Cube Weight (kg)
1	**8.28**
2	**8.58**
3	**9.11**

Table 2 - Record measurements of cube weight were taken from the Cube Test

8. The cube was placed to be tested at the center plate of the compression machine. Both plates were in contact with the lower surface of the concrete plate and it was ensured by them. The load value was released to raise up the bottom plate until the cube touches the above plate. The maximum load that would crush the tested cube was recorded.

Figure 11 - The cube was placed at the center plate of the compression machine for testing

9. The above steps were repeated using the other cubes. Accordingly, the result was recorded by him.

Cube No.	Maximum Load (Peak value)
1	**332.00**
2	**350.28**
3	**396.47**

Table 3 - Record measurements of maximum load to bear each cube were taken from the Cube Test

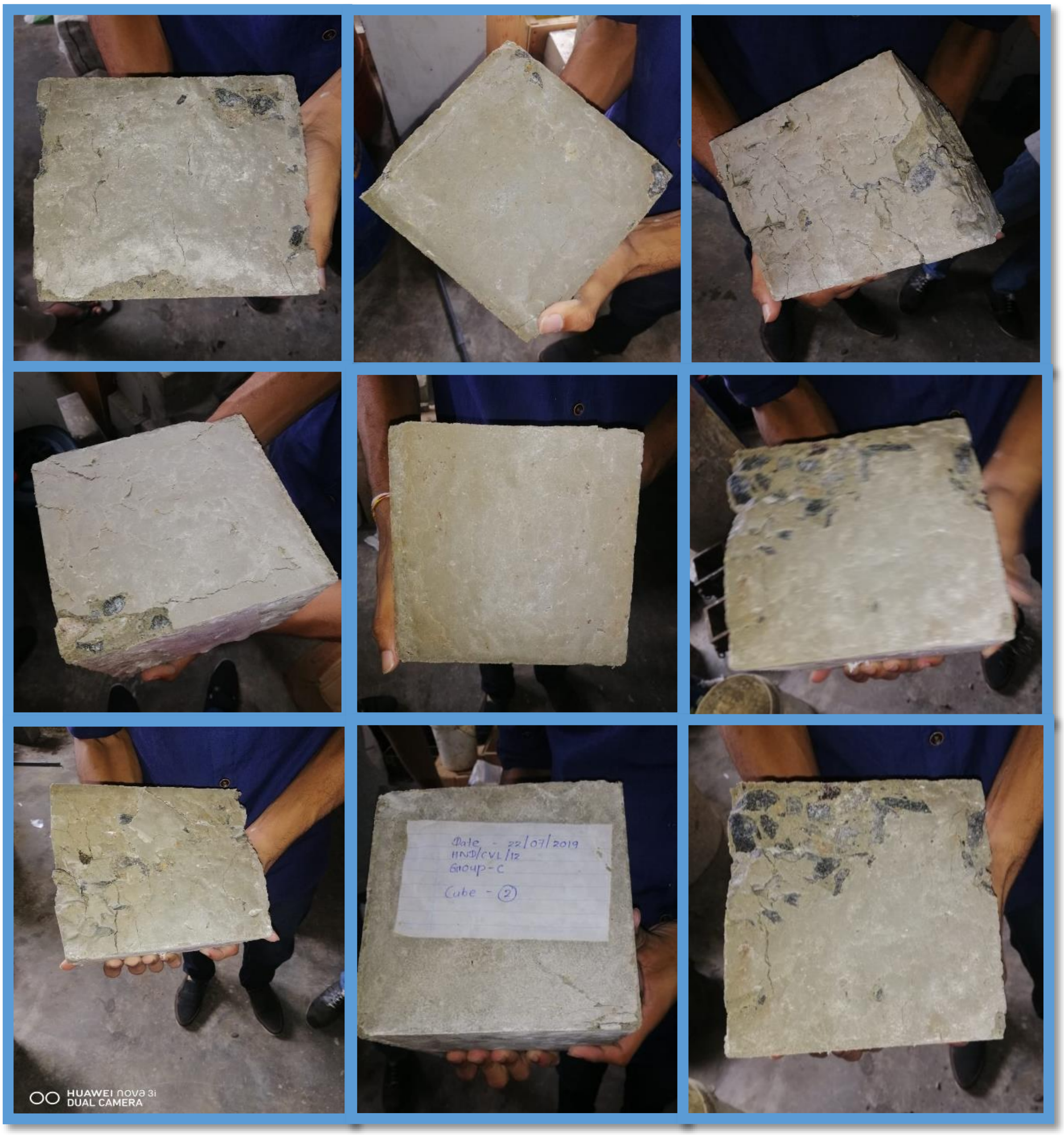


Figure 12 - After the cube test, how all 3 cubes were shown

4.0 Results

Table 4 - Calculation the Average of Cube Weight and Average of Compression Strength

Cube No.	Date of Cube made	Date of Testing	Age during testing	Cube Weight (kg)	Compression Strength (MPa)
1	22/07/2019	31/07/2019	7 days	**8.28**	**14.75**
2	22/07/2019	31/07/2019	7 days	**8.58**	**15.56**
3	22/07/2019	31/07/2019	7 days	**9.11**	**17.62**
Average				**8.65**	**15.97**

Calculations:

- **Average of Cube Weight** = $\frac{(8.28 + 8.58 + 9.11)\text{kg}}{3}$

  = **8.65 kg**

- Percentage of Compressive Strength in 7 days = 65%

  The Grade 30 (M30) concrete mix is used in the Cube Test. It means the Compressive Strength of 30N/mm^2 in 28 days.

  Thus,

  Compressive Strength for Grade 30 (M30) concrete after 7 days = $30\text{Nmm}^{-2} \times \frac{65}{100}$

  = $\underline{\underline{19.5\ \text{Nmm}^{-2}}}$

- Size of Cube = 150mm x 150mm x 150mm

Area of Concrete Cube = 150mm x 150mm

= <u>22 500mm²</u>

- Compressive Strength $= \frac{\text{Maximum Load}}{\text{Cross-Sectional Area}}$

- Compressive Strength of Cube 1 $= \frac{332.00 \times 1000 \text{ kN}}{22\,500 \text{ mm}^2}$

  = **14.75 MPa**

- Compressive Strength of Cube 1 $= \frac{350.28 \times 1000 \text{ kN}}{22\,500 \text{ mm}^2}$

  = **15.56 MPa**

- Compressive Strength of Cube 1 $= \frac{396.47 \times 1000 \text{ kN}}{22\,500 \text{ mm}^2}$

  = **17.62 MPa**

Average of Compressive Strength in Concrete Cubes $= \frac{(14.75+15.56+17.62)\text{MPa}}{3}$

= **15.97 MPa**

- Standard Deviation $= \sqrt{\frac{\sum(x-\bar{x})^2}{n-1}}$

$$= \sqrt{\frac{(14.75-15.97)^2+(15.56-15.97)^2+(17.62-15.97)^2}{3-1}}$$

$$= \sqrt{\frac{(-1.22)^2+(-0.41)^2+(1.65)^2}{2}}$$

$$= \sqrt{\frac{1.4884+0.1681+2.7225}{2}}$$

$$= \sqrt{\frac{4.379}{2}}$$

= 1.4796 MPa = **1.48 MPa**

5.0 Discussion

1. Why the inner surface of the mold shall be coated with the grease oil?

➢ The inner surface of the mold shall be coated with the grease oil because to prevent leakage during filling the concrete and to prevent the concrete from sticking to it, otherwise, the hardening concrete cube won't release from the mold.

2. How can the value of standard deviation describe the strength and quality of the concrete?

➢ Standard Deviation indicates the deviation of a set of variables from the mean value. The less the standard deviation value is, the more values are close together and indicates more consistency results. It is a measure of how the strength behavior of the concrete is changing. That when the cubes are tested compressive strength the range of minimum and maximum value determine the SD. Its value increases along with the strength of cement required, as much more accuracy is required for making high strength grade mixture. SD will be less if the quality at the materials of a concrete mixture is better and if the quality is poor, the SD will be high. Thus, Standard Deviation inversely proportional to the Quality of concrete. It is best if our compressive strength value is a bit less than our minimum range of strength.

According to our cube test results, our SD value is 1.48. Thus, it is a very low value. Therefore, the strength and quality of our concrete are very high.

3. Describe how the strength can be affected with the variation of water cement ratio?

➢ The ratio of the amount of water to the amount of cement by weight is known as the "water-cement ratio". The strength of concrete depends on this ratio. In a hardened concrete, strength is inversely proportional to the water/cement ratio. The quantity of water added to the cement while preparing concrete mixes has been known to exert tremendous influence on the quality of concrete. Water affects the durability and strength of concrete.

The relation between the water-cement ratio and the strength of concrete in 28 days is shown in the below figure. Compressive strength is high when the water-cement ratio is low. The lower water-cement ratio could be used when the concrete is vibrated to achieve higher strength. The lower water-cement ratio means less water, or more cement and lower workability.

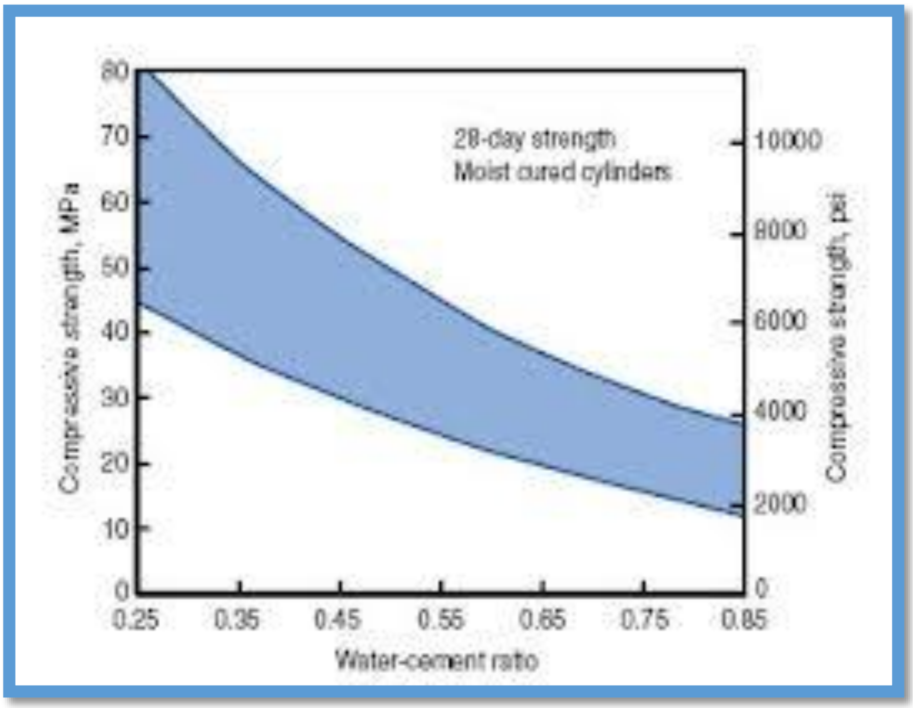


Figure 13 - Water-Cement ratio versus Strength

✓ When the water-cement ratio is high

- If the W / c ratio is high, a large quantity of water can be obtained per unit weight of cement in the concrete mix. Then some water will still be left when the concrete hardens and is ready for use. This trapped water was evaporated, leaving some air voids in the concrete block. The presence of voids results in reduced strength.

✓ When the water-cement ratio is low

- In this case, there will be very less amount of water in the block of formwork when the concrete is poured into it, and hence lesser voids.

Therefore, low water and cement ratio can cause serious problems in hard concrete. Thus, the water-cement ratio is the most important factor in the concrete.

6.0 Conclusion

- In the Cube Test is determined the Compressive Strength of hardening concrete.
- The apparatus of the cube molds, steel rod, hand float, and compression testing machine (CTM) are used for doing the cube test.
- The ratio of cement, fine aggregate, coarse aggregate and water to 1: 2: 4: ½ were used to prepare the concrete mixture.
- The Grade 30 (M30) concrete mix is used in the Cube Test.
- After removing cubes the age of 3, 7, 14, 21 and 28 days in curing bath, the cube test can be done for the harden concrete cubes.
- After 28 days, the compressive strength of hardening concrete is very high.
- We were done our cube test after 7 days.
- According to our results, we were done our cube practical test in very successfully.
- But some of the factors such as the first time we added water, we got a dry mix and after we added water, then the concrete mix is too wet, the top surface was absorbed some water from the concrete mix, the cement is spread through the air because of the wind and when mixing the material of concrete mix, they were spread everywhere and some of the cubes are loose, therefore that cubes can't be fixed properly were affected our cube test results.
- However, our cube practical test was a success and we got the idea such as how to do the cube test, the situation of freshly mixed concrete and how to do the practicals in the practical lab with safety, how to use the material of concrete, how to prepare the good concrete mix are some of them.

Table 5 - The Compressive Strength of concrete at different Ages (Anon., 2014)

Age	Percentage of Compressive Strength
1 day	**16%**
3 day	**40%**
7 day	**65%**

14 day	**90%**
28 day	**99%**

Table 6 - Compressive Strength of Different Grades of Concrete at 7 and 28 Days (Anon., 2014)

Grade of Concrete	Minimum compressive strength N/mm^2 at 7 days	Specified characteristic compressive strength (N/mm^2) at 28 days
M15	10	15
M20	13.5	20
M25	17	25
M30	20	30
M35	23.5	35
M40	27	40
M45	30	45

- Finally, I would like to thank our guide Ms. Eeshani Perera in our practical tests to give your knowledge clearly to us.
- And also, I think these practical tests benefit a lot on my subject and for my future as it prepares me to overcome many upcoming problems. Overall, it was a great experience for me.

Week 2-3

Tests on Fresh Concrete:

Slump Test

Objective

To determine the relative consistency of freshly mixed concrete.

Standards : ASTM C 143 and BS 1881 : 103

Principles

- Slump test is the most commonly used method of measuring consistency of concrete which can be employed either in laboratory or at site of work.
- It is not a suitable method for very wet or very dry concrete.
- It does not measure all factors contributing to workability, nor is it always representative of the placability of the concrete.
- The slump test is used to ensure uniformity for different batches of similar concrete under field conditions and to ascertain the effects of plasticizers on their introduction.
- This test is very useful on site as a check on the day-to-day or hour- to-hour variation in the materials being fed into the mixer. An increase in slump may mean, for instance, that the moisture content of aggregate has unexpectedly increases.
- Other cause would be a change in the grading of the aggregate, such as a deficiency of sand.
- Too high or too low a slump gives immediate warning and enables the mixer operator to remedy the situation.

Apparatus :

- Slump cone (Figure 1) : metal cone with form with the base 200mm diameter and 300mm height with the top diameter 100mm. the top and base of cylindrical mould is open and parallel to each other. The mould is provided with foot pieces and handles.
- Temping rod (steel) with dimensions of 16mm diameter and 600 mm length.
- Balance.

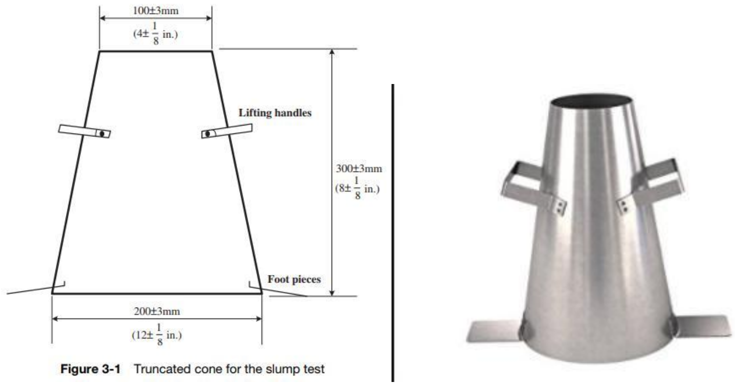


Figure (1)

Materials

Fresh concrete mix (cement, sand, gravel and water)

Test Procedure

Figure (2) illustrates the steps for slump test:

1. The base is placed on a smooth surface and the container is filled with concrete in three layers, whose workability is to be tested .
2. Each layer is temped 25 times with a standard 16 mm diameter steel rod, rounded at the end.
3. When the mold is completely filled with concrete, the top surface is struck off (leveled with mold top opening) by means of screening and rolling motion of the temping rod.
4. The mold must be firmly held against its base during the entire operation so that it could not move due to the pouring of concrete and this can be done by means of handles or foot – rests brazed to the mold.
5. Immediately after filling is completed and the concrete is leveled, the cone is slowly and carefully lifted vertically (Figure 3), an unsupported concrete will now slump.
6. The decrease in the height of the center of the slumped concrete is called slump (Figure 3-step6) .
7. The slump is measured by placing the cone just besides the slump concrete and the temping rod is placed over the cone so that it should also come over the area of slumped concrete.
8. The decrease in height of concrete to that of mould is noted with scale. (usually measured to the nearest 5 mm.

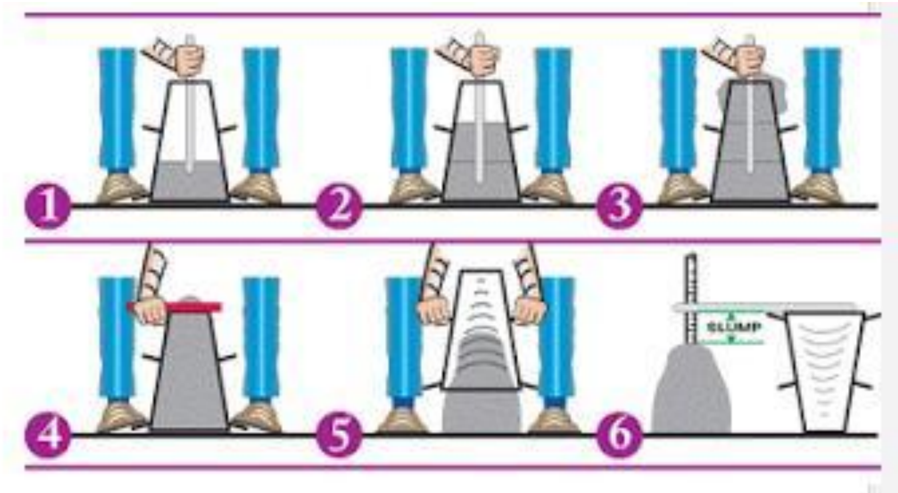


Figure (2)

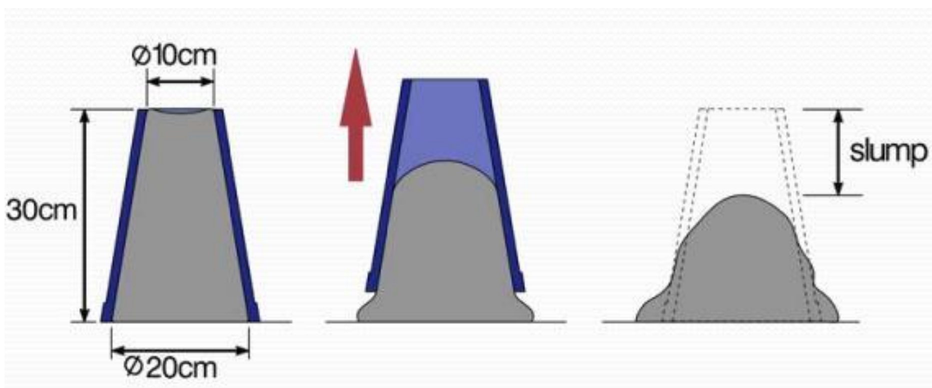


Figure (3)

Types of Slump:

The concrete slump can be classified according to the nature of concrete fall. There are 3 types of the slump (Figure 4). These are:

1. **True slump:** In a true slump concrete just subsides shortly and more or less maintain the mould shape. This type of slump is most desirable.
2. **Shear slump:** If one-half of the cone slides down in an inclined plane, it is called a shear slump. Shear slump indicates lack of cohesion in the concrete mix. Shear slump may occur in the case of a harsh mix.
3. **Collapse slump:** In this case, fresh concrete collapses completely.

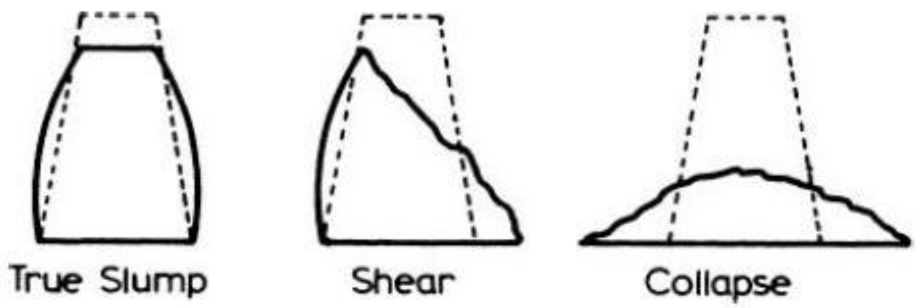


Figure (4)

Note :
Description of workability & magnitude of slump is shown in the table below:

Description of workability	*Slump* *mm*
No slump	0
Very low	5–10
Low	15–30
Medium	35–75
High	80–155
Very high	160 to collapse

Week 4-5

EXPERIMENT NO.: 4

TENSION TEST OF MILD STEEL SPECIMEN

Experiment No.: 4
Tension test of Mild Steel Specimen

1. OBJECTIVE

-To determine the mechanical properties of steel specimen.
-To perform the tensile test of mild steel.
-To observe the tensile strength of different steel grades.
-To study the failure pattern of different steel grades.
-To compare the performances different steel grades.

2. ASTM REFERENCE

ASTM E 8 Standard Test Methods for Tension Testing of Metallic Materials

3. SIGNIFICANCE

This experiment provides fundamental knowledge on tension behaviour of materials specially mild steel, test procedure, universal testing machine and its working principal, tension specimens, failure patterns etc.

4. APPARATUS AND MACHINE

UTM, stop watch, digital slide calipers and computer.

5. SPECIMEN

Mild steel specimens (40, 60, and 72.5 grades) of 25mm diameter.

6. THEORY

Elasticity & Plasticity: When external forces are applied on a body, made of engineering materials, the external forces tend to deform the body while the molecular forces acting between the molecules offer resistance against deformation or displacement of the particles continues till full resistance to the external forces is setup. If the forces are now gradually diminished, the body will return, wholly or partly to its original shape. Elasticity is the property by virtue of which a material deformed under the load is enabled to return to its original dimension when the load is removed. If a body regains completely its original shape, it is said to perfectly elastic.

Plasticity is the converse of elasticity. A material in plastic state is permanently deformed by the application of load, and it has no tendency to recover. Every elastic material possesses the property of plasticity. Under the action of large forces, most engineering materials become plastic and behave in a manner similar to a viscous liquid. The characteristic of the material by which it undergoes inelastic strains beyond those at the elastic limit is known as plasticity. When large deformations occur in a ductile material loaded in the plastic region, the material is aid to undergo plastic flow.

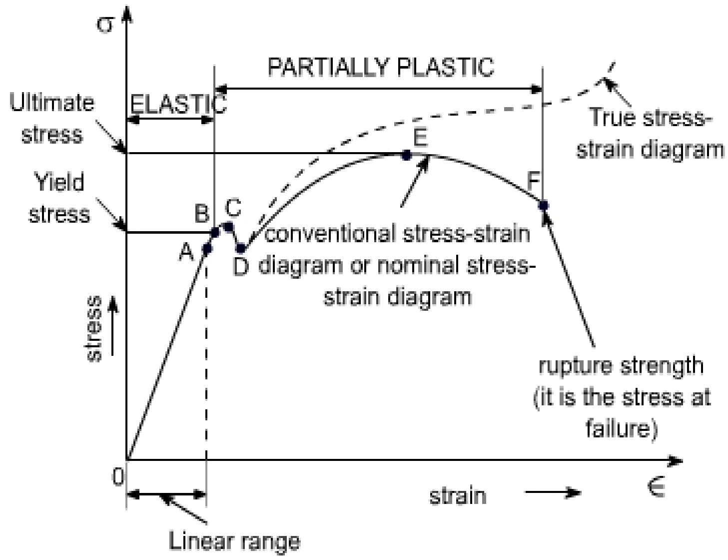


Figure 1: Stress-strain diagram of Mild Steel in tension

Proportional Limit (Point A): It is the limitingvalue of the stress upto which stress is proportional to strain.

Elastic Limit (Point B): This is the limiting value of stress upto which if the material is stressed and then released (unloaded), strain disappears completely the original length is regained. Its determination, experimentally, is extremely difficult, and therefore its exact location on the stress-strain diagram is usually not known, even though it is generally higher than the proportional limit.

Permanent set/permanent deformation: If the load exceeds the elastic limit before it is removed, the material does not fully regain its initial dimensions. In such a case the material is said to experience a permanent deformation.

Elastic Recovery: The recovered deformation after removal of load.

Yield stress (Point C and D): Soon after the stress the elastic limit, low carbon steel attains it yield point stress. The yield point of a material is defined as that unit stress that will cause an increase in deformation without an increase in load. Upon the arrival of yield point, a ductile material such as low carbon steel stretches an almost unbelievable amount, frequently 10%of the original length. When the yield stress is reached elongation takes place more rapidly as plastic flow takes place over and atoms move into new positions and a return to the original shape of the test piece is impossible.

Upper Yield Point (Point C): This is the stress at which the load starts reducing and the extension.

Lower Yield Point (Point D): At this stage the stress remains same but strain increases for some time.

The upper yield point is influenced considerably by the shape of the test specimen, speed of testing, accuracy of alignment , the condition of the test piece (especially the presence of residual stresses in a test on the full cross section) and by the testing machines itself and is sometimes completely suppressed. The lower yield points much less sensitive and is considered to be more representative.

Yield Strength by Offset Method: For materials having a stress-strain diagram such as shown in figure (those that do not exhibit a well-defined yield point) a value of stress, known as the yield strength for the material, is defined as one producing a certain amount of permanent strain.

Ultimate Strength/Tensile Strength (Point E): This is the maximum stress the material can resist. The ultimate strength represents the ordinate to the highest point in the stress-strain diagram and is equal to the maximum load carried by the specimen divided by the original cross-sectional area.

Breaking Strength/Fracture Strength/Rupture Strength (Point F): The stress at which finally the specimen fails is called breaking point. It is the engineering stress at which specimen fracture and complete separation of the specimen parts occurs.

Strain Hardening/Work Hardening: If a ductile material can be stressed considerable beyond the yield point without failure, it is said to strain harden (When a material deformed plasticity, it work hardens, that is, the stress has to be increased to give further deformation).

Necking: After reducing the maximum stress, a localized reduction in area, called necking, begins, and elongation continues with diminishing load until the specimen breaks.

Modulus of Rigidity (G): It is defined as the ratio of shearing stress to shearing strain within elastic limit.

Modulus of Resilience: The work done on a unit volume of material, as a simple tensile force is gradually increased from zero to such a value that the proportional limit of the material is reached, is defined as the modulus of resilience.

Modulus of Rupture/ Modulus of Toughness: The work done on a unit volume of material as a simple tensile force is gradually increased from zero to the value causing rupture is defined as the modulus of toughness.

Various machine and structure components are subjected to tensile loading in numerous applications. For safe design of these components, their ultimate tensile strength and ductilityto be determined before actual use. A material when subjected to a tensile load resists the applied load by developing internal resisting force. These resistances come due to atomic bonding between atoms of the material. The resisting force for unit normal cross-section area is known as stress.

The value of stress in material goes on increasing with an increase in applied tensile load, but it has a certain maximum (finite) limit too. The minimum stress, at which a material fails, is called ultimate tensile strength.

The end of elastic limit is indicated by the yield point (load). This can be seen during experiment as explained later in procedure with increase in loading beyond elastic limit, initial cross-section area (A_i) goes on decreasing and finally reduces to its minimum value when the specimen breaks. Some typical mechanical properties of mild steel are as follows:

Proportional Limit, σ_p = 30~65 ksi (larger for stronger specimens)
Yield Strength, σ_y = 35~75 ksi (larger for stronger specimens)
Ultimate Strength, σ_{ult} = 60~100 ksi (larger for stronger specimens)
Modulus of Elasticity, E = 29000~30000 ksi (almost uniform for all types of specimens)
Poisson's Ratio, ν = 0.20~0.30 ksi (larger for stronger specimens)
Modulus of Resilience = 0.02~0.07 ksi (larger for stronger specimens)
Modulus of Toughness = 7~15 ksi (smaller for stronger specimens)
Ductility = 10~35% (smaller for stronger specimens)
Reduction of Area = 20~60% (smaller for stronger specimens)

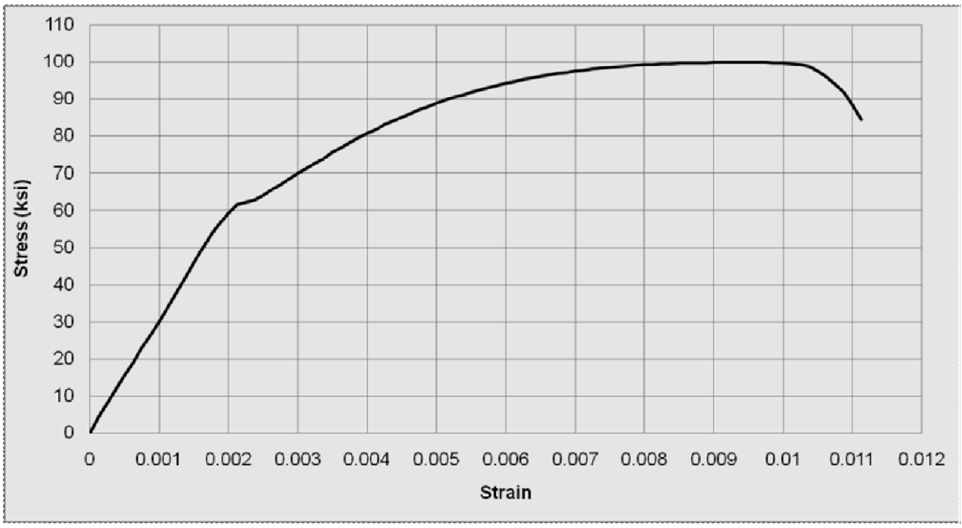


Figure 2: Typical stress-strain curve of Mild Steel in Tension done in the lab.

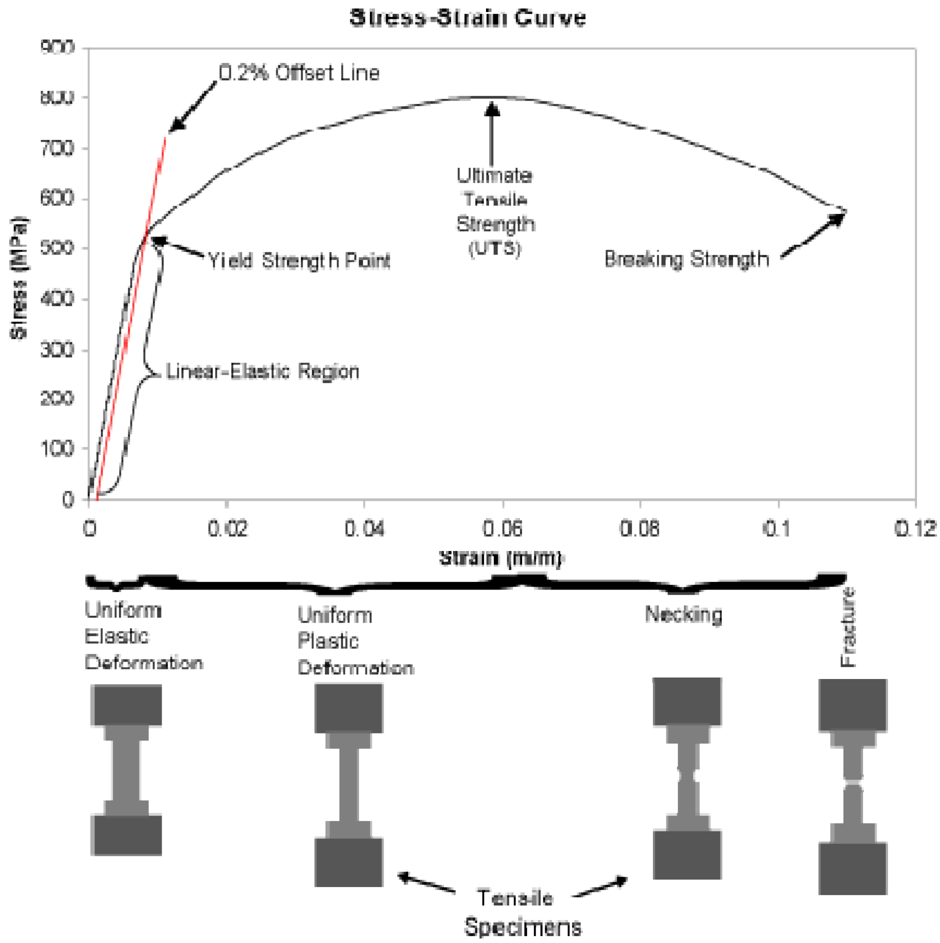


Figure 3: Specimen condition in the stress-strain curve of Mild Steel in Tension.

7. FAILURE PATTERNS

Cup-cone fracture (necking found, i.e. Ductile)

Incomplete Cup-cone fracture (necking found, i.e. Ductile)

Incomplete Cup-cone fracture (necking found, i.e. Ductile)

Figure 4: Different ductile and brittle failure patterns of mild steel specimen.

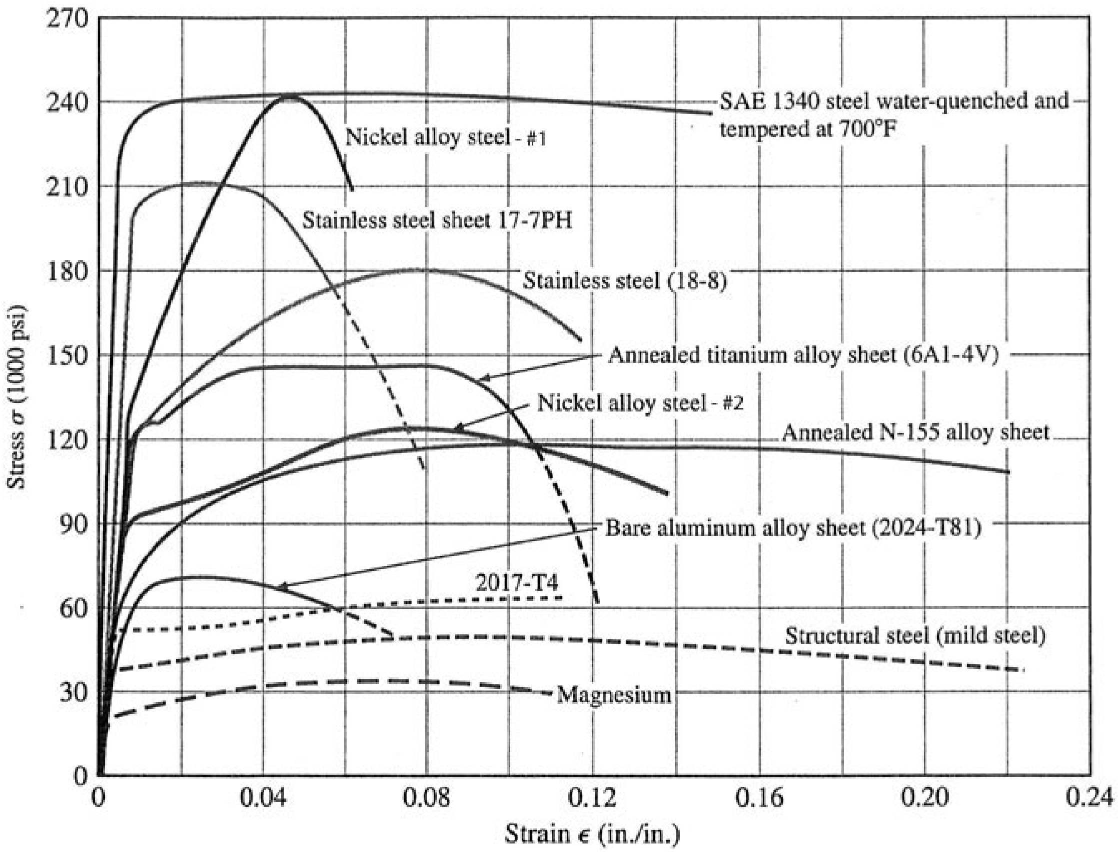


Figure 5: Comparative stress-strain diagram of different metals and alloys

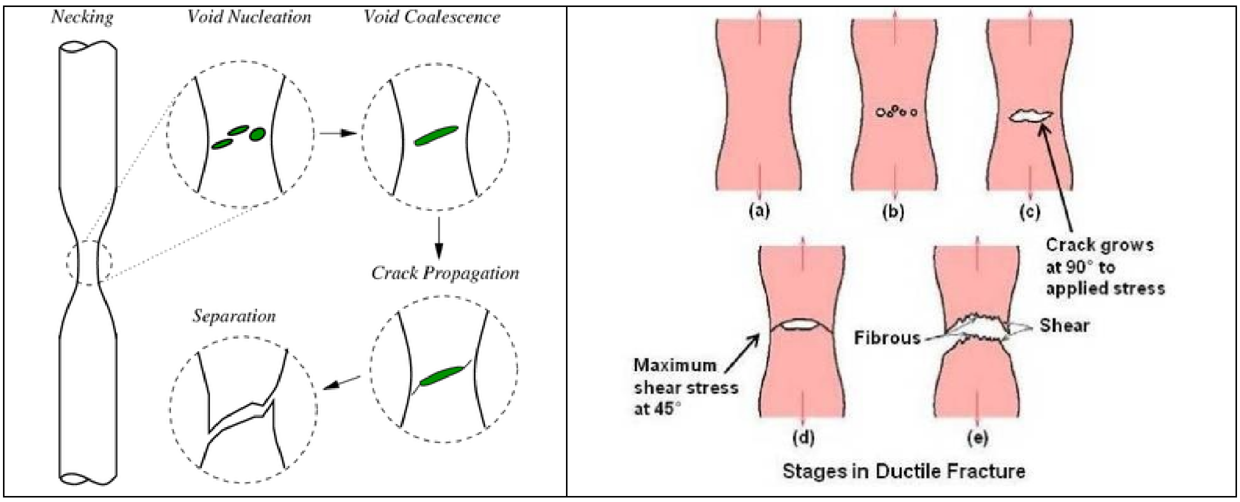


Figure 6: Mechanism of necking

Typical tension test result from BUET

TENSION TEST OF DEFORMED M.S. BARS

BRTC No.: 1100-72282/CE/14-15; Dt. 15/10/2014

Sent by: Col. Towficur Rahman(Rtd), Sr. General Manager(Marketing& Sales), Ratanpur Steel Re-rolling Mills Ltd., Nahar Mansion, 116 CDA Avenue, Muradpur, Chittagong

Project: Test of deformed MS bars for RSRM

Ref.: RSRM/BUET (BRTC)/400W&500W-8/14; Dt. 15/10/2014

Date of Test: 16/10/2014

Contractor: -

Sl. No.	Frog Mark	Nominal Dia	Actual Dia	Actual Unit Weight	Average Actual Unit Weight	Yield or Proof Load	Yield or Proof Strength *	Average Yield or Proof Strength (YS)	Ultimate Load	Ultimate Strength *	Average Ultimate Strength (TS)	TS/YS	Elongation (%) (Gauge length = 203.2 mm)	Average Elongation (%) (G. length = 203.2 mm)	Bend Test (ISO 6935)	Rebend Test (ISO 6935)
		mm	mm	kg/m	kg/m	kN	MPa	MPa	kN	MPa	MPa					
1	RSRM.G60.400W	25	**24.8**	3.795		225	**458**	**469**	368	**750**	**725**		**19**		Satisfactory	-
2	RSRM.G60.400W	25	**24.9**	3.809	**3.810**	226	**460**	(68000 psi)	339	**690**	(105000 psi)	**1.54**	**20**	**20**	Satisfactory	-
3	RSRM.G60.400W	25	**24.9**	3.825		240	**489**	(4780 kg/sq.cm)	363	**740**	(7390 kg/sq.cm)		**20**		Satisfactory	-
4	RSRM.G60.400W	20	**19.9**	2.441		140	**446**	**452**	216	**690**	**700**		**19**		Satisfactory	-
5	RSRM.G60.400W	20	**19.9**	2.435	**2.440**	144	**459**	(65500 psi)	227	**725**	(102000 psi)	**1.55**	**16**	**17**	Satisfactory	-
6	RSRM.G60.400W	20	**19.9**	2.445		142	**452**	(4610 kg/sq.cm)	217	**690**	(7150 kg/sq.cm)		**17**		Satisfactory	-
7	RSRM.G60.400W	16	**15.9**	1.560		86.4	**430**	**425**	136	**680**	**670**		**19**		Satisfactory	-
8	RSRM.G60.400W	16	**15.9**	1.558	**1.558**	86.4	**430**	(61500 psi)	134	**670**	(97500 psi)	**1.58**	**19**	**19**	Satisfactory	-
9	RSRM.G60.400W	16	**15.9**	1.557		83.3	**415**	(4335 kg/sq.cm)	134	**670**	(6850 kg/sq.cm)		**19**		Satisfactory	-
10	RSRM.G60.400W	12	**12.0**	0.883		48	**425**	**425**	71	**625**	**625**		**18**		Satisfactory	-
11	RSRM.G60.400W	12	**12.0**	0.884	**0.884**	46.9	**425**	(61500 psi)	71	**625**	(91000 psi)	**1.48**	**18**	**18**	Satisfactory	-
12	RSRM.G60.400W	12	**12.0**	0.884		48.6	**430**	(4335 kg/sq.cm)	71	**625**	(6400 kg/sq.cm)		**19**		Satisfactory	-
13	RSRM.G60.400W	10	**10.0**	0.621		36.7	**465**	**465**	55	**700**	**700**		**15**		Satisfactory	-
14	RSRM.G60.400W	10	**10.0**	0.622	**0.624**	37.2	**471**	(67500 psi)	56	**705**	(102000 psi)	**1.51**	**15**	**15**	Satisfactory	-
15	RSRM.G60.400W	10	**10.1**	0.628		36.3	**459**	(4740 kg/sq.cm)	55	**695**	(7150 kg/sq.cm)		**16**		Satisfactory	-

8. PROCEDURE

i) Measure the diameter of the specimen by slide calipers. Record gage length.
ii) Fix the specimen in proper position and apply the load
iii) Record the maximum load and apply load till the breakage.
iv) Remove the broken specimen and measure the smallest cross-sectional area and the final length between the gage marks by fitting the two ends of the broken pieces together.
v) Note the characteristics of the fractured surface.

9. SAMPLE CALCULATIONS

Strain rate =
Initial length of specimen, h_i =
Final length of specimen, h_f =
Initial diameter of specimen, d_i =
Final diameter of specimen, d_f =
Initial cross-section area, A_i =
Final cross-section area, A_f =

1. Draw stress-strain curve in tension.

2. Determine Modulus of Elasticity,

$$E = \frac{\Delta Stress}{\Delta Strain}$$

and Modulus of Resilience in tension

3. Determine ultimate (max.) tensile strength from graph

4. Determine yield stress from graph

5. Determine percentage elongation in length (or height) of the specimen

$$\% \ Elongation \ of \ length = \frac{l_f - l_i}{l_i} \times 100\%$$

6. Determine EMF (elongation at maximum force) from graph

7. Also determine proportional limit (σ_p), elastic limit (σ_E), yield point (σ_y), ultimate load (σ_u), breaking strength (σ_b), etc.

10. DATA TABLE

Deformation rate= mm/min, Grade= ksi, Brand=							
Time (s)	**Load (N)**	**Time (s)**	**Load (N)**	**Time (s)**	**Load (N)**	**Time (s)**	**Load (N)**
0		470		560		740	
10		480		570		750	
20		490		580		760	
30		500		590		770	
40		510		600		780	
50		520		610		790	
60		530		620		800	
70		540		630		810	
80		550		640		820	
90		560		650		830	
100		570		660		840	
110		580		670		850	
120		590		680		860	
130		600		690		870	
140		610		700		880	
150		620		710		890	
160		630		720		900	
170		640		730		910	
180		650		740		920	
190		660		750		930	
200		670		760		940	
210		680		770		950	
220		690		780		960	
230		700		790		970	
240		710		800		980	
250		720		810		990	
260		730		820		740	
270		740		830		750	
280		750		840		760	
290		760		560		770	
300		770		570		780	
310		780		580		790	
320		790		590		800	
330		800		600		810	
340		810		610		820	
350		820		620		830	
360		830		630		840	
370		840		640		850	
380		470		650		860	
390		480		660		870	
400		490		670		880	
410		500		680		890	
420		510		690		900	
430		520		700		910	
440		530		710		920	
450		540		720		930	
460		550		730		940	

11. GRAPH

1. Tensile stress vs. strain curve of 40 Grade bar.
2. Tensile stress vs. strain curve of 60 Grade bar.
3. Tensile stress vs. strain curve of 72.5 Grade bar.
4. Combined Tensile stress vs. strain curve of 40, 60 and 72.5 grade bar.
5. Show all the points on the graphs 1, 2, and 3.

12. RESULT

(Students will fill up this section with their individual outcome/result about the test. Write the stress values in psi and MPa as shown in Table)

Properties	**40 grade steel**	**60 grade steel**	**72.5 grade steel (500W grade)**
E, psi (MPa)			
σ_{p}, psi (MPa)			
ε_{p}, in/in (mm/mm)			
σ_{E}, psi(MPa)			
ε_{E}, in/in (mm/mm)			
σ_{y}, psi(MPa)			
ε_{y}, in/in (mm/mm)			
σ_{u}, psi(MPa)			
ε_{u}, in/in (mm/mm)			
σ_{b}, psi(MPa)			
ε_{b}, in/in (mm/mm)			
Ductility ratio, σ_u/σ_y			
% Elongation			
TS/YS			
EMF, in/in (mm/mm)			
Failure pattern			
Failure type			

13. DISCUSSION

(Discuss on the results found, graphs, and failure patterns and also compare the results found, graphs and failure patterns.) Point out the discussion

14. ASSIGNMENT

1. Which type of steel have you tested? What is its carbon content?
2. What general information is obtained from tensile test regarding the properties of a material?
3. Which stress have you calculated: nominal/engineering stress or true stress?
4. What kind of fracture has occurred in the tensile specimen and why?
5. Which is the most ductile metal? How much is its elongation?

Week 6-7

EXPERIMENT No. 5

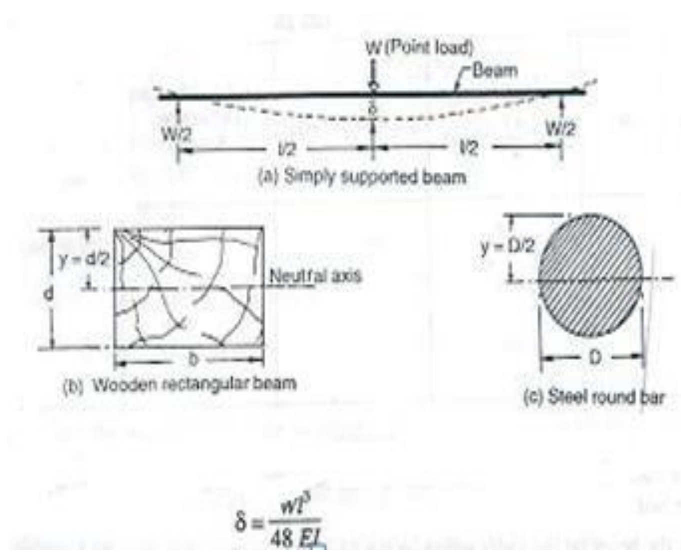
DEFLECTION TEST ON SIMPLY SUPPORTED BEAM

AIM: Determine the deflection and bending stress of simply supported subjected to concentrated load at the center.

APPARATUS:

Beam apparatus, Bending fixture, vernier caliper, meter rod, test piece & dial gauge.

DIAGRAM:



THEORY:

Bending test is performing on beam by using the three point loading system. The bending fixture is supported on the platform of hydraulic cylinder of the UTM. The loading is held in the middle cross head. At a particular load the deflection at the center of the beam is determined by using a dial gauge. The deflection at the beam center is given by:

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

PROCEDURE:

1. Measure the length, width and thickness of test piece, by vernier caliper.
2. Place the bending fixture on the lower cross head of the testing machine.
3. Place the test piece on the rollers of the bending fixture.
4. By loading the dial gauge in a stand, make its spindle knob the test piece.
5. Start the m/c and note down the load and dial gauge readings.

6. Plot the graph between load and deflection.

OBSERVATIONS:

1. Least count of vernier caliper = -----
2. Length of beam (L) = ------
3. Width of beam (b) = ------
4. Thickness of beam (t) = ------

TABLE:

S.No	**Load 'W' in N**	**Deflection 'δ' in mm.**	**Young's Modulus 'E'** $\frac{N}{mm^2}$

CALCULATIONS:

1. $I = \frac{b\,t^3}{12}$

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

PRECAUTIONS:

1. The length of the simply supported should be measured properly.
2. The dial gauge spindle knob should always touch the beam at the bottom of loading point.
3. Loading hanger should be placed at known distance
4. Al the errors should be eliminated while taking readings.
5. Beam should be positioned horizontally.

RESULT:

The Bending strength of given specimen = -------$\frac{N}{mm^2}$

VIVA QUESTIONS

1. Types of beams.
2. What is deflection?
3. Write the equation for the Slope for a cantilever beam with point load
4. Write the deflection equation for the simply supported beam with point load at the center
5. How many types of bending are there?

APPLICATIONS:

1. for construction of bridges

Week 8-9

Designation: C 496/C 496M – 04$^{\epsilon 1}$

Standard Test Method for Splitting Tensile Strength of Cylindrical Concrete Specimens[1]

This standard is issued under the fixed designation C 496/C 496M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

ϵ^1 NOTE—Footnote 3 was reinserted editorially to correct a typo in December 2006.

1. Scope*

1.1 This test method covers the determination of the splitting tensile strength of cylindrical concrete specimens, such as molded cylinders and drilled cores.

1.2 The values stated in either inch-pound or SI units are to be regarded separately as standard. The SI units are shown in brackets. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in nonconformance with the standard.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

1.4 The text of this standard references notes that provide explanatory material. These notes shall not be considered as requirements of the standard.

2. Referenced Documents

2.1 *ASTM Standards:* [2]

C 31/C 31M Practice for Making and Curing Concrete Test Specimens in the Field

C 39/C 39M Test Method for Compressive Strength of Cylindrical Concrete Specimens

C 42/C 42M Test Method for Obtaining and Testing Drilled Cores and Sawed Beams of Concrete

C 192/C 192M Practice for Making and Curing Concrete Test Specimens in the Laboratory

C 670 Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials

3. Summary of Test Method

3.1 This test method consists of applying a diametral compressive force along the length of a cylindrical concrete specimen at a rate that is within a prescribed range until failure occurs. This loading induces tensile stresses on the plane containing the applied load and relatively high compressive stresses in the area immediately around the applied load. Tensile failure occurs rather than compressive failure because the areas of load application are in a state of triaxial compression, thereby allowing them to withstand much higher compressive stresses than would be indicated by a uniaxial compressive strength test result.

3.2 Thin, plywood bearing strips are used to distribute the load applied along the length of the cylinder.

3.3 The maximum load sustained by the specimen is divided by appropriate geometrical factors to obtain the splitting tensile strength.

4. Significance and Use

4.1 Splitting tensile strength is generally greater than direct tensile strength and lower than flexural strength (modulus of rupture).

4.2 Splitting tensile strength is used in the design of structural lightweight concrete members to evaluate the shear resistance provided by concrete and to determine the development length of reinforcement.

5. Apparatus

5.1 *Testing Machine*—The testing machine shall conform to the requirements of Test Method C 39/C 39M and be of a type with sufficient capacity that will provide the rate of loading prescribed in 7.5.

5.2 *Supplementary Bearing Bar or Plate*—If the diameter or the largest dimension of the upper bearing face or the lower bearing block is less than the length of the cylinder to be tested, a supplementary bearing bar or plate of machined steel shall be used. The surfaces of the bar or plate shall be machined to within ± 0.001 in. [0.025 mm] of planeness, as measured on any line of contact of the bearing area. It shall have a width of at least 2 in. [50 mm], and a thickness not less than the distance

[1] This test method is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.61 on Testing for Strength.

Current edition approved Feb. 1, 2004. Published March 2004. Originally approved in 1962. Last previous edition approved in 1996 as C 496 – 96.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

***A Summary of Changes section appears at the end of this standard.**

from the edge of the spherical or rectangular bearing block to the end of the cylinder. The bar or plate shall be used in such manner that the load will be applied over the entire length of the specimen.

5.3 *Bearing Strips*—Two bearing strips of nominal ⅛ in. [3.2 mm] thick plywood, free of imperfections, approximately 1 in. [25 mm] wide, and of a length equal to, or slightly longer than, that of the specimen shall be provided for each specimen. The bearing strips shall be placed between the specimen and both the upper and lower bearing blocks of the testing machine or between the specimen and supplemental bars or plates, when used (see 5.2). Bearing strips shall not be reused.

6. Test Specimens

6.1 The test specimens shall conform to the size, molding, and curing requirements set forth in either Practice C 31/C 31M (field specimens) or Practice C 192/C 192M (laboratory specimens). Drilled cores shall conform to the size and moisture-conditioning requirements set forth in Test Method C 42/C 42M. Moist-cured specimens, during the period between their removal from the curing environment and testing, shall be kept moist by a wet burlap or blanket covering, and shall be tested in a moist condition as soon as practicable.

6.2 The following curing procedure shall be used for evaluations of light-weight concrete: specimens tested at 28 days shall be in an air-dry condition after 7 days moist curing followed by 21 days drying at 73.5 ± 3.5°F [23.0 ± 2.0°C] and 50 ± 5 % relative humidity.

7. Procedure

7.1 *Marking*—Draw diametral lines on each end of the specimen using a suitable device that will ensure that they are in the same axial plane (see Fig. 1, Fig. 2 and Note 1), or as an alternative, use the aligning jig shown in Fig. 3 (Note 2).

NOTE 1—Figs. 1 and 2 show a suitable device for drawing diametral lines on each end of a 6 in. by 12 in. [150 mm by 300 mm] cylinder in the same axial plane. The device consists of three parts as follows:

(1) A length of 4-in. [100-mm] steel channel, the flanges of which have been machined flat,

(2) A section, part a, that is grooved to fit smoothly over the flanges of the channel and that includes cap screws for positioning the vertical member of the assembly, and

(3) A vertical bar, part b, for guiding a pencil or marker,

The assembly (part a and part b) is not fastened to the channel and is positioned at either end of the cylinder without disturbing the position of the specimen when marking the diametral lines.

NOTE 2—Fig. 4 is a detailed drawing of the aligning jig shown in Fig. 3 for achieving the same purpose as marking the diametral lines. The device consists of:

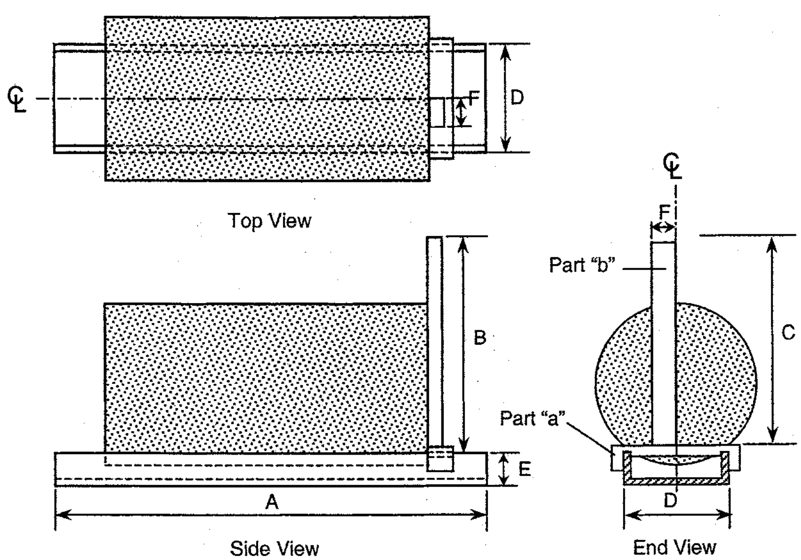
(1) A base for holding the lower bearing strip and cylinder,

(2) A supplementary bearing bar conforming to the requirements in Section 5 as to critical dimensions and planeness, and

(3) Two uprights to serve for positioning the test cylinder, bearing strips, and supplementary bearing bar.

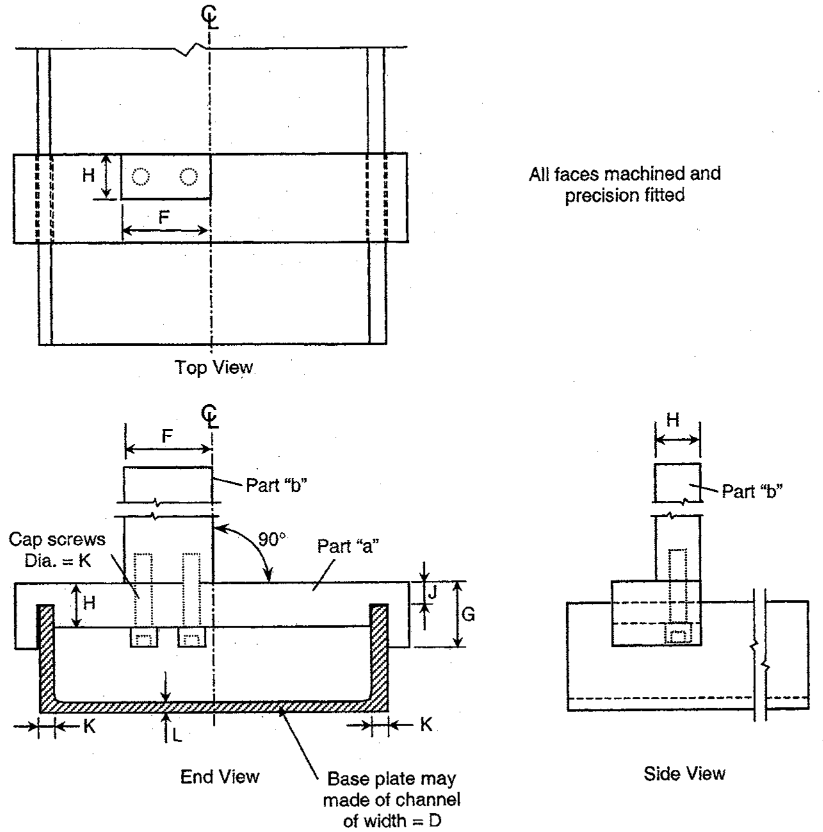
7.2 *Measurements*—Determine the diameter of the test specimen to the nearest 0.01 in. [0.25 mm] by averaging three diameters measured near the ends and the middle of the specimen and lying in the plane containing the lines marked on the two ends. Determine the length of the specimen to the nearest 0.1 in. [2 mm] by averaging at least two length measurements taken in the plane containing the lines marked on the two ends.

7.3 *Positioning Using Marked Diametral Lines*—Center one of the plywood strips along the center of the lower bearing block. Place the specimen on the plywood strip and align so that the lines marked on the ends of the specimen are vertical and centered over the plywood strip. Place a second plywood strip lengthwise on the cylinder, centered on the lines marked on the ends of the cylinder. Position the assembly to ensure the following conditions:



A	B	C	D	E	F
16 in	8 ¼ in.	8 in.	4 in.	1 ¼ in.	1 in.
400 mm	205 mm	200 mm	100 mm	32 mm	25 mm

FIG. 1 General Views of a Suitable Apparatus for Marking End Diameters Used for Alignment of Specimen in Testing Machine



D	F	G	H	J	K	L
4 in.	1 in.	¾ in.	½ in.	¼ in.	3/16 in.	1/8 in.
100 mm	25 mm	20 mm	13 mm	6 mm	4.8 mm	3.2 mm

FIG. 2 Detailed Plans for a Suitable Apparatus for Marking End Diameters Used for Aligning the Specimen

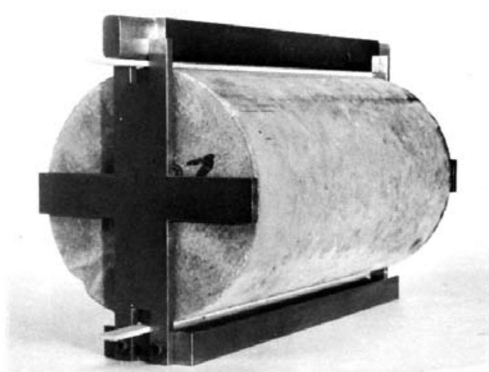


FIG. 3 Jig for Aligning Concrete Cylinder and Bearing Strips

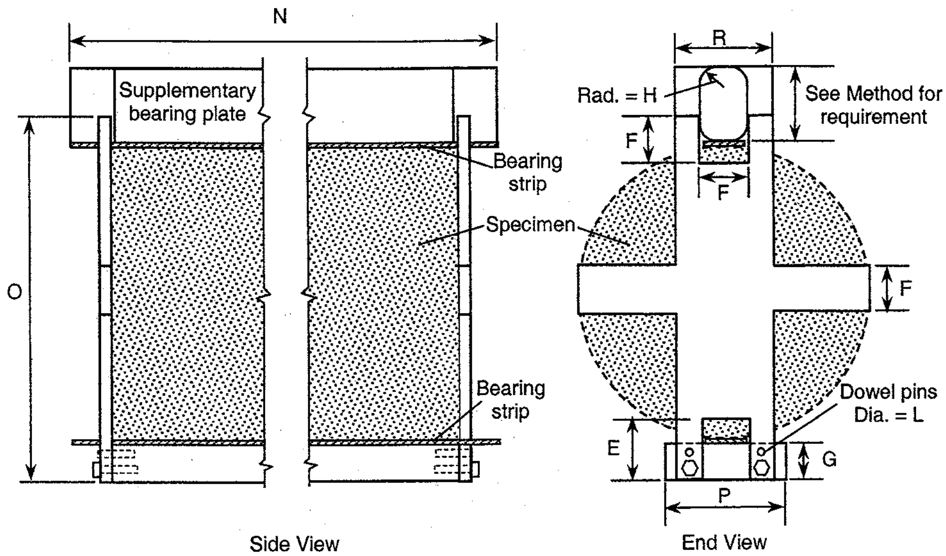
7.3.1 The projection of the plane of the two lines marked on the ends of the specimen intersects the center of the upper bearing plate, and

7.3.2 The supplementary bearing bar or plate, when used, and the center of the specimen are directly beneath the center of thrust of the spherical bearing block (see Fig. 5).

7.4 *Positioning by Use of Aligning Jig*—Position the bearing strips, test cylinder, and supplementary bearing bar by means of the aligning jig as illustrated in Fig. 3 and center the jig so that the supplementary bearing bar and the center of the specimen are directly beneath the center of thrust of the spherical bearing block.

7.5 *Rate of Loading*—Apply the load continuously and without shock, at a constant rate within the range 100 to 200 psi/min [0.7 to 1.4 MPa/min] splitting tensile stress until failure of the specimen (Note 3). Record the maximum applied load indicated by the testing machine at failure. Note the type of failure and the appearance of the concrete.

NOTE 3—The relationship between splitting tensile stress and applied load is shown in Section 8. The required loading range in splitting tensile stress corresponds to applied total load in the range of 11 300 to 22 600 lbf [50 to 100 kN]/min for 6 by 12-in. [150 by 300-mm] cylinders.



N	O	P	R	E	F	G	H	L
15 in.	7 ½ in.	2 ½ in.	2 in.	1 ¼ in.	1 in.	¾ in.	½ in.	1/8 in.
375 mm	190 mm	65 mm	50 mm	32 mm	25 mm	20 mm	13 mm	3 mm

FIG. 4 Detailed Plans for a Suitable Aligning Jig for 6 by 12 in. [150 by 300 mm] Specimen

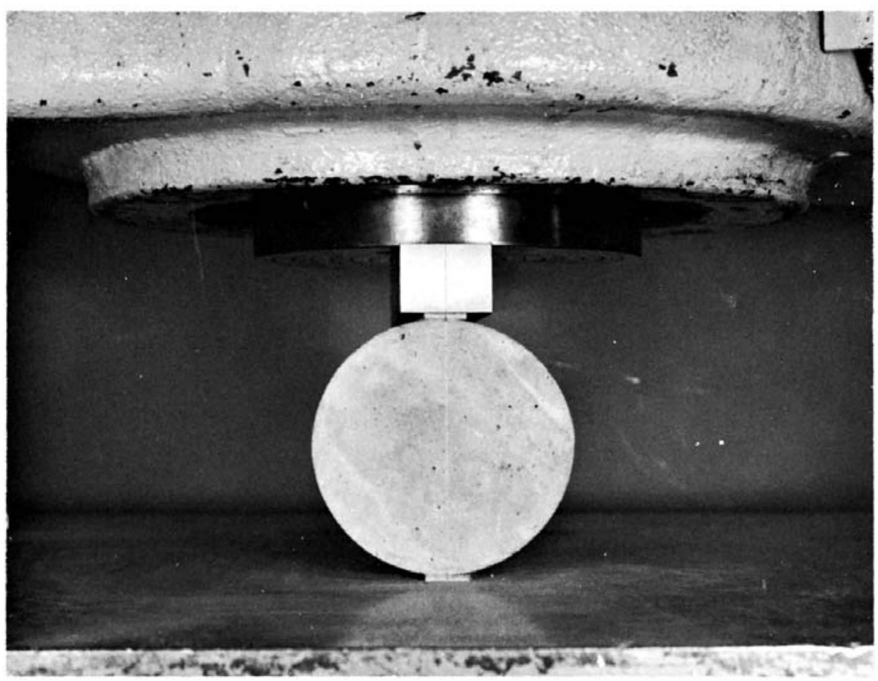


FIG. 5 Specimen Positioned in a Testing Machine for Determination of Splitting Tensile Strength

8. Calculation

8.1 Calculate the splitting tensile strength of the specimen as follows:

$$T = 2P/\pi ld \quad (1)$$

where:

T = splitting tensile strength, psi [MPa],
P = maximum applied load indicated by the testing machine, lbf [N],
l = length, in. [mm], and
d = diameter, in. [mm].

9. Report

9.1 Report the following information:

9.1.1 Identification number,

9.1.2 Diameter and length, in. [mm],

9.1.3 Maximum load, lbf [N],

9.1.4 Splitting tensile strength calculated to the nearest 5 psi [0.05 MPa],

9.1.5 Estimated proportion of coarse aggregate fractured during test,

9.1.6 Age of specimen,

9.1.7 Curing history,

9.1.8 Defects in specimen,

9.1.9 Type of fracture, and

9.1.10 Type of specimen.

10. Precision and Bias

10.1 *Precision*—An interlaboratory study of this test method has not been performed. Available research data,[3] however, suggests that the within batch coefficient of variation is 5 % (see Note 4) for 6 × 12-in. [150 × 300-mm] cylindrical specimens with an average splitting tensile strength of 405 psi [2.8 MPa]. Results of two properly conducted tests on the same material, therefore, should not differ by more than 14 % (see Note 4) of their average for splitting tensile strengths of about 400 psi [2.8 MPa].

NOTE 4—These numbers represent, respectively, the (1s %) and (d2s %) limits as defined in Practice C 670.

10.2 *Bias*—The test method has no bias because the splitting tensile strength can be defined only in terms of this test method.

11. Keywords

11.1 cylindrical concrete specimens; splitting tension; tensile strength

[3] Wright, P. J. F., "Comments on an Indirect Tensile Test on Concrete Cylinders," Magazine of Concrete Research, Vol 7, No. 20, July 1955, pp. 87–95.

SUMMARY OF CHANGES

Committee C09 has identified the location of selected changes to this test method since the last issue, C 496 – 96, that may impact the use of this test method. (Approved February 1, 2004)

(*1*) Revised 1.2.
(*2*) Added 1.4.
(*3*) Revised 5.1, 6.1, Section 2, and Note 1 to correct references.
(*4*) Revised 5.2, 6.2, 7.2, 7.5, 10.1, and Note 4 by metrication rules.
(*5*) Revised Section 4.
(*6*) Revised 3.2 and 5.3.
(*7*) Revised Note 2.
(*8*) Figs. 1, 2, and 4 were revised and redrawn.

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1. Dr. Ishtiaque Ahmed, Mechanics of Solids Sessional Manual, Department of Civil Engineering, Bangladesh University of Engineering and Technology (BUET).
2. Md. Ruhul Amin, Mechanics of Solids Sessional Manual, Department of Civil Engineering, Bangladesh University of Engineering and Technology (BUET).
3. ASTM E8 / E8M, Standard Test Methods for Tension Testing of Metallic Materials, ASTM International, West Conshohocken, PA, 2016, www.astm.org
4. ASTM A370-17, Standard Test Methods and Definitions for Mechanical Testing of Steel Products, ASTM International, West Conshohocken, PA, 2017, www.astm.org
5. ASTM A48 / A48M, Standard Specification for Gray Iron Castings, ASTM International, West Conshohocken, PA, 2016, www.astm.org
6. ASTM E18, Standard Test Methods for Rockwell Hardness of Metallic Materials, ASTM International, West Conshohocken, PA, 2017, www.astm.org
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8. ASTM A370, Standard Test Methods and Definitions for Mechanical Testing of Steel Products, ASTM International, West Conshohocken, PA, 2017, www.astm.org
9. ASTM E 23, Standard Test Methods for Notched Bar Impact Testing of Metallic Materials, ASTM International, West Conshohocken, PA, 2017, www.astm.org

Week 10-11

EXPERIMENT NO.: 6

HARDNESS TEST OF METAL SPECIMENS

Experiment No.: 6
Hardness test of Metal Specimens

1. OBJECTIVES

-To study the Rockwell Hardness testing machine
-To determine the Hardness of the given specimens using Rockwell Hardness Testing Machine.
-To observe the failure pattern of different metals tested in different scale.

2. ASTM REFERENCE

ASTM E 8M-13a	Standard Test Methods for Tension Testing of Metallic Materials
ASTM E 370-07a	Standard Test Methods and Definitions for Mechanical Testing of Steel Products
ASTM A 48	Standard Specification for Gray Iron Castings
ASTM E 18-15	Standard Test Methods for Rockwell Hardness of Metallic Materials

3. SIGNIFICANCE

This experiment provides fundamental knowledge on hardness of materials, hardness test procedure, hardness testing types, hardness testing machine, hardness of different metal specimens, failure patterns etc.

4. APPARATUS

Rockwell Hardness Testing Machine

5. SPECIMEN

Specimen of mild steel (MS), brass, cast iron, aluminum and high strength steel (HSS).

6. THEORY

Hardness is a measure of the resistance of material to permanent deformation. Hardness represents the resistance of material surface to abrasion, scratching and cutting above all resistance to permanent deformation. Hardness gives clear indication of strength. In all hardness tests, a defined force is mechanically applied on the test piece, varies in size and shape for different tests. Common indenters are made of hardened steel or diamond. Hardness test is used to give a guide to the overall strength of a material.

Hardness is a measure of a material plastic flow resistance, and especially useful for this purpose when comparative assessments are made. Moreover, since hardness test are more convenient to carry out than other tensile tests, the hardness test has found widespread use in industrial applications and research studies.

Depending on the particular deformation type (or for that matter particular of stressing), hardness may be of the following types:

(1) Indentation hardness test (by indenting)
(2) Scratch hardness test (by scratching, Moh's Scale)
(3) Dynamic hardness test (by impact)
(4) Rebound hardness test (by the rebound of a falling ball)
(5) Wear hardness (by abrasion)
(6) Machinability (by cutting or drilling)

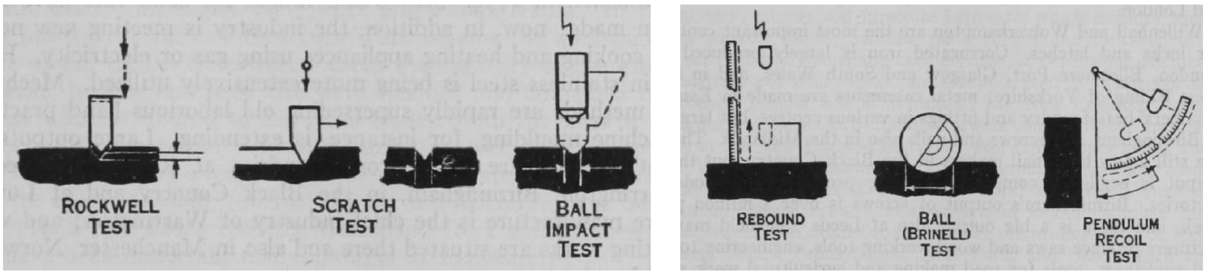


Figure 1: Various method of hardness test

Four indentation hardness tests are customarily used:
(1) Brinell
(2) Vickers
(3) Rockwell
(4) Shore scleroscope

The first three is known as static indentation hardness test and the last one is called dynamic indentation hardness test. Hardness number depends on (i) the applied load, (ii) the shape of the indentation and (iii) the depth to which the indenter penetrates the specimen.

Rockwell B scale: For softer materials, a 1/16-inch diameter steel ball is used, the major load is 90 kg and minor load is 10 kg (100 kg load in total) and the hardness is

$$HRB = 130 - \frac{d}{0.002}$$

where, d=depth of the indenter in mm, relative to the zero position.

Rockwell C scale: For harder materials, a conical – shaped diamond of 120 apex angel is used, the major load is 140 kg and minor load is 10 kg (150kg load in total), and the hardness is

$$HRC = 100 - \frac{d}{0.002}$$

Rockwell hardness tester presents direct reading of hardness number on a dial provided with the machine. Principally this testing is similar to Brinell hardness testing. It differs only in diameter and material of the indenter and the applied force. Although there are many scales having different combinations of load and size of indenter but commonly 'C' scale is used and hardness is presented as HRC. Here the indenter has a diamond cone at the tip and applied force is of 150 kgf. Soft materials are often tested in 'B' scale with a 1.58mm dia. steel indenter at 100 kgf.

Figure 2: Rockwell Hardness testing machine

7. SPECIFICATION OF HARDNESS TESTING MACHINE AND INDENTERS

A hardness test can be conducted on Brinell hardness testing machine, Rockwell hardness machine or Vicker hardness testing machine. The specimen may be a cylinder, cube, thick or thin metallic sheet. A Rockwell hardness testing machine along with the specimen is shown in Figure 2.

Table 1: Various scales in Rockwell hardness test

Scale	**Type of indenter (Dimension)**	**Initial/Minor load (kgf)**	**Major load (kgf)**	**Kind of material may be tested**
HRA	Cone, 120^o	10	50	Much harder such as carburized steel, cemented carbides, plastics & polymers
HRB	Ball, 1.58mm	10	90	Soft steels, copper, aluminum, brass, grey cast iron.
HRC	Cone, 120^o	10	140	Hard steels, HSS, Ti, W, Va, etc.

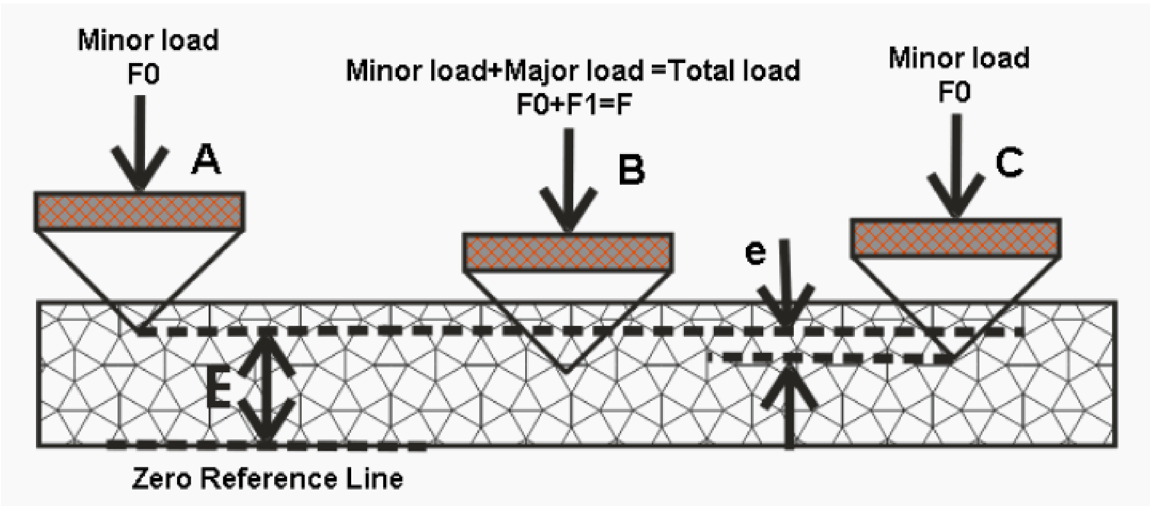
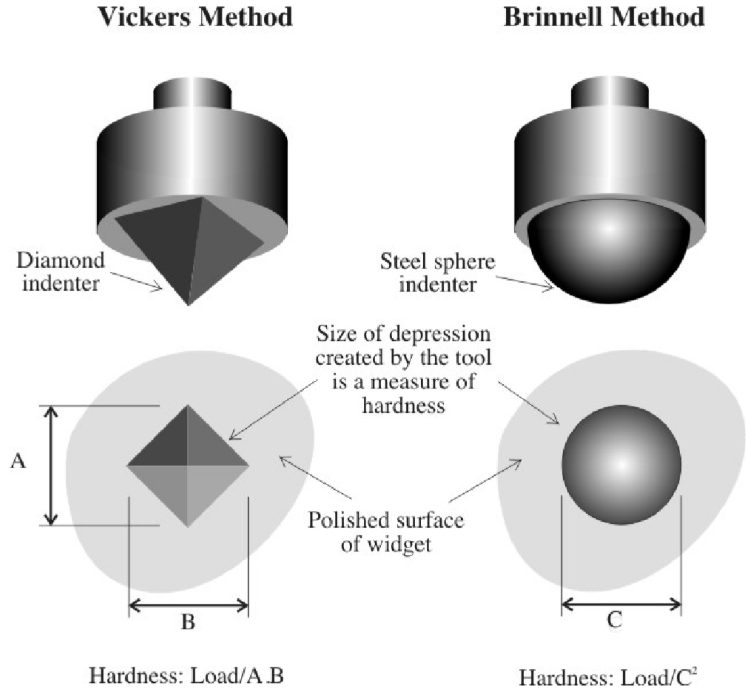


Figure 3: Major and minor load

Rockwell Method

(a) Cone Indenter

(b) Ball Indenter



(c) Vicker’s method (d) Brinell Method

Figure 4: Typical Indenters of Hardness testing

Figure 5: Typical specimens of Hardness test

Table 2: Approximate hardness conversion numbers for non-austenitic steels (ASTM A370-07a)

HRC	Appx.Tensile Strength (ksi)	HRB	Appx.Tensile Strength (ksi)
68	-	100	116
67	-	99	114
66	-	98	109
65	-	97	104
64	-	96	102
63	-	95	100
62	-	94	98
61	-	93	94
60	-	92	92
59	351	91	90
58	338	90	89
57	325	89	88
56	313	88	86
55	301	87	84
54	292	86	83
53	283	85	82
52	273	84	81
51	264	83	80
50	255	82	77
49	246	81	73
48	238	80	72
47	229	79	70
46	221	78	69
45	215	77	68
44	208	76	67
43	201	75	66
42	194	74	65
41	188	73	64
40	182	72	63
39	177	71	62
38	171	70	61
37	166	69	60
36	161	68	59
35	156	67	58
34	152	66	57
33	149	65	56
32	146	64	-
31	141	63	-
30	138	62	-
29	135	61	-
28	131	60	-
27	128	59	-
26	125	58	-
25	123	57	-
24	119	56	-
23	117	55	-
22	115		
21	112		
20	110		

Note: Table 2 gives the approximate relationships of hardness values and approximate tensile strength of steels. It is possible that steels of various compositions and processing histories will deviate in hardness-tensile strength relationship from the data presented in these Tables.

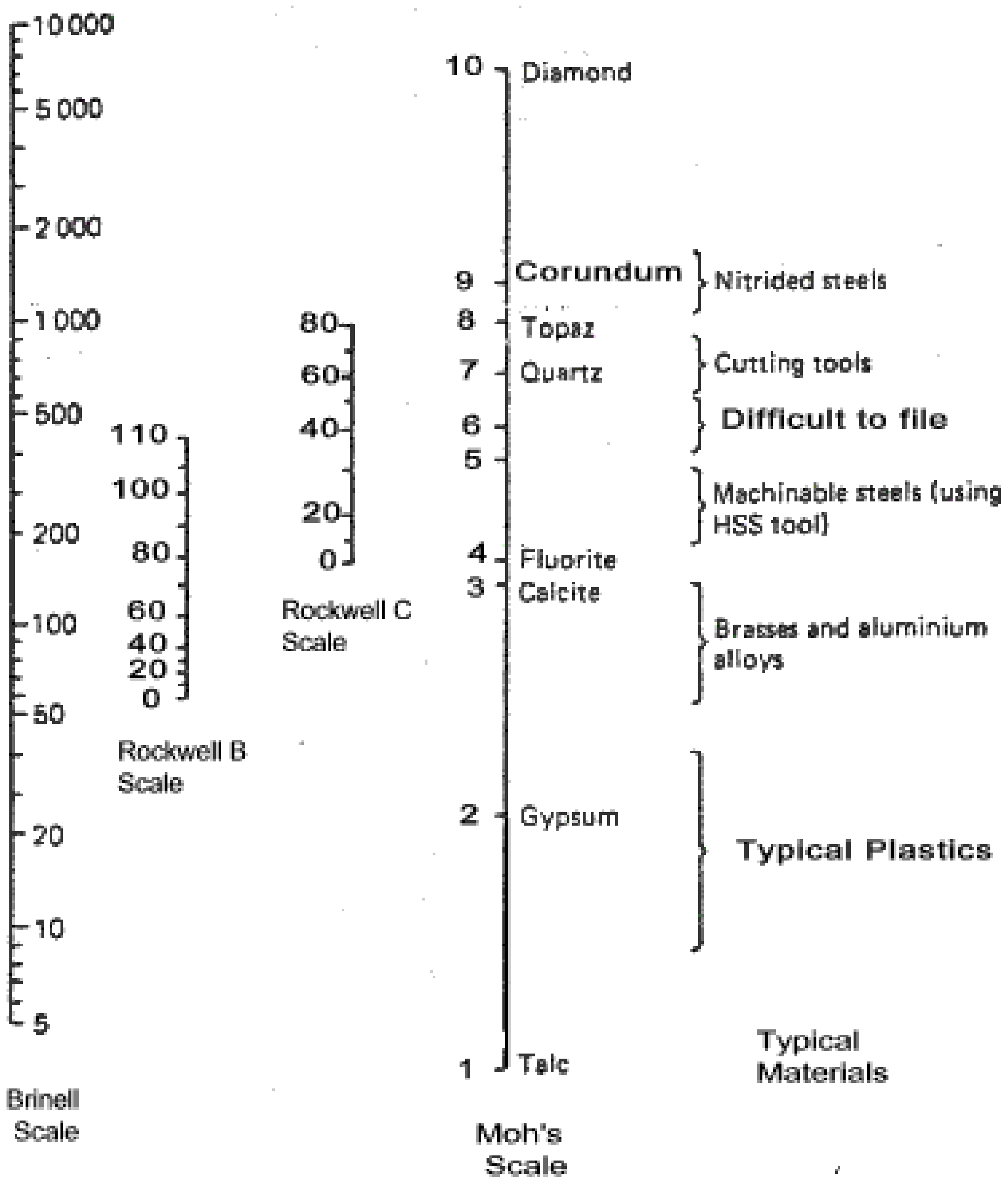


Figure 6: Relation among different hardness scales.

8. PROCEDURE

1. Examine the machine and make sure that the correct scale (A, B or C) is set for testing.
2. Place the specimen upon the anvil of the machine.
3. Raise the anvil and the test piece by elevating screw until the specimen comes in contact with the indenter.
4. Firstly, apply minor load on the specimen by touching the pointer to the specimen.
5. Then apply the major load on the same specimen by pressing upward.
6. After few seconds of the application of load, a beep sound would be heard.
7. Read carefully and record the hardness number from the display of the machine.

9. CALCULATIONS

(Students will fill up this section with their individual observation and calculation about the test, as par teacher's direction.)

<u>For HRB 35 to HRB 100</u>

$$BHN = \frac{7300}{130 - HRB}$$

<u>For HRC 20 to HRC 40</u>

$$BHN = \frac{20000}{100 - HRC}$$

<u>For HRC 41 and above</u>

$$BHN = \frac{25000}{100 - HRC}$$

10. GRAPHS

1. Tensile strength vs. HRC using Table 2.
2. Tensile strength vs. HRB using Table 2.

Also show the corresponding tensile strengths of tested specimens in the graphs.

11. DATA TABLE

Sl. No.	**Specimen**	**Name of the metal**	**Type of indenter**	**Applied load (kg)**	**HRB**	**HRC**
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
11						
12						
13						
14						
15						

12. RESULT

(Students will fill up this section with their individual outcome/result about the test.)

Sl. No.	Specimen	Name of the metal	Applied load (kg)	HRB (Ball indenter)	HRC (Cone indenter)	BHN	Tensile strength (ksi)	Moh's scale Hardness	Depth of indentation, d (mm)

13. DISCUSSION

Point out the discussion

1.
2.
3. ….

(Discuss on the results found, graphs, and failure patterns and also compare the results found, graphs and failure patterns.)

14. ASSIGNMENT

1. What is the importance of minor load in Hardness test?
2. Write down the names of materials you can find hardness in the all three scales.
3. What result have you obtained in your laboratory test? Do you think the result is justified by the test method?
4. Describe the hardness testing machine being operated at your laboratory; also describe its working procedure.
5. Calculate the hardness of the tested materials in Moh's scale using Figure 6 and also calculate the depth of penetration for all specimens.

Week 12-14

EXPERIMENT NO.: 7

IMPACT TEST OF METAL SPECIMEN

Experiment No.: 7

Impact test of Metal Specimen

1. OBJECTIVE

-To study the Impact testing machine

-To evaluate the energy absorbing characteristics of metal materials at room temperature using the Charpy, Izod, and tension impact methods.

-To observe the failure patterns and failure surface

2. ASTM REFERENCE

ASTM E 23-16b	Standard Test Methods for Notched Bar Impact Testing of Metallic Materials
ASTM A370-07a	Standard Test Methods and Definitions for Mechanical Testing of Steel Products

3. SIGNIFICANCE

This experiment provides fundamental knowledge on impact behaviour of materials, test procedure, impact testing machine and its working principal, impact specimens, failure patterns etc.

4. APPARATUS AND MACHINE

Digital pendulum impact testing machine.

5. SPECIMENS

Charpy (simple beam specimens), Izod (cantilever specimens), Tension Impact specimens made of different metals.

6. THEORY

An impact test normally determines the energy absorb in fracturing a test piece under high speed loading. Toughness is often measured by impact testing rather than by load – deformation (stress vs. strain) curves.

An impact test is a dynamic test in which a selected specimen which is usually notched, is struck and broken by a single blow in a specially designed machine. Using an impact. Machine, the energy absorbed while breaking the specimen is measured.

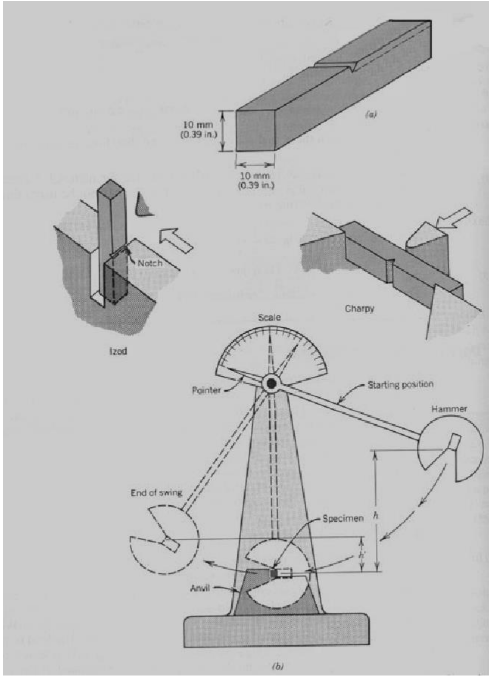
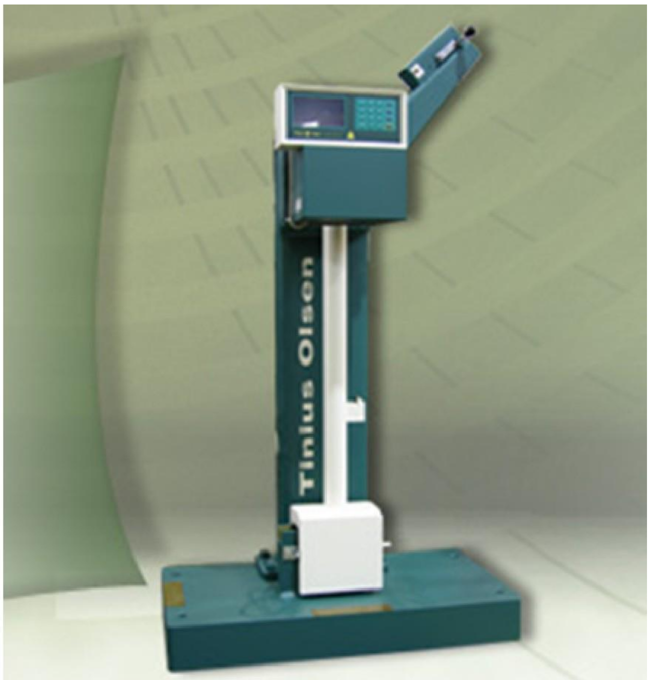


Figure 1: (a) Impact test mechanism
(Image source: Internet)



(b) Impact testing machine
(Image source: Internet)

Dynamic Load is that load which varies with respect to time.

Types of dynamic Load:
(1) Harmonic Load (machine)
(2) Periodic Load (dancing)
(3) Transient Load (walking)
(4) Impact Load (jumping)

Impact or shock loading differs from static and cyclic loads in two respects:
(i) Load is applied rapidly, that is with appreciable speed, and
(ii) Loading is seldom repeated, since failure often occurs on the first application, if it occurs at all.

Types of impact test are as follows:
(a)Bending impact test
(1) Charpy simple beam
(2) Izod cantilever beam
(b) Tensile impact test

In both methods the tested pieces are notched. The intention of the notch is to approximate end use conditions; the notch serves as a stress concentrator. These tests give a value for toughness, yet their respective values are not directly comparable. This is due to the differences in how they are tested.

The major factors that affect the results of an impact test are:
(a)Velocity (b)Specimen (c)Temperature

Table 1: Features of different types of fracture

Ductile fracture	**Brittle fracture**
A mode of fracture characterized by the slow creak propagation which usually follows a zigzag path alone planes where a maximum resolved shear stress has occurred.	A mode of fracture characterized by the nucleation and rapid propagation of a crack, with little accompanying plastic deformation.
A surface experiencing ductile fracture generally has a dull, fibrous appearance.	Brittle fracture surfaces in crystalline materials can be identified by the shiny, granular appearance.
Example: Fracture of mild steel, aluminum,	Example: Fracture of cast iron, high carbon steel.

Table 2: Effect of angle of notch on energy of rupture of mild steel

Angle of notch (degree)	Sketch of specimen	Charpy impact value
0		22.1
30		24.4
45		23.1
90		25.9
120		41.8
150		66.2
180		63.1

In manufacturing locomotive wheels, coins, connecting rods etc. the components are subjected to impact (shock) loads. These loads are applied suddenly. The stresses induced in these components are many times more than the stress produced by gradual loading. Therefore, impact tests are performed to assess shock absorbing capacity of materials subjected to suddenly applied loads.

Impact tests provide information on the resistance of a material to sudden fracture where a sharp stress rise or flaw is present. In addition to providing information not available from any other simple mechanical test, these tests are quick and inexpensive. The data obtained from such impact test is frequently employed for engineering purposes.

Various standard impact tests are widely employed in which notched specimens are broken by a swinging pendulum. The most common tests of this type are the Charpy V-notch test and the Izod test which are described in ASTM E23, Standard test Methods for notched bar impact testing of metallic materials. Another test method, although not a standard test method, is the tension impact test.

These types of impact tests have given way to testing methods that make use of fracture mechanics. Fracture mechanics allow more sophisticated analysis of materials containing cracks and sharp notches. However, the advantages of fracture mechanics are achieved at the sacrifice of simplicity and economy. Impact tests such as the Charpy, Izod, and tension impact have thus remained popular despite their shortcomings, as they serve a useful purpose in quickly comparing materials and obtaining general information on their behavior.

Many materials, including metals, exhibit marked changes in impact energy with temperature. It is known that there tends to be a region of temperatures over which the impact energy increases rapidly from a lower level that may be relatively constant to an upper level that may also be relatively constant. Such temperature transition behavior is common for metal materials. This temperature dependence for various steel alloys with the same hardness but different carbon contents is graphically shown in Figure 2. This figure shows the impact energy obtained from Charpy V-notch impact specimens as a function of temperature. The temperature transition behavior is of engineering significance since it aids in comparing materials for use at various temperatures. In general, a material should not be severely loaded at temperatures where it has low impact energy.

In charpy test, the specimen is placed as ‘Simply supported beam’ and In Izod test, the specimen is placed as ‘cantilever beam’ (Figure 3). The specimens have V-shaped notch of 45°. U-shaped notch is also common. 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. Table 2 represents typical response of angle of notch on charpy impact strength

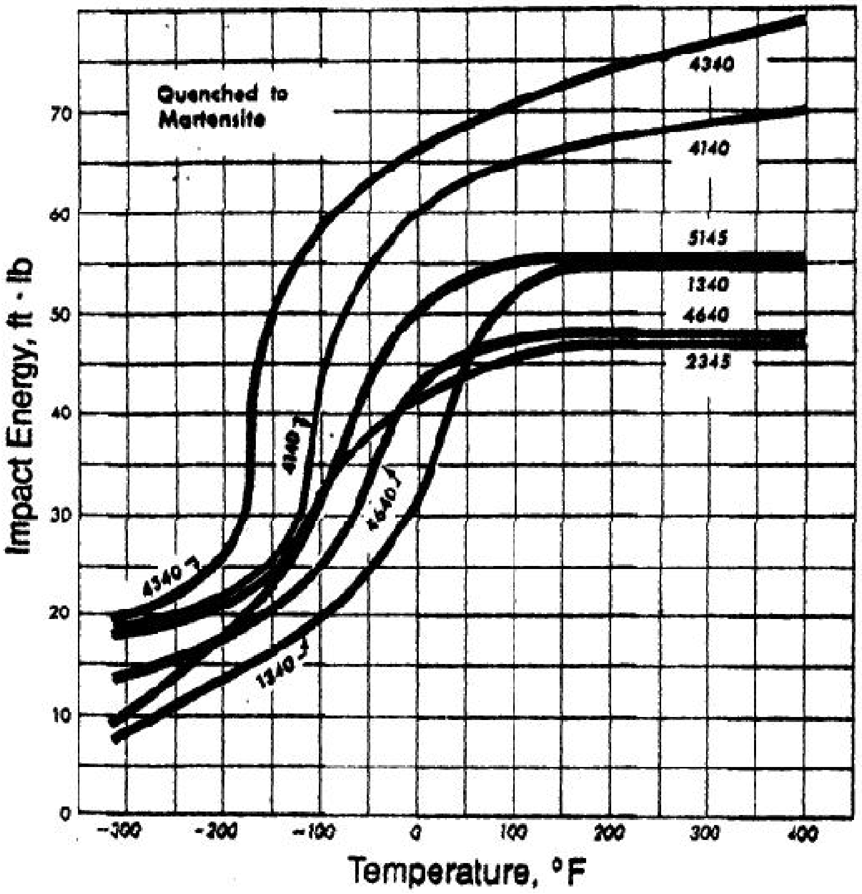


Figure 2: Temperature Dependence of Charpy V-Notch Impact Resistance for Different Alloys Hardened to HRC 34 (N.E. Dowling). (Image source: Internet)

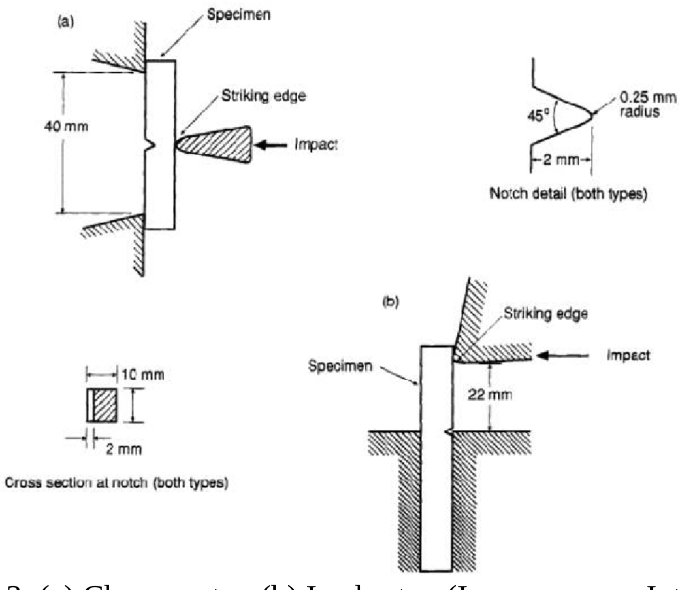


Figure 3: (a) Charpy setup (b) Izod setup (Image source: Internet)

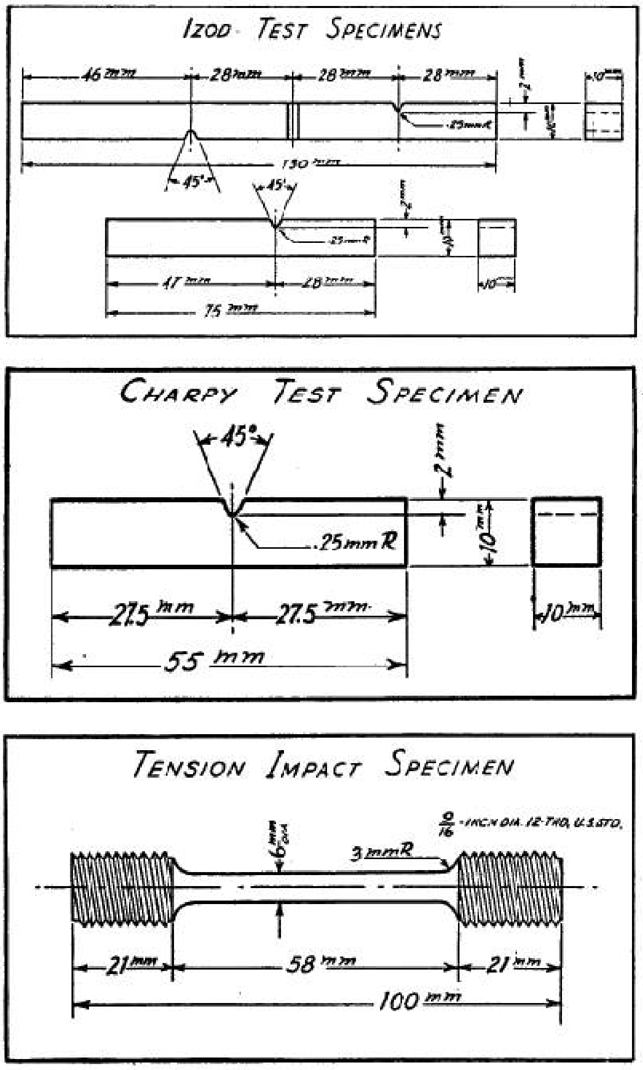


Figure 4: Impact test specimen with specification (Image source: Internet)

7. SPECIFICATION OF MACHINE AND SPECIMEN

Impact testing machine:

Impact capacity = 407.74 joule
Weight of striking hammer = 27.22 kg (60 lb)
Swing radius of hammer = 900.1 mm (35.437 inch)
Angle of hammer before striking = 160°
Striking velocity of hammer = 5.47 m/sec. (17.9 ft/sec.)

Specimen:

Specimen size = (Figure 4)
Type of notch = (Figure 4)

Angle of notch = (Figure 4)
Depth of notch = (Figure 4)

8. PROCEDURE

i) Measure the lateral dimensions of the specimen at full section and at the notch.
ii) Place the specimen in proper position. Set the hammer block at a certain height and then release it.
iii) When the hammer block stops swinging, record the value of absorbed energy displayed on the screen.

9. DATA

Obs. No.	Type of test	Name of metal	Specimen type	Specimen depth	Specimen width	Depth of notch	Depth at notch	Absorbed Energy, E (J)
1	Charpy							
2	Izod							
3	Tension							

Depth at notch = Specimen depth - Depth of notch
Cross sectional area at notch, A_{Notch} = Depth at notch × Specimen width
Energy required to break the specimen = Absorbed Energy, E
Notch impact strength / Impact toughness, U = Absorb energy / Effective cross section area at notch = E/A_{Notch}

10. FAILURE PATTERNS

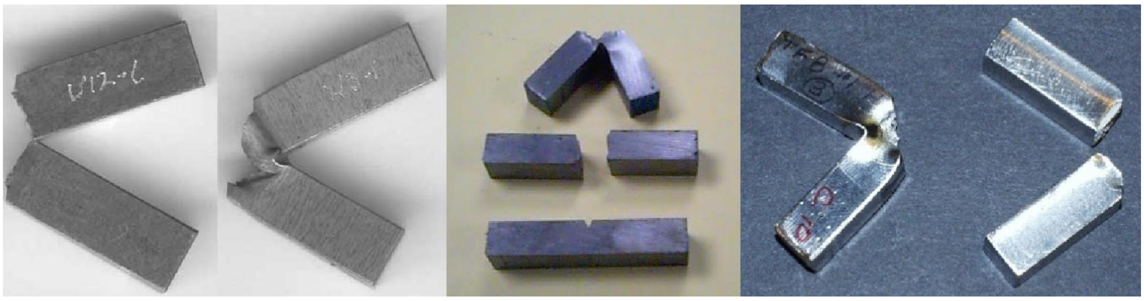
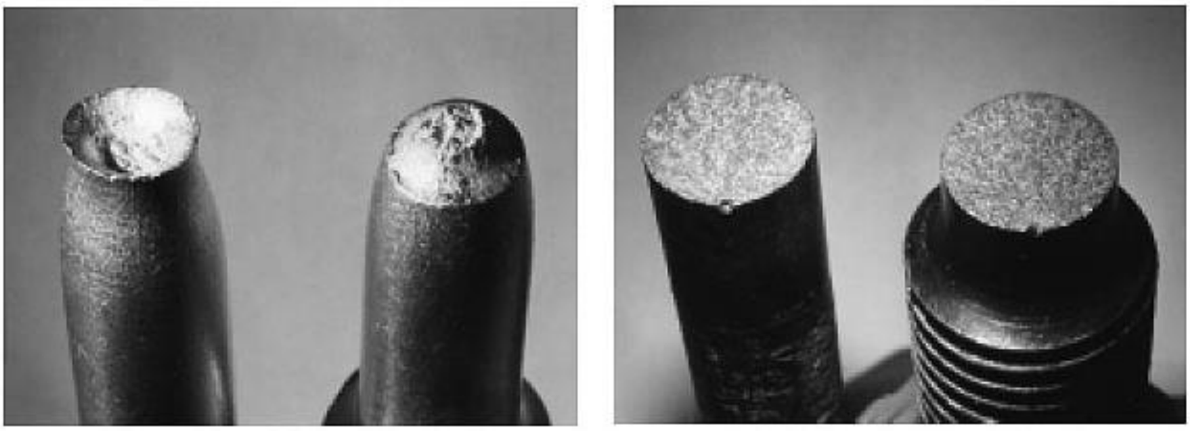


Figure 5: Fractured pieces of Charpy Impact specimens



Cup-and-cone fracture in aluminum. Brittle fracture in a mild steel.

Figure 6: Fractured piece of Charpy tension Impact specimens

Figure 7: Fractured piece of Izod(top) and Charpy(bottom) specimens

11. PRECAUTIONS

1. The specimen should be prepared in proper dimensions.
2. Do not stand in front of swinging hammer or releasing hammer.
3. Place the specimen in proper position.

12. GRAPHS

1. Charpy Impact Strength vs. HRB
2. Izod Impact Strength vs. HRB
3. Tension Impact Strength vs. HRB

13. RESULT

Table 1: Charpy simple beam

Obs. No.	Name of metal	Group	Area at notch, A_{Notch} (mm)	HRB	Absorbed Energy, E (J)	Impact toughness, $U=E/A_{Notch}$ (J/mm^2)	Failure Pattern	Failure Surface
1								
2								
3								
4								
5								
6								

Table 2: Izod cantilever beam

Obs. No.	Name of metal	Group	Area at notch, A_{Notch} (mm)	HRB	Absorbed Energy, E (J)	Impact toughness, $U=E/A_{Notch}$ (J/mm^2)	Failure Pattern	Failure Surface
1								
2								
3								
4								
5								
6								

Table 3: Tension Impact Specimen

Obs. No.	Name of metal	Group	Area at notch, A_{Notch} (mm)	HRB	Absorbed Energy, E (J)	Impact toughness, $U=E/A_{Notch}$ (J/mm^2)	Failure Pattern	Failure Surface
1								
2								
3								
4								
5								
6								

14. DISCUSSION

(Discuss on the results found, graphs, and failure patterns and also compare the results found, graphs and failure patterns.)

Point out the discussion
1.
2.
3. ….

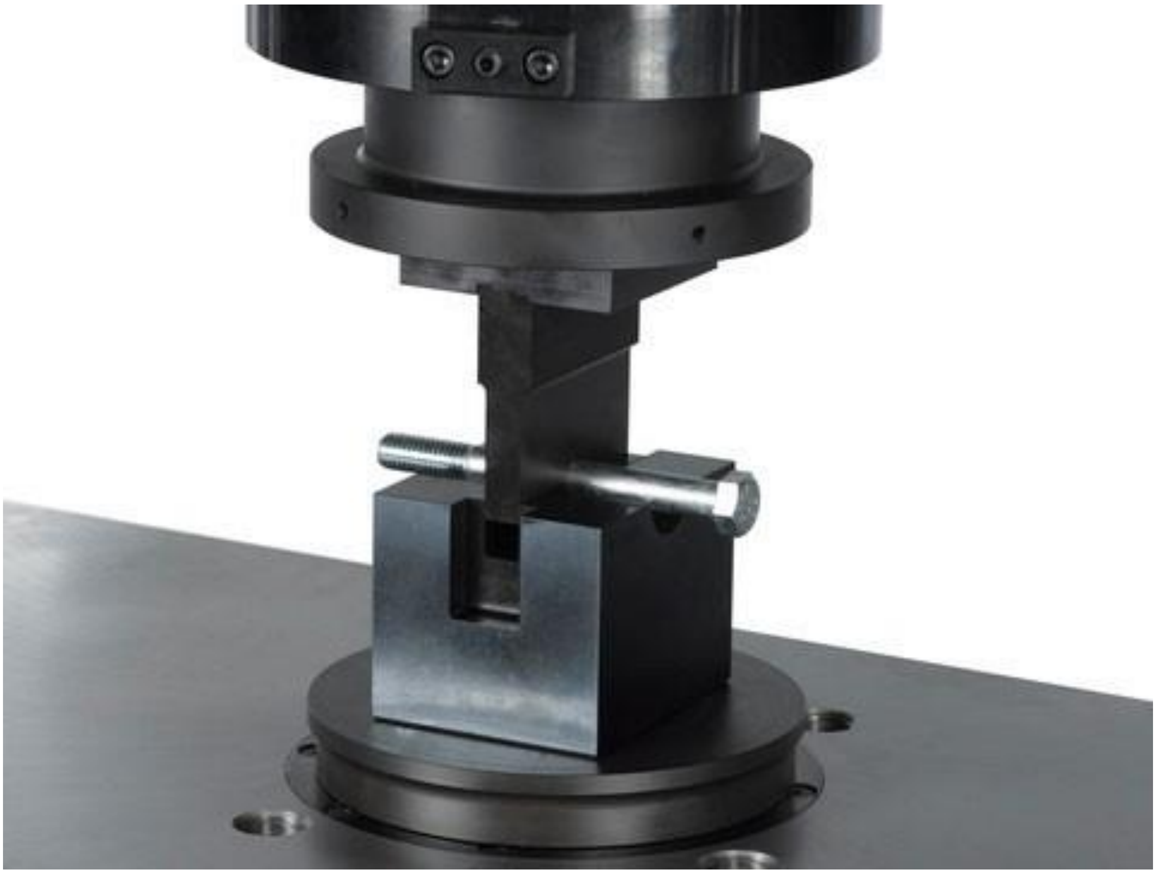
15. ASSIGNMENT

1) Discuss the relative toughness and hardness values obtained for all materials tested.
2) What is the necessity of making a notch in impact test specimen?
3) Describe the fracture surface of the different materials tested.
4) If the sharpness of V-notch is more in one specimen than the other, what will be its effect on the test result?
5) What is the effect of temperature on the values of rupture energy and notch impact strength?

Week 15

EXPERIMENT NO.: 8

DIRECT SHEAR TEST OF METAL SPECIMENS



Experiment No.: 8
Direct Shear Test of Metal Specimens

1. OBJECTIVE

-To make a shear of metal specimens approximating the conditions of shear existing in rivets, pins, and bolts
-To determine the strength in single and double shear
-To observe the shape and texture of the fractured surface.

2. APPARATUS AND MACHINE

UTM, shear tool, Slide calipers, stop watch and computer.

3. SIGNIFICANCE

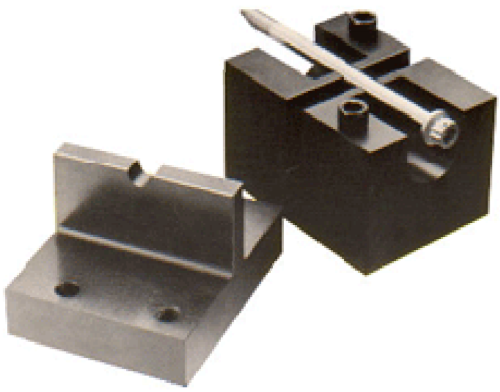
This experiment provides fundamental knowledge on direct shear behaviour of materials, test procedure, universal testing machine and its working principal, specimens, failure patterns etc.

4. SPECIMENS

Steel screws.

5. THEORY

Shearing stress is one that acts parallel or tangential to stressed surface. It is different from normal stress that acts perpendicular to the stressed surface, e.g. tension, compression or bending stresses. It resists the tendency of a part of the body on one side of the plane to slide against the other side of the same plane.



(a)

(b)

Figure 1: (a) Johnson Shear Tool, (b) Customized Shear Tool

The direct shear test (also called transverse shear test) gives an approximation to the correct values of shearing strength. This test is usually done in a Johnson type shear (Figure 1) of shear tool by clamping a portion of a material so that bending stress are minimized across the plane along which the shearing load is applied. Because of inevitable bending and friction between part of tool, it gives an indication of the shearing resistance of materials. The direct shear test has further limitation for the determination of elastic strength or of the modulus of rigidity or shear rigidity, because of difficulty to measure shearing strain.

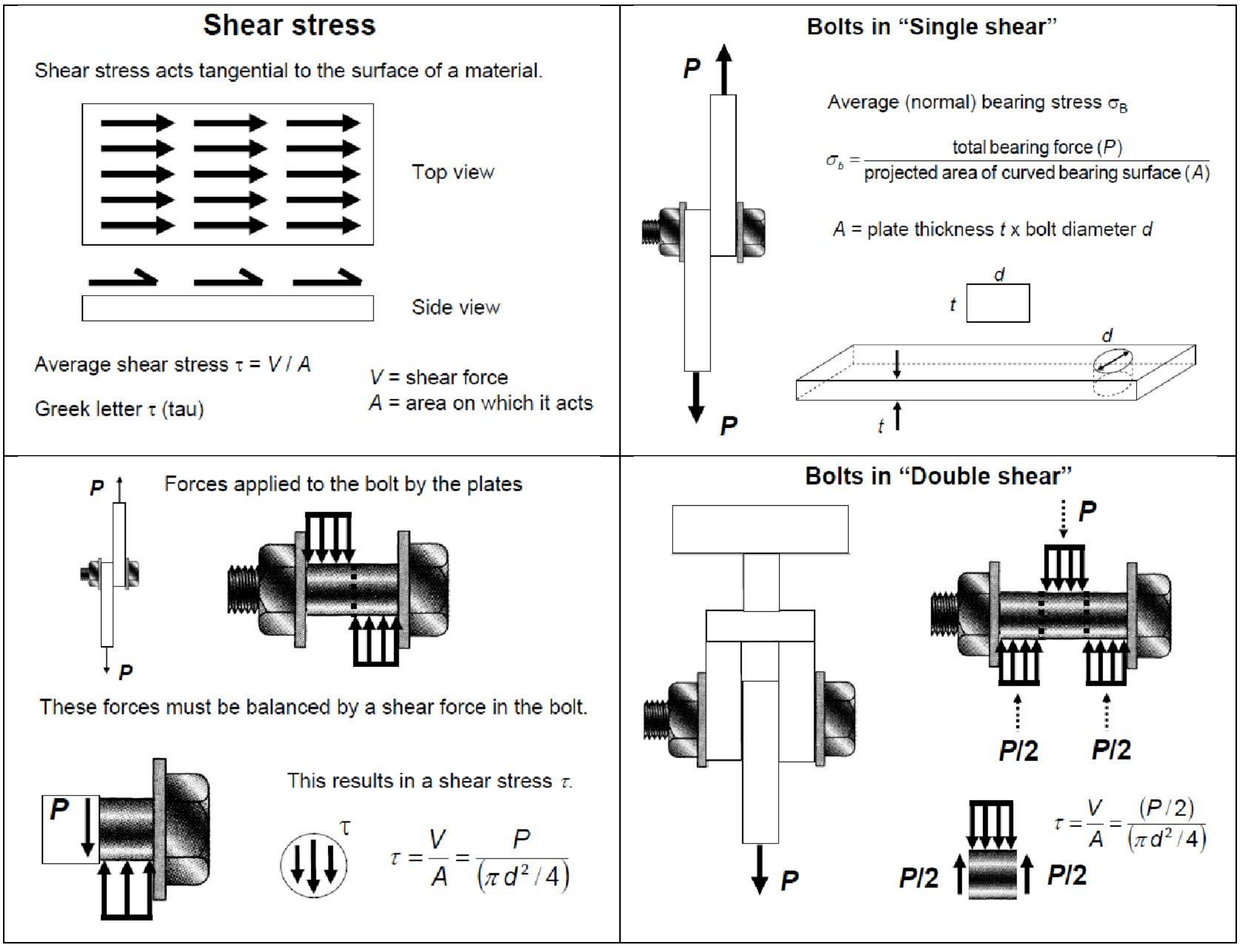


Figure 2: Shear force acted upon the specimens in single and double shear

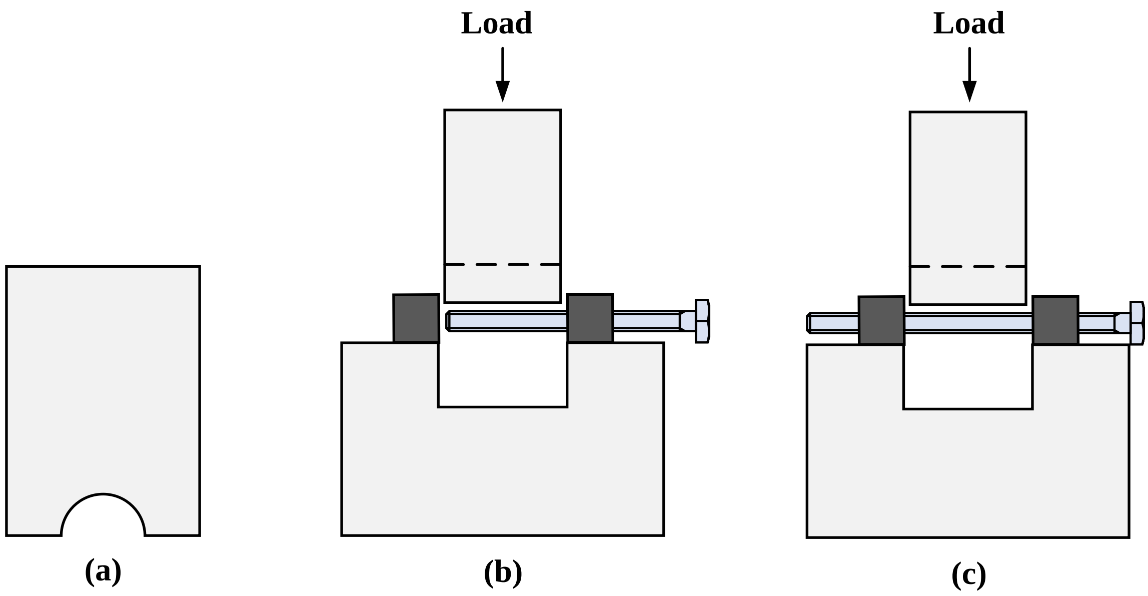


Figure 3: Schematic representation of Johnson shear tool, (a) Shear cutter, (b) Single shear and (c) Double shear.

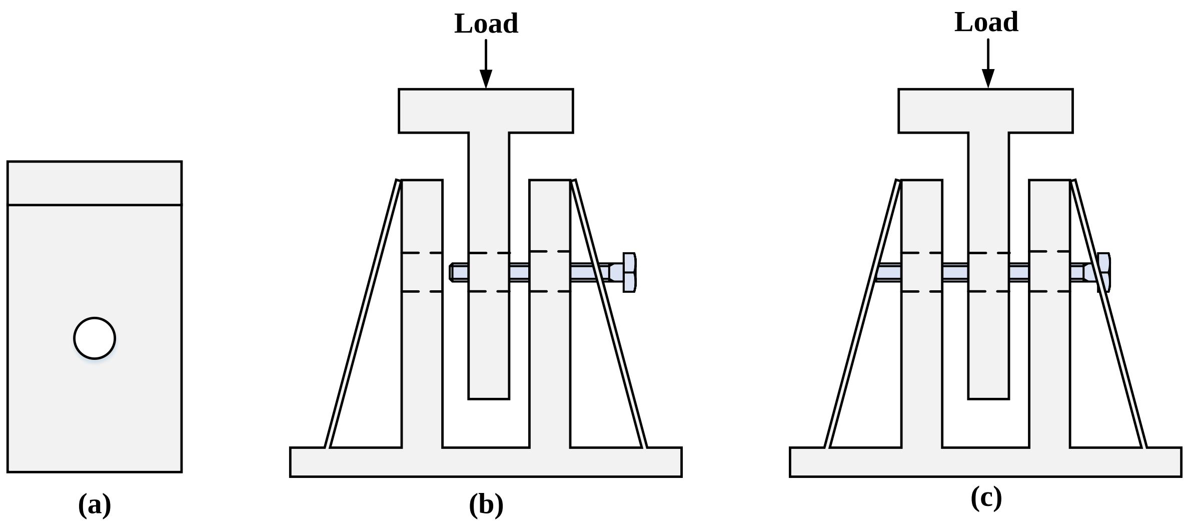


Figure 4: Schematic representation of modified Johnson shear tool, (a) Shear cutter, (b) Single shear and (c) Double shear.

6. PROCEDURE

i) Measure the diameter of the specimen with the slide calipers.

ii) Fix the specimen in the shear tool such that it is in single shear and apply load until rupture takes place.

iii) In the same way test the specimen for double shear.

7. SAMPLE CALCULATIONS

Calculate double, unit double and single shear stresses from maximum shear force data.

8. GRAPH

1. Combined Double Shear, Unit Double Shear and Single Shear force vs. displacement graph.

9. RESULT

Type of Shear	Dia (mm)	Shear Area (mm^2)	Maximum force (N)	Maximum Shear stress or Shear strength (MPa)	Failure pattern	Fracture surface
Double Shear						
Unit Double Shear						
Single Shear						

10. DISCUSSION

(Discuss on the results found, graphs, and failure patterns and also compare the results found, graphs and failure patterns.)

Point out the discussion

1.
2.
3. ….

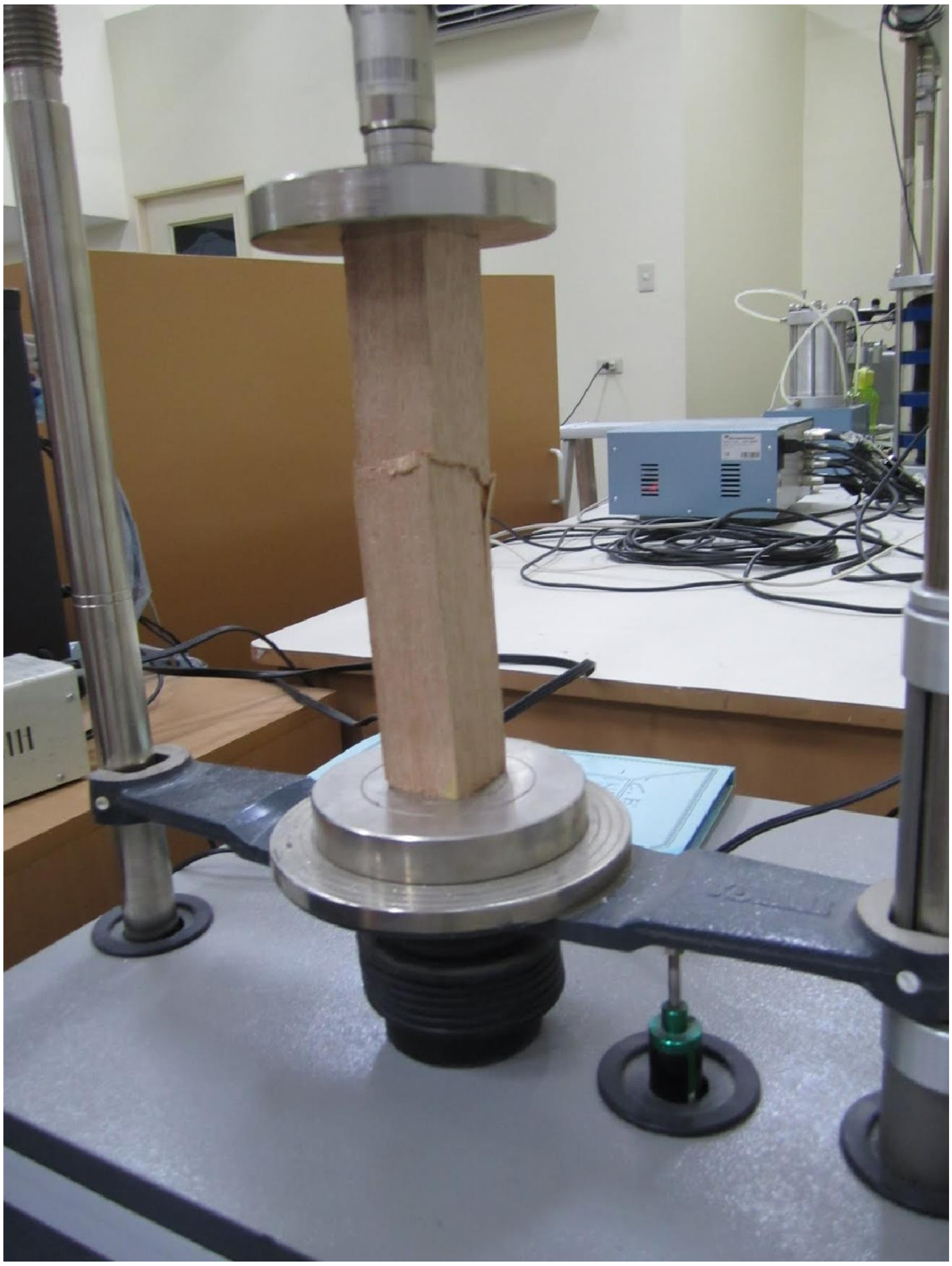
11. ASSIGNMENT

1. Why single shear strength is greater than unit double shear?
2. How we can measure shear rigidity?

Week 16

EXPERIMENT NO.: 9

COMPRESSION TEST OF TIMBER BLOCK



Experiment No.: 9
Compression test of Timber Block

1. OBJECTIVE

-To perform compression test of timber block on UTM.
-To observe the effect of slenderness ratio.
-To study the effects of parallel and perpendicular loading.
-To evaluate the failure patterns based on slenderness ratio and loading direction

2. ASTM REFERENCE

ASTM D 143-09 Standard Test Methods for Small Clear Specimens of Timber

3. SIGNIFICANCE

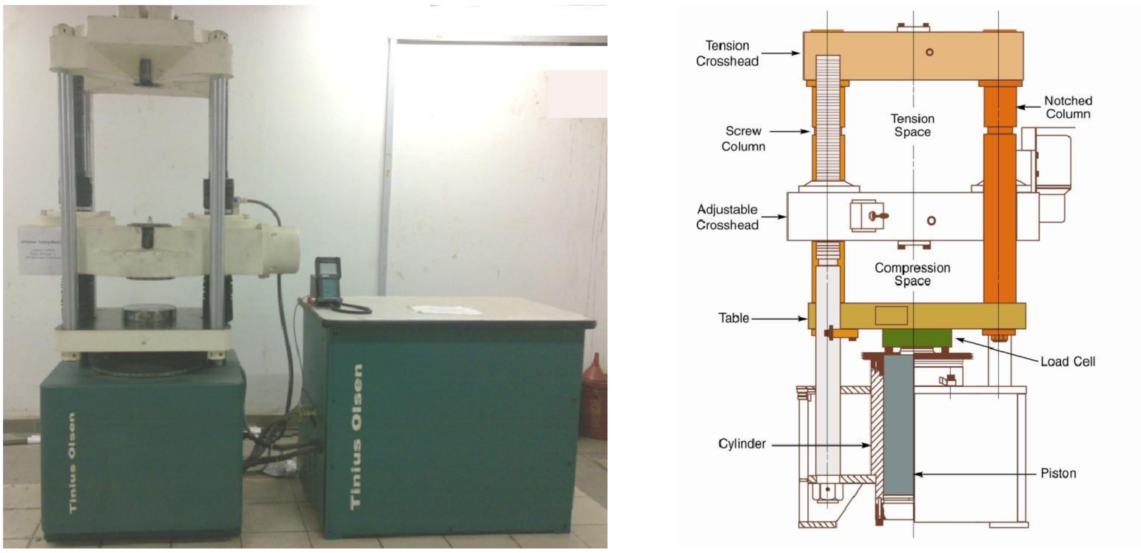
This experiment provides fundamental knowledge on compression behaviour of materials specially wood/timber, test procedure, universal testing machine and its working principal, compression specimens, failure pattern etc.

4. APPARATUS AND MACHINE

Digital Universal testing machine (UTM), digital slide calipers, steel tape, stop watch and computer.

5. SPECIMEN

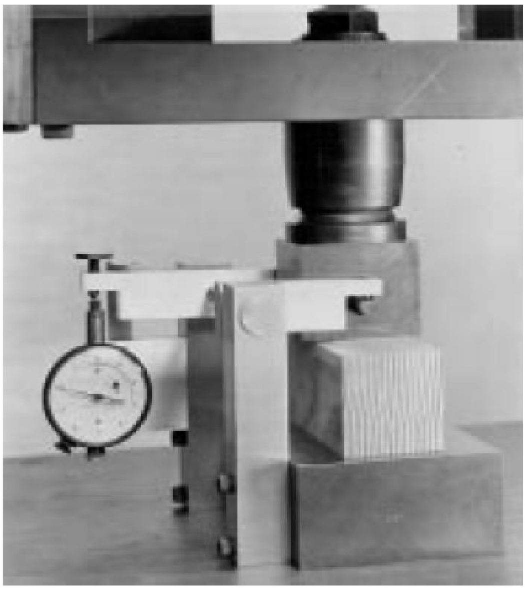
Cube shaped 2″x2″x8″ (parallel loading) and 2″x2″x6″ (perpendicular loading) wooden blocks.



(a) (b)

Figure 1: (a) Universal Testing Machine (UTM) (b) Schematic diagram of UTM

(a)



(b)

Figure 3: (a) Compression-Parallel-to-Grain Test Assembly, (b) Compression-Perpendicular-to-Grain Test Assembly (image from ASTM D 143)

6. THEORY

Stress – strain relationship for timber is exceedingly complex, resulting from the facts that,

(a) Timber does not behave in a truly elastic mode; rather is behavior is time dependent.

(b) The magnitude of strain is influenced by a wide range of factors; some of those are property dependent, such as density of the timber, angle of grain relative to direction of load application, angle of the micro-fibrils within the cell wall; others are environmentally dependent, such as temperature and relative humidity.

There are several limitations to the compression test to which attention should be directed:

(1) The difficulty of applying a truly concentric or axial load.

(2) The relatively unstable character of this type of loading as contrasted to the tensile loading. There is always a tendency for bending stresses to be set up and for the effect of accidental irregularities in alignment with the specimen to be accentuated as loading proceeds.

(3) Friction between the heads of the testing machine or bearing plates and the end surface of the specimen due to lateral expansion of the specimen. This may alter considerably the results that would be obtained if such a condition of test were not present.

(4)The relatively larger cross – sectional areas of the compression test specimen, in order to obtain a proper degree of stability of the piece. This results in the necessity for a relatively large –capacity testing machine or a specimen so small and therefore so short that is difficult to obtain from them strain measurements of suitable precision . It is presumed that the simple compression characteristics of materials are desired and not the column action of structural members, so that attention here confined to the short compression block.

Wood is commonly used engineering material showing different mechanical behavior under tension and compression loading. However, contrary to gray cast Iron or concrete, it does not show brittle characteristics under tensile loading and surprisingly, it is considerably stronger in tension than compression. The fact that the cell structures in the material are stronger in the longitudinal than transverse direction is the major factor leading to this unusual mechanical behavior of wood.

Wood exhibits, under compressive loading, a behavior peculiar to itself. it is anything but an isotropic material, being composed of cell formed by organic growth which align themselves to from a series of tubes or columns in the direction to the grain. As a result of this structure, the elastic limit is relatively low, there is no definite yield point, and considerable set takes place before failure. These properties vary with the orientation of the load with respect to the direction of the grain. For loads normal to grain, the load that causes lateral collapse of the tubes or fibers is the significant load. For load parallel to grain, not only the elastic strength important but also the strength at rupture. Rupture often occurs because of collapse of the tubular fibers as column.

Compression load parallel to grain can be carried by the strongest fibers, whereas compression loads perpendicular to the grain are carried by both weak and strong fibers. Wood in compression parallel to the grain can carry three to four times the load that wood in compression perpendicular to the grain can carry.

Compression failure of wood perpendicular to the grain involves the complete crushing of the wood fiber (the cell with the thinnest walls collapse first, and the action proceeds gradually). Compression failure of wood parallel to the grain involves the bending or buckling of the wood fibers.

Several materials, which are good in tension, are poor in compression. Contrary to this, many materials poor which are in tension but very strong in compression. Several machine and structure components such as columns and struts are subjected to compressive load in applications. These components are made of high compressive strength materials. Not all the materials are strong in compression. That is why determination of ultimate compressive strength is essential before using a material.

Compression test is just opposite in nature to tensile test. Nature of deformation and fracture is quite different from that in tensile test. Compressive load tends to squeeze the specimen. Brittle materials are generally weak in tension but strong in compression. Hence this test is normally performed on cast iron, cement concrete, wood etc. But ductile materials like aluminum and mild steel which are strong in tension are also tested in compression.

A compression test can be performed on UTM by keeping the test-piece on base block and moving down the central grip to apply load. It can also be performed on a compression testing machine. A compression testing machine has two compression plates/heads. The upper head moveable while the lower head is stationary. One of the two heads is equipped with a hemispherical bearing to obtain uniform distribution of load over the test- piece ends. A load gauge is fitted for recording the applied load.

In cylindrical specimen, it is essential to keep $h/d < 2$ to avoid lateral instability due to bucking action. In cubic specimen, d is the minimum width.

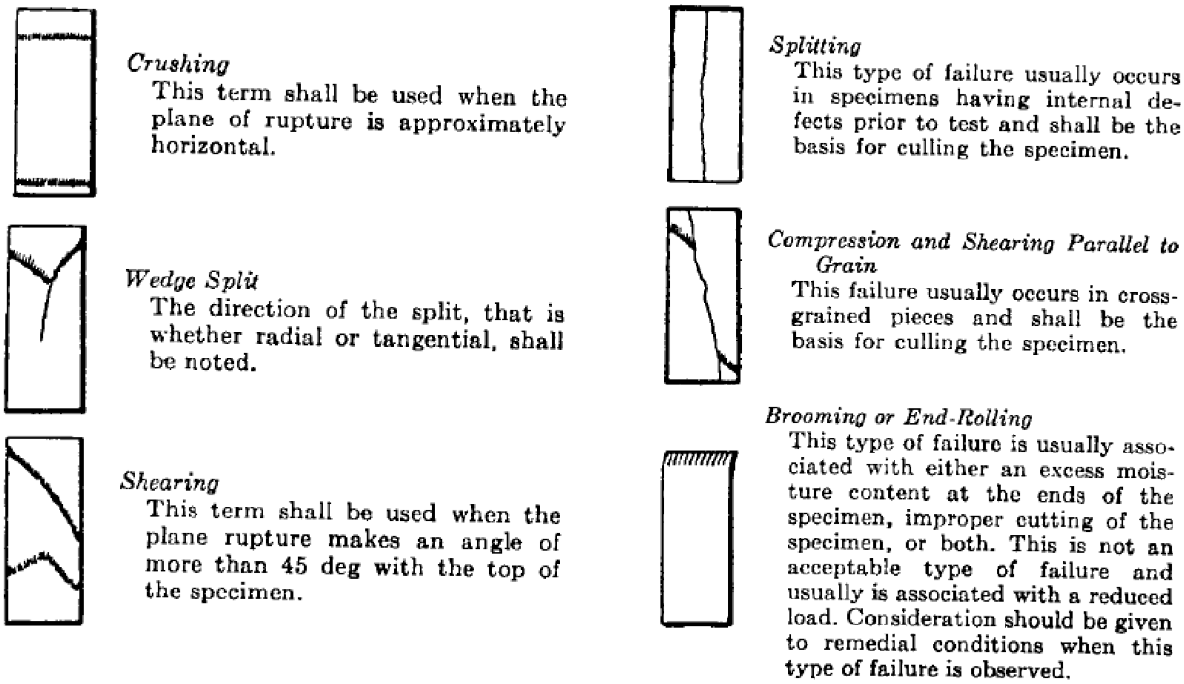
7. PROCEDURE

i) Measure the size of the specimen with a slide calipers.
ii) Place the block on the proper position of the testing machine.
iii) Apply load continuously on the specimen until failure.
iv) Record the maximum load at failure.
v) Note the characteristics of the fractured surfaces and show the failure plane.

8. SAMPLE CALCULATIONS

Strain rate =
Initial length or height of specimen, h_i =
Final length or height of specimen, h_f =
Initial minimum width of specimen, d_i =
Final minimum width of specimen, d_f =
Initial cross-sectional area, A_i =
Final cross-sectional area, A_f =

9. FAILURE PATTERNS



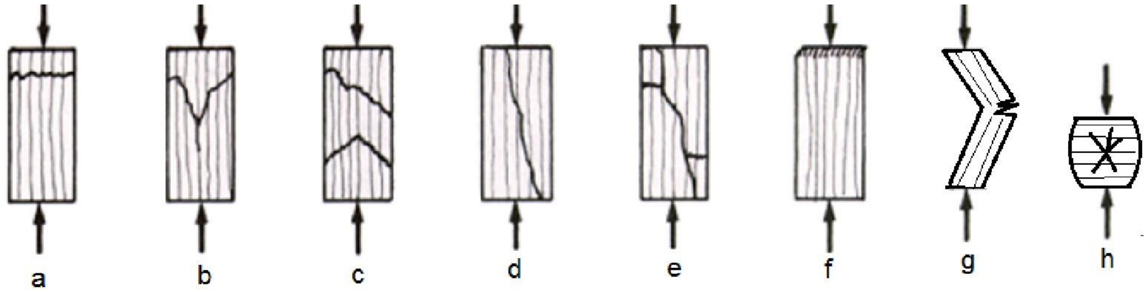


Figure 2: Schematic diagram of failure pattern of wooden specimens.

Parallel Loading:

a = crushing,

b = wedge split,

c = shearing,

d = splitting,

e = compression and shearing parallel to plane,

f = brooming or end rolling,

g = bending or buckling,

Perpendicular Loading

h = barreling or bulging

10. SAMPLE CALCULATIONS

1. Draw stress-strain curve in compression.
2. Determine Modulus of Elasticity in compression,

$$E = \frac{\Delta Stress}{\Delta Strain}$$

3. Determine proportional limit, σ_{PL} , ultimate (max.) compressive strength, σ_{ult} , and strain at $\sigma_{PL,}$ ultimate strain ε_{ult} from graph.
4. Determine percentage reduction in length (or height) to the specimen

$$\% \ \ Reduction\,of\ length\ = \frac{h_i - h_f}{h_i} \times 100\,\%$$

5. Determine Poisson's ratio,

$$v = \frac{lateral\ Strain}{axial\ strain} = \frac{\frac{d_f - d_i}{d_i}}{\frac{h_i - h_f}{h_f}}$$

6. Observe failure patterns and failure location w.r.t. loading direction.

11. GRAPH

1. Compressive stress vs. Strain for parallel loading.
2. Compressive stress vs. Strain for perpendicular loading.
3. Combined Compressive stress vs. Strain for all specimens.

12. RESULT

(Students will fill up this section with their individual outcome/result about the test.)

	Case 1 (Parallel loading)	Case 2 (Perpendicular loading)
Ultimate Load, *P* (N)		
Modulus of Elasticity, *E* (MPa)		
Ultimate Stress, σ_{ult} (MPa)		
% Reduction in length		
Poisson's ratio, v		
Ultimate Strain, ε_{ult}		
Modulus of Resilience, G=0.5 σ_{PL} ε_{PL} (MPa)		
Failure pattern		
Failure location		

13. DISCUSSION

(Discuss on the results found, graphs, and failure patterns and also compare the results found, graphs and failure patterns.)

Point out the discussion

1.

2.

3. ….

14. ASSIGNMENT

1. Compression tests are generally performed on brittles materials, why? Justify your answer.
2. Which will have a higher strength: a small specimen or a full-size member made of the same material?
3. What is column action? How does the h/d ratio of specimen affect the test result?
4. How do ductile and brittle materials differ in their behavior in compression test?

Courtesy: AUST, Bd, Lab Manual

Review and Problem Solving Class

Week 17

Thank you for your kind attention

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