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**Vishwanathrao Deshpande Institute of Technology
Haliyal - 581329**

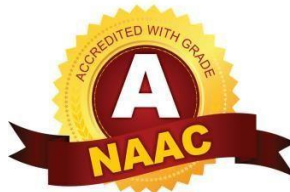
Civil Engineering Department

LAB Manual

2022 Scheme

Semester : 4th

Sl.No.	Lab Details	Lab Code	Pg. No.
1	Fluid Mechanics and Hydraulics Laboratory	BCV402	1-58
2	Transportation Engineering Laboratory	BCV403	59-126
3	Building Materials and Testing Laboratory	BCVL404	127-224
4	GIS with Quantum GIS Laboratory	BCV456B	225-258



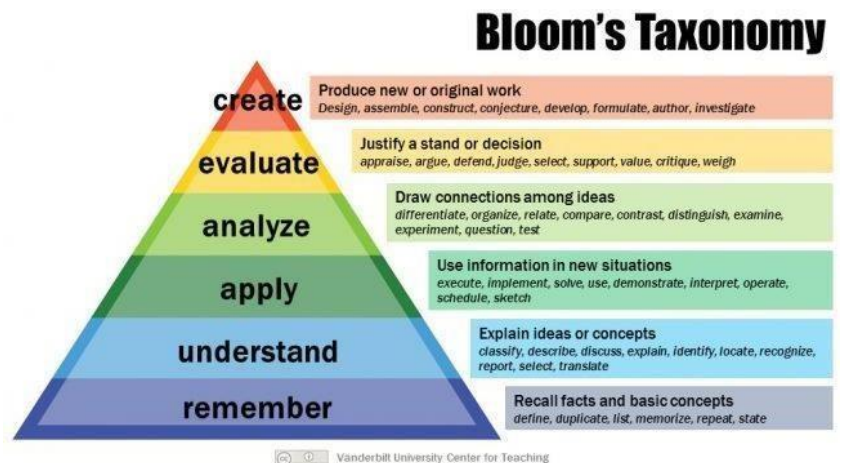
As prescribed by

**VISVESVARAYA TECHNOLOGICAL UNIVERSITY,
BELAGAVI - 590014**

PROGRAM OUTCOMES(POs)

Program Outcomes as defined by NBA (PO) Engineering Graduates will be able to:

- 1. Engineering knowledge:** Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.
- 2. Problem analysis:** Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.
- 3. Design/development of solutions:** Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.
- 4. Conduct investigations of complex problems:** Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.
- 5. Modern tool usage:** Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.
- 6. The engineer and society:** Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice.
- 7. Environment and sustainability:** Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.
- 8. Ethics:** Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.
- 9. Individual and team work:** Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.
- 10. Communication:** Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.
- 11. Project management and finance:** Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.
- 12. Life-long learning:** Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.



Vision (College)	
To nurture talent & enrich society through excellence in technical education, research & innovation.	
Mission (College)	
<ol style="list-style-type: none"> 1. To augment innovative. Pedagogy & kindle quest for interdisciplinary learning & to enhance conceptual understanding. 2. To build competence, professional ethics & develop entrepreneurial thinking. 3. To strengthen Industry Institute Partnership & explore global collaborations. 4. To inculcate culture of socially responsible citizenship. 5. To focus on Holistic & Sustainable development 	
Vision (Dept)	
“To excel in imparting civil engineering knowledge of global standards in meeting societal and environmental challenges with professional ethics.”	
Mission (Dept)	
<ol style="list-style-type: none"> 1. To develop entrepreneurial and skill and team work among students. 2. To inculcate basics of civil engineering knowledge to meet the professional challenges through research and innovation in collaboration with industries. 3. To cultivate qualities of professional ethics and commitment towards welfare of the society and environment. 	
Program Educational Objectives (PEO)	
PEO1	To design and utilize new materials, processes, and projects through research and development for the welfare of society
PEO2	To communicate feasible technical solutions for civil engineering problems faced by public through presentations and demonstrations.
PEO3	To enhance the personal knowledge, leadership quality and entrepreneurial skill to succeed in civil engineering profession.
Program Specific Outcomes (PSO)	
PSO 1	Graduates will be able to plan, analyse and design in order to execute and maintain civil engineering structures using alternative materials and innovative construction practices for sustainable infrastructural development of the nation.
PSO 2	Graduates will be able to pursue career opportunities for personal and professional growth by demonstrating leadership skill, professional integrity and solve issues related to civil engineering and allied fields.

Fluid Mechanics and Hydraulics Laboratory

(BCV402)

CO's And PO's Mapping Chart

S.No	Description	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO 10	PO 11	PO 12	PSO 1	PSO 2
1	To explain the fundamental properties of fluids and solve problems on fluid pressure and hydrostatics.		3		3										
2	To apply the principles of kinematics and dynamics of fluid flow to solve problems on velocity and pressure.				3										
3	To compute the discharge through pipes, notches and weirs.					3									
4	To design the turbines and open channels of different sections and to estimate the energy loss in hydraulic jump.		2	3										3	
5	Able to interpret the experimental results of discharge, efficiency based on the test conducted in the laboratory.			3										3	

Evaluation:

Integrated Lab(IPCC)		
CIE		
Particulars	Marks	Total
Performance	07	15
Journal	05	
Viva Voce	03	
Lab IA		
Particulars	Marks	Total
IA	100	10 (Reduced)
Total (CIE +Lab IA)		25

Mapping of Experiments with CO, PO and PSO

S.No.	Experiment Details	CO	PO	PSO
1	Verification of Bernoulli's Equation	1	2	
2	Determination of Cd for Venturi-meter/ Orificemeter	2	4	
3	Determination hydraulic coefficient of small vertical orifice	2	4	
4	Determination of Cd Triangular notch	3	5	
5	Determination of Cd for Cipoletti notch	3	5	
6	Determination of Major Loss in Pipes	4	3	1
7	Determination of Cd for Ogee weir/broad crested weir	3	5	
8	Determination of efficiency of jet on flat and curved vanes.	5	3	1
9	Determination of Cd for Venturiflume	2	4	
10	Demo of determination of efficiency of centrifugal pump	5	3	1
11	Demo of determination of efficiency of Francis turbine/kaplan turbine	5	3	1
12	Demo of determination of efficiency of Pelton wheel turbine	5	3	1

EXPERIMENT WISE LESSON PLAN

Experiment No.1	
Name	Verification of Bernoulli's Equation
Objectives	Students will able to investigate the validity of the Bernoulli equation when it is applied to a steady flow of water through a tapered duct.
Experiment No.2	
Name	Determination of Cd for Venturi-meter/ Orificemeter

Objectives	Students will able to obtain the coefficient of discharge from experimental data by utilizing venturi meter and, also the relationship between Reynolds number and the coefficient of discharge.
Experiment No.3	
Name	Determination hydraulic coefficient of small vertical orifice
Objectives	Students will able to determine the coefficients of velocity and discharge of two small orifices in the lab and compare them with values and other reliable sources.
Experiment No.4	
Name	Determination of Cd Triangular notch
Objectives	Students will able to determine the characteristics of flow over a triangular notch, and to determine the value of the discharge coefficient for both notches.
Experiment No.5	
Name	Determination of Cd for Cipoletti notch
Objectives	Students will able to determine the characteristics of flow over a cipoletti and to determine the value of the discharge coefficient for both notches.
Experiment No.6	
Name	Determination of Major Loss in Pipes
Objectives	Students will able to investigate head loss due to friction in a pipe, and to determine the associated friction factor under a range of flow rates and flow regimes, i.e., laminar, transitional, and turbulent.
Experiment No.7	
Name	Determination of Cd for Ogee weir/broad crested weir
Objectives	Students will able to determine the characteristics of flow over Ogee and Broad crested weir, & to determine the value of the discharge coefficient for both weir.
Experiment No.8	
Name	Determination of force exerted by a jet on flat and curved vanes.

Objectives	Students will able to investigate the reaction forces produced by the change in momentum of a fluid flow when a jet of water strikes a flat plate or a curved surface, and to compare the results from this experiment with the computed forces by applying the momentum equation.
Experiment No.9	
Name	Determination of Cd for Venturiflume
Objectives	Students will able to understand discharge through venturiflume
Experiment No.10	
Name	Demo of determination of efficiency of centrifugal pump
Objectives	Students will able to determine the operational characteristics of centrifugal pump
Experiment No.11	
Name	Demo of determination of efficiency of Francis turbine/kaplan turbine
Objectives	Students will able to characteristic curves of a Francis/Kaplan turbine operating at a different fluid flow rates with high head.
Experiment No.12	
Name	Demo of determination of efficiency of Pelton wheel turbine
Objectives	Students will able to characteristic curves of a Pelton turbine operating at a different fluid flow rates with high head.

LIST OF EXPERIMENTS

S. No.	Experiment	Page. No
1	Verification of Bernoulli's Equation	6-9
2	Determination of Cd for Venturi-meter/ Orificemeter	10-16
3	Determination hydraulic coefficient of small vertical orifice	17-19
4	Determination of Cd Triangular notch	20-23
5	Determination of Cd for Cipoletti notch	24-26
6	Determination of Major Loss in Pipes	27-30
7	Determination of Cd for Ogee weir/broad crested weir	31-37
8	Determination of efficiency of jet on flat and curved vanes.	38-41
9	Determination of Cd for Venturiflume	42-44
10	Demo of determination of efficiency of centrifugal pump	45-48
11	Demo of determination of efficiency of Francis turbine/kaplan turbine	49-52
12	Demo of determination of efficiency of Pelton wheel turbine	53-57

LAB SAFETY & USAGE INSTRUCTIONS

1. Eating, drinking, or smoking is strictly prohibited inside the computer laboratory.
2. Maintain clean and orderly laboratories and work area.
3. Discard immediately unwanted items.
4. Students should maintain discipline and follow instructions given by the lab instructor.
5. Students are responsible for maintaining work area in a safe and reasonable condition.
6. Bags and personal belongings should be kept in designated areas.
7. Be aware of the various experiment controls (start button, stop button, speed control) for each lab.
8. Be aware of the experiment harness when conducting experiments.
9. Do not leave experiments running unattended.
10. Any injuries should be reported immediately for proper care.

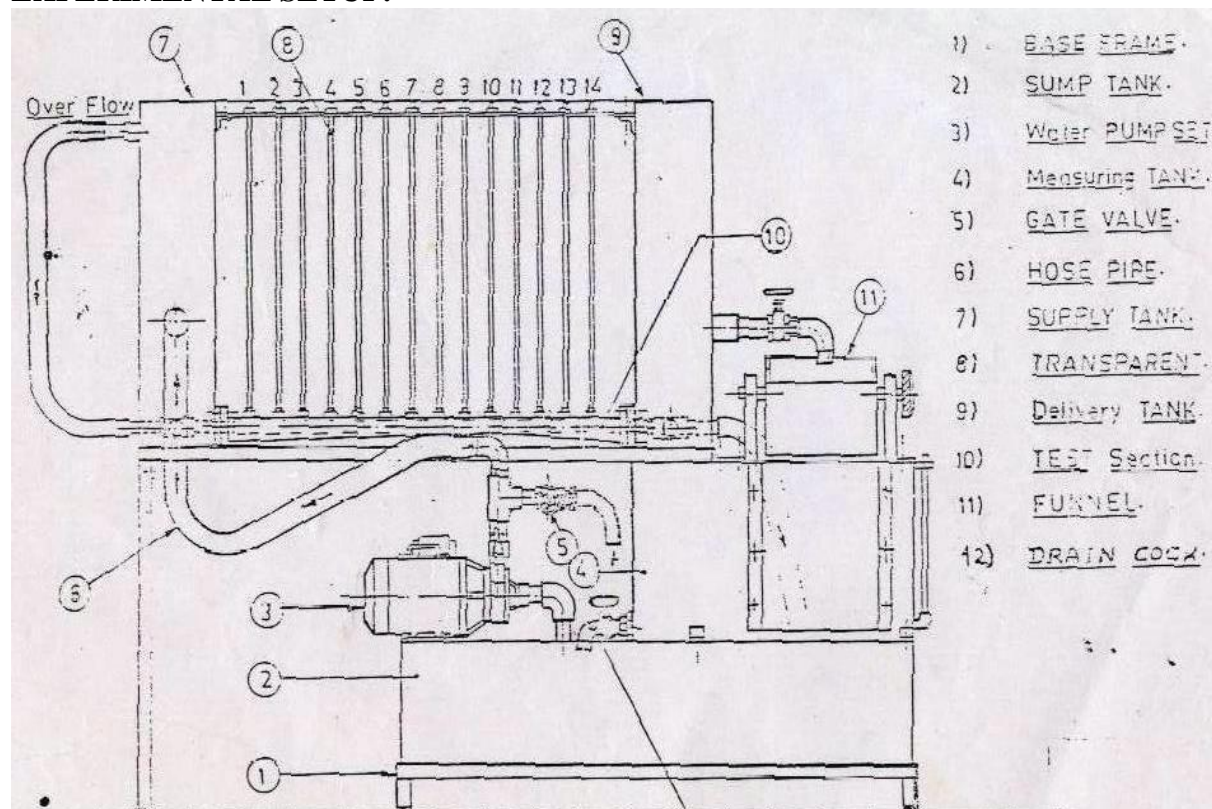
**VERIFICATION OF BERNOULLI'S
EQUATION**

EXPT. NO: 1

DATE:

VERIFICATION OF BERNOULLI'S EQUATION**AIM:** To verify the Bernoulli's energy equation.**APPARATUS REQUIRED:**

1. Bernoulli's equipment
2. Stop watch
3. Meter scale

EXPERIMENTAL SETUP:

The apparatus consists of a receiving cylinder to store water to the required head, a closed conduit of uniformly varying cross - section, number of piezometers take along the path of the conduit to measure the pressure head at the point, and a controlling valve to control rate of flow of water. A collecting tank is provided to find out the actual discharge. According to Bernoulli's theorem, the sum of pressure head, velocity head and elevation head is constant for all points along a continuous conduit of frictionless flow.

THEORY:

For a steady, continuous, incompressible, non-viscous fluid flow, the Bernoulli's equation represents the total energy or total head at all sections along the fluid flow which remains constant. It is given by $p/\rho g + V^2/2g + Z = \text{Constant}$

where, $p/\rho g$ is the pressure head (m), $V^2/2g$ the velocity and kinetic head (m), z the potential head, p the pressure intensity, ρg the specific weight of fluid, V the mean velocity of the flow and g is acceleration due to gravity.

As the fluid flows, the total energy is reduced in the direction of the flow due to losses (h_L). Hence, the Bernoulli's equation is modified as

$$P_1/\rho g + V_1^2/2g + Z_1 = p_2/\rho g + V_2^2/2g + Z_2 + h_L$$

Where suffices 1 and 2 represents two sections in the direction of flow.

The pressure head at any point in a fluid is represented by the fluid level in the piezometer tube. The line joining the water surface elevation in piezometers gives hydraulic grade line (HGL). The HGL

represents the piezometer head, which is the sum of pressure head ($p/\rho g$) and potential head (Z). If the kinetic head, $V^2/2g$ is added to the piezometer head at every point along the flow direction, it results into total energy line (TEL) or energy grade line (EGL).

PROCEDURE:

1. Open the gate valve and allow the water to flow through receiving cylinder
2. Slowly open outlet gate valve and adjust the supply such that for a particular head in the receiving cylinder, the inflow and outflow are equal.
3. Note the height of water above the center of conduit in each tube.
4. Find out the rise of water level in the collecting tank for 10cm.
5. Calculate the area of cross-section of the conduit at points where the pressure heads are measured.
6. Change the discharge and repeat the procedure.

OBSERVATIONS:

Area of the measuring tank (A): 0.25 mm^2

Piezometer pipes	1	2	3	4	5	6	7	8	9	10
Area of pipes(mm)	491	357	245	153	123	153	202	279	369	471

TABULAR COLUMN:

Sl. no	Static head losses (m)										Depth of water in tank 'r' (m)	Time of collection 't' (sec)	Discharge 'Q' (m^3/s)	Piezometer no	1	2	3	4	5	6	7	8	9	10
	1	2	3	4	5	6	7	8	9	10				Area of pipes 'a' (m^2)										
1														'V' (m/s)										
														'(p/ρg)' (m)										
														'(V ² /2g)' (m)										
														'(Z)' (m)										
														(p/ρg + Z) (m)										
														(p/ρg + V ² /2g + Z) (m)										
Average total head =																								

SPECIMEN CALCULATION:

1. Velocity = $V = Q/a \dots \dots \dots \text{m/s}$

2. Pressure intensity = $P = \rho \cdot g \cdot h$

(Where h = rise of water level in different piezometers)

3. Actual discharge = $Q = A \times r / t \dots \dots \dots \text{m}^3/\text{s}$

4. Total head = $(p/\rho g + V^2/2g + Z) = \dots \dots \dots \text{m}$

GRAPH:

Plot hydraulic grade line (HGL) and total energy line (TEL)

RESULT:

Bernoulli's theorem is verified experimentally.

REVIEW OF LEARNING OBJECTIVES:

1. What is Bernoulli's equation?
2. What is the practical application of Bernoulli's equation?
3. What do you mean by piezometric head, HGL and TEL.?

**DETERMINATION OF Cd FOR VENTURI-
METER**

EXPT. NO:2(a)

DATE:

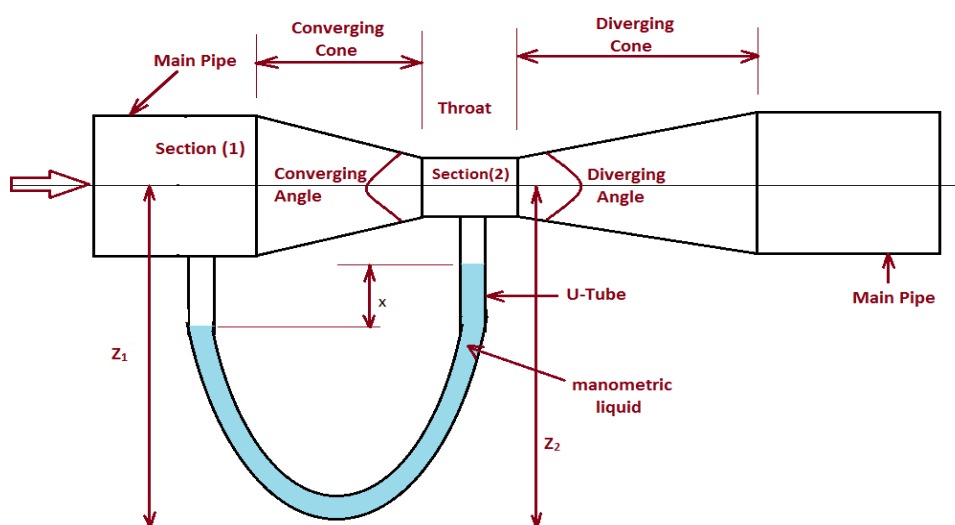
DETERMINATION OF Cd FOR VENTURI-METER

AIM: To determine the coefficient of discharge of a venturi meter.

APPARATUS REQUIRED:

1. Venturi meter set-up
2. Stopwatch
3. Scale
4. Manometer

DIAGRAM:



THEORY:

A venturi meter is a device which is used to measure the rate of flow or discharge in a pipe. The experimental set-up illustrating the use of venturi meter fitted in a pipe is shown in the figure. It works on the principle of measurement of pressure drop in the direction of flow that facilitates in the measurement of discharge. The pressure drop is created by reduction of flow area in the flow direction. The reduction in flow area is made gradual by providing a convergent cone, throat and a divergent cone. The pressure difference between inlet section 1 and throat section 2 is measured using U-tube differential manometer as presented in figure. The manometric head 'x' is used in discharge calculations as given below.

PROCEDURE:

1. Note down the diameter of the inlet pipe (d_1) and the throat (d_2).
2. Compute the cross-sectional areas of flow at inlet (a_1) and throat (a_2) section.
3. Record the dimensions of the measuring tank (length & width)
4. Open an inlet valve and allow the water to flow through the pipe.
5. Note down the mercury level in the two limbs of the manometer (h_1 and h_2).
6. Compute the pressure head between the section 1 and 2 as 'x'.
7. Calculate the pressure head in terms of water depth by $h = (S_m / S_w - 1)x$, where S_m is the specific gravity of manometric liquid and S_w the specific gravity of water.
8. Collect the water in the measuring tank for a known height (r) and record the time of collection (t).
9. Calculate the volumetric discharge Q_{act}

10. Compute the theoretical discharge Q_{th}
11. Determine the coefficient of discharge C_d
12. Repeat the procedure for different discharge (increasing/ decreasing) values.

OBSERVATIONS:

1. Diameter of inlet pipe, $d_1 = 26\text{mm} = \dots\dots\dots \text{m}$
2. Area of the inlet pipe, $a_1 = \pi/4 (d_1)^2 = \dots\dots\dots \text{m}^2$
3. Diameter of inlet pipe, $d_2 = 13\text{mm} = \dots\dots\dots \text{m}$
4. Area of the inlet pipe, $a_2 = \pi/4 (d_2)^2 = \dots\dots\dots \text{m}^2$
5. Acceleration due to gravity, $g = 9.81\text{m/s}^2$
6. Area of measuring tank, $A = 500\text{mm} \times 330\text{mm} = 0.165\text{m}^2$
7. Specific gravity of mercury, $S_m = 13.6$
8. Specific gravity of water, $S_w = 1$

TABULAR COLUMN:

Sl. no	Manometer reading (m)		Pressure head in terms of depth of water 'h' (m)	Depth of water collected 'r' (m)	Time of collection 't' (m)	Actual discharge ' Q_{act} ' m^3/s	Theoretical discharge ' Q_{th} ' m^3/s	Coefficient of discharge $C_d = Q_{act}/Q_{th}$
	Left ' h_1 ' (m)	Right ' h_2 ' (m)						
1.								
2.								
3.								
4.								
5.								

SPECIMEN CALCULATION:

1. Actual discharge, $Q_{act} = Axr/t = \dots\dots\dots \text{m}^3/\text{s}$
2. Theoretical discharge, $Q_{th} = \sqrt{2gh} \cdot (a_1 a_2 / \sqrt{a_1^2 - a_2^2}) \dots\dots \text{m}^3/\text{s}$
3. Pressure head in terms of water depth, $h = (S_m / S_w - 1)x \dots\dots\dots \text{m}$
4. Coefficient of discharge, $C_d = Q_{act}/Q_{th}$

GRAPHS:

1. Plot Q_{act} versus h .
2. Plot $\log(Q_{act})$ versus $\log(h)$ on natural graph or Q_{act} versus h on log-log graph.

NATURE OF GRAPH:**RESULT:**

Obtain K and n from the graph of $\log(Q_{act})$ versus $\log(h)$ and compute

$$C_d = K \sqrt{a_1^2 - a_2^2} / a_1 a_2 \sqrt{2g}$$

REVIEW OF LEARNING OBJECTIVES:

1. What is the use of venture meter?
2. What is the basic principle on which venture meter works?
3. Explain the construction of venture meter.
4. What is the range of angle of the convergent and divergent cones?
5. Whether the convergent cone is longer or divergent cone? why?
6. Why there is no pressure tapping in divergent cone of the venture meter?
7. What is venture head?
8. Define the coefficient of discharge.

DETERMINATION OF C_d FOR ORIFICE-METER

EXPT. NO:2(b)

DATE:

DETERMINATION OF C_d FOR ORIFICE-METER

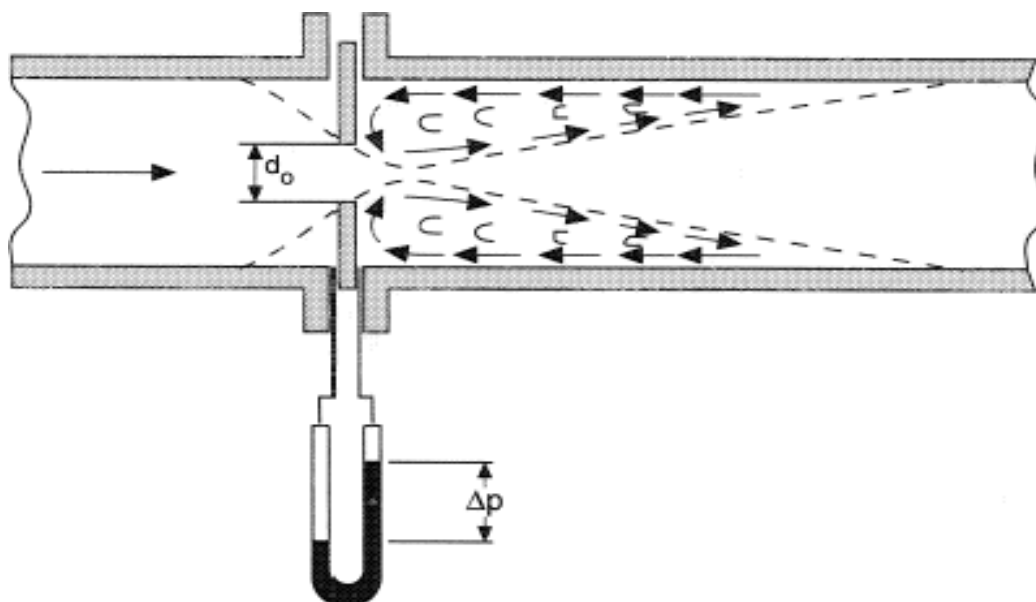
AIM: To determine co-efficient of discharge of an Orifice-meter

APPARATUS REQUIRED:

1. Orifice-meter set up
2. Stopwatch
3. Scale
4. manometer

EXPERIMENTAL SETUP:

The figure below shows the experimental set-up for calibration of orifice-meter as well as details of orifice meter.



THEORY:

An orifice meter is used to measure the discharge in a pipe. The experimental set-up illustrating the use of orifice meter fitted in a pipe is shown in the figure. An orifice meter consists of a plate provided with an orifice-plate (a circular opening) fitted concentric with the axis of the pipe as shown in the figure. It is suitable in locations where Venturi meter cannot be fitted due to space restrictions. When the jet comes out of the orifice plate, its diameter decreases to a minimum at a section called vena contracta and then expands to occupy the full pipe size. At, vena contracta, the stream lines will be parallel to each other and they will be perpendicular to the cross-sectional area of flow. Due to decrease in area, a pressure drop is created between the upstream section of the orifice plate and vena contracta, which is used to compute the discharge through the pipe.

PROCEDURE:

1. Note down the diameter of the inlet pipe (d_1) and the orifice (d_o).
2. Compute the cross-sectional area of flow at inlet (a_1) and the orifice (a_o)
3. Record the dimension of the measuring tank (length a and breadth b).
4. Open an inlet valve and allow the water to flow through the pipe.
5. Note down the mercury level in the two limbs of the manometer (h_1 and h_2).

6. Compute the pressure head between sections 1 and 2 as $x = h_2 - h_1$.
7. Calculate the pressure head in terms of water depth by $h = (S_m/S - 1) x$.
8. Collect the water in the measuring tank for a known height (H) and record the time of collection (t).
9. Calculate the volumetric (actual) discharge $Q_{act} = (a \times b \times h)/t$.
10. Determine the coefficient of discharge $C_d =$
11. Repeat the procedure for different discharge (increasing/decreasing) values.

OBSERVATIONS:

1. Diameter of inlet pipe, $d_1 =$mm.
2. Diameter of orifice, $d_o =$mm.
3. Cross-sectional dimensions of measuring tank, $a \times b =$ mm x.....mm.
4. Cross-sectional area of inlet pipe, $a_1 =$mm².
5. Cross-sectional area of orifice, $a_o =$mm².
6. Specific gravity of manometric liquid, $S_m =$
7. Specific gravity of water, $S =$

TABULAR COLUMN:

Sl. No	Manometer readings (mm)			Pressure head in terms of depth of water h (mm)	Depth of water collected H (mm)	Time of collection t (sec)	Volumetric discharge Q_{act} (mm ³ /s)	Coefficient of discharge C_d
	Left limb h_1	Right limb h_2	Manometer head $x = h_2 - h_1$					
1								
2								
3								
4								
5								

SPECIMEN CALCULATION:

1. Volumetric discharge, $Q_{act} =$
2. Coefficient of discharge, $C_d =$

GRAPH:

1. Plot Q_{act} versus h or Q_{act} versus h on log-log paper.
2. Plot $\log(Q_{act})$ versus $\log(h)$ on natural graph.

NATURE OF GRAPH:**RESULT:**

Obtain K and n from graph of $\log(Q_{act})$ versus $\log(h)$ and compute $C_d =$

REVIEW OF LEARNING OBJECTIVES:

1. What is the use of orifice meter?
2. What is the range of orifice diameter?
3. Define the vena contracta.
4. What is the difference between orifice meter and venturimeter?

**DETERMINATION OF HYDRAULIC
COEFFICIENTS OF SMALL VERTICAL
ORIFICE**

EXPT. NO:3

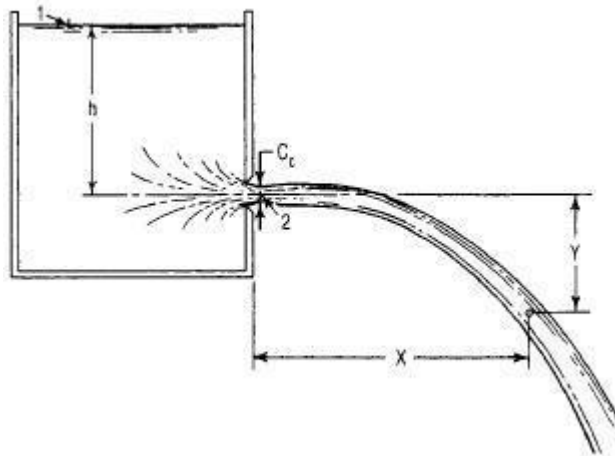
DATE:

DETERMINATION OF HYDRAULIC COEFFICIENTS OF SMALL VERTICAL ORIFICE**AIM:** To determine the hydraulic coefficients of small vertical orifice**APPARATUS REQUIRED:**

1. Experimental set-up fitted with orifice
2. Stopwatch
3. Scale

EXPERIMENTAL SETUP:

The figure shown below represents the experimental set-up for calibration of orifice.

**THEORY:**

An orifice is an opening provided in the side or at the bottom of a tank for emptying purpose. The discharging capacity of the orifice depends on the head. The head losses through the orifice are expressed in terms of its hydraulic coefficients.

PROCEDURE:

1. Note down the diameter of orifice (d_o).
2. Compute the cross-sectional area of the orifice (a_o).
3. Record the dimensions of the measuring tank (length a , and width b).
4. Fix the orifice to the overhead tank.
5. Open the inlet valve and allow the water to attain a constant head in the overhead tank and note down the head (H).
6. Collect the water in the measuring tank for a known height (h) and record the time of collection (t).
7. Calculate the volumetric discharge $Q_{act} = (a \times b \times h)/t$ (m^3/s)
8. Determine the theoretical discharge $Q_{th} = a_o \sqrt{2gH}$ (m^3/s)
9. Calculate the coefficient of discharge $C_d = Q_{act} / Q_{th}$
10. Obtain the coordinates of the jet (x and y)
11. Compute the coefficient of contraction $C_c = C_d / C_v$
12. Repeat the procedure for different discharge (increasing /decreasing) values.

OBSERVATIONS:

1. Diameter of orifice, $d_o =$ mm.
2. Cross-sectional dimensions of measuring tank, $a \times b =$ mm x mm.
3. Cross-sectional area of orifice, $a_o =$ mm^2 .

TABULAR COLUMN:

Sl. no	Constant head in tank H (mm)	x (mm)	y (mm)	Depth of water collected 'r' (mm)	Time of collection t (sec)	Actual discharge Q_{act} (m^3/s)	Theoretical discharge Q_{th} (m^3/s)	Coefficient of discharge C_d	Coefficient of velocity C_v	Coefficient of contraction C_c
1										
2										
3										
4										
5										

SPECIMEN CALCULATION:

1. Volumetric discharge $Q_{act} = (a \times b \times h)/t = \dots$ (m^3/s)
2. Theoretical discharge $Q_{th} = a\sqrt{2gH} = \dots$ (m^3/s)
3. coefficient of discharge $C_d = Q_{act} / Q_{th}$
4. coefficient of contraction $C_c = C_d/C_v$

GRAPH:

1. Plot Q_{act} versus H .
2. Plot x and $2\sqrt{Hy}$

NATURE OF GRAGH:**RESULT:**

The average C_d of vertical orifice is

REVIEW OF LEARNING OBJECTIVES:

1. What is an orifice? Explain its classifications.
2. Define coefficient of resistance.
3. Define C_d , C_v & C_c .
4. How do you determine C_d of an orifice?
5. Differentiate between a large and small orifice.

**DETERMINATION OF Cd FOR
TRIANGULAR NOTCH**

EXPT. NO:4

DATE:

DETERMINATION OF C_d FOR TRIANGULAR NOTCH

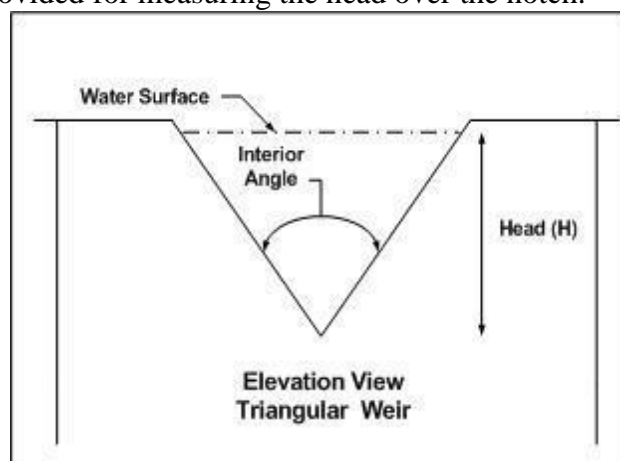
AIM: To determine the coefficient of discharge of a triangular notch.

APPARATUS REQUIRED:

1. Triangular Notch setup
2. Collecting tank with piezometer
3. Scale
4. Stop watch

EXPERIMENTAL SETUP:

The setup consists of a shallow open channel provided on the top of the hydraulic bench. A sharp edge V-notch is fitted at the downstream end of the channel. Water is supplied through an inlet valve provided in the supply pipeline connected to a constant overhead tank. A honey comb wall is placed at the entrance to stabilize the flow and to reduce the velocity of approach. A pointer gauge is provided for measuring the head over the notch.



THEORY:

A notch may be defined as an opening provided in the side of a tank such that the fluid surface in the tank is below the top edge of the opening. The water flowing through the notch is known as nappy. The bottom edge of a notch over which the water flows is known as the sill and its height above the bottom of the tank or channel is known as crest height. The notches are usually classified according to the shape of openings. The edges of the notch are leveled on the Down-stream side so as to have sharp edged sides and crest, resulting minimum contract with the flowing liquid

The discharge Q over the triangular notch is given by the following expression.

$$Q = (8/15) \times C_d \times (\sqrt{2g}) \times \tan(\theta/2) \times (H)^{5/2} \dots \dots \dots (1)$$

Where,

C_d = Coefficient of discharge

g = Acceleration due to gravity (9.81 m/s^2)

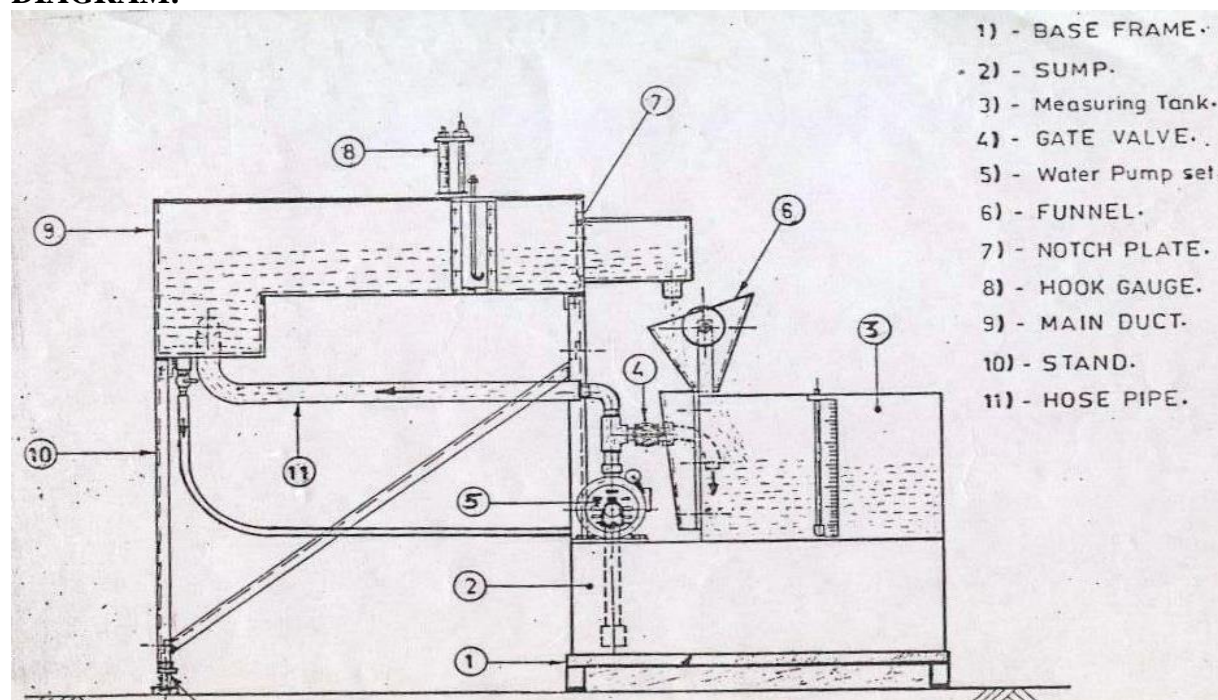
θ = angle of notch (in degree)

H = head of the water above crest or sill of the notch.

PROCEDURE:

1. Note down the crest angle (θ).
2. Record the dimensions of the measuring tank (length a and width b).

3. Open an inlet valve and allow the water to flow in the channel and rise up to the crest of the notch.
4. Adjust the point gauge to touch the free surface and note down the point gauge reading (H_1).
5. Increase the inflow discharge to certain value and wait till the flow reaches the steady state. Adjust the point gauge to touch the surface of water and record the point gauge reading (H_2).
6. Hence, the head over the crest of the notch is $H = H_2 - H_1$.
7. Now, collect the water in the measuring tank for a known depth (r) and record the time of collection (t). Or collect the water for a known time interval and note down the depth of water in the tank.
8. Calculate the volumetric (actual) discharge $Q_{act} = (a \times b \times r)/t$.
9. Compute the theoretical discharge Q_{th} from equation (1).
10. Determine the coefficient of discharge $C_d = Q_{act} / Q_{th}$.
11. Repeat the procedure for different discharge (increasing / decreasing) values.

DIAGRAM:**OBSERVATIONS:**

1. Crest angle of V-notch = $\theta = 60^\circ$
2. Cross-sectional dimensions of measuring tank, $a \times b = \dots\dots\dots\text{mm} \times \dots\dots\dots\text{mm}$.

TABULAR COLUMN:

Sl.no	Pointer gauge		Head over crest $H = (H_2 - H_1)$ (m)	Depth of water collected 'r' (m)	Volumetric discharge Q_{act} (m^3/s)	Time of collection 't' (s)	Theoretical discharge Q_{th} (m^3/s)	Coefficient of discharge $C_d = Q_{act} / Q_{th}$
	H_1 (m)	H_2 (m)						

1.								
2.								
3.								
4.								
5.								

SPECIMEN CALCULATIONS:

1. Volumetric (actual) discharge, $Q_{act} = a \times b \times r / t = \dots\dots\dots (m^3/s)$.
2. Theoretical discharge, $Q_{th} = (8/15) \times (\sqrt{2g}) \tan (\theta/2) (H)^{5/2} = \dots\dots\dots (m^3/s)$.
3. Coefficient of discharge, $C_d = Q_{act} / Q_{th}$.

GRAPHS:

1. Plot Q_{act} versus H .
2. Plot $\log (Q_{act})$ on natural graph or Q_{act} versus H on log-log graph.

NATURE OF GRAGH:**RESULT:**

Obtain K and n from graph of $\log (Q_{act})$ versus $\log (H)$ and compute

$$C_d = K / [(8/15) \times (\sqrt{2g}) \tan (\theta/2)]$$

REVIEW OF LEARNING OBJECTIVES:

1. Define notch and explain its classifications.
2. Define the coefficient of discharge, C_d . What is its significance?
3. Why a triangular notch is preferred over a rectangular notch for measuring low discharge?
4. Explain the advantages of triangular notch over rectangular notch.
5. Under what condition you prefer triangular notch?

What is the meaning of calibration?

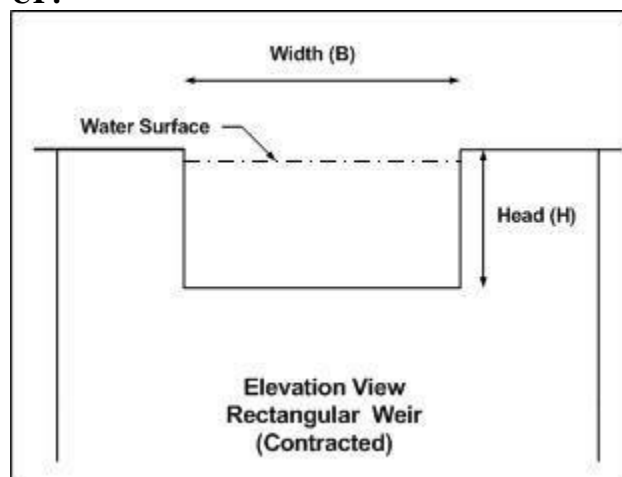
**DERERMINATION OF C_d FOR CIPOLETTI
NOTCH**

EXPT. NO: 5

DATE:

DETERMINATION OF THE COEFFICIENT OF DISCHARGE FOR CIPOLETTI NOTCH**AIM:** TO determine the coefficient of discharge of a rectangular notch.**APPARATUS REQUIRED:**

1. Experimental set-up fitted with rectangular notch
2. Stopwatch
3. Scale

EXPERIMENTAL SET-UP:**THEORY:**

Consider a rectangular notch of crest length, L , fitted at the end of a channel as shown in the figure. Let H be the head of the water over the crest of notch.

Therefore, total discharge is

$$Q = \frac{2}{3} \times C_d \times L \times \sqrt{2g} \times (H)^{3/2}$$

PROCEDURE:

1. Note down the crest length of the notch (L).
2. Record the dimensions of the measuring tank.
3. Open an inlet valve and allow the water to flow into the channel and rise up to the crest of the notch.
4. Adjust the point gauge to touch the free surface and note down the point gauge reading (H_1).
5. Increase the inflow discharge to certain value and allow it to reach steady state. Adjust the point gauge to touch the surface of water and record the point gauge reading (H_2).
6. Calculate the head over the crest of the notch by $H = H_2 - H_1$
7. Collect the water in the measuring tank for a known height (r) and record the time of collection (t).
8. Calculate the actual discharge, Q_{act} .
9. Compute the theoretical discharge, Q_{th} .
10. Determine the coefficient of discharge, C_d .
11. Repeat the procedure for different discharge (increasing/ decreasing) values.

OBSERVATIONS:

1. Crest length of the notch, $L = 7.5$ cm.
2. Cross-sectional dimension of measuring tank, $A = 0.25\text{m}^2$.

TABULAR COLUMN:

Sl.no	Point gauge reading		Head over the crest $H = H_2 - H_1$ (m)	Depth of water collected 'r' (m)	Time of collection 't' (sec)	Volumetric discharge ' Q_{act} ' (m^3/s)	Theoretical discharge ' Q_{th} ' (m^3/s)	Coefficient of discharge $C_d = Q_{act} / Q_{th}$
	H_1 (m)	H_2 (m)						
1								
2								
3								
4								
5								

SPECIMEN CALCULATION:

1. Actual discharge, $Q_{act} = A \times r/t$
2. Theoretical discharge, $Q_{th} = 2/3 \times L \times \sqrt{2g} \times (H)^{3/2}$
3. Coefficient of discharge $C_d = Q_{act} / Q_{th}$

GRAPHS:

1. Plot Q_{act} versus H .
2. Plot $\log(Q_{act})$ versus $\log(H)$.

NATURE OF GRAPHS:**RESULT:**

1. The actual coefficient of discharge $C_d = Q_{act} / Q_{th} = \dots\dots\dots$
2. The graphical value of $C_d = K / (2\sqrt{2g} \cdot L/3) = \dots\dots\dots$

REVIEW OF LEARNING OBJECTIVES:

1. When do you use rectangular notch?
2. What is the end contraction? What are its effects?
3. Define the nappe and crest.

**DERERMINATION OF MAJOR LOSS IN
PIPES**

EXPT. NO: 6

DATE:

DERERMINATION OF MAJOR LOSS IN PIPES

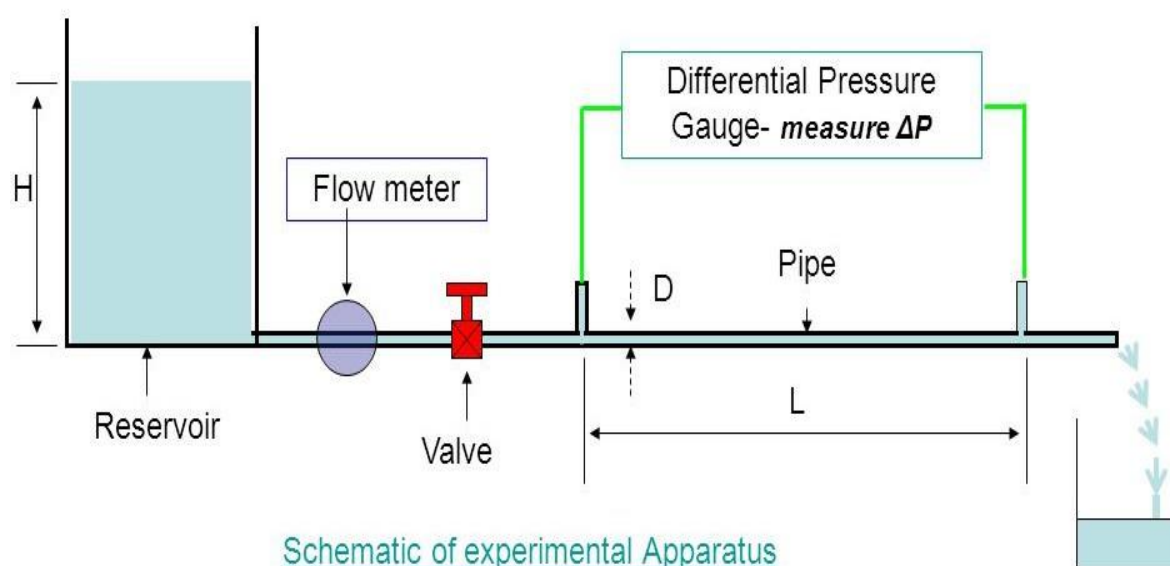
AIM: To determine major loss in pipes

APPARATUS:

1. Pipe set-up
2. Stopwatch
3. Scale
4. Manometer

EXPERIMENTAL SETUP:

The figure represents the experimental set-up for friction loss in pipe.



THEORY:

As the fluid flows through a pipe, it has to overcome the losses. The losses in the pipes are categorized into major and minor losses. The friction loss is considered as a major loss as its magnitude is very large as compared with other losses due to change in pipe size, change in direction and loss at pipe fittings. The friction loss can be determined using Darcy's – Weisbach's equation.

PROCEDURE:

1. Note down the diameter of the pipe (D) and length (L) between the pressure tapping points.
2. Determine the cross-sectional area of the pipe (A)
3. Record the dimensions of the measuring tank (length, a and width, b).
4. Connect the manometer to the pressure tapping points.
5. Open an inlet valve and allow the water to flow through the pipe.
6. Upon reaching the steady state, note down the mercury level in the two limbs of the manometer (h_1 and h_2).
7. Compute the pressure head between the sectional 1 and 2 as $x = h_2 - h_1$.
8. Calculate the pressure head in term of water depth by $h_f = (S_m/S - 1) x$.

9. Collect the water in the measuring tank for a known height (H) and record the time of collection (t).
10. Calculate the volumetric discharge $Q = (a \times b \times H)/t$.
11. Compute the mean velocity of flow $V = Q/A$.
12. Determine the friction factor $f = 2gD h_f/Lv^2$.
13. Calculate the flow Reynolds number as $Re = VD/v$, where v is the kinematic viscosity (take $1 \text{ mm}^2/\text{s}$).
14. Repeat the procedure for different discharge (increasing/ decreasing) values.

OBSERVATIONS:

1. Diameter of the pipe, $D = \dots\dots\dots \text{mm}$.
2. Length of the pipe, $L = \dots\dots\dots \text{mm}$.
3. Cross-sectional dimensions of measuring tank, $a \times b = \dots\dots \text{mm} \times \dots\dots \text{mm}$.
4. Cross-sectional area of the pipe, $A = \dots\dots\dots \text{mm}^2$.
5. Specific gravity of mercury, $S_m = \dots\dots\dots$
6. Specific gravity of water, $S_w = \dots\dots\dots$

TABULAR COLUMN:

S l. n o	Manometer readings (mm)			Pressur e head in terms of head of water h_f (mm)	Depth of water collecte d H (mm)	Time of collection t (sec)	Volume tric dischar ge Q (mm^3/s)	Mean velocity $V = Q/A$	Fricti on facto r F	Reynol ds numbe r Re
	Left limb h_1	Right limb h_2	Manomete r head $x = h_2 - h_1$							
1										
2										
3										
4										
5										
6										
7										

SPECIMEN CALCULATION:

1. Volumetric discharge, $Q = (a \times b \times H)/t \dots\dots\dots (\text{mm}^3/\text{s})$.
2. Mean velocity, $V = Q/A \dots\dots\dots (\text{mm}/\text{s})$.
3. Friction factor, $f = 2gD h_f/Lv^2$
4. Reynolds number, $Re = VD/v$.

GRAPH:

1. Plot $\log f$ versus $\log Re$ on natural graph or f versus Re on log-log paper and find relation between them.

2. Plot $\log (h_f/L)$ versus $\log (V)$ on natural graph or (h_f/L) versus V on log-log paper.

NATURE OF GRAGH:**RESULT:**

Obtain K and n from graph of $\log (h_f/L)$ versus $\log (V)$ and compute $f = K (2gD)$

REVIEW OF LEARNING OBJECTIVES:

1. What is practical application of Dracy's –Weisbach equation?
2. What is the relationship between friction factor and Renolds number?
3. Define hydraulic mean depth. What is the value of hydraulic mean depth for a fully flowing pipe?

**DETERMINATION OF C_d FOR OGEE
WEIR**

EXPT. NO:7

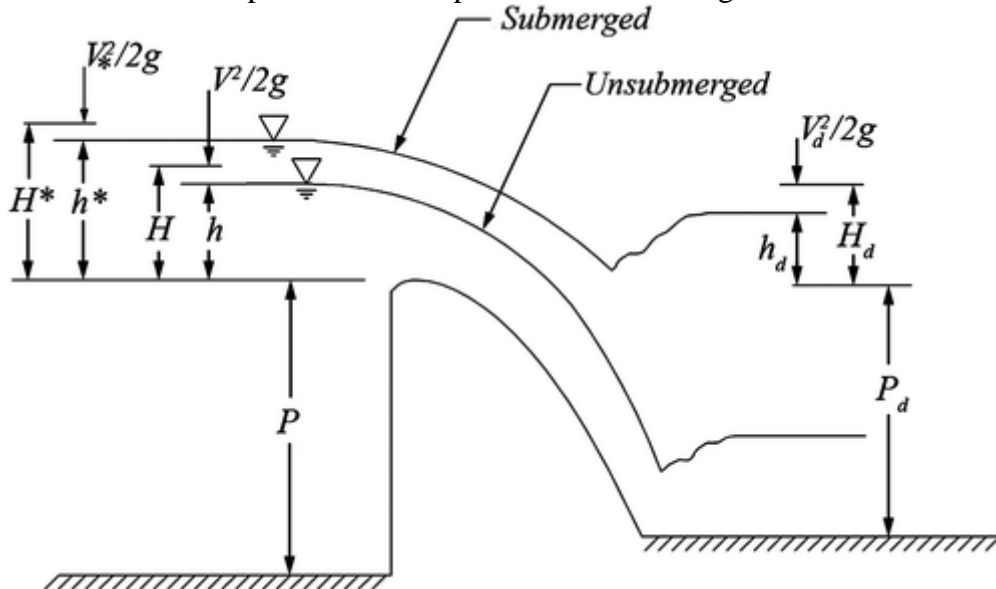
DATE:

DETERMINATION OF C_d FOR OGEE/BROAD CRESTED WEIR**AIM:** To determine the C_d for Ogee weir**APPARATUS REQUIRED:**

1. Experimental set-up fitted with weir model
2. Stopwatch
3. Scale.

EXPERIMENTAL SETUP:

The figure below shows the experimental set-up for calibration of ogee weir.

**THEORY:**

An S-shaped smooth weir is called an ogee weir. The surface profile is obtained when the shape below a freely falling nappe discharging from a rectangular notch is filled by certain material. Consider an ogee weir of crest length L with head over the crest as H as shown in the figure. The discharge over the weir is obtained by the discharge of rectangular notch having the crest of the weir raised by $0.115H$ above the crest of a sharp crested notch. Where C_d is the coefficient of discharge

PROCEDURE:

1. Note down the length of the weir, L .
2. Record the dimensions of the measuring tank (length a , and width b).
3. Open an inlet valve and allow the water to flow in to the channel and rise up to the crest of the weir.
4. Adjust the point gauge to touch the free surface and note down the point gauge reading (H_1).
5. Increase the inflow discharge to certain value and wait till the flow reaches the steady state. Adjust the point gauge to touch the surface of water and record the point gauge reading (H_2).
6. The head over the crest of weir is $H = H_2 - H_1$.

7. Then collect the water in the measuring tank for a known height (h) and record the time of collection (t) or collect the water for a known time interval and note down the depth of water in the tank.
8. Calculate the volumetric discharge, $Q_{act} = (a \times b \times h)/t$.
9. Compute the theoretical discharge, $Q_{th} =$
10. Determine the coefficient of discharge $C_d = Q_{act} / Q_{th}$.
11. Repeat the procedure for different discharge (increasing/decreasing) values.

OBSERVATIONS:

1. Length of the weir, $L = \dots\dots\dots mm$.
2. Cross-sectional dimensions of measuring tank, $a \times b = \dots\dots\dots mm \times \dots\dots\dots mm$.

TABULAR COLUMN:

Sl. no	Point gauge reading		Head over crest $H = H_2 - H_1$ (mm)	Depth of water collected h (mm)	Time of collection t (sec)	Volumetric discharge Q_{act} (mm ³ /s)	Theoretical discharge Q_{th} (mm ³ /s)	Coefficient of discharge C_d
	H_1 (mm)	H_2 (mm)						
1								
2								
3								
4								
5								

SPECIMEN CALCULATION:

1. Volumetric discharge, $Q_{act} = (a \times b \times h)/t$.
2. Discharge, $Q_{th} =$
3. Coefficient of discharge $C_d = Q_{act} / Q_{th}$.

GRAPH:

1. Plot Q_{act} versus H .
2. Plot $\log(Q_{act})$ versus $\log(H)$ on natural graph or Q_{act} versus H on log-log graph.

NATURE OF GRAGH:**RESULT:**

Obtain K and n from graph of $\log(Q_{act})$ versus $\log(H)$ and compute $C_d =$

REVIEW OF LEARNING OBJECTIVES:

1. What is the use of ogee weir?
2. How is the shape of the ogee weir obtained?
3. What is the effect of variation in design head on the ogee profile?

**DETERMINATION OF C_d FOR BROAD
CRESTED WEIR**

EXPT. NO: 7

DATE:

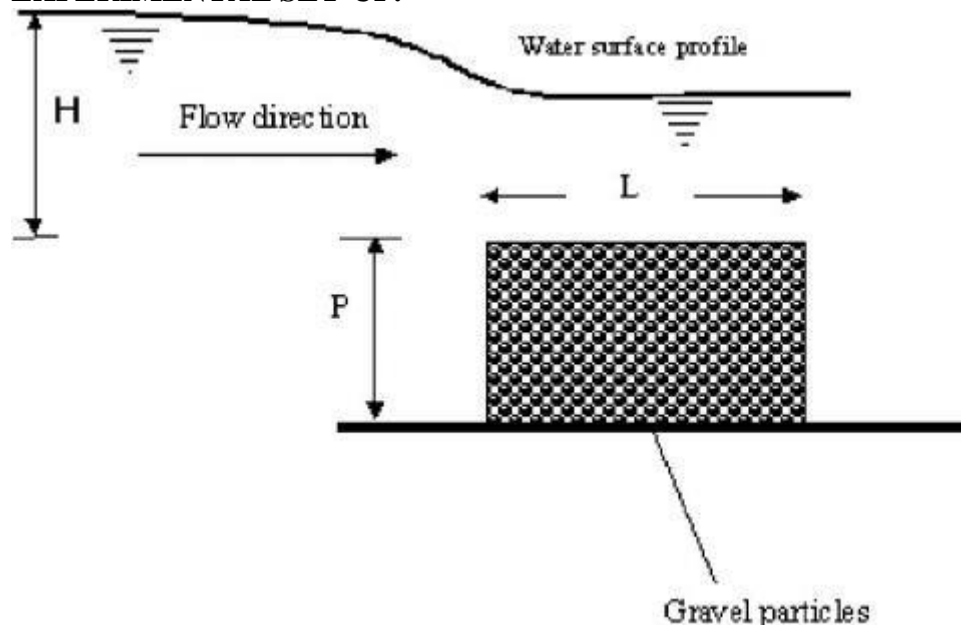
DETERMINATION OF Cd FOR BROAD CRESTED WEIR

AIM: To determine the coefficient of discharge of a broad crested weir

APPARATUS:

1. Experimental set-up fitted with weir model.
2. Stopwatch
3. Scale

EXPERIMENTAL SET-UP:



THEORY:

A weir is an opening in the side walls of an open channel. The water which flows over the crest is called as nappe or vein. There is no difference between notch and weir, except that notch is a small structure and has a sharp edge. Weir, on the other hand, is generally is an over flow structure with broad crested, built across an open channel.

It is built across a river in order to raise water on the upstream and to allow excess water to flow over the entire length to the downstream side. Weirs are used for measuring the rate of flow of water in rivers or stream.

PROCEDURE:

1. Note down the crest length (L) of the broad-crested weir.
2. Record the dimensions of the measuring tank.
3. Open the inlet valve and allow the water to flow into the channel and rise up to the crest of the weir.
4. Adjust the point gauge to touch the free surface and note down the point gauge reading (H_1).
5. Increase the inflow discharge to a certain value and wait till the flow reaches steady state. Adjust the point gauge to touch the surface of water and record the point gauge reading (H_2).
6. The head over the crest of the weir is $H = H_2 - H_1$.

7. Then collect the water in the measuring tank for a known height (r) and record the time of collection (t).
8. Calculate the actual discharge Q_{act} .
9. Compute the theoretical discharge Q_{th} .
10. Determine the coefficient of discharge C_d .
11. Repeat the procedure for different discharge (increasing/decreasing) values.

OBSERVATIONS:

1. Length of the weir, $L = 0.2m$
2. Area of the measuring tank $A = 0.25m^2$.

TABULAR COLUMN:

Sl. no	Point gauge reading		Head over the crest $H = H_2 - H_1$ (m)	Depth of water collected 'r' (m)	Time of collection 't' (sec)	Volumetric discharge ' Q_{act} ' (m^3/s)	Theoretical discharge ' Q_{th} ' (m^3/s)	Coefficient of discharge $C_d = Q_{act} / Q_{th}$
	H_1 (m)	H_2 (m)						
1								
2								
3								
4								
5								

SPECIMEN CALCULATION:

1. Actual discharge, $Q_{act} = Ax r/t$
2. Theoretical discharge, $Q_{th} = 1.705 \times L \times H^{3/2}$
3. Coefficient of discharge $C_d = Q_{act} / Q_{th}$

GRAPHS:

3. Plot Q_{act} versus H .
4. Plot $\log(Q_{act})$ versus $\log(H)$.

NATURE OF GRAPHS:**RESULT:**

3. The actual coefficient of discharge $C_d = Q_{act} / Q_{th} = \dots\dots\dots$
4. The graphical value of $C_d = K / (1.705L) = \dots\dots\dots$

REVIEW OF LEARNING OBJECTIVES:

1. Define the term weir.
2. How are weirs classified?

3. What is the difference between a notch and weir?
4. What is the use of weirs?
5. What is a submerged weir?

**DETERMINATION OF FORCE EXERTED
BY A JET ON FLAT AND CURVED VANES**

EXPT. NO:8

DATE:

DETERMINATION OF FORCE EXERTED BY A JET ON FLAT AND CURVED VANES**AIM:** To determine the coefficient of discharge of a triangular notch.**APPARATUS:**

1. Impact of jet apparatus
2. Stopwatch
3. Weights
4. Scale

THEORY:

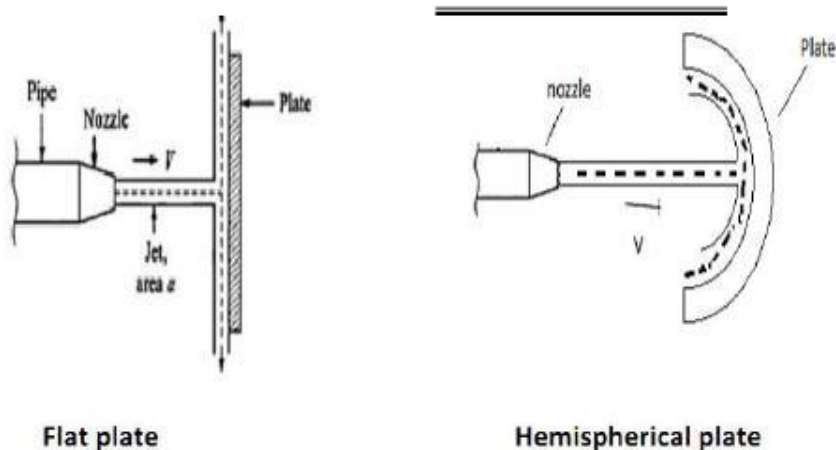
When a jet of water from a nozzle impinges on a vane, the kinetic energy possessed by the jet is partly transmitted to the vane in the form of lifting force. The quantity of kinetic energy transmitted to the vane (either in rest or in motion relative to the velocity of the jet).

The study of impact of a jet of water is essential to understand the principle of an impulse turbine such as Pelton Wheel Turbine. When high pressure water from a source such as a dam flows through a nozzle in the form of a jet, the entire pressure energy of the water is converted into kinetic energy at the nozzle. When this jet of water hits a vane positioned in front of it, the vane deflects the jet and due to the change in the momentum of the water jet, a force is imparted to the vane by the water.

EXPERIMENTAL SET-UP:

The equipment consists of a high efficiency gun metal nozzle fitted to a 8 mm diameter pipe supply line with a gate valve. Vertically above the nozzle, a gun metal vane is fitted to a bracket of a differential lever which balances the upward force of the jet from the nozzle. The lever is provided with an adjustable no load screw mechanism. The force due to the jet on the lever is counter balanced by weights placed on a hanger. Different types of vanes can be fitted to the bracket. The complete assembly is enclosed in a framed structure housing with two leak proof transparent sides for visual observation. The water deflected by the vane is collected in the collecting tank of the hydraulic bench. For experimental purposes, two brass nozzle outlet and two gunmetal vanes of the following shape are provided.

1. Semi-circular vane (120° or 180° Angle of deflection)
2. Horizontal flat vane (90° angle of deflection)

DIAGRAM:

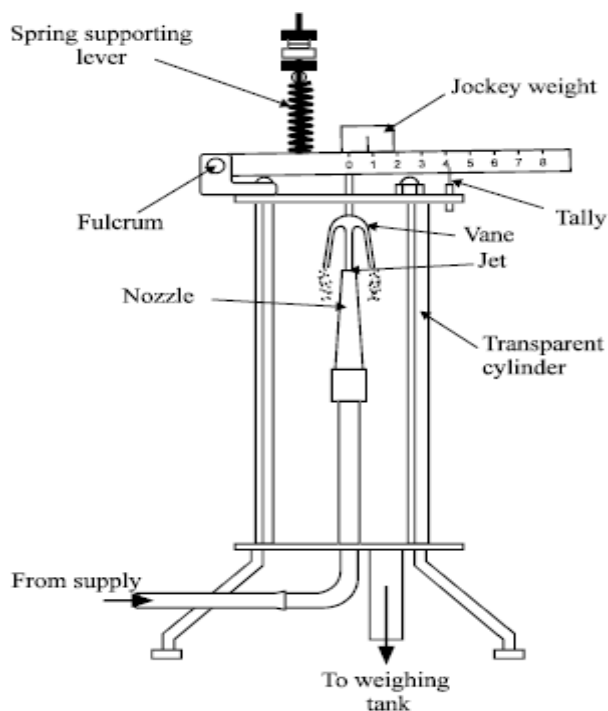


Fig 11.1 Arrangement of Apparatus

EXPERIMENTAL PROCEDURE:

1. Measure the jet diameter (d) and calculate the cross-sectional area of jet (a)
2. Fit the required vane on the lever and assemble the set-up
3. Balance the lever systems by means of counter weight for no load.
4. Place a weight on the hanger.
5. Open the gate valve and adjust the jet, so that the lever arm is balanced.
6. Collect water in the collecting tank.
7. Note: (a) The weight placed – W .
(b) Time for 5 cm. rise in the collecting tank – t
8. Compute the jet velocity – $V = Q/a$
9. Calculate the lift force from the equation
10. Compute the efficiency of the jet η from equation
11. Repeat the procedure for different loads/weights (increasing or decreasing) and for different shapes of vanes.

OBSERVATIONS:

1. Diameter of the nozzle, $d = 8\text{mm} = \dots\dots\dots\text{m}$.
2. Cross-sectional area of the nozzle, $a = \dots\dots\dots\text{m}^2$.
3. Area of measuring tank, $A = 400\text{mm} \times 250\text{mm} = \dots\dots\dots\text{m}^2$.
4. Arm length (X) = $180\text{mm} = \dots\dots\dots\text{m}$.
5. Arm length (Y) = $455\text{mm} = \dots\dots\dots\text{m}$.
6. Density of water, $\rho = 1000\text{ kg/m}^3$.
7. Acceleration due to gravity, $g = 9.81\text{m/s}^2$.

TABULAR COLUMN:

Type of vane	No.	Weight 'W' (N)	Depth of water 'r' in tank (m)	Time 't' (s)	Discharge 'Q' (m ³ /s)	Jet velocity 'V' (m/s)	Lift force 'F _y ' (N)	Efficiency 'η'
Flat vane	1							
	2							
	3							
	4							
	5							
Semi - Circular Vane	1							
	2							
	3							
	4							
	5							
								Avg η =

SPECIMEN CALCULATION:

1. Discharge $Q = Axr/t = \dots\dots\dots m^3/s$.
2. Velocity of jet $V = Q/a = \dots\dots\dots m/s$.
3. Actual force on flat plate vane, $F_{act} = WgY/X = \dots\dots\dots N$.
4. Theoretical force, $F_{th} = \rho.a.V^2 = \dots\dots\dots N$.

TABULAR COLUMN:

Sl.no:	F _{act}	F _{th}	C _d = F _{act} / F _{th}
1			
2			
3			
4			
5			
			Avg C _d =

NATURE OF GRAPH:**RESULT:**

The efficiency of the Jet is = _____

Review of Learning Objectives:

1. Define impulse and momentum.
2. What are the applications of vanes?
3. Define efficiency?

**DETERMINATION OF Cd FOR
VENTURIFLUME**

EXPT. NO:9

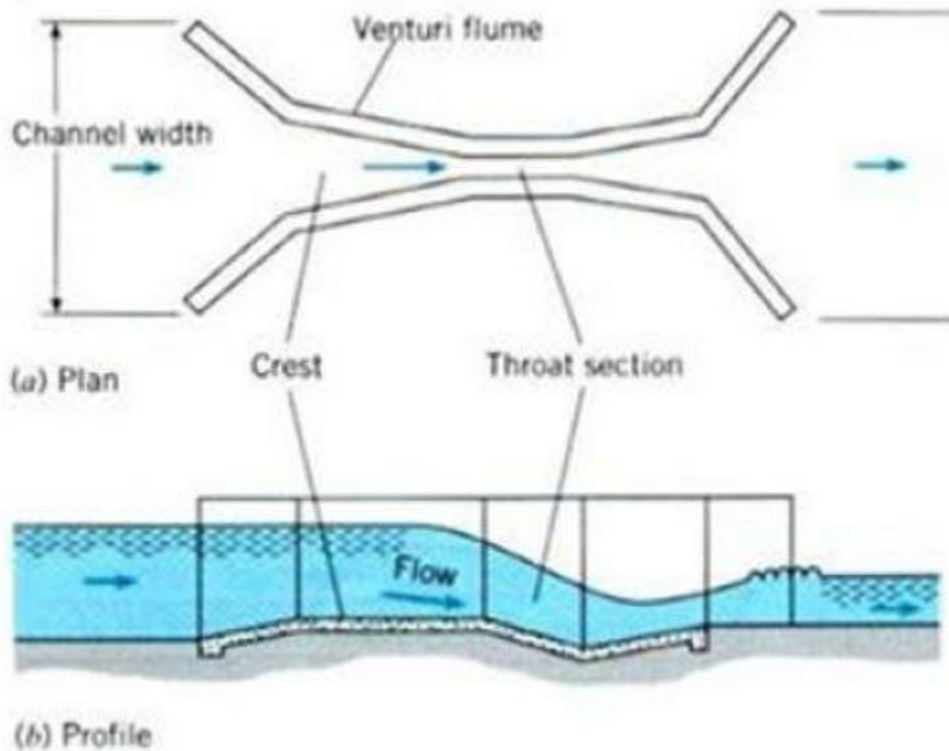
DATE:

DETERMINATION OF Cd FOR VENTURIFLUME**AIM:** To Determine the coefficient of discharge of a Venturiflume**APPARATUS:**

1. Hydraulic flume fitted with venturi flume model
2. Stopwatch
3. Scale
4. Manometer.

EXPERIMENTAL SETUP:

The figure shows the experimental set-up used for the calibration of venturi flume.

**THEORY:**

In order to gauge the discharge or rate of flow in open channels, the width of the flume is constructed at certain section similar to venturi meter. Such flumes are called gauging flumes.

Gauging flumes are of two types:

1. Non-modular flumes or the venturi flume in which the velocity of flow at the throat is less than the critical velocity so that the standing wave (hydraulic jump) will not occur in the flume.
2. Modular flume or the standing wave flume in which the velocity of the flow at the throat equal to the critical velocity.

When the rate of flow through the venturi flume is maximum a standing wave will occur at its downstream. Such a venture flume is called standing wave venture flume or a modular venturi flume.

The fluming is done by one of the following ways:

- (a) By reducing the width of the channel in the direction of the flow, called channel contraction.
- (b) By raising the bed level of the flume with the provision of hump.
- (c) By combining both channel contraction and hump.

PROCEDURE:

1. Select the venture flume set-up.
2. Note down the widths of the open channel and flumed (throat) section.
3. Allow the water to flow in the channel by opening the gate valve.
4. Note down the gauge readings at the entrance and throat sections.
5. Note down the time required to collect a known height of water in the collecting tank.
6. Repeat steps 4 and 5 for various discharges by varying the gate valve for more trails.

OBSERVATIONS:

1. Area of the flume at the entrance of venture flume. $a_1 = b_1 \times h_1 = \dots\dots\dots m^2$
2. Area of the flume at the throat of venture flume. $a_2 = b_2 \times h_2 = \dots\dots\dots m^2$

TABULAR COLUMN:

Sl. no	Gauge readings		Differential Head (h) = (h ₂ - h ₁) (m)	Area of flow		Time for rise of water in tank t (sec)	Actual discharge Q _{act} (m ³ /s)	Theoretical discharge Q _{th} (m ³ /s)	Coefficient of discharge C _d = Q _{act} / Q _{th}
	Entrance (h ₁) (m)	Throat (h ₂) (m)		a ₁ = b ₁ × h ₁ (m)	a ₂ = b ₂ × h ₂ (m)				
1									
2									
3									
4									
5									

SPECIMEN CALCULATION:

1. Actual discharge $Q_{act} = A \times r / t$ (m³/s).
2. Theoretical discharge $Q_{th} =$
3. Coefficient of discharge $C_d = Q_{act} / Q_{th}$

GRAPH:

1. Plot the graph of Q_{act} versus h
2. Plot the graph of $\log Q_{act}$ versus $\log h$

NATURE OF GRAGH:**RESULT:**

Obtain **K** and **n** from graph of $\log (Q_{act})$ versus $\log (h)$ and compute $C_d =$

REVIEW OF LEARNING OBJECTIVES:

1. Define the venture flume.
2. What is the use of venture flume?
3. What is the difference between venture meter and venture flume?
4. Define specific energy.
5. What do you mean by standing wave?

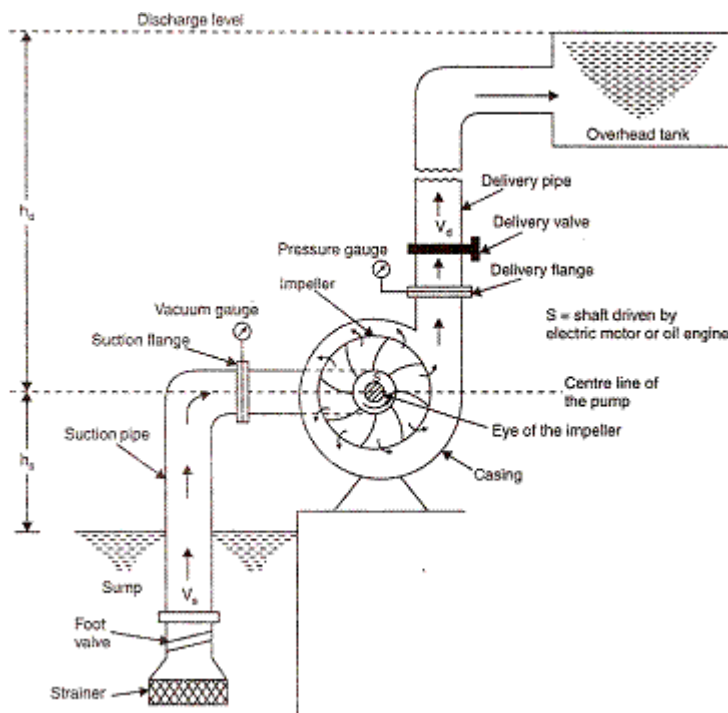
**DERERMINATION OF EFFICIENCY OF
CENTRIFUGAL PUMP**

EXPT. NO: 10

DATE:

DETERMINATION OF EFFICIENCY OF CENTRIFUGAL PUMP**AIM:** To determine efficiency of centrifugal pump**APPARATUS:**

1. Centrifugal pump test rig
2. Tachometer
3. Stopwatch

EXPERIMENTAL SETUP:**THEORY:**

The hydraulic machine which converts mechanical energy into hydraulic energy is called as pump. The hydraulic energy is in the form of pressure energy. If mechanical energy is converted into pressure energy by means of centrifugal force which is acting on fluid. This hydraulic machine is called as a centrifugal pump. A centrifugal pump consist of an impeller which is rotating inside a spiral/ volute casing. Liquid is admitted to the impeller in an axial direction through a central opening in it side called the Eye. It then flows radially outward & is discharged around the entire circumference into a casing. As the liquid flows through the rotating impeller, energy is imparted to the fluid, which results in increase in both: the Pressure Energy, and the Kinetic Energy. The name of pump Centrifugal is derived from the fact that, the discharge of liquid from the rotating impeller is due to the centrifugal head created in it when a liquid mass is rotated in a vessel. This results in a pressure rise throughout the mass, the rise at any point being proportional to the square of the Angular Velocity & the distance of the point from the axis of rotation.

PROCEDURE:

1. Record the dimensions of the measuring tank.
2. Prime the pump; close the delivery gate valve completely.
3. Switch on the motor and check the direction of rotation of pump in proper direction.
4. Record the pump speed (N) using tachometer.
5. Note down the following readings:
 - a) The pressure gauge reading.

- b) The vacuum gauge reading.
 - c) Time for known revolutions (10 numbers) of energy meter (T).
 - d) Time for collection of known height (r) of water in the measuring tank (t).
6. Repeat steps 5 for 3 to 4 discharge when the gate valve is fully open.
 7. Repeat step 4 to 6 for different speeds of the pump.

OBSERVATIONS:

1. Head = 10m.
2. Speed of motor = 1440 rpm
3. Speed of pump = 1500rpm
4. Torque arm = 0.1m
5. Impeller diameter = 213mm
6. Energy meter constant = 1280 pulse/hr
7. Transmission efficiency = 60%
8. Area of measuring tank = 0.45 m x 0.45 m
9. Difference in pressure gauge = 0.55
10. Number of revolutions = 10

TABULAR COLUMN:

Sl. no	Suction head mm of Hg	Delivery head kgf/cm ²	Time taken for 10 cm water rise t (sec)	Time taken for 10 revolutions of energy meter 'T'
1				
2				
3				
4				
5				

SPECIMEN CALCULATION:

1. Suction head $H_s = H_g \times 13.6 / 1000 = \dots\dots\dots m$
2. Delivery head $H_d = p \times 10 = \dots\dots\dots m$
3. Total head $H = H_s + H_d + 0.55 = \dots\dots\dots m$
4. Input power $IP = [3600 / (T \times C)] \times (\text{no of revolutions of energy meter disc}) = \dots\dots\dots kW$

5. Actual discharge $Q_{act} = A \times r / t = \dots\dots\dots m^3/s.$
6. Water power $WP = (\rho \times g \times Q_{act} \times H / 1000) = \dots\dots\dots kW$
7. Efficiency $\eta = (WP/IP) \times 100 = \dots\dots\dots \%$
8. Specific speed $N_s = N \times \sqrt{\text{output power} / H^{3/4}} = \dots\dots\dots rpm$

GRAPH:

1. Plot *efficiency η versus Q_{act}*
2. Plot *output power IP versus Q_{act}*
3. Plot *input power OP versus Q_{act}*
4. Plot *total head H versus Q_{act}*

NATURE OF GRAGH:**RESULT TABLE:**

Sl. no	Total head H (m)	Actual discharge Q_{act} (m^3/s)	Input power IP (kW)	Water power WP (kW)	Efficiency η (%)	Specific speed N_s (rpm)
1						
2						
3						
4						
5						

REVIEW OF LEARNING OBJECTIVES:

1. Define a pump.
2. How are pumps classified?
3. What is the difference between a pump and a turbine?
4. How does a centrifugal pump works?
5. What is a priming of a pump?
6. Define the static head, manometric head, suction head and delivery head.
7. What is the use of non-return valve?

**DERERMINATION OF EFFICIENCY OF
KAPLAN OR FRANCIS TURBINE**

EXPT. NO: 11

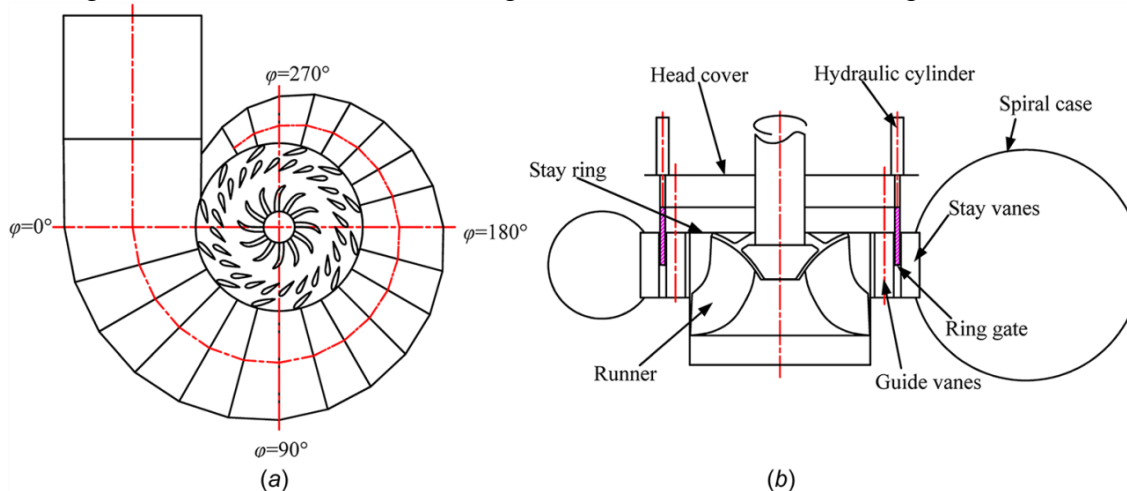
DATE:

DERERMINATION OF EFFICIENCY OF FRANCIS TURBINE**AIM:** To determine efficiency of Kaplan turbine**APPARATUS:**

1. Centrifugal pump to supply water at a required head.
2. Francis turbine
3. Pipe network systems with necessary control valves
4. Pressure gauge and vacuum gauge
5. Tachometer to measure the speed of the shaft
6. Venturimeter to measure discharge.
7. Rope brake with spring balance and weighing pan to measure torque.

EXPERIMENTAL SETUP:

The figure illustrates the schematic diagram of a Francis turbine test rig.

**THEORY:**

Francis turbine is a mixed flow type of reaction turbine named after the American engineer James B. Francis. In a reaction turbine, only part of total head of water is converted into velocity head before it reaches the runner. Water fills completely the entire passage in the runner. The pressure energy of water gradually changes as it passes through the runner. Further, in the mixed flow turbine, water enters the runner at the outer periphery in the radial direction and leaves at the centre in the direction parallel to the axis of rotation of the runner. It is used under the medium head (60m to 250m) condition with medium quantity of water. The specific speed of Francis turbine usually varies from 60 to 400 rpm.

The figure represents the schematic diagram of a Francis turbine. It consists of a scroll (spiral) casing through which water enters the runner. The casing is made spiral; in shape so that the velocity of water remains approximately constant throughout its passage. Water enters the runner vane by passing through stay vanes and guide vanes. The stay vanes direct the water from the casing to the guide vanes and guide vanes regulate and direct the water to the runner at an appropriate angle. The runner vanes are so shaped that water enters the runner radially at the outer periphery and leaves it axially at the inner periphery. The change in direction of flow of water as it travels through the runner produces a circumferential force on the runner, which rotates the runner, and the shaft coupled to it generates the mechanical energy. The water after passing through the runner flows to the tailrace through a draft tube. The draft tube is a gradually enlarging pipe with its lower end submerged in tailrace. It converts a large amount of kinetic energy possessed by water leaving the runner into pressure energy.

PROCEDURE:

1. Note down the weight of the hanger, diameter of the break drum and diameter of the rope.
2. The input pump is primed and started.
3. Start the turbine and set the gate opening $\frac{1}{4}$ th of full.

4. Open the valve such that the constant pressure head during flow of water is maintained.
5. Note down the speed using tachometer.
6. Repeat step 4 and 5 for increased load on turbine on the break drum.
7. Calculate actual discharge Q_{act} , input power IP , & output power OP , & efficiency η .
8. Repeat step 4 to 6 for different gate openings (1/2, 3/4 and full).
9. Calculate the unit quantities (N_u , P_u and Q_u).

OBSERVATIONS:

1. Diameter of the break drum $D = 270mm$.
2. Diameter of the rope $d = 20mm$.
3. Density of water $\rho = 1000 \text{ kg/m}^3$.
4. Acceleration due to gravity $g = 9.81m/s^2$.
5. Co-efficient of discharge $Cd = 0.92$
6. Diameter of converging cone $d_1 = 0.065m$
7. Diameter of throat $d_2 = 0.038m$
8. No of divisions on the nozzle $H = p \times 10 \text{ m}$

TABULAR COLUMN:

Sl. no	Gate opening	Speed N (rpm)	Pressure gauge		Dynamometer reading		
			P ₁ (kgf/cm ³)	P ₂ (kgf/cm ³)	Load (kg)	Spring load 's' (N)	Net load
1							
2							
3							
4							
5							
1							
2							
3							
4							
5							

SPECIMEN CALCULATION:

1. Head of water $H = p \times 10 = \dots\dots\dots m$
2. Head $(P_1 - P_2) \times 10 = \dots\dots\dots m$
3. Actual discharge $Q_{act} =$
4. Input power, $IP = \rho \times g \times H \times Q_{act} / 1000 = \dots\dots\dots Kw$.

5. Output power, $OP = (2 \pi N / 60 \times 1000) \times (W - S) \times 9.81 \times (D + d/2) = \dots\dots\dots \text{Kw}$.
6. Efficiency, $\eta = OP/IP \times 100 = \dots\dots\dots \%$
7. Specific speed, $N_s = N \sqrt{OP/H^{5/4}} = \dots\dots\dots \text{rpm}$.
8. Unit discharge, $Q_u = Q_{act} / \sqrt{H} = \dots\dots\dots \text{m}^3/\text{s}$.
9. Unit power, $P_u = IP/H^{3/2} = \dots\dots\dots \text{kW}$
10. Unit speed, $N_u = N / \sqrt{H} = \dots\dots\dots \text{rpm}$.

GRAPH:

1. Plot N_u versus η
2. Plot N_u versus Q_u
3. Plot N_u versus P_u

NATURE OF GRAGH:**RESULT TABLE:**

Sl. no	Q_{act} (m^3/s)	IP (kW)	OP (kW)	H (%)	N_s (rpm)	Q_u (m^3/s)	P_u (kW)	N_u (kW)
1								
2								
3								
4								
5								
				Avg =				

RESULT:

The average efficiency of Francis turbine is = $\dots\dots\dots \%$

REVIEW OF LEARNING OBJECTIVES:

1. Define a reaction turbine with some examples.
2. Under what conditions are reaction turbines used?
3. What is the radial flow turbine?
4. Define the draft tube. What are its uses? Which are the different shapes of draft tubes?
5. What is cavitation? How do you prevent it?
6. What do you mean by governing of turbines?
7. State the uses of characteristic curves.

**DERERMINATION OF EFFICIENCY OF
PELTON WHEEL TURBINE**

EXPT. NO: 12

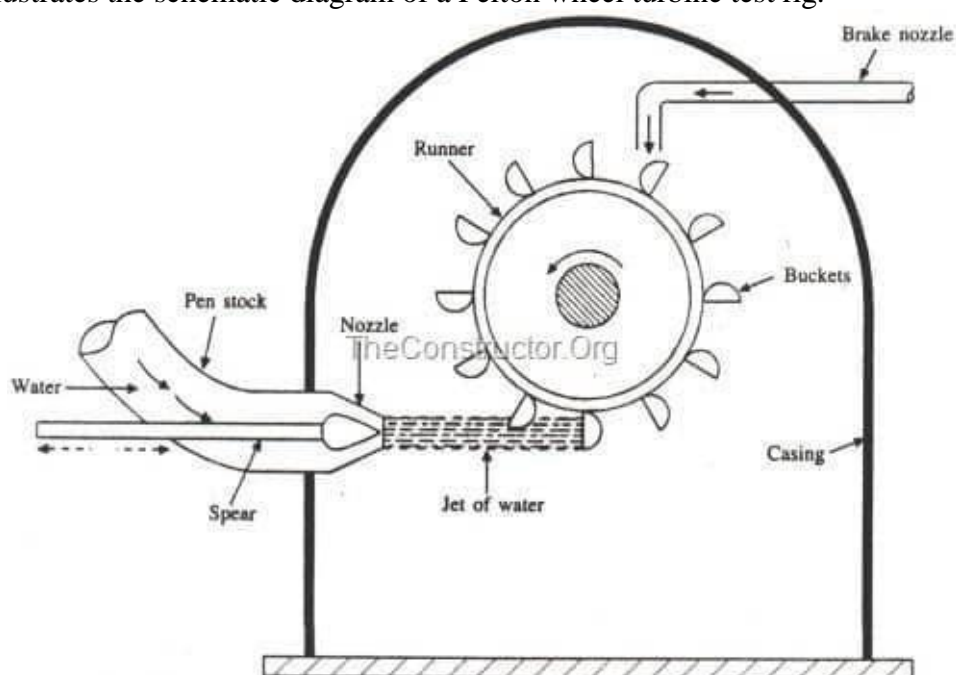
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DETERMINATION OF EFFICIENCY OF PELTON WHEEL TURBINE**AIM:** To determine efficiency of Pelton wheel turbine**APPARATUS:**

1. Centrifugal pump to supply water at required head
2. Pelton wheel
3. Pipe network system with necessary control valves.
4. Pressure gauges
5. Tachometer to measure the speed of the shaft
6. Venturi meter along with manometer to measure the discharge
7. Rope brake with spring balance and weighing pan to measure torque.

EXPERIMENTAL SETUP:

The figure illustrates the schematic diagram of a Pelton wheel turbine test rig.

**THEORY:**

Pelton wheel turbine is an impulse type of hydraulic turbine developed by the American engineer Pelton in about 1880. It is a tangential flow type turbine used under high head and low discharge conditions. Pelton wheel turbine has low specific speed.

A Pelton wheel turbine consists of circular runner fitted with equally spaced buckets on its periphery. The buckets are semi-ellipsoidal cup shapes, each divided into two symmetrical parts separated by a splitter so as to neutralize the axial thrust. One or more number of nozzles is mounted in such a way that they release the jet tangential to the pitch circle. The jet of water impinges on the splitter, which divides the jet into two equal portions. The jet after flowing along the inner surface of the bucket leaves the bucket at the outer edge. To control the discharge of striking water, the nozzle fitted at the end of the penstock is provided with the spear. The spear is either operated by wheel or by governor.

Important characteristic curves of a turbine:

1. Main characteristics curves or constant head curves: Main characteristic are obtained by maintaining a constant head and a constant gate opening on the turbine. The speed of the turbine is varied by changing load on turbine. For each value of speed, the corresponding value of the

power and discharge are obtained. Then overall efficiency for each of the speed is calculated from these readings various graphs can be plotted.

- Operating characteristic or constant speed curves: operating characteristics curves are plotted, and then the speed on the turbine is constant. In case of turbine, the head is generally constant. These are three independent parameters (N, H & Q). For operating characteristics N & H are constant.

Characteristic curves of hydraulic turbines.

These are the curves, with the help of exact behaviour and performance of turbine under different working condition can be known. These curves are plotted from the result of the tests performed on the turbine under different working condition.

The important parameters which are varied during a test on a turbine are: speed (N), Head (H), Discharge (Q) is independent parameters. Out of independent parameters hence variation of power and efficiency with respect to discharge Q are plotted. The power curve for turbine shall not pass through origin because certain amount of discharge is needed to produce power to overcome initial friction hence the power and efficiency curves will be slightly away from the origin X –axis. As to overcome initial friction certain amount of discharge will be required

PROCEDURE:

- Prime the pump with water.
- Keep the nozzle-opening to the required position.
- Open the gate valve.
- Start the motor
- Allow the water into the turbine and the turbine will start rotating.
- Fix the weighing hanger to the rope of the brake drum with no load on weight hanger.
- By varying the gate valve, keep the head constant using the pressure gauge to the required head in case of experiment on constant head or keeps the speed constant using the tachometer to the required speed in case of experiment on constant speed.
- Note down the following readings:
 - Pressure gauge reading
 - Speed of the turbine
 - Load on weight hanger
 - Spring balance reading indicating the frictional loss between the brake drum and rope.
- Repeat step 8 for different load conditions by varying the load on the weight hanger either to constant head or for constant speed.
- Take at least 5 set of readings by varying the load.
- Calculate the efficiency of the turbine.

OBSERVATIONS:

- Diameter of the brake drum, $D = 310mm$.
- Diameter of the rope, $d = 20mm$.
- Density of water, $\rho = 1000kg/m^3$.
- Acceleration due to gravity, $g = 9.81m/s^2$.
- Co-efficient of discharge, $C_d = 0.962$
- Diameter of conveying cone, $d_1 = 100mm$
- Diameter of throat, $d_2 = 59.16mm$
- No. of divisions of nozzle at $H = p \times 10$

9. No. of divisions on nozzle, $n = 10$
10. Weight of empty hanger, $W_o = 1kg$

TABULAR COLUMN:

Sl.no	Gate opening	Speed 'N' (rpm)	Pressure gauge		Dynamometer reading		
			P ₁ (kgf/cm ³)	P ₂ (kgf/cm ³)	Load (kg)	Spring load 's' (kg)	Net load
1	%						
2							
3							
4							
5							
1	%						
2							
3							
4							
5							

SPECIMEN CALCULATION:

1. Head of water, $H = p \times 10 = \dots\dots\dots m$
2. Venturimeter Head = $(P_1 - P_2) \times 10 = \dots\dots\dots m$
3. Actual discharge $Q_{act} =$
4. Input power (water power), $IP = \rho \times g \times H \times Q / 1000 = \dots\dots\dots kW$
5. Output power (brake power) $OP = (2 \pi N / 60 \times 1000) \times (W - S) \times 9.81 \times (D + d/2)$
6. Efficiency, $\eta = OP/IP \times 100 = \dots\dots\dots \%$
7. Specific speed, $N_s = N \sqrt{OP/H^{5/4}} = \dots\dots\dots rpm.$
8. Unit discharge, $Q_u = Q_{act} / \sqrt{H} = \dots\dots\dots m^3/s.$
9. Unit power, $P_u = IP/H^{3/2} = \dots\dots\dots kW$
10. Unit speed, $N_u = N / \sqrt{H} = \dots\dots\dots rpm.$

GRAPH:

1. Plot N_u versus Q_u .
2. Plot N_u versus OP power.
3. Plot N_u versus η .

NATURE OF GRAGH:

RESULT TABLE:

Sl. no	Q _{act} (m ³ /s)	IP (kW)	OP (kW)	η (%)	N _s (rpm)	Q _u (m ³ /s)	P _u (kW)	N _u (kW)
1								
2								
3								
4								
5								
				Avg =				

RESULT:

The efficiency of Pelton turbine is..... %

REVIEW OF LEARNING OBJECTIVES:

1. What is a turbine?
2. Define the impulse turbine.
3. How turbines are are classified?
4. How does an impulse differ from a reaction turbine?
5. What is a penstock?
6. What is the specific speed of a turbine?
7. What is the jet ratio?
8. Define the breaking jet.

TRANSPORTATION ENGINEERING LABORATORY

(BCV403)

CO's And PO's Mapping Chart

Sl. No.	Description	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PS O1	PS O2
1	Assess the suitability of soil, aggregates and bitumen as a pavement construction material	2												3	
2	Design the flexible and rigid pavements as per the latest relevant IRC standards		3											3	
3	Design Bituminous mixes for pavement layers			3										3	
4	Conduct the traffic studies			3										3	

Evaluation:

Integrated Lab (IPCC)		
CIE		
Particulars	Marks	Total
Performance	07	15
Journal	05	
Viva Voce	03	
Lab IA		
Particulars	Marks	Total
IA	100	10 (Reduced)
Total (CIE +Lab IA)		25

Mapping of Experiments with CO, PO and PSO

Sl.No.	Experiment Details	CO	PO	PSO
1	Tests on Aggregates a. Crushing Strength Test b. Los Angeles abrasion test c. Impact test d. Shape tests (combined index and angularity number)	1	1	1
2	Tests on Bituminous Materials a. Penetration test b. Ductility test c. Softening point test d. Specific gravity test e. Viscosity test by tar viscometer f. Flash and fire point test	1	1	1
3	Tests on Soil a. Wet sieve analysis b. CBR Test on soil	1	1	1
4	Design of flexible pavement as per IRC 37-2018	2	2	1
5	Design of Rigid pavement as per IRC 58-2015	2	2	1
6	Bituminous Mix Design by Marshall Method (Demonstration only)	3	3	1
7	Traffic Engineering studies	4	3	1

LAB SAFETY & USAGE INSTRUCTIONS

1. Eating, drinking, or smoking is strictly prohibited inside the computer laboratory.
2. Do not bring liquids near computers, electrical connections, or peripherals.
3. Ensure proper handling of computers, keyboards, mouse, and UPS systems.
4. Students should maintain discipline and follow instructions given by the lab instructor.
5. Report any hardware, software, or network issues immediately to the instructor or lab staff.
6. Do not install, uninstall, or modify software settings without permission.
7. Use only authorized datasets and software provided for the laboratory exercises.
8. Save work frequently and maintain backup copies of files to avoid data loss.
9. Switch off systems properly after use and log out of user accounts.
10. Bags and personal belongings should be kept in designated areas.
11. Maintain cleanliness and ensure proper cable management around workstations.

EXPERIMENT WISE LESSON PLAN

Experiment No.1	
Name	Tests on Aggregates a. Crushing Strength Test b. Los Angeles abrasion test c. Impact test d. Shape tests (combined index and angularity number)
Objectives	<ul style="list-style-type: none"> To evaluate the suitability of aggregates as paving materials
Experiment No.2	
Name	Tests on Bituminous Materials a. Penetration test b. Ductility test c. Softening point test d. Specific gravity test e. Viscosity test by tar viscometer f. Flash and fire point test
Objectives	<ul style="list-style-type: none"> To evaluate the suitability of bitumen as paving materials
Experiment No.3	
Name	Tests on Soil a. Wet sieve analysis b. CBR Test on soil
Objectives	<ul style="list-style-type: none"> To evaluate the suitability of bitumen as paving materials
Experiment No.4	
Name	Design of flexible pavement as per IRC 37-2018
Objectives	<ul style="list-style-type: none"> To understand design procedure of flexible pavements as per IRC
Experiment No.5	
Name	Design of Rigid pavement as per IRC 58-2015
Objectives	<ul style="list-style-type: none"> To understand design procedure of rigid pavements as per IRC
Experiment No.6	
Name	Bituminous Mix Design by Marshall Method (Demonstration only)
Objectives	<ul style="list-style-type: none"> To demonstrate the bituminous mix design by Marshall method
Experiment No.7	
Name	Traffic Engineering studies
Objectives	<ul style="list-style-type: none"> To conduct traffic engineering studies

EXPERIMENT NO. 1 TESTS ON AGGREGATES

1a. AGGREGATE CRUSHING TEST

1a.1 AIM: To find the crushing strength of the given aggregate sample

1a.2 APPARATUS: i. Steel cylinder of internal diameter 15.2 cm

ii. Square base plate, plunger of 15 cm diameter

iii. Cylindrical measure

iv. Steel tamping rod

v. Weighing balance accurate to 1 g

vi. Compression testing machine

1a.3 THEORY:

One of the main mechanical properties required for road stones is the satisfactory resistance to crushing under the roller during construction and also surface stresses under rigid tyre rims of heavily loaded animal drawn vehicles are high enough to consider the crushing strength of road aggregates as an essential requirement in India.

Aggregates used in road construction should be strong enough to resist the crushing under traffic wheel loads. If the aggregates are weak, the stability of the pavement is likely to be adversely affected. The strength of coarse aggregates is assessed by aggregate crushing test. The aggregate crushing value gives a relative measure of resistance to crushing under gradually applied compressive load. To achieve a high quality of pavement, aggregates possessing low crushing value should be preferred. The Fig. 1a.1 shows the apparatus used for conducting aggregate crushing value test.

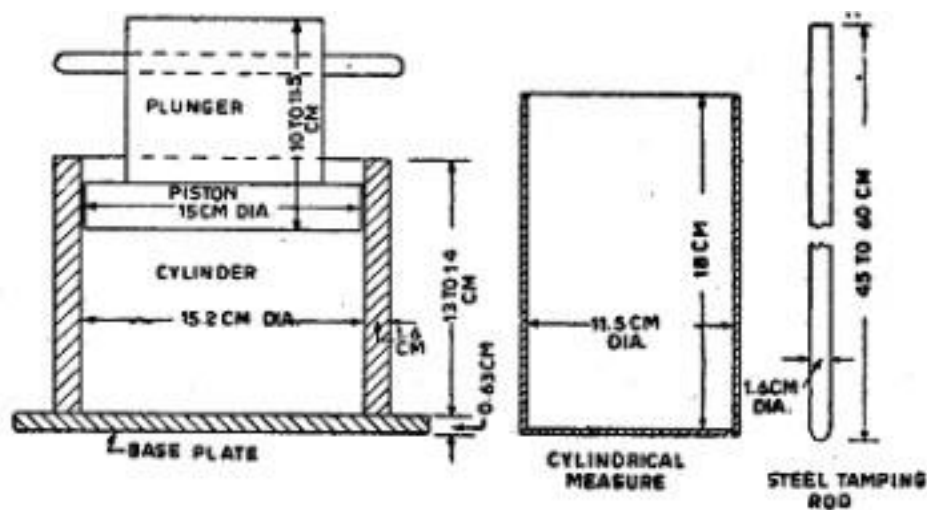


Fig. 1a.1

Aggregate Crushing Test Apparatus

1a.4 PROCEDURE:

1a.4.1 The aggregates in surface dry condition and passing 12.5 mm IS sieve and retained on 10.0 mm IS sieve is selected for the test.

1a.4.2 The cylindrical measure is filled by the sample of aggregates in three layers of approximately equal depth, each layer being tamped 25 times by the rounded end of the tamping rod.

1a.4.3 After the third layer is tamped, the aggregates at the top of the cylindrical measure are leveled off by using the tamping rod as a straight edge. Then the test sample is weighed. Let that be W_1 g.

1a.4.4 The total depth of material in the cylinder after tamping shall be 10 cm.

1a.4.5 The plunger inserted in the cylinder with the test sample so that it rests on the aggregate surface in a level position.

1a.4.6 The cylinder with the test sample and plunger in position is placed in a compression testing machine.

1a.4.7 Load is then applied through the plunger at a uniform rate of 4 tonnes per minute until the total load is 40 tonnes and the load is then released.

1a.4.8 Aggregates including the crushed portion are removed from the cylinder and sieved on a 2.36 mm IS sieve and the material which passes this sieve is collected and weighed (W_2 g).

1a.4.9 The aggregate crushing value of the given sample is calculated using the relation:

$$\text{Aggregate Crushing Value} = \frac{W_2}{W_1} \times 100, \%$$

OBSERVATIONS AND CALCULATIONS:

Trial No.	Weight of the surface dry aggregates, W_1 g	Weight of crushed portion passing through 2.36 mm IS sieve, W_2 g	Aggregate Crushing value of the given sample, $= \frac{W_2}{W_1} \times 100, \%$	Aggregate Crushing value of the given sample, %
1.				
2.				
3.				

1a.5 RESULTS:

The average crushing value of the given aggregate sample = _____%

1a.6 CONCLUSIONS:

EXPERIMENT NO. 1 TESTS ON AGGREGATES

1b. LOS ANGELES ABRASION TEST

1b.1 AIM: To determine the abrasion value of the given aggregate sample by Los-Angeles abrasion test

1b.2 APPARATUS: i. Los Angeles abrasion machine
 ii. Spherical abrasive charges
 iii. Standard IS sieves.
 iv. Weighing balance.

1b.3 THEORY:

Abrasion is a measure of resistance to wear or hardness. It is an essential property for road aggregates especially when used in wearing course. Due to the movements of the traffic, the road stones used in the surfacing course are subjected to wearing actions at the top. When traffic moves on the road, the sand particles between the wheel and the road surface causes abrasion of the road aggregates.

The principle of Los Angeles abrasion test is to find the percentage wear due to the relative rubbing action of the steel balls used as abrasive charge. Pounding action of the balls also exist while conducting the test.

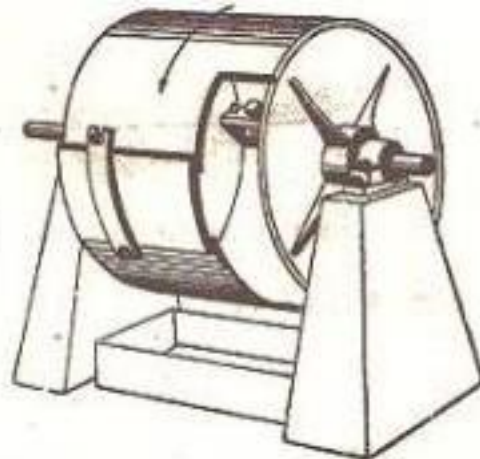
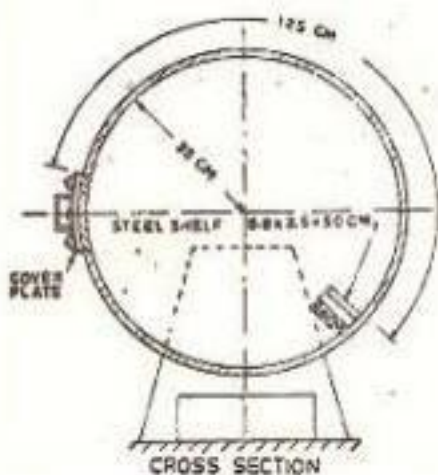


Fig. 1c.1

Los Angeles abrasion machine

1b.4 PROCEDURE:

1b.4.1 Weigh 5 kg of clean and dry aggregates as given below (W_1 kg). Passing 40 mm and retained on 25 mm – 1.25 kg, Passing 25 mm and retained on 20 mm – 1.25 kg, Passing 20 mm and retained on 12.5 mm – 1.25 kg, Passing 12.5 mm and retained on 10 mm – 1.25 kg.

1b.4.2 Abrasive charges – 12 spheres weighing 5000 ± 25 g. Or Passing 20 mm and retained on

12.5 mm – 2.50 kg, Passing 12.5 mm and retained on 10 mm – 2.50 kg, Abrasive charges – 11 spheres weighing 4584 ± 25 g.

- 1b.4.3. The abrasive charges and the aggregates are placed in the cylinder of the machine and the cover is fixed to make it dust-tight.
- 1b.4.4 The machine is rotated at a speed of 30-33 revolutions per minute. 4. The machine is stopped after 500 revolutions and the aggregates are removed from the machine taking care to remove the entire stone dust.
- 1b.4.5 The material is then sieved on a 1.70 mm IS sieve and the weight of aggregate retained on the sieve is taken (W_2 kg).
- 1b.4.6 The Los Angeles abrasion value is calculated as a percentage wear of the aggregates using the following relation:

$$\text{Los-Angeles Abrasion Value} = \frac{W_2 - W_1}{W_1} \times 100$$

OBSERVATIONS AND CALCULATIONS:

Trial No.	Weight of the aggregates taken, W_1 kg	Weight of the aggregates retained on 1.70 mm IS sieve, W_2 kg	Los-Angeles Abrasion Value = $\frac{W_2 - W_1}{W_1} \times 100$	Average Los Angeles Abrasion Value of the given sample, %
1.				
2.				
3.				

1b.5 RESULT:

The average Los-Angeles Abrasion value of the given sample of aggregates = _____%

1b.6 Conclusions

EXPERIMENT NO. 1 TESTS ON AGGREGATES

1c. AGGREGATE IMPACT TEST

1c.1 AIM: To determine the impact value of the given aggregate sample

1c.2 APPARATUS:

- i. Aggregate impact testing machine
- ii. Hammer of weight 13.5-14.0 kg having a free fall of 38 cm
- iii. IS sieves of 12.5 mm, 10 mm and 2.36 mm.
- iv. Cylindrical measure
- v. Tamping rod

1c. 3 THEORY:

Toughness is the property of a material to resist impact. Due to traffic loads the aggregates are subjected to pounding action or impact and there is a possibility of the aggregate breaking into smaller pieces. The road stones should be tough enough to resist fracture under impact. A test designed to evaluate the toughness of stones, i.e., the resistance of stones to fracture under repeated impacts may be called an impact test for road aggregates.

The aggregate impact value indicates a relative measure of the resistance of an aggregate to a sudden shock or an impact, which in some aggregates differs from its resistance to a slow compressive load. A modified Impact test is also often carried out in the case of soft aggregates to find the wet Impact value after soaking the test sample.

The maximum allowable aggregate Impact value for Sub-Base course 50% whereas cement concrete used in base course is 45%. Base courses with Bitumen surfacing should have an A.I.V of 40%. Bituminous Macadam base course should have A.I.V of 35%. All the surface courses should possess an A.I.V below 30%.

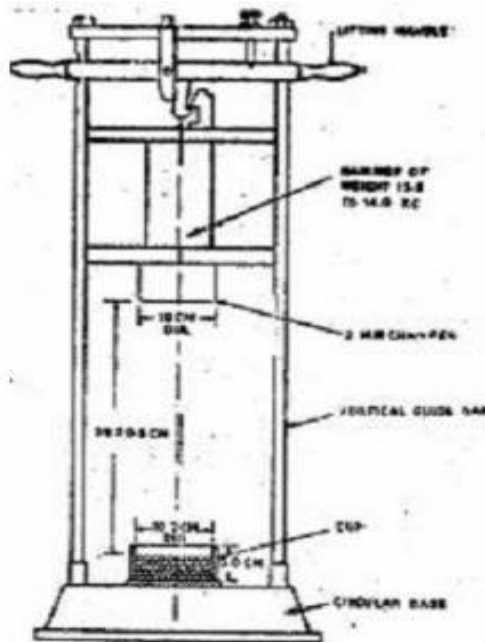


Fig. 1c.1 Impact testing machine

1c.4 PROCEDURE:

- 1c.4.1 The aggregates passing 12.5 mm IS sieve and retained on 10.0 mm IS sieve is selected for the test. The aggregates should be in surface dry condition.
- 1c.4.2 The aggregates are filled into the cylindrical measure in three equal layers by tamping each layer 25 times with the rounded edge of the tamping rod. The test sample is weighed to the nearest gram (W_1 g).
- 1c.4.3. The sample is transferred from the cylindrical measure to the cup of the aggregate testing machine and compacted by tamping 25 times with the rounded edge of the tamping rod.
- 1c.4.4 The hammer is raised to a height of 38 cm above the upper surface of the aggregate in the cup and is allowed to fall freely on the specimen.
- 1c.4.5. The test sample is subjected to a total of 15 such blows, each being delivered at an interval of one second.
- 1c.4.6. The crushed aggregate is then removed from the cup and the whole of it is sieved in 2.36 mm IS sieve until no significant amount passes. The fraction passing the sieve is weighed (W_2 g).
- 1c.4.7. The aggregate impact value is expressed as a percentage of the fines formed in terms of the total weight of the sample using the following relationship:

$$\text{Aggregate Impact Value} = \frac{W_2}{W_1} \times 100$$

OBSERVATIONS AND CALCULATIONS:

Trial No.	Weight of the surface dry aggregates, W_1 g	weight of crushed portion passing through 2.36 mm IS sieve, W_2 g	Aggregate Impact value of the given sample, = $\frac{W_2}{W_1} \times 100, \%$	Aggregate Impact value of the given sample, %
1.				
2.				
3.				

1c.5 RESULTS:

The average impact value of the given aggregate sample = _____%

1c.6 CONCLUSIONS:

EXPERIMENT NO. 1 TESTS ON AGGREGATES

1d. SHAPE TESTS (COMBINED INDEX AND ANGULARITY NUMBER)

1d.1 AIM: To determine the combined index and angularity number of the given sample of aggregates

1d.2 APPARATUS:

For combined index: i. Standard thickness gauge

ii. IS sieves of sizes 63, 50, 40, 31.5, 25, 20, 16, 12.5, 10 and 6.3 mm

iii. Weighing balance.

iv. Standard length gauge

For Angularity Number

i. A metal cylinder of 3 litre capacity

ii. Metal tamping rod of circular cross section

iii. Standard IS sieves for the required sizes

1d.3 THEORY:

The shape of aggregate particles is determined by the percentages of flaky and elongated particles contained in the aggregate sample. Flakiness and Elongation tests are conducted on coarse aggregates to assess the shape of aggregates. Aggregates which are flaky or elongated are detrimental to the workability and stability of bituminous mixes. They do not provide good interlocking and hence the mixes with an excess of such particles are difficult to compact to the required degree. For base course and the construction of bituminous and cement concrete types, the presence of flaky and elongated particles are considered undesirable as they may cause inherent weakness with probabilities of breaking down under heavy loads. Rounded aggregates are preferred in cement concrete road construction as the workability of concrete increases. Angular shape of aggregates are desirable for granular base course due to increased stability derived from better interlocking when the shape of the aggregates deviates more from the spherical shape. As in the case of angular, flaky and elongated aggregates, the void content in an aggregate sample of any specified size increases and hence the grain size distribution of the graded aggregates are suitably altered in order to obtain minimum voids in the dry mix or the highest dry density.

The flakiness index of aggregates is the percentage of particles whose least dimension (thickness) is less than $(3/5)^{\text{th}}$ or 0.6 of their mean dimension. The test is not applicable to sizes smaller than 6.3 mm. The Fig 11.1 shows the standard thickness gauge used for the determination of the Flakiness index.

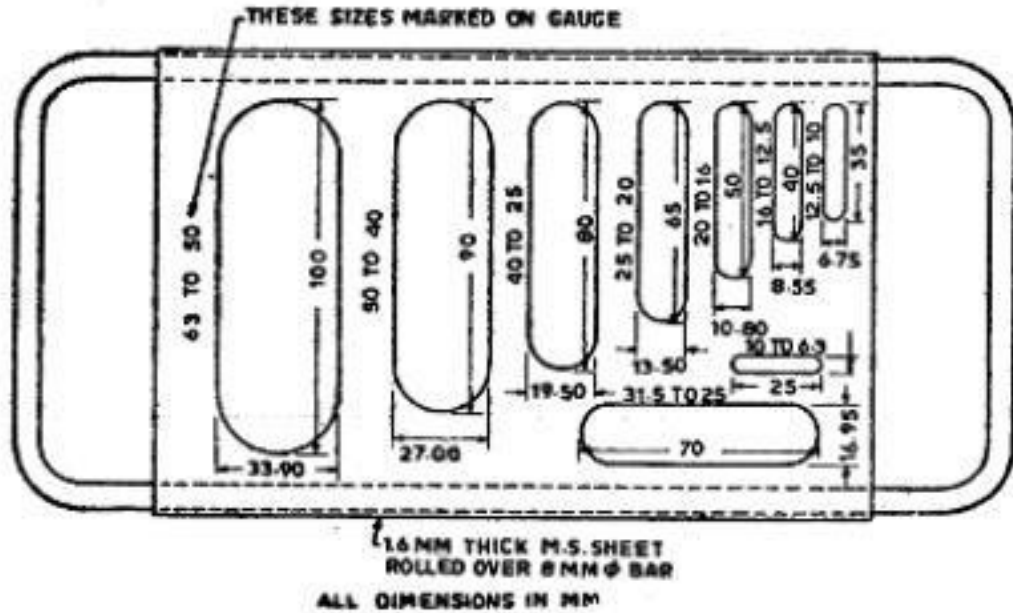


Fig 1d.1 Standard Thickness Gauge

The elongation index of an aggregate is the percentage by weight of particles whose greatest dimension (length) is greater than 1 and (4/5)th times or (1.8 times) their mean dimension. The test is not applicable to sizes smaller than 6.3 mm.



Fig 1d.2 Standard Length Gauge

Table 1d.1 Dimensions of thickness and length gauges

Size of the aggregate		(a) Thickness Gauge (0.6 times the mean sieve), mm	(b) Length gauge (1.8 times the mean sieve), mm
Passing through IS Sieve, mm	Retained on IS Sieve, mm		
(1)	(2)	(3)	(4)
63.0	50.0	33.90	--
50.0	40.0	27.00	81.0

40.0	31.5	21.50	64.4
31.5	25.0	16.95	--
25.0	20.0	13.50	40.5
20.0	16.0	10.80	32.4
16.0	12.5	8.55	25.6
12.5	10.0	6.75	20.2
10.0	6.3	4.89	14.7

The angularity number of an aggregate is the amount by which the percentage voids exceeds 33 after being compacted in a prescribed manner. Angular particles possess well defined edges formed at the intersection of roughly plane faces and are commonly found in aggregates prepared by crushing of rocks. Angularity of aggregates can be estimated from the properties of voids in a sample of aggregates compacted in a particular manner. Angularity number is defined as 67 minus percent solid volume. The solid volume of the aggregates is found by filling it in a vessel in a specified manner. The value 67 represents the volume of solids (in percent) of the most rounded gravel in a well compacted state which would then have 33 percent voids. Thus, angularity number measures the voids in excess of 33 percent. Higher the number, more angular is the aggregate.

1d. 4 PROCEDURE (COMBINED INDEX):

- 1d.4.1 The sample is sieved with sieves mentioned in Table 1d.1.
- 1d.4.2. A minimum of 200 pieces of each fraction to be tested are taken and weighed.
- 1d.4.3. In order to separate the flaky materials, each fraction is then gauged for thickness on the thickness gauge.
- 1d.4.4. The widths of the each slot of the thickness gauge are of the dimensions specified in column 3 of Table 1d.1 for the appropriate size of the material.
- 1d.4.5. The amount of flaky material passing the thickness gauge is weighed to an accuracy of at least 0.1 percent of the test sample.
- 1d.4.6. Let the weight of the flaky materials passing the thickness gauge be w g. Similarly the weights of the fractions passing and retained on the thickness gauge be W g.
- 1d.4.7. Let the weights of the flaky materials passing through the specified sieves be $w_1, w_2, w_3, w_4 \dots$ grams so that the total weight of material passing the thickness gauge is equal w g. Similarly let the weights of the material passing and retained on the specified sieves be

W1, W2, W3, W4... grams so that the total weight of material passing and retained the thickness gauge is equal to W g

1d.4.8. Then the flakiness index is the total weight of the flaky material passing the various thickness gauges expressed as a percentage of the total weight of the sample gauged using the following relation:

$$\text{Flakiness Index} = (w_1+w_2+w_3+w_4\dots/W_1+W_2+W_3+W_4)*100$$

$$\text{Flakiness Index} = (w/W)*100$$

1d.4.9 The flaky aggregates are removed and the elongation test on only non-flaky aggregates from each sieve sizes are conducted.

1d.4.10 In order to separate the elongated materials, each fraction is then gauged for length on the length gauge.

1d.4.11 The lengths of the each slot of the length gauge are of the dimensions specified in column 4 of Table 1d.1 for the appropriate size of the material.

1d.4.12 The pieces of aggregates from each fraction which could not pass through the specified gauge length with its longest side are elongated particles and are collected separately to find the total weight of aggregates retained on the length gauge from each fraction.

1d.4.13 The total amount of elongated material retained by the length gauge is weighed to an accuracy of at least 0.1% of the weight of the test sample.

1d.4.14 Let the weight of the elongated materials retained on the length gauge be w g. Similarly the weights of the fractions passing and retained on the length gauge be W g.

1d.4.15 Let the weights of the elongated materials retained on the specified sieves be w1, w2, w3, w4... grams so that the total weight of material retained on the length gauge is equal w g. Similarly let the weights of the material passing and retained on the specified sieves be W1, W2, W3, W4... grams so that the total weight of material passing and retained on the length gauge is equal to W g.

1d.4.16 Then the elongation index is the total weight of the elongated material retained on various slots of the length gauge expressed as a percentage of the total weight of the sample gauged using the following relation:

$$\text{Elongation Index} = (w_1+w_2+w_3+w_4\dots/W_1+W_2+W_3+W_4)*100$$

$$\text{Elongation Index} = (w/W)*100$$

1d.4.17 The combined index is calculated as sum of Flakiness Index and Combined Elongation Index.

OBSERVATIONS AND CALCULATIONS: (Flakiness Index)

Size of the aggregate		Thickness gauge (0.6 times the mean sieve), mm	Weight of the fraction consisting of at least 200 pieces, w g	Weight of aggregates in each fraction passing thickness gauge, W g
Passing through IS Sieve, mm	Retained on IS Sieve, mm			
(1)	(2)	(3)		
63.0	50.0	33.90		
50.0	40.0	27.00		
40.0	31.5	21.50		
31.5	25.0	16.95		
25.0	20.0	13.50		
20.0	16.0	10.80		
16.0	12.5	8.55		
12.5	10.0	6.75		
10.0	6.3	4.89		

OBSERVATIONS AND CALCULATIONS: (Combined Elongation Index)

Size of the aggregate		Length	Weight of the	Weight of
Passing through IS Sieve, mm	Retained on IS Sieve, mm	gauge (1.8 times the mean sieve), mm	fraction consisting of non-flaky aggregate pieces, w g	aggregates in each fraction retained on length gauge, W g
(1)	(2)	(3)		
63.0	50.0	--		
50.0	40.0	81.0		
40.0	31.5	64.4		
31.5	25.0	--		
25.0	20.0	40.5		
20.0	16.0	32.4		
16.0	12.5	25.6		
12.5	10.0	20.2		
10.0	6.3	14.7		

$$\text{Combined Elongation Index} = (w_1+w_2+w_3+w_4\dots/W_1+W_2+W_3+W_4)*100$$

$$\text{Elongation Index} = (w/W)*100$$

1d.5 PROCEDURE (FOR ANGULARITY NUMBER)

1d.5.1. The sample of aggregates retained between the specified set of sieves is dried in an oven at a temperature of 100°C to 110°C for 24 hours and cooled prior to testing.

1d.5.2. The aggregates are placed in the cylinder in three equal layers by giving each layer 100 blows of the tamping rod at a rate of about 2 blows per second.

1d.5.3 After the third layer is tamped, the cylinder is filled to over flowing and the aggregates are

struck off level with the top using a tamping rod as a straight edge.

1d.5.4 The aggregate with cylinder is weighed accurately (W_1 kg).

1d.5.5. The aggregates are removed from the cylinder and the cylinder is filled with water and the weight of water filling the cylinder is noted (W_2 kg).

1d.5.6. The Angularity number of the given sample of aggregates is calculated using the following relationship:

$$\text{Angularity Number} = 67 - \frac{100 \cdot W_1}{W_2 G}$$

OBSERVATIONS AND CALCULATIONS:

Trial No.	Weight of the aggregates in the cylinder, W_1 kg	Weight of the water in the cylinder, W_2 kg	Angularity Number $= 67 - \frac{100 \cdot W_1}{W_2 G}$	Average Angularity Number of the given sample
1.				
2.				
3.				

1d.6 RESULT:

The combined index of the given aggregate sample =

The average Angularity Number of the given aggregate sample = _____

1d.7 Conclusions

EXPERIMENT NO. 2 TESTS ON BITUMINOUS MATERIALS

2a. PENETRATION TEST

2a.1 AIM: To determine the grade of the given bitumen.

2a.2 APPARATUS: i. Penetrometer with needle assembly

ii. Stop watch

iii. Flat bottomed cylindrical container

2a.3 THEORY:

The consistencies of bituminous materials vary depending upon several factors such as constituents, temperature, etc. As temperature ranges between 25° and 50°C most of the paving bitumen grades remain in semi-solid or in plastic states and their viscosity is so high that they do not flow as liquid.

Determination of absolute viscosity of bituminous material is not so simple. Therefore the consistency of these materials is determined by indirect methods. The consistency of bitumen is determined by penetration test which is a very simple test. Various types and grades of bituminous materials are available depending on their origin and refining process. The penetration test determines the consistency of these materials for the purpose of grading them, by measuring the depth (in units of one tenth of a millimeter or one hundredth of a centimeter) to which a standard needle will penetrate vertically under specified conditions of standard load, duration and temperature. Thus the basic principle of the penetration test is the measurement of the penetration (in units of one tenth of a mm) of a standard needle in a bitumen sample maintained at 25°C during five seconds, the total weight of the needle assembly being 100 g. The softer the bitumen, the greater will be the penetration.

2a.4 PROCEDURE:

2a.4.1 The bitumen is softened to a paving consistency between 75° and 100°C above the approximate temperature at which bitumen softens.

2a.4.2 The sample material is thoroughly stirred to make it homogeneous and free from air bubbles and water.

2a.4.3. The bituminous sample is then transferred to the flat bottomed cylindrical container of the Penetrometer.

2a.4.4. The weight of needle, shaft and additional weight are checked. The total weight of this assembly should be 100 g.

2a.4.5. Using the adjusting screw, the needle assembly is lowered and the tip of the needle is made to just touch the top surface of the sample.

2a.4.6. The initial reading of the Penetrometer dial is either adjusted to zero or the initial reading is noted.

- 2a.4.7. Then the needle is released by pressing a button and a stop watch is started. The needle is released exactly for a period of 5 seconds.
- 2a.4.8. At least 3 measurements are made on this sample by testing at distance of not less than 10 mm apart.
- 2a.4.9. The difference between the initial and final penetration readings are taken as the penetration value.

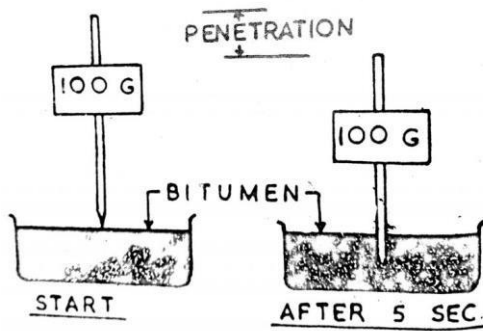


Fig 2a.1. Penetration test concept

OBSERVATIONS AND CALCULATIONS:

Trials	Readings		Penetration Value, mm	Mean Penetration Value, mm
	Initial dial reading, mm	Final dial reading, mm		
1				
2				
3				

2a.5 RESULT: The average penetration value of the given bitumen sample is _____ and the grade of bitumen is _____ as per penetration grading.

2a.6 CONCLUSIONS:

EXPERIMENT NO. 2 TESTS ON BITUMINOUS MATERIALS

2b. DUCTILITY TEST

2b.1 AIM: To determine the ductility of the given bitumen sample

2b.2 APPARATUS: i. Briquette mould

ii. Ductility machine

iii. Thermometer

2b.3 THEORY:

In the flexible pavement construction, it is desirable that the bitumen binders used in the bituminous mixes form ductile thin films around the aggregates. This serves as a satisfactory binder in improving the physical interlocking of the aggregates. The binder which does not possess sufficient ductility would crack and thus provide pervious pavement surface. This in turn results in damaging effect to the pavement structure.

The ductility value of bitumen binder is expressed as the distance in centimetres to which a standard briquette of bitumen can be stretched before the thread breaks. The test is conducted at $27\pm 0.5^{\circ}\text{C}$ and a rate of pull of 50 ± 2.5 mm per minute. The concept of ductility test is as shown in Fig.2b.1.

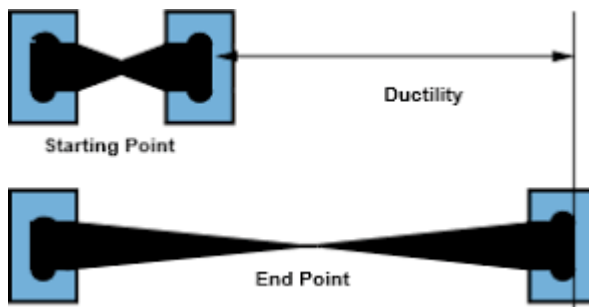


Fig.2b.1 Ductility test concept

2b.4 PROCEDURE:

2b.4.1 The bitumen sample is melted to a pouring temperature (75°C to 100°C) and poured into the mould assembly and placed on a brass plate, where a solution of glycerin or soap solution is applied at all surfaces of Briquette mould exposed to bitumen.

2b.4.2 The bitumen is then poured into the Briquette moulds and the plate assembly along with the sample is kept for air cooling in room temperature for 30 to 40 minutes.

2b.4.3 The air-cooled specimen is then placed in a water bath maintained at 27°C for 30 minutes.

2b.4.4 Then the sample is removed from the water bath maintained at 27°C and excess bitumen

material is cut off by levelling the surface using hot knife.

2b.4.5 After trimming the specimen, the mould assembly containing sample is replaced in water bath maintained at 27°C for 85 to 95 minutes. Then the sides of the mould are removed and the clips are carefully hooked on the machine without causing any initial strain. Two or more specimens may be prepared in the moulds and clipped to the machine so as to conduct these tests simultaneously.

2b.4.6 The pointer is set to read zero. The machine is started and the two clips are thus pulled apart horizontally.

2b.4.7 While the test is in operation, it is checked whether the sample is immersed in water at depth of at least 10mm. The distance at which the bitumen thread of each specimen breaks is recorded (in cm) to report as ductility value.

OBSERVATIONS AND CALCULATIONS:

Test property	Trials			Mean Ductility Value, cm
	1	2	3	
Ductility value, cm				

2b.5 RESULT: The ductility value of the given bitumen sample is _____cm.

2b.6 CONCLUSION:

EXPERIMENT NO. 2 TESTS ON BITUMINOUS MATERIALS

2c. SOFTENING POINT TEST

2c.1 AIM: To determine the softening point of the given bituminous sample

2c.2 APPARATUS: i. Ring and Ball apparatus

ii. Water bath with stirrer

iii. Thermometer

2c.3 THEORY:

Bitumen does not suddenly change from solid to liquid state, but as the temperature increases, it gradually becomes softer until it flows readily. All semi-solid state bitumen grades need sufficient fluidity before they are used for application with the aggregate mix. The common procedure adopted to liquefy bitumen is by heating.

The softening point is the temperature at which the substance attains particular degree of softening under specified condition of test. For bitumen, it is usually determined by Ring and Ball apparatus. The concept of determining the softening point by Ring and Ball apparatus is shown in Figure below.

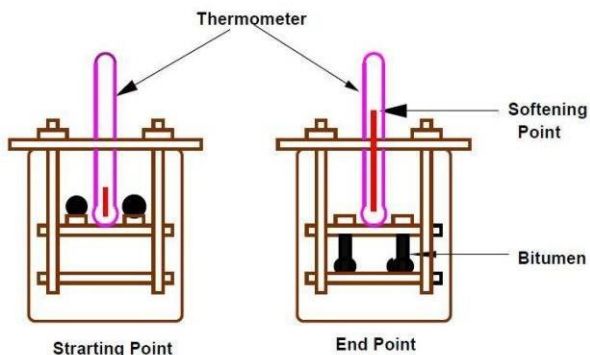


Fig.2c.1 Softening point test concept

2c.4 PROCEDURE:

2c.4.1 Sample material is heated to a temperature between 75°C and 100°C above the approximate softening point until it is completely fluid and is poured in heated rings placed on the metal plate.

2c.4.2 To avoid sticking of the bitumen to the metal plate, coating is done to this with a solution of glycerin and dextrin.

2c.4.3 After cooling the rings in air for 30 minutes, the excess bitumen is trimmed and rings are placed in the support.

2c.4.4 At this time the temperature of distilled water is kept at 5°C. This temperature is maintained for 15 minutes after which the balls are placed in position.

2c.4.5 Then the temperature of water is raised at a uniform rate of 5°C per minute with a controlled heating unit until the bitumen softens and touches the bottom plate by sinking of balls. At least two observations are made.

2c.4.6 The temperature at the instant when each of the ball and sample touches the bottom plate of support is recorded as softening point value.

OBSERVATIONS AND CALCULATIONS:

Test Property	Trial		Mean temperature
	1	2	
Softening Point			
Temperature °C at which the first ball touches the bottom plate			
Temperature in °C at which the second ball touches the bottom plate			

2c.5 RESULT: The Softening point of the given bituminous sample = _____ °C

2c.6 CONCLUSION:

EXPERIMENT NO. 2 TESTS ON BITUMINOUS MATERIALS

2d. SPECIFIC GRAVITY TEST

2d.1 AIM: To determine the specific gravity of the given bitumen sample

2d.2 APPARATUS: i. Weighing balance accurate to 1g.

ii. Specific gravity bottle

2d.3 THEORY:

The density of a bitumen binder is a fundamental property frequently used as an aid in classifying the binders for use in paving jobs. In most applications, the bitumen is weighed, but finally in use with aggregate system, the bitumen content is converted on volume basis. Thus an accurate density value is required for conversion of weight to volume. The specific gravity is greatly influenced by the chemical composition of binder. Increased amounts of aromatic type compounds cause an increase in the specific gravity. The specific gravity is defined by ISI as the ratio of the mass of a given volume of the bituminous material to the mass of an equal volume of water, the temperature of both being specified at 27°C±0.1°C.

2d.4 PROCEDURE:

2d. 4.1 The specific gravity bottle is cleaned, dried and weighed (W_1 g)

2d.4.2 Fill the specific gravity bottle completely with distilled water.

2d.4.3 The specific gravity bottled containing the distilled water is cleaned from the outside with an absorbent cloth and weighed (W_2 g).

2d.4.4 The specific gravity bottle is cleaned and dried.

2d.4.5 The given sample of bitumen is placed in the specific gravity bottle and weighed (W_3 g).

2d.4.6. The remaining space in the specific gravity bottle is filled with distilled water. The bottle containing the bituminous material and distilled water is cleaned from the outside and is again weighed (W_4 g).

2d.4.7 The specific gravity of the given bituminous sample is calculated follows:

OBSERVATIONS AND CALCULATIONS:

Trail No.	1	2	3
W ₁ , g			
W ₂ , g			
W ₃ , g			
W ₄ , g			
Specific Gravity			

2d.5 RESULT: The specific gravity of the given bituminous sample is = _____.

2d.6 CONCLUSION:

EXPERIMENT NO. 2 TESTS ON BITUMINOUS MATERIALS

2e. VISCOSITY TEST BY TAR VISCOMETER

2e.1 AIM: To determine the viscosity of given bitumen sample by Tar Viscometer

2e.2 APPARATUS: i. Tar Viscometer with 4mm and 10mm orifices – The apparatus consists of main parts like cup, valve, water bath, sleeves, stirrer, receiver, and thermometer etc.
ii. 50 ml bitumen

2e.3 Theory:

Viscosity is defined as inverse of fluidity. Viscosity thus defines the fluid property of bituminous material. The degree of fluidity at the application temperature greatly influences the ability of bituminous material to spread, penetrate into the voids and also coat the aggregates and hence affects the strength characteristics of the resulting paving mixes.

2e.4 PROCEDURE:

2e.4.1 The tar cup is properly levelled and water in the bath is heated to the temperature specified for the test and is maintained throughout the test. Stirring is also continued.

2e.4.2 The sample material is heated at the temperature 20⁰C above the specified test temperature, and the material is allowed to cool. During this the material is continuously, stirred.

2e.4.3 When material reaches slightly above test temperature, the same is poured in tar cup, until the levelling peg on the valve rod is just immersed. In the graduated receiver (cylinder), 25ml of mineral or one percent by weight solution of soft soap is poured. The receiver is placed under the orifice.

2e.4.4 When the sample material reaches the specified testing temperature within +/- 0.10C and is maintained for five minutes, the valve is opened.

2e.4.5 The stopwatch is started, when cylinder records 25ml. The time is recorded for flow up to a mark of 75ml (i.e., 50ml of test sample to flow through the orifice).

Observations and Calculation:

Sl. No.	Description	Test - 1	Test – 2	Mean value
1.	Specified Test Temp. ⁰ C	60 ⁰ C	60 ⁰ C	
2.	Size of Orifice in mm			
3.	Viscosity in Seconds			

2e.5 **RESULT:** The average viscosity value of the given sample of bitumen.....

2e.6 **CONCLUSIONS:**

EXPERIMENT NO. 2 TESTS ON BITUMINOUS MATERIALS

2f. FLASH AND FIRE POINT TEST

2f.1 **AIM:** To determine the flash and fire point of given bitumen samples by Pensky-Martens closed tester.

2f.2 **APPARATUS:** i. Pensky-Martens closed tester consisting of cup, lid, stirrer, shutter, flame exposure device.

ii. Thermometer (0-350⁰ C) with sensitivity of 0.1⁰ C.

2f.3 THEORY:

Bituminous materials leave out volatiles at high temperatures depending upon their grade. These volatile catch fire causing a flash. This condition is very hazardous, and it is therefore essential to qualify this temperature for each bitumen grade.

FLASH POINT: the flash point of a material is the lowest temperature at which the vapour

of the substance momentarily takes fire in the form of flash under specified condition of test. FIRE POINT: The fire point is the lowest temperature at which the material gets ignited and burns under specified condition of test.

2f.4 PROCEDURE:

2f.4.1 The material is filled in the cup up to a filling mark.

2f.4.2 The lid is placed to close the cup in a closed system. All accessories including thermometer of the specified range are suitably fixed.

2f.4.3 The bitumen sample is then heated. The flame is lit and adjusted in such a way that the size of a bleed is of 4 mm diameter.

2f.4.4 The heating is done at the rate of 5°C to 6°C per minute.

2f.4.5. The stirring is done at the rate of approximately 60 revolutions per minute.

2f.4.6 The test flame is applied at intervals depending upon the expected flash and fire points.

2f.4.7 First application is made at least 17°C below the actual flash point and then at every 1°C to 3°C.

2f.4.8 The stirring is discontinued during the application of the test flame.

2f.5 RESULT: The flash and fire point of bitumen are..... & repectively

2f.6 CONCLUSION:.....

EXPERIMENT NO. 3 TESTS ON SOIL

3a. WET SIEVE ANALYSIS

3a.1 AIM: To determine the gradation of given soil sample

3a.2 APPARATUS: i. A series of sieve sets ranging from 4.75mm to 75µm
ii. Balance sensitive to ± 0.01g

3a.3 THEORY:

Soil gradation (sieve analysis) is the distribution of particle sizes expressed as a percent of the total dry weight. Gradation is determined by passing the material through a series of sieves stacked with progressively smaller openings from top to bottom and weighing the material retained on each sieve.

The results of testing will reflect the condition and characteristics of the aggregate from which the sample is obtained. Therefore, when sampling, it is important to obtain a disturbed representative sample that is representative of the source being tested because the distribution of different grain sizes affects the engineering properties of soil. Soil passing 4.75mm I.S. Sieve and retained on 75micron I.S. Sieve contains no fines. Those soils can be directly dry sieved rather than wet sieving. If the soil contains a substantial quantity (say

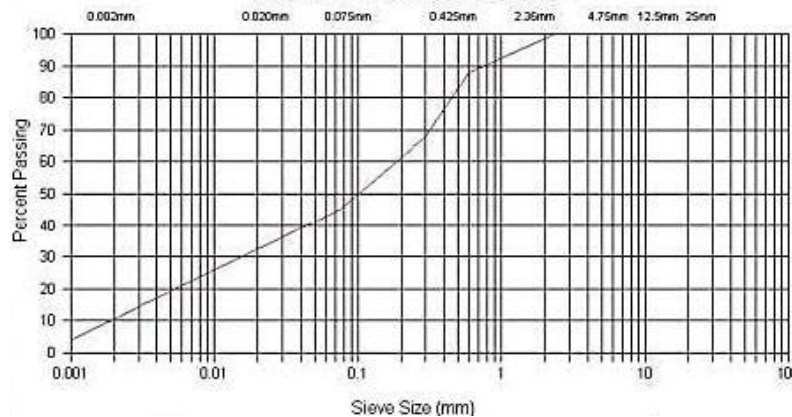
more than 5%) of fine particles, a wet sieve analysis is required.

3a.4 PROCEDURE:

- 3a.4.1 All lumps are broken into individual particles.
- 3a.4.2 Take 500gm of oven dried soil sample and soaked in water.
- 3a.4.3 For heavy clays if deflocculation is required, 2% calgon solution is used instead of water.
- 3a.4.4. The sample is stirred and left for soaking period of at least 10 minutes.
- 3a.4.5. The material is sieved through 75-micron sieve and the material is washed until the water filtered becomes clear.
- 3a.4.6. The soil retained on 75-micron sieve is collected and dried in oven.
- 3a.4.7. It is then sieved through the sieve shaker for ten minutes and retained material on each sieve is collected and weighed.
- 3a.4.8 The material that would have been retained on pan is equal to the total mass of soil taken for dry sieve analysis minus the sum of the masses of material retained on all sieves.
- 3a.4.9 Draw the grain size distribution curve for the soil in a semi-logarithmic graph.

Observations and Calculations

- 1. Sample Details
Location:
- 2. Weight of Sample taken for Sieve Analysis =_gms.



Sample plot

Sl. No.	IS Sieve No.	Weight retained in gms	Cumulative weight retained in gms	Percent (%) weight retained	Percent (%) weight passing
1.	4.75 mm				
2.	2.36 mm				
3.	1.18 mm				

4.	600 microns				
5.	300 microns				
6.	150 microns				
7.	75 microns				
8.	Pan				

3a.5 RESULTS: i. % of Gravel:

ii. % of Sand:

iii. % of Silt and Clay:

iv. Uniformity of coefficient, $C_u = D_{60}/D_{10}$

v. Uniformity of curvature: $C_c = D_{30}^2 / (D_{10} \times D_{60})$

3a.6 CONCLUSION

EXPERIMENT NO. 3 TESTS ON SOIL

3b. CBR TEST ON SOIL

3b.1 AIM: To determine the California Bearing Ratio (CBR) of given soil sample

3b.2 APPARATUS: i. Standard Proctor mould with rammer

ii. CBR apparatus with surcharge weight and spacer disc

iii. Standard plunger

iv. Proving ring to measure the loads applied

v. Dial gauge to measure the penetration

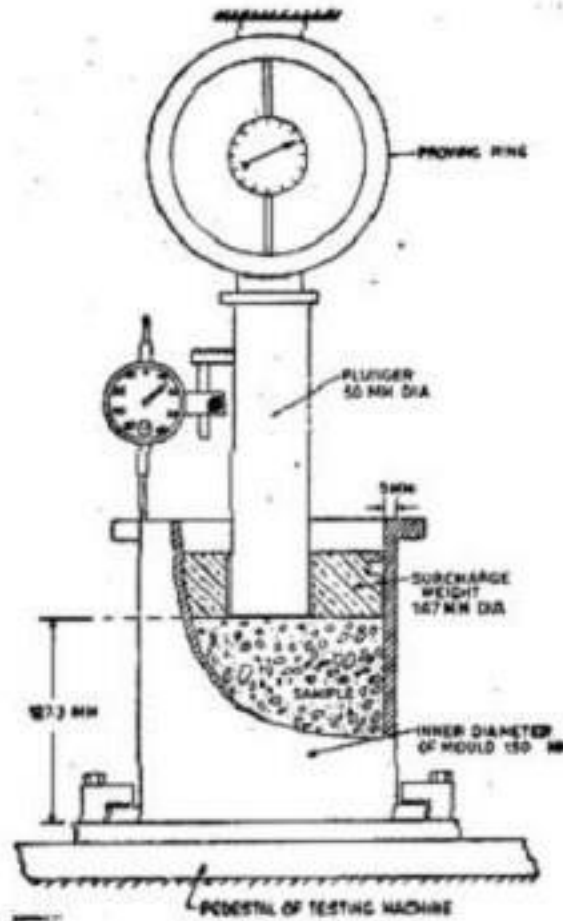
3b.3 THEORY:

The CBR test is a penetration test developed by the California Division of Highways as a method for evaluating the stability of soil subgrade and other flexible pavement materials. The CBR is a measure of resistance of a material to penetration of standard plunger under controlled density and moisture conditions. The CBR test may be conducted in re-moulded or undisturbed specimen in the laboratory. The test is simple and has been extensively investigated for field correlations of flexible pavement thickness requirement. The test is conducted by causing a cylindrical plunger of some diameter to penetrate a

pavement component material at 1.25mm/minute. The loads, for 2.5mm and 5mm are recorded. This load is expressed as a percentage of standard load value at a respective deformation level to obtain C.B.R. value. The values are tabulated in Table below. The Fig shows the experimental set up.

Table 3b.1 : Standard Load values

Penetration, mm	Standard Load, kg	Unit Standard Load, kg/cm²
2.5	1370	70
5.0	2055	105
7.5	2630	134
10.0	3180	162
12.5	3600	183



3b.1 Fig. CBR test apparatus

3b.4 PROCEDURE:

- 3b.4.1 A known quantity of soil is taken and mixed with water up to the Optimum Moisture Content (OMC) of the soil.
- 3b.4.2. The spacer disc is placed at the bottom of the mould over the base plate and a coarse filter paper is placed over the spacer disc.
- 3b.4.3 The moist soil sample is compacted over the spacer disc in the mould by adopting either I.S. light compaction or I.S. heavy compaction.
- 3b.4.4 After compacting the last layer, the collar is removed and the excess soil above the mould is evenly trimmed off by means of a straight edge.
- 3b.4.5. The clamps are removed and the mould with the compacted soil is lifted leaving below the base plate and the spacer disc is removed.
- 3b.4.6 In places where flooding is expected the entire assembly of mould and the subgrade soil is immersed in water for a period of 96 hours to simulate the worst subgrade moisture condition. If flooding is unlikely to occur in the place where the pavement is to be constructed the soil sample is tested in unsoaked condition.
- 3b.4.7 Surcharge weights of 2.5 to 5.0 kg are placed over the soil sample in the mould.

3b.4.8 The penetration plunger is seated at the centre of the specimen and is brought in contact

with the top surface of the soil sample.

- 3b.4.9 The dial gauge for measuring the penetration of the plunger is fitted in position. The dial gauge of the proving ring and the penetration dial gauge are set to zero.
- 3b.4.10 The load is applied through the penetration plunger at a uniform rate of 1.25mm/minute. The load readings are recorded at penetration readings of 0.0, 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 4.0, 5.0, 7.5, 10.0 and 12.5 mm. The maximum load value and the corresponding penetration value are recorded.
- 3b.4.11 After the final reading, the load is released and the mould is removed from the loading machine. The proving ring calibration factor is noted so that the load dial values can be converted into load in kg.
- 3b.4.12 A graph is plotted between penetration in mm on X-axis and the load in kg on Y-axis. Two typical graphs are obtained – the normal curve with initial convexity upwards and a curve with initial upward concavity.
- 3b.4.13 When initial upward concavity is observed correction is made by drawing a tangent from the steepest point on the curve to obtain the new origin or corrected origin.
- 3b.4.14 Then the load values corresponding to 2.5 and 5.0 mm penetration values are obtained from the graph. Then the CBR value is calculated from the formula:

$$\text{CBR, \%} = \frac{\text{Load or pressure sustained by the specimen at 2.5 mm or 5.0 mm penetration}}{\text{Load or pressure sustained by standard aggregates at corresponding penetration level}} \times 100$$

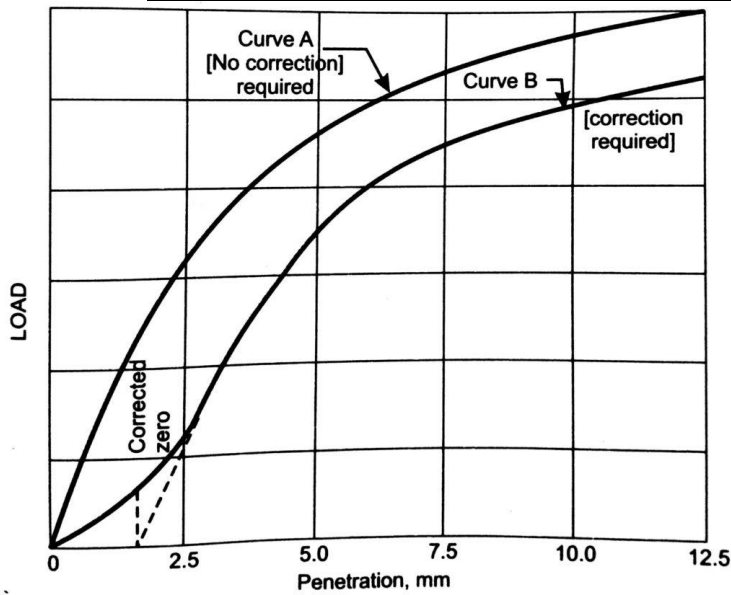
- 3b.4.15 The CBR values at 2.5mm and 5.0mm penetration levels are calculated for each specimen from the corresponding graphs. Generally the CBR value at 2.5mm penetration is higher and the value is adopted as the CBR value of the soil specimen. However if higher CBR value is obtained at 5.0mm penetration, the test is to be repeated to verify the results. If the value at 5.0mm penetration is again higher, this is adopted as the CBR value of the soil sample.

OBSERVATIONS AND CALCULATIONS

1. Diameter of the plunger, d = cm
2. Area of the plunger, $\pi d^2/4 = \dots\dots\dots \text{cm}^2$
3. Least count of the Proving Ring = kg

Penetration of Plunger, mm	Proving Reading, divisions	Ring (PRR),	Load, Kg, (PRR X LC)
---------------------------------------	---	------------------------	---------------------------------

0.0		
0.5		
1.0		
1.5		
2.0		
2.5		
3.0		
4.0		
5.0		
7.5		
10.0		
12.5		



From the graph,
 Load corresponding to 2.5 mm penetration of the specimen = kg
 Load corresponding to 5.0 mm penetration of the specimen = kg

$$\text{CBR at 2.5 mm penetration} = \frac{\text{Load or pressure sustained by the soil specimen at 2.5 mm}}{\text{Load or pressure sustained by standard aggregates at 2.5 mm penetration}} \times 100$$

$$\text{CBR at 5.0 mm penetration} = \frac{\text{Load or pressure sustained by the soil specimen at 5 mm}}{\text{Load or pressure sustained by standard aggregates at 5 mm penetration}} \times 100$$

$$\text{CBR of the soil specimen at 2.5 mm penetration} = \underline{\hspace{2cm}} \%$$

$$\text{CBR of the soil specimen at 5.0 mm penetration} = \underline{\hspace{2cm}} \%$$

3b.5 RESULT: The CBR of the given soil sample is %

3b.6 CONCLUSION:

EXPERIMENT NO. 4 DESIGN OF FLEXIBLE PAVEMENT AS PER IRC 37-2018

4.1 AIM: To design flexible pavement as per IRC 37- 2018.

4.2 THEORY:

Following are the salient features of IRC 37-2018

- Recommendation of better performing bituminous mixes and binders for surface and base/binder courses
- Guidelines for selection of appropriate elastic moduli for bituminous mixes used in the surface and other courses
- Recommendation of minimum thicknesses of granular and cement treated sub-bases and bases and bituminous layers from functional requirements
- Generalization of the procedure for the estimation of the effective resilient modulus/CBR of subgrade
- Provision for the use of geo-synthetics and
- Rationalization of the design approach for stage construction.

4.3 PROCEDURE FOR DESIGN WITH EXAMPLE

4.3.1 Materials and Data: Traffic data: Average Daily Traffic (ADT), Vehicle Damage Factor (VDF), Subgrade soil properties: California Bearing Ratio (CBR), Resilient Modulus and Pavement materials: Granular Sub-base (GSB), Bituminous layers

4.3.2 Traffic Analysis: Collected traffic data over a period of one year, Calculated the design traffic in terms of Million Standard Axles (MSA) using the formula:

$$N = 365 \cdot \frac{[(1+r)^n - 1]}{r} A \cdot D \cdot F$$

$$A = P(1+r)^x$$

4.3.3 Subgrade Evaluation:

Conducted laboratory tests to determine the CBR value of the subgrade soil and Measured the Resilient Modulus of the subgrade material.

4.3.5 Pavement Composition:

From charts of IRC: 37-2018 guidelines:

Granular Sub-base (GSB)

Base layer (Wet Mix Macadam)

Bituminous layers (Dense Bituminous Macadam and Bituminous Concrete)

4.3.6 Design Calculations:

Used the IITPAVE software to analyze the stress and strain values at critical locations within the pavement structure.

Ensured the pavement design met the criteria for fatigue and rutting life.

4.4 RESULTS AND DISCUSSIONS

Design Traffic: 50 MSA

Subgrade CBR: 8%

Layer Thicknesses:

Granular Sub-base: 200 mm

Base layer: 250 mm

Dense Bituminous Macadam: 100 mm

Bituminous Concrete: 40 mm

- The design follows the mechanistic-empirical approach as per IRC:37-2018.
- The selected layer thicknesses ensure adequate structural capacity and durability.
- The use of IITPAVE software facilitated accurate stress and strain analysis, enhancing the reliability of the design.

4.5 CONCLUSION:

The flexible pavement design for National Highway complies with IRC:37-2018 guidelines. The pavement structure is expected to perform well under the projected traffic loads and environmental conditions.

EXPERIMENT NO. 5 DESIGN OF RIGID PAVEMENT AS PER IRC 58-2015

5.1 AIM: To design rigid pavement as per IRC 58-2015.

5.2 THEORY:

Following are the salient features of IRC 58-2015

- Covers **jointed plain concrete pavements** with or without **tied shoulders**.

-
- The design is based on Finite element analysis (FEA).

- Provides **design specifications for joint and thickness design.**

5.3 PROCEDURE FOR DESIGN WITH EXAMPLE

5.3.1 Materials and Data: Traffic data: Average Daily Traffic (ADT), Vehicle Damage Factor (VDF), Subgrade soil properties: California Bearing Ratio (CBR), Modulus of Subgrade Reaction (k-value), Pavement materials: Concrete mix, Reinforcement details

5.3.2 Traffic Analysis: Collected traffic data over a period of one year, Calculated the design traffic in terms of Million Standard Axles (MSA) using the formula:

$$N = 365 \cdot \frac{[(1+r)^n - 1]}{r} A \cdot D \cdot F$$

$$A = P(1+r)^x$$

5.3.3 Subgrade Evaluation: Conducted laboratory tests to determine the CBR value of the subgrade soil and measured the Modulus of Subgrade Reaction (k-value).

5.3.4 Design Calculations:

Used the FEA theory to analyze the stress and strain values at critical locations within the pavement structure.

Ensured the pavement design met the criteria for fatigue and cracking life.

5.3.5 Results and Discussion

- Design Traffic: 50 MSA
- Subgrade CBR: 8%
- Layer Thicknesses:
- Concrete slab: 300 mm
- Reinforcement: Steel bars placed at 150 mm intervals dowel of dia 33 mm c/c at expansion joints.
- The design follows the mechanistic-empirical approach as per IRC:58-2015.
- The selected layer thicknesses and reinforcement details ensure adequate structural capacity and durability.
- The use of FEA analysis facilitated accurate stress and strain analysis, enhancing the reliability of the design.

5.3.6 Conclusion:

- The rigid pavement design for National Highway complies with IRC:58-2015 guidelines.
- The pavement structure is expected to perform well under the projected traffic loads and environmental conditions.

EXPERIMENT NO. 6 BITUMINOUS MIX DESIGN BY MARSHALL METHOD (DEMONSTRATION ONLY)

6.1 AIM: To determine optimum binder content of given bituminous mix by Marshall Method of mix design.

6.2 APPARATUS: i. Mould assembly

ii. Sample extractor

- iii. Compaction pedestal and hammer
- iv. Breaking head
- v. Loading machine flow meter
- vi. Thermometers
- vii. Water bath
- viii. oven

6.3 THEORY:

In this method, the resistance to plastic deformation of cylindrical specimen of bituminous mixture is measured when the same is loaded at the periphery at 5 cm per minute. This test procedure is used in designing and evaluating bituminous paving mixes. There are two major features of the Marshall method of designing mixes (i) density-void analysis (ii) stability-flow test. The Marshall stability of the mix is defined as a maximum load carried by a compacted specimen at a standard test temperature at 60 °C. The flow value is the deformation at which the Marshall test specimen undergoes during the loading upto the maximum load, in 0.25 mm unit. In this test an attempt is made to obtain optimum binder content for the type of aggregate mix and traffic intensity.

6.4 PROCEDURE:

- 6.4.1 The coarse aggregates, fine aggregates and mineral filler material should be proportioned and mixed in such a way that final mix after blending has the gradation within the specified range.
- 6.4.2 Approximately 1200 grams of aggregates and filler are taken and heated to a temperature of 170 °C.
- 6.4.3 The compaction mould assembly and rammer are cleaned and kept pre- heated to a temperature of 100 °C to 145 °C. The bitumen is heated to temperature of 150 °C and the required quantity of first trial percentage of bitumen is added to the heated aggregate and thoroughly mixed using a mechanical mixer or by hand mixing with trowel.
- 6.4.4 Then the mix is heated and a temperature of 154 °C to 160°C is maintained and then the mix is transferred into the pre-heated mould and compacted by giving 75 blows on either side at temp. of 140°C.
- 6.4.5 The weight of the mixed aggregate taken for the preparation of the specimen may be suitably altered to obtain a compacted thickness of 63.5 +/- 3.0 mm.
- 6.4.6 Three or four specimens may be prepared using each trial bitumen content.
- 6.4.7 Soon after the compacted bituminous mix specimens have cooled to room temperature, the weight, average thickness and diameter of the specimen are noted. The specimens are weighted in air and also suspended in water.
- 6.4.8 Then the specimen to be tested is kept immersed under water in a thermostatically controlled water bath maintained at 60 °C ± 1°C for 40 minutes.
- 6.4.9 The specimens are taken out one by one, placed in the Marshall test head and the Marshall stability value and flow are noted.
- 6.4.10 The corrected Marshall Stability value of each specimen is determined by applying the appropriate correction factor, if the average height of the specimen is not exactly 63.5mm.

Correction Factor for Marshall Stability value

Volume of specimen in cc	Thickness of specimen in mm	Correction factor
457-470	57.1	1.19
471-482	58.7	1.14
483-495	60.3	1.09
496-508	61.9	1.04
509-522	63.5	1.00
523-535	65.1	0.96
536-546	66.7	0.93
547-559	68.3	0.89
560-573	69.9	0.86

6.4.11 Five graphs are plotted with values of bitumen content against the values of Marshall Stability, Flow value, Unit weight, Percent voids in total mix, Percent voids filled with bitumen.

6.4.12 Let the bitumen contents corresponding to maximum stability be B1, corresponding to maximum unit weight be B2, and that corresponding to the percent air voids in total mix (at 4.0%) be B3. Then the optimum bitumen content for mix design is given by: $B_o = (B_1+B_2+B_3)/3$

6.5 OBSERVATIONS, NATURE OF GRAPH AND CALCULATIONS

- $$G_t = \frac{100}{\left(\frac{W_1}{G_1} + \frac{W_2}{2} + \frac{W_3}{G_3} + \frac{W_4}{G_4}\right)}$$

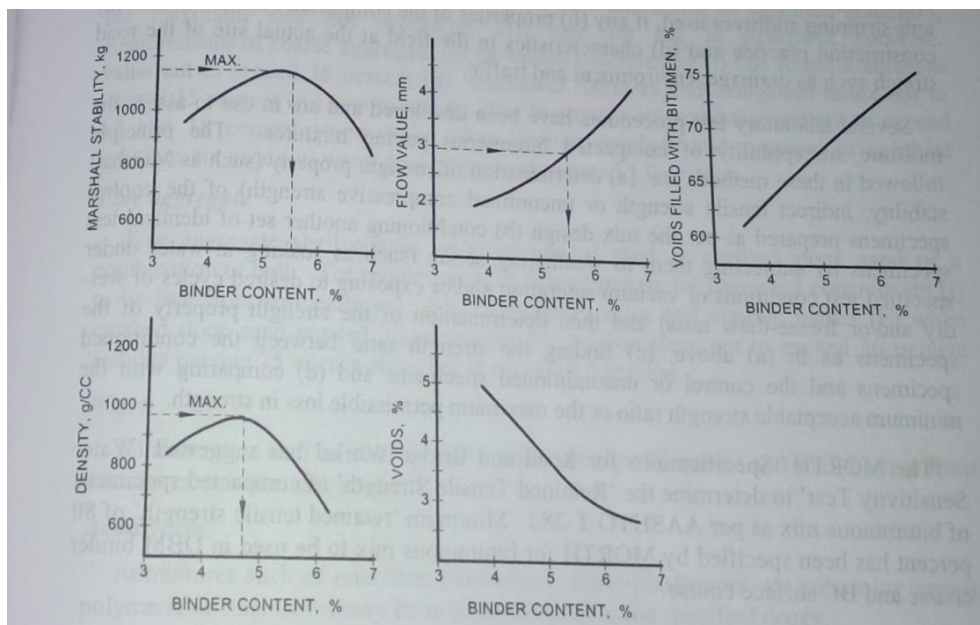
Where: W1, W2 and W3 percent by weight of aggregates 1, 2 & 3 and W4 is percent by weight of Bitumen.

G1, G2 and G3 are specific gravities of the respective aggregates and G4 is specific gravity of Bitumen

• $G_b = \frac{\text{weight in air}}{\text{weight in air (Saturated)} - \text{weight in water}}$
 Where G_b is specific gravity of compacted mix

- $V_v = (G_t - G_b) / G_t * 100 \dots \dots \%$
- $V_b = W_4 / G_4 * G_b \dots \dots \%$
- $VMA = V_v + V_b \dots \dots \%$
- $VFB = V_b / VMA * 100 \dots \dots \%$

Where : G_b = specific gravity of compacted mix,
 G_t = theoretical specific gravity,
 V_v = volume of air voids,
 VMA = voids in mineral aggregates,
 V_b = volume of bitumen, VFB = voids filled with bitumen,
 W_4 = percentage by weight of bitumen added and
 G_4 = Specific gravity of Bitumen



6.6 RESULTS

The optimum binder content of the given mix is _____

6.7 CONCLUSIONS

EXPERIMENT NO.7: TRAFFIC ENGINEERING STUDIES : MANUAL METHOD FOR TRAFFIC VOLUME STUDY

7.1 AIM: To conduct a traffic volume study and to determine different volume statistics for a particular road section.

7.2 THEORY: In this method, vehicles are counted manually. There are two methods of manual

counting:

1. Direct method
2. Indirect method

Direct Method: In this method, data is recorded using a hand tally on the observation sheets.

Advantages:

- Traffic volume, as well as vehicle classification, can be obtained.
- Data can be used immediately after collection.

Disadvantages:

- This method is not practical for long-duration counts and when the traffic flow is high.
- The counts cannot be cross-checked, increasing the probability of errors.
- This method is very difficult when the volume is high and/or there are three or more traffic lanes.
- The counts cannot be recorded in bad weather.

Indirect Method: In this method, data is collected using a video camera. The video is captured for a particular duration and data is retrieved and entered into the observation sheets later by rewinding.

Advantages:

- Besides traffic volume, several traffic parameters can be obtained from the recorded film.
- Data can be cross-checked and quality can be ensured.
- Applicable when the volume is high.
- Suitable for non-lane-based traffic operation.

Disadvantages:

- Data cannot be used immediately after collection.
- This process is time-consuming and tedious.
- Not suitable for very long-duration counts.

7.3 APPARATUS:

1. Observation sheets
2. A stopwatch
3. Video camera (in case of indirect methods)

7.4 PROCEDURE:

- 7.4.1. First, a section of the road is to be selected according to the guidelines, and all necessary lab preparations are to be completed in advance.
- 7.4.2. Traffic volume is a unidirectional study. Therefore, it is more desirable to record traffic in each direction of travel and keep separate observers for each direction.
- 7.4.3. The number of observers required to count the vehicles depends on the number of lanes and the type of information required.
- 7.4.4. The time slots and number of shifts could vary depending on the members of the field team. For example, for all-day counts, work in three shifts of 8 hours each could be organized.
- 7.4.5. Data is to be recorded on tally sheets/field data observation sheets. First, the observer records the date, location, weather condition, direction, and time of the study. One or more sheets may be required for observing and recording the traffic data.
- 7.4.6. The observer counts the vehicles and records observations in the respective vehicle type column with the help of hand tallies called the Five-Dash system (vertical strokes for the first four

vehicles followed by an oblique for the fifth vehicle, depicting a total of five) for each count

interval, mostly 15 minutes.

- 7.4.7. Data is collected for each type of vehicle and filled in tally sheets for the whole time of the study.
- 7.4.8. Calculate the hourly volume (vehicles/hour). Volume can be expressed as Average Daily Traffic (ADT) and Annual Average Daily Traffic (AADT) depending on the data recorded.
- 7.4.9. Also, determine the peak rate of flow and Peak Hour Factor (PHF) during both peak and off-peak periods for data recorded in the field.

7.5. OBSERVATIONS AND CALCULATION:

Observation Table

Classified Traffic Volume Count Study for Mid-Block Section

Name of the Road:							Day & date:						
Section from:				to:			Hour:						
Location:							Weather:						
Direction:				Sheet No.:			Name of the observer(s):						
Vehicle Type	FAST MOVING VEHICLES						SLOW MOVING VEHICLES						
	Two-Wheeler	Three Wheeler	Four Wheeler	Bus		LCV	Truck		Cycle	Cycle Rickshaw	Animal Drawn		Others
Mini				Full	2-Axle		Multi-Axle	Bullock cart			Horse		
Time													
00-15													
15-30													
30-45													
45-60													
TOTAL													
PCU Factor													
TOTAL PCU													

$PCU, \text{ vehicles} = \text{Number of vehicles} \times PCU \text{ factor}$

$$volume = \frac{\text{total no. of vehicles}}{\text{total time}} PCU/hr$$

$$volume = \underline{\hspace{2cm}} PCU/hr$$

$$Peak \text{ hour factor} = \frac{\text{total hourly volume}}{(4 \times \text{maximum 15 minute volume within the hour})}$$

$$Peak \text{ hour factor} = \underline{\hspace{2cm}}$$

7.6 RESULTS:

Traffic volume =

Peak hour factor =

7.7 CONCLUSIONS:**B. VIRTUAL LABS (SUPPORTED BY NITK)**

<https://ts-nitk.vlabs.ac.in/exp/california-bearing-ratio-test/index.html>

CALIFORNIA BEARING RATIO TEST ON SOIL

Aim: To determine California Bearing Ratio value of soil by conducting load penetration test.



[Civil Engineering](#) > [Transportation Engineering](#) > [Experiments](#)

California Bearing Ratio Test on Soil

INTRODUCTION

The California Bearing Ratio (CBR) test is a penetration test meant for the estimation of subgrade strength of roads and pavements. The results found by these tests are used with the empirical curves to find the thickness of pavement and its component layers. This is the most commonly used method for the design of flexible pavement. California Division of Highway developed CBR test as a method of classifying and evaluating soil-sub grade and base course materials for flexible pavements. An empirical test, the CBR test has been used to find the material properties for pavement design.

It is a penetration test in which a standard piston, with a diameter of 3 in or 76 mm, is used to penetrate the soil at a standard rate of 1.25 mm/minute. The pressure up to a penetration of 12.5 mm and its ratio to the bearing value of a standard crushed rock is defined as CBR. In most of the cases, CBR value decreases as the penetration value increases. The ratio is usually determined for the penetration of 2.5mm and 5.0mm.

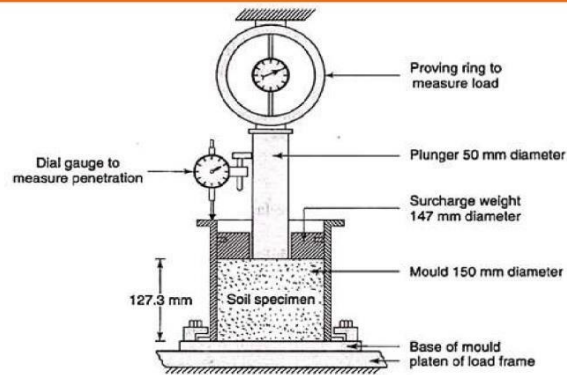
In some cases, the ratio at 5 mm may be greater than that at 2.5 mm. If this occurs, the ratio at 5 mm must be used. The CBR is a measure of resistance of a material to penetration of a standard plunger under controlled density and moisture conditions. The test procedure should be strictly adhered, if a high degree of reproducibility is desired.

The CBR test is conducted on a remolded or undisturbed specimen in the laboratory. The test is simple and has been widely investigated for field correlations of flexible pavement thickness condition.

CBR apparatus consists a mould of 150 mm diameter with a base plate and a collar, a loading frame and dial gauges for measuring the penetration values and the expansion on soaking. The specimen in the mould is soaked in water for four days and the swelling and water absorption values are noted. The surcharge weight is placed on the top of the specimen in the mould and the assembly is placed under the plunger of the loading frame.

Load is applied on the sample by a standard plunger with diameter of 50 mm at the rate of 1.25 mm/min. A load penetration curve is drawn. The load values on standard crushed stones are 1370 kg, 2055 kg, 2630 kg, 3180 kg and 3600 kg at 2.5 mm, 5.0 mm, 7.5 mm, 10.0 mm and 12.5 mm penetrations respectively. CBR value is defined as the percentage of the actual load causing the penetrations of 2.5 mm or 5.0 mm to the standard loads mentioned above. The test is carried out on the undisturbed specimens and on remoulded specimens which may be compacted either statically or dynamically. For light compaction, compact the soil in 3 equal layers, each layer being given 55 blows with 2.6 kg rammer. For heavy compaction compact the soil in 5 layers, 56 blows to each layer with 4.89 kg rammer.

Generally, the CBR value at 2.5 mm will be greater than that at 5 mm and in such a case the former shall be taken as CBR for design purpose. If CBR for 5 mm exceeds that for 2.5 mm, the test should be repeated. The CBR can therefore be mathematically expressed as below:



Schematic Diagram of CBR Experimental Setup

Source: (http://www.soilmanagementindia.com/wp-content/uploads/2018/05/clip_image020_thumb-3.png)

$$CBR = \frac{p}{p_s} \times 100$$

Where,

p = measured pressure for site soils [N/mm²]

p_s = pressure to achieve equal penetration on standard soil [N/mm²]

The California Bearing Ratio (CBR) test is a strength test that compares the bearing capacity of a material with that of a well-graded crushed stone. The harder the surface, the higher the CBR value. Typically, a value of 2% equates to clay, while some sands may have a CBR value of 10%. High quality sub-base will have a value of between 80-100% (maximum).

As per IRC: 37-2001, if the maximum variation in CBR values among the three specimens tested in the laboratory exceed the permissible variation in CBR values for different ranges (as given in the table below), the CBR test should be repeated on additional three specimens and the average value of six specimens is to be accepted as the CBR value.

CBR value (%)	Maximum permissible variation in CBR values between 3 individual test value (±, %)
< 5	1
5 - 10	2
11 - 30	3
31 or above	5

(Source: IS 2386(Part 4):1963)

Relevant Indian Standard for CBR Test on Soil:

1. IS 2720 (Part-16) : 1979 - Methods of Test for Soil : Laboratory Determination of CBR (Second Revision).
2. IS 2720 (Part 16) : 1987 - Methods of Test for Soil : Laboratory Determination of CBR (Second Revision). Reaffirmed- Dec 2016.

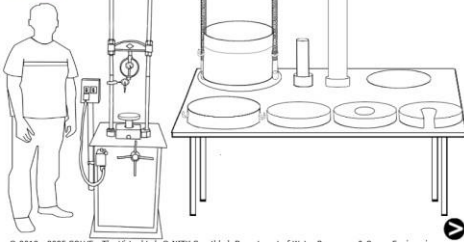
SIMULATION

CALIFORNIA BEARING RATIO TEST ON SOIL

Objective:
To determine California Bearing Ratio value of soil by conducting load penetration test.

Apparatus used:
CBR Setup, CBR Mould, Filter Paper, Rammer, Plunger, Spacer Disc, Surcharge Weight, Slotted Weight.

Description



CALIFORNIA BEARING RATIO TEST ON SOIL

STEP 1 Take sample, sieve it in 20mm IS sieve using mechanical shaker and then add measured quantity of water to it.



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CALIFORNIA BEARING RATIO TEST ON SOIL

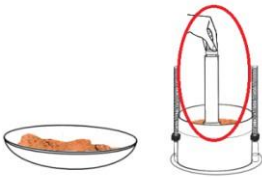
STEP 2 Place the spacer disc over the base plate and coarse filter paper on it.



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CALIFORNIA BEARING RATIO TEST ON SOIL

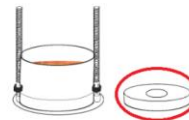
STEP 3 Fill one fifth of the mould with the soil sample. Each layer is compacted by giving 56 evenly distributed blows using a hammer of weight 4.89kg.



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CALIFORNIA BEARING RATIO TEST ON SOIL

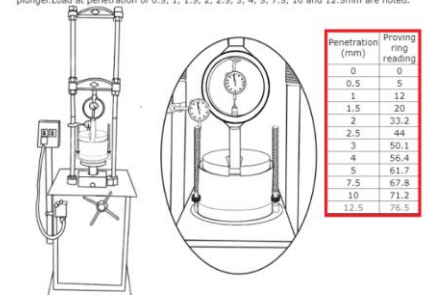
STEP 4 Remove base plate and invert the mould, then it is clamped to baseplate. Place the surcharge weight above the mould.



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CALIFORNIA BEARING RATIO TEST ON SOIL

STEP 5 Specimen is placed in position on the testing machine along with the half weight and plunger. Load at penetration of 0.5, 1, 1.5, 2, 2.5, 3, 4, 5, 7.5, 10 and 12.5mm are noted.



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CALIFORNIA BEARING RATIO TEST ON SOIL

STEP 6 Observation and Calculations.

Diameter of plunger = 50mm
Area of plunger = 19.63cm²
Optimum moisture content = 15%

$$\text{Load (kg)} = \frac{\text{Proving Ring Reading} \times 5 \times 1000}{225} = 9.81$$

$$\text{Axial Load (kg/cm}^2\text{)} = \frac{\text{Load (kg)}}{\text{Area of plunger}}$$

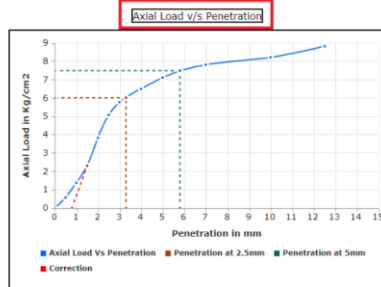
Enter key to be pressed to save values in table

Penetration (mm)	Proving ring reading	Load in (kg)	Axial load in (kg/cm ²)
0	0	0	0
0.5	18	40.78	2.08
1	27.1	61.39	3.13
1.5	32.2	72.94	3.72
2	35.6	80.64	4.11
2.5	39.1	88.57	4.51
3	43	97.4	4.96
4	47.3	107.15	5.46
5	51.2	115.98	5.91
7.5	57.4	130.03	6.62
10	63	142.71	7.27
12.5	69	156.3	7.96

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CALIFORNIA BEARING RATIO TEST ON SOIL

STEP 7 Plot graph of Axial Load Vs Penetration.



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CALIFORNIA BEARING RATIO TEST ON SOIL

STEP 8 Observation and Results.

Unit standard load for 2.5mm = 70kg/m²

Unit standard load for 5mm = 105kg/m²

Refer Graph

$$\text{California Bearing Ratio } CBR_{2.5\text{mm}} = \frac{\text{Load corresponding to 2.5mm penetration (P}_2\text{)}}{\text{Standard load corresponding to 2.5mm penetration (P}_s\text{)}} \times 100$$

$$\text{California Bearing Ratio } CBR_{5\text{mm}} = \frac{\text{Load corresponding to 5mm penetration (P}_5\text{)}}{\text{Standard load corresponding to 5mm penetration (P}_s\text{)}} \times 100$$

Since the soil is within the specified range it is suitable for pavement construction

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REFERENCES

1. S K Khanna and C E G Justo, "Highway Engineering", Nem Chand Bros, Roorkee.

2. L R Kadiyali, “Highway Engineering”, Khanna Publishers, New Delhi.
3. “Roads, Railways, Bridges, Tunnels and Harbour Dock Engineering by B L Gupta, Amit Gupta.
4. S K Khanna, C E G Justo and A Veeraragavan, “Highway Materials Testing Laboratory Manual”, Nem Chand Bros, Roorkee.
5. Relevant IRC and IS codes

Lab Manual 3

Building Materials Testing Laboratory

(BCVL404)

CO's And PO's Mapping Chart

S.N	Description	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO 8	PO9	PO10	PO 11	PO 12	PSO1	PSO2
1	Analyze the physical characteristics, and behavior of common building materials	3	2				2	2		2				2	
2	Reproduce the basic knowledge of mathematics and engineering in finding the strength in tension, compression, shear, and torsion for steel	3	3				2	2		2				2	1
3	Evaluate the impact of engineering solutions on society and demonstrate awareness of contemporary issues related to structural failures caused by unsuitable materials, while recognizing the importance of ethical conduct, professional integrity, and accuracy in materials testing and reporting	2	2				3	2	2	2			2	1	2

Degree of compliance Low:1

Medium:2

High:3

Evaluation:

Non Integrated Lab		
CIE		
Particulars	Marks	Total
Performance	15	30
Journal	10	
Viva Voce	05	
Lab IA		
Particulars	Marks	Total
IA	100	20 (Reduced)
Total (CIE +Lab IA)		50

Mapping of Experiments with CO, PO and PSO

S.No.	Experiment Details	CO	PO	PSO
1	Tests on Bricks, Tiles, Cement Concrete blocks (Weight & Dimensionality, Water Absorption, Strength)	1	1,2,6,7,9	-
2	Tests on Fine aggregates - Sieve Analysis, Moisture content, Specific gravity, Bulk density, Bulking and Silt Content	1	1,2,6,7,9	-
3	Tests on Coarse aggregates- Sieve Analysis, Water absorption, Moisture content, specific gravity and Bulk density	1	1,2,6,7,9	-
4	Compression test on mild steel, cast iron and wood	2	1,2,6,7,9	1,2
5	Tension test on mild steel and HYSD bars	2	1,2,6,7,9	1,2
6	Torsion test on mild steel circular sections.	2	1,2,6,7,9	1,2
7	Bending Test on Wood under two-point loading.	2,3	1,2,6,7,8,9	1,2
8	Shear Test on Mild steel – single and double shear	2	1,2,6,7,9	1,2
9	Impact test on Mild Steel (Charpy & Izod)	2	1,2,6,7,9	1,2
10	Hardness tests on ferrous and non-ferrous metals- Brinell's, Rockwell and Vicker's.	2,3	1,2,6,7,8,9	1,2
11	Demonstration of Strain gauges and Strain indicators	2	1,2,6,7,9	1,2

EXPERIMENT WISE LESSON PLAN

Experiment No.1	
Name	Tests on Bricks, Tiles, Cement Concrete blocks (Weight & Dimensionality, Water Absorption, Strength)
Objectives	<ul style="list-style-type: none"> To identify the strength and quality of bricks, tiles and cement blocks
Experiment No.2	
Name	Tests on Fine aggregates - Sieve Analysis, Moisture content, Specific gravity, Bulk density, Bulking and Silt Content
Objectives	<ul style="list-style-type: none"> To determine fineness modulus by sieve analysis, Moisture content, Specific gravity, Bulk density, Bulking and Silt Content for fine aggregate
Experiment No.3	
Name	Tests on Coarse aggregates- Sieve Analysis, Water absorption, Moisture content, specific gravity and Bulk density
Objectives	<ul style="list-style-type: none"> To determine fineness modulus by sieve analysis, Water absorption, Moisture content, specific gravity and Bulk density for Coarse aggregate
Experiment No.4	
Name	Compression test on mild steel, Wood, Cast iron
Objectives	<ul style="list-style-type: none"> To determine maximum compressive strength on Mild steel, Wood and Cast iron
Experiment No.5	
Name	Tension test on Mild steel and HYSD bars
Objectives	<ul style="list-style-type: none"> To determine maximum tensile strength and maximum elongation of Mild steel and HYSD Bars.
Experiment No.6	
Name	Torsion test on mild steel circular sections
Objectives	<ul style="list-style-type: none"> To determine maximum Torque, and maximum angle of twist of mild steel circular sections.
Experiment No.7	
Name	Bending Test on Wood under two-point loading.
Objectives	<ul style="list-style-type: none"> To determine maximum flexural strength of wood subjected to two-point loading
Experiment No.8	
Name	Shear Test on Mild steel – single and double shear
Objectives	<ul style="list-style-type: none"> To determine the maximum shear strength of mild steel in single and double shear.
Experiment No.9	
Name	Impact test on Mild Steel (Izod & Charpy)
Objectives	<ul style="list-style-type: none"> To determine the impact value of the mild steel specimen by izod and charpy test.
Experiment No.10	
Name	Hardness tests on ferrous and non-ferrous metals- Brinell's, Rockwell and Vicker's.
Objectives	<ul style="list-style-type: none"> To determine the hardness number of ferrous and nonferrous metals.
Experiment No.11	
Name	<ul style="list-style-type: none"> Demonstration of Strain gauges and Strain indicators
Objectives	<ul style="list-style-type: none"> To study the behaviour of strain gauges and strain indicators on metals

Index

SL. No.	Content	Page No.
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LAB SAFETY & USAGE INSTRUCTIONS

1. Wearing of Apron and Safety Shoes is Mandatory

No student will be permitted to perform experiments without proper lab apron and safety shoes.

2. Operate Machines Only with Permission

Use CTM, UTM, torsion, impact, and hardness testing machines only under faculty supervision.

3. Ensure Proper Specimen Fixing

Align and secure specimens correctly before loading; stand clear during testing to avoid injury from sudden failure.

4. Maintain Cleanliness & Care

Keep the work area clean, handle materials carefully, and switch off equipment after use.

5. Report Hazards Immediately

Inform the instructor about any damage, malfunction, injury, or unsafe condition without delay.

TESTS ON BRICKS, TILES, CEMENT CONCRETE BLOCKS (WEIGHT & DIMENSIONALITY, WATER ABSORPTION, STRENGTH)**WEIGHT AND DIMENSIONALITY TEST ON BRICK****AIM**

To test the weight and dimensionality of the brick in laboratory.

THEORY

Bricks are the most commonly used construction material. In this test randomly collected 20 bricks are stacked along lengthwise, width wise and height wise and then those are measured to know the variation of sizes as per standard. Bricks are closely viewed to check if its edges are sharp and straight and uniform in shape. A good quality brick should have bright and uniform colour throughout. For good quality bricks the result should be within the following permissible limits. Length: 3680 mm to 3920 mm Width: 1740 mm to 1860 mm Height: 1740 mm to 1860 mm

APPARATUS

Measuring tape (steel tape), Weighing Balance

PROCEDURE

- Collect randomly 20 number of bricks of standard size.
- Stack these bricks along lengthwise, measure the length of 20 bricks and note down its length.
- Stack along the width wise, measure the width of 20 bricks and note down the measurement.
- Stack along the height wise, measure the height of 20 bricks and note down the measurement
- Check the weight of each brick at room temperature.

OBSERVATIONS AND CALCULATION

The measured length (M_l) of 20 bricks = -----mm

The measured width (M_w) of 20 bricks =----- mm

The measured height (M_h) of 20 bricks =----- mm

Average Weight of 20 Bricks = ----- kg

RESULT

1. The measured length (M_l) is found to be ---- mm.
2. The measured width (M_w) is found to be -----mm.
3. The measured height (M_h) found to be----- mm.
4. The weight of the brick= ----- kg

CONCLUSION

The number of standard size brick is **less or more** due to randomly collected different size of bricks.

SIGNIFICANCE

The size of a brick not only influences the aesthetics of a building but also its structural integrity and construction efficiency. Larger bricks reduce the number of joints and can speed up the building process but may be heavier and harder to handle.

APPLICATION

The results of this test will be useful for determining the suitability of bricks for various construction applications.

WATER ABSORPTION TEST ON BRICKS

AIM

To determine the percentage of water absorption of given sample of bricks.

APPARATUS

Weighing balance, Immersion tank and oven.

THEORY

The percentage of water absorption is expressed in terms of its dry wt. The brick is immersed in water for 24 hrs. The water absorption of well burnt brick should not exceed 20% of its dry wt. A brick with higher water absorption when used in masonry work causes shrinkage of mortar and plaster resulting in cracks.

PROCEDURE

- 1) Five brick samples are selected in random way.
- 2) Dry the specimens in ventilated oven at 105°C to 115°C till it attains substantially constant weight.
- 3) Cool the specimen to room temperature and obtain its weight W_1 .
- 4) Immerse the specimen completely in water at a temperature of $27 \pm 2^\circ\text{C}$ for 24hrs.
- 5) Remove the specimen from water and wipe its surface, with clean cloth and get its Wet weight W_2 .

FORMULA

Percentage of water absorption = $\{(W_2 - W_1)/W_1\} * 100$

TABULATION

Sl. No.	IDENTIFICATION	DRY Wt. W1 gms	WET Wt. W2 gms	% of water Absorption	Avg % of water Absorption
1	A				
2	B				
3	C				

RESULT AND CONCLUSION

Average percentage water absorption = _____%

RELEVANT I.S. CODES AND SPECIFICATIONS/ACCEPTABLE LIMITS

I.S: 3495 (part II)-1992: Methods of test of burnt clay Building bricks.

The water absorption of first class well burnt brick should not exceed **20%** of its dry wt.

SIGNIFICANCE

Water absorption is an important property in masonry. This property can affect the quality of the brick itself and the bond strength between the brick and mortar in masonry structures and can result in reducing its strength properties.

APPLICATION

The results of this test will be useful for determining the suitability of bricks for various construction applications.

COMPRESSION TEST ON BRICKS

AIM

To determine the average compressive strength and to classify the given sample of bricks as per Indian standard.

APPARATUS

Compression testing machine, scale, jute bag, cement and sand.

THEORY

Bricks are subjected to compressive stresses. Crushing strength of common hand moulded well burnt brick varies according to the nature of preparation of clay. Pressed and machine moulded bricks made of thoroughly mixed and proportionate ingredients are much stronger than the common hand moulded bricks made up of ordinary clay.

PROCEDURE

1. Take five bricks remove unevenness observed on the faces to provide two smooth and perfect faces by grinding.
2. Immerse the bricks in the water at room temperature for 24 hours. Remove the specimen from the water and drain out any extra moisture at room temperature.
3. Fill the frog(where provided) and all voids in the bed face flush with cement mortar(1 part of cement and 1 part of coarse sand of 3mm and down size).
4. Store under damp jute bag for 24 hrs followed by immersion in clean water for 3 days. Remove and wipe out any traces of moisture.
5. Place the specimen with a flat face horizontal and mortar filled face facing upward between two 3-ply plywood sheets each of 3 mm thickness and carefully centre between the plates of the compression testing machine.
6. Apply the load axially at uniform rate of 14N/mm^2 per minute till failure occurs and note the maximum load at failure.
7. The load at failure shall be the maximum load at which the specimen fails to produce any further increase in the indicator reading on the testing machine.

FORMULA

$$\text{Crushing strength} = \frac{\text{maximum load at failure}}{\text{original cross sectional area}}$$

TABULATION

SL.No	Identification	Area of bed surface(mm)	Maximum Crushing load(kN)	Crushing strength(N/mm ²)	Mean compressive strength(N/mm ²)

RELEVANT I.S. CODE AND SPECIFICATION / ACCEPETABLE LIMITS**1. Specifications of Common Clay Building Bricks**

Dimensions: The standard size of clay bricks shall be as follows

Length (mm)	Width (mm)	Height (mm)
190	90	90
190	90	40

- The minimum **crushing / compressive** strengths of burnt **bricks** : (i) Common building **bricks**—35 kg/sq. cm, (ii) Second class **bricks**—70 kg/sq. cm, (iii) First class **bricks**— 105 kg/sq. cm
- According to BIS: 1077-1957, the minimum compressive strength of bricks is 3.50 N/mm². The bricks with crushing strength of 7 to 14 N/mm² are said to be grade A and those having above 14 N/mm² are grade AA.
- I.S. 3495(PART 1)-1992; Methods of test of burnt clay building bricks

RESULTS

- The mean compressive strength of brick is _____ N/mm²

SIGNIFICANCE

Bricks are generally used for construction of load bearing masonry walls, columns and footings. These load bearing masonry structures experiences mostly the compressive loads. Thus, it is important to know the compressive strength of bricks to check for its suitability for construction.

APPLICATION OF THE TEST

Compressive strength test on bricks are carried out to determine the load carrying capacity of bricks under compression with the help of compression testing machine. Bricks are generally used for construction of load bearing masonry walls, columns and footings.

COMPRESSION TEST ON CONCRETE BLOCKS

AIM

To determine the average compressive strength and to classify the given sample of blocks as per Indian standard.

APPARATUS

Compression testing machine, scale

THEORY

The age of each block shall be 28 days. The compressive strength testing machine consist of two steel bearing blocks, one is in rigid position on which the masonry unit is placed and another one is movable which transmit the load to the masonry unit when applied.

PROCEDURE

1. Eight blocks are taken to determine the average compressive strength of concrete masonry block. The blocks should be tested with in 3days after collected in lab. The age of each block shall be 28 days.
2. The compressive strength testing machine consist of two steel bearing blocks, one is in rigid position on which the masonry unit is placed and another one is movable which transmit the load to the masonry unit when applied.
3. If the bearing area of masonry unit is more than the bearing area of steel blocks, then separate steel plates are used. The plates are arranged on steel blocks in such a way that the centroid of masonry unit coincide with the center of thrust of blocks.
4. Bearing area of concrete masonry units are capped with the Sulphur and granular materials coating or gypsum plaster capping. After placing the unit in testing machine, one-half of the expected maximum load is applied at a constant rate, and the remaining load is applied in not less than 2 minutes.
5. Note down the load at which masonry unit fails and the maximum load divided by gross sectional area of unit will give the compressive strength of block. Similarly, test the remaining 7 blocks and the average of 8 blocks strength is the final compressive strength of concrete masonry unit.

FORMULA

$$\text{Crushing strength} = \frac{\text{Maximum load}}{\text{gross sectional area}}$$

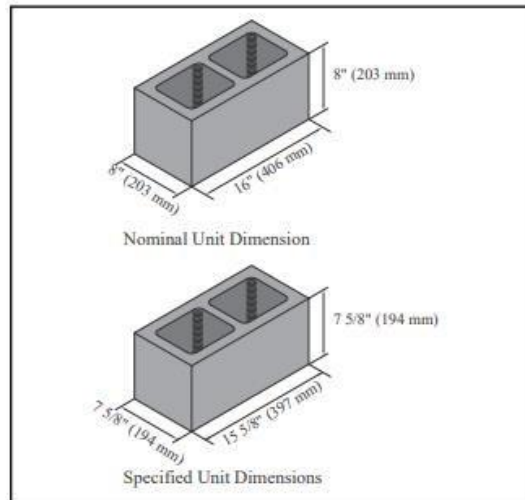
TABULATION

SL.No	Identification	Area of bed surface(mm)	Maximum Crushing load(kN)	Crushing strength(N/mm ²)	Mean compressive strength(N/mm ²)

RELEVANT I.S. CODE AND SPECIFICATION / ACCEPETABLE LIMITS

1. Specifications of Blocks

Dimensions: The standard size of nominal block 8 x 8 x 16 in. (203 x 203 x 406 mm)



2. Minimum compressive strength of Individual blocks according to grades

Type of unit	Grade	Min average compressive strength of individual units (N/mm ²)
Hollow type concrete masonry unit	A(3.5)	2.8
	A(4.5)	3.6
	A(5.5)	4.4
	A(7.0)	5.6

	A(8.5)	7.0
	A(10.0)	8.0
	A(12.5)	10.0
	A(15.0)	12.0
	B(3.5)	2.8
	B(5.0)	4.0
Solid type unit	C(5.0)	4.0
	C(4.0)	3.2

- IS: 2185 (part-I)1979, 1987, 1998 – **Specifications for concrete masonry. Units part-I Hollow and Solid Concrete Blocks**
- The minimum compressive strength of blocks **4 to 5** N/mm²

RESULTS

- The mean compressive strength of block is _____ N/mm²

SIGNIFICANCE

Solid Concrete Blocks are ideal for construction of Chimney & Fireplaces, yet they equally excel at Non-load Bearing Walls & Garden Walls. Hollow Concrete Blocks are widely used for Exterior & Interior Load-bearing Walls, Partition Walls, Panel Walls, Boundary Walls, etc

APPLICATION OF THE TEST

Concrete blocks are a prefabricated material mainly used to build walls. Like bricks, the blocks are stacked together and joined with a mortar, usually consisting of cement, sand, and water. The blocks are hollow inside to allow for steel bars and mortar filling.

TILE ABRASION TEST

AIM

To determine the resistance to wear of cement concrete flooring tiles and natural building stones by Tile Abrasion test Machine.

THINGS NEEDED

Abrasive powder, dial gauge of 0.01mm.

THEORY:

It consists of a rotating disc (4) rotating on a shaft connected to a reduction gear box (17) which is coupled to an electric motor (15). The grinding path (5) is fixed firmly over the rotating disc. The grinding path along with the rotating disc revolves at 30 ± 1 revolutions per minute. The rotating disc and the grinding path are enclosed by a circular tray (3). A specimen holding attachment is firmly fixed with the main frame (2). The specimen is kept in position by a clamp and is loaded by a self-aligning loading platen (9) which is attached to a lever (8) having a ratio 1:4. A weight (12) of 7.5 kg on the hanger of lever gives a resultant load of 30kgf on the specimen through the loading platen to the maximum variation of load being one percent. A preset automatic preset revolution counter (10) is fixed on the machine and a stud (6) is fixed on the rotating disc to operate it. The automatic counter is set for 22 revolution, on the completion of which machine automatically stops. Knob (11) on the counter is for resetting the counter for next operation. A hopper (19) is provided for facilitate charging the grinding path with abrasive powder. A counter-balance weight (7) is provided for initial balancing of the lever arm (8). The whole assembly is firmly fixed on a sturdy frame (2). Four levelling screws (1) are provided for initially levelling the machine.

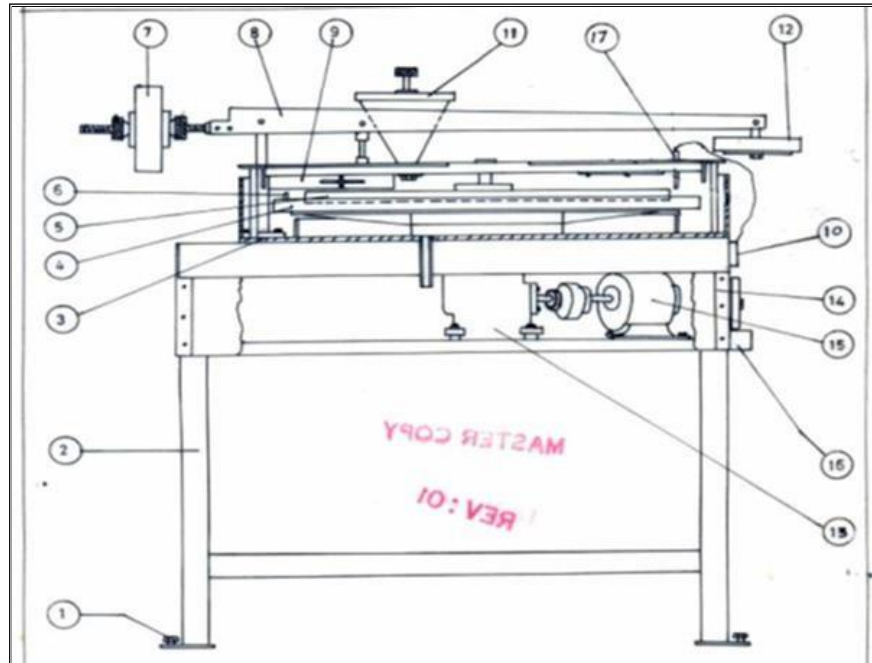
PROCEDURE

1. Adjust the counter balance weight so that the lever is in levelled position. Put the specimen in the specimen holder and clamp it by the moveable clamp. Keep the loading platen on the specimen and level the lever by operating the capstan of the loading platen with the help of tommy pin. Keep the weight on the hanger of the lever. Connect the junction box (16) to 415 volts, 50 Hz. Ac supply. Ensure that the position of cam is exactly opposite to that of

revolution counter and reset the counter by pressing the knob The machine is ready for operation.

2. Take the test specimen square in shape, and of size of 70.6 x 70.6mm (area of each face being 50cm²). The maximum variation in the specimen size can be up to ± 1.4 mm. The surface to be tested shall be ground smooth and filling if any removed.
3. Before and after the test of each specimen place the specimen on the base of the Tile abrasion machine. Thickness Measuring Device with the wearing surface upward. Fix the dial gauge on the thickness measuring device firmly such that the plunger rests on the surface of the specimen and take the reading of the dial gauge. The difference between readings before and after the test gives the amount of wear of the specimen.
4. Dry the specimen at 110°C for 24 hours and then weigh to the nearest 0.1g. Place the specimen after initial drying and weighing in the thickness measuring holder as described above and take the reading of the dial gauge.
5. Screw 20g of abrasive powder evenly in the grinding path of the Abrasion Testing Machine. The abrasive should have an aluminium oxide content of not less than 95 percent by weight.
6. Fix the specimen in the holding device with the surface to be ground facing the grinding path and apply the load of 30kg. A pointer is fitted on the reset knob which is to be put on the index mark before the machine is operated. After the completion of 22 revolutions, a micro-switch automatically stops the machine, for resetting rotate the knob anticlockwise and bring the pointer to the index mark. Never mishandle the reset knob or try to rotate in clockwise direction otherwise the setting will be disturbed. Put the grinding disc in motion continuously feeding back the abrasive powder on the grinding path so that it remains uniformly distributed in a track corresponding to the width of the test piece. After every 22 revolutions when the disc stops, turn the tile under test about the vertical axis through an angle of 90° in the clockwise direction. Apply 20g of fresh abrasive powder evenly on the grinding path. Repeat the grinding. It should be repeated 9 times thereby giving total number of 220 revolutions.

7. After 110 revolutions turn the specimen through an angle of 90° about the vertical axis and then continue the test under the same conditions till altogether 220 revolutions are completed. Keep the disc, the specimen and the abrasive powder dry throughout the test duration. After the abrasion is over, re-weigh the specimen to the nearest 0.1g. Place it in the thickness measuring device and take the reading of the dial gauge with the same position and setting of the dial gauge as for the measurement before abrasion.



CALCULATION

Determine the wear from the difference in readings obtained by the measuring gauge before and after the abrasion of the specimen. Check the value with the average loss of thickness of the specimen by the following formula:

$$t = 10 \frac{(W_1 - W_2) V_1}{W_1 \times A}$$

Were

t = Average loss of thickness, in mm

W₁ = Initial weight of specimen, in grams

W₂ = Final weight of the abraded specimen, in grams

V₁ = Initial volume of specimen, in cm³

A = Surface area of specimen, in square centimetres

RESULTS AND DISCUSSION

Abrasion Testing Machine for Glazed Tiles-BIS 13630-11, EN ISO 10545-7.

Glazed porcelain tiles would receive a value of 7 but unglazed porcelain tiles would receive a value of 8. Because the glaze on that tile is a little more prone to scratches than an unglazed porcelain tile.

The average loss of thickness of the specimen subjected to wear is _____

SIGNIFICANCE

This test method is designed to measure the resistance of tile surfaces to visible surface abrasion.

This procedure may be used to compare tiles of like colour and finish.

APPLICATION

Abrasion testing determines the relative quality, toughness, and durability of mineral aggregates subjected to impact and abrasion. Values derived from both the Micro Deval and the Los Angeles

Abrasion tests offer information about the performance of aggregate in use

TEST ON FINE AGGREGATE

PARTICLE SIZE DISTRIBUTION AND FINENESS MODULUS OF FINE AGGREGATE

AIM

To determine the particle size distribution and fineness modulus of given sample of fine aggregate.

APPARATUS

Weighing Balance, A set of sieves arranged in a following order of sizes 4.75mm, 2.36mm, 1.18mm, 600micron, 300micron, 150 micron and pan.

THEORY

The Particle size of distribution is an important physical property of the aggregate which affects the physical and mechanical properties of concrete. Aggregates are classified into coarse aggregate and fine aggregate based on particle size. The aggregates higher than 4.75mm are considered as coarse aggregate and those passing through 4.75mm sieve are considered as fine aggregate. The fine aggregate are classified as Grading zone I, II, III& IV as per Table 4 of 383-1970 on the basis of particle size distribution.

Sieve analysis is conducted to determine the particle size of an aggregate. Sieve analysis is a simple test consisting of sieving a measured quantity of material through successively smaller sieves. The weight retained each sieves is expressed as a percentage of the total sample.

Fineness modulus is an empirical factor indicating the relative coarseness or fineness of the aggregate sample and is obtained by adding the cumulative percentage of aggregate retained on each sieves and dividing by 100.

PROCEDURE

- 1) Take 1kg of air dried fine aggregate sample.
- 2) Choose the appropriate sieve set and arrange the sieves in order of sizes 4.75mm, 2.36mm, 1.18mm, 600micron, 300micron, 150micron and pan at the bottom
- 3) The weighed sample is placed on the largest appropriate sieve set & sieving is carried out with varied motion backward and forward, left and right, circular clockwise and anti clock wise. The period of sieving should not be less than 2 mins. If sieving is done on a machine not less than 10 mins sieving will be required for each test.
- 4) The fraction of the sample which passes the sieve is placed on next successive sieve and sieving is done in the same manner.

- 5) On completion of sieving the material retained on each sieve is weighed and recorded.
- 6) Calculate the percentage retained, percentage passing and cumulative percentage of weight retained.
- 7) Plot the graph of percentage passing versus IS sieve size on semi log graph.

OBSERVATION

1) Weight of fine aggregate= gms

TABULATION

SL.No	IS sieve No	Weight retained (gms)	% of Wt. retained	Cumulative % of Wt. retained	Cumulative Passing %
1)	4.75mm				
2)	2.36mm				
3)	1.18mm				
4)	600micron				
5)	300micron				
6)	150micron				
7)	PAN				
			TOTAL ΣC=		

DIAGRAM

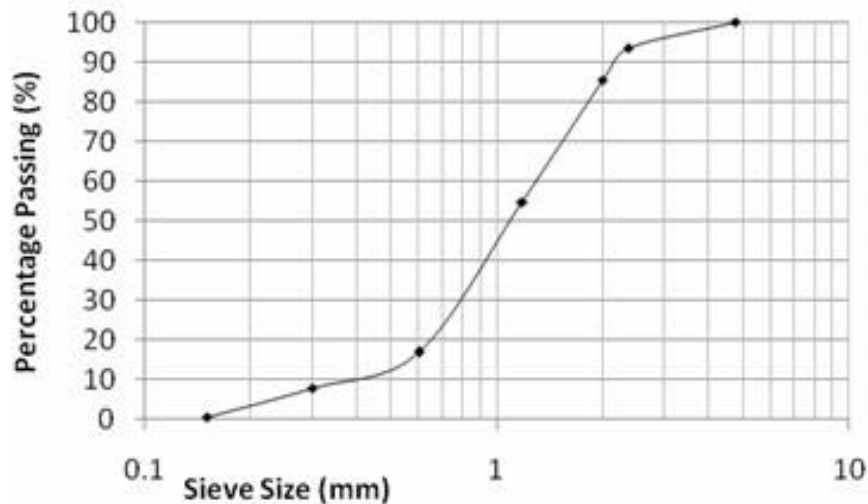


Fig: IS Sieve for Fine aggregate

FORMULA

$$\text{Fineness Modulus} = \frac{\sum \text{Cumulative \% of wt. retained}}{100}$$

NATURE OF GRAPH



RESULT AND DISCUSSION

1. The particle size distribution of the aggregate sample is in accordance to IS 383-1970 for the given maximum size of the aggregate and testing is done according to I.S.2386 (part I)-1963
2. For fine aggregate obtained from natural source, fineness modulus lies between **2.2 to 3.2**
3. Fineness modulus of fine aggregate is _____ and lies within the normal range.

SIGNIFICANCE

The sieve analysis determines the gradation (the distribution of aggregate particles, by size, within a given sample) in order to determine compliance with design, production control requirements, and verification specifications. Grading limits and maximum aggregate size are specified because these properties affect the amount of aggregate used as well as cement and water requirements, workability, pumpability, and durability of concrete.

APPLICATION OF THE TEST

This test is useful in concrete mix design. Sieve analysis test results help in combining of aggregate in required proportion so as to obtain the desired aggregate grading which is an important aspect of concrete mix design.

MOISTURE CONTENT TEST FOR FINE AGGREGATE

AIM

To determine the moisture content of a Fine aggregate by drying method.

APPARATUS

Weighing balance, oven etc.

THEORY

Determination of moisture content in aggregate is of vital importance in the control of the quantity of concrete particularly with respect to workability and strength. The aggregate will absorb a certain quantity of water depending on its porosity. The water content can be expressed in terms of the weight of the aggregate when absolutely dry, surface dry or when wet. Water content means the water held on the surface of the aggregate or the water held in the interior portion of aggregate particles.

The application of drying method is practically simple. Drying is carried out in an oven and the loss in weight before and after drying will give the moisture content of the aggregate. If drying is done completely at high temperature for a long time, the loss in weight will include not only the surface water but also some absorbed water. A practically quick result can be obtained by heating the aggregate quickly in an open pan.

PROCEDURE

1. Weigh the given wet fine aggregate sample of aggregate with tray and take it as W_1
2. All moisture is removed from the aggregate by heating along with tray in an oven at 105 C to attain constant weight, all pores are empty. Weigh the oven dried aggregate with tray and take it as W_2
3. Take the empty weight of the tray W_3 .
4. Calculate the loss in moisture content of the aggregate in percentage.

FORMULA

Moisture content of the fine aggregate in percentage = $(W_1 - W_2 / W_2 - W_3) * 100$

OBSERVATION

SL. No	OBSERVATION	SAMPLE 1
1	Weight of given sample and tray = W_1	
2	Weight of oven dried sample and tray= W_2	
3	Weight of the empty tray= W_3	
4	Weight of the water content = (W_1-W_2)	
5	Weight of the dry sample= (W_2-W_3)	
6	Moisture content in percentage = $(W_1-W_2/W_2-W_3)*100$	

RESULT

Moisture content of fine aggregate sample is _____

I.S.2386 (part III)-1963; Methods of test for aggregate for concrete

The moisture content of fine aggregate should be **nearest to 0.1%**

SIGNIFICANCE

The varying moisture contained on aggregates is one of the major causes of inconsistency in batching concrete from one batch to another. Moisture content can have dramatic effect on the concrete compressive strength and durability because it has a great influence on the water/cement ratio.

APPLICATION

The moisture content in aggregate is used to determine the binder content for hot Mix Asphalt HMA during production of the mixture in a plant. The procedure requires that a known amount of aggregate be obtained, the aggregate heated to remove the moisture, and the percentage of moisture determined

SPECIFIC GRAVITY OF FINE AGGREGATE

AIM

To determine specific gravity of fine aggregate.

APPARATUS

Weighing Balance, Pycnometer with brass cap, Metal tray, Spatula.

THEORY

Specific gravity of an aggregate is the measure of its strength or quality of material. Aggregate having low specific gravity is generally weak in strength. Specific gravity is defined as the ratio of mass of given volume of aggregate sample to the mass of an equal volume of distilled water at the same temperature.

PROCEDURE

- 1) First take the empty weight of pycnometer. Determine the weight as W₁ gms.
- 2) Take 500gms of the fine aggregate sample.
- 3) Place 1/3rd of surface dry aggregate sample into the pycnometer and take the weight as W₂ gms
- 4) Fill the Pycnometer along with water and surface dry aggregate sample and take the weight as W₃ gms
- 5) Fill the Pycnometer with water up to the mark and take the weight as W₄ gms.
- 6) Calculate the specific gravity of sample.

FORMULA

$$\text{Specific gravity} = \frac{\text{Dry weight of fine aggregate}}{\text{Weight of equal volume of water}}$$

$$G = \frac{(W_2 - W_1)}{(W_2 - W_1) - (W_3 - W_4)}$$

OBSERVATION AND CALCULATION

OBSERVATION	SAMPLE 1	SAMPLE 2
Mass of empty pycnometer/container = W ₁ gms =		
Mass of pycnometer + 1/3 rd surface dry aggregate sample = W ₂ gms =		
Mass of pycnometer + 1/3 rd surface dry aggregate sample + water = W ₃ gms =		
Mass of pycnometer + water = W ₄ gms =		
Specific gravity = $\frac{W_2 - W_1}{(W_2 - W_1) - (W_3 - W_4)}$		
AVG =		

DIAGRAM**RESULT**

The specific gravity of aggregate sample is _____

RELEVANT I.S. CODES AND SPECIFICATIONS/ACCEPTABLE LIMITS

I.S:2386 (part III)-1963; Methods of test for aggregate for concrete

I.S:383-1970; Specification for coarse and fine aggregates obtained from natural sources for concrete.

The specific gravity of fine aggregates obtained from river beds normally ranges from about **2.5 to 3.0** with an average value of about **2.68**.

SIGNIFICANCE OF THE TEST

To determine the ratio of the weight of a given volume of aggregate to the weight of an equal volume of water. To know the strength or quality of material. Some deleterious particles are lighter than the good aggregates. Tracking specific gravity indicate a change of material or possible contamination.

APPLICATION OF THE TEST

Specific gravity of aggregates is required for calculation in concrete mix design. Knowing the specific gravity of each constituent and its mass, solid volume is calculated from which yield of the concrete is calculated.

BULK DENSITY OF FINE AGGREGATE

AIM

To determine bulk density of fine aggregate.

APPARATUS

- a) Measuring cylinder of appropriate capacity.
- b) Balance having sensitivity equal to 0.5% of the weight of test sample.
- c) Tamping rod

THEORY

The bulk density or unit weight is the weight of material in a given volume. The bulk density depends upon the particle size distribution, the shape of the aggregate particles and the manner in which the aggregates are filled into the measuring container. The bulk density of aggregate is measured by filling a container of known volume in a standard manner and weighing it. Based on the manner in which aggregates are filled into the measuring cylinder, bulk density is determined for the following conditions;

- 1) Rodded or compacted condition
- 2) Loose condition.

The aggregate sample giving maximum bulk density will have minimum voids and shall result in an economical concrete mix. The bulk density is expressed in Kg/litre. Knowing the specific gravity of aggregate sample the percentage of voids is calculated. The nominal capacity of the measuring cylinder is based on the maximum nominal size of the aggregate and I.S: 2386 stipulates as follows

Max nominal size of aggregate	Capacity of measuring cylinder
4.75mm	3 litre
4.75mm to 40mm	15 litre
Over 40mm	30 litre

PROCEDURE

The measuring cylinder is to be calibrated by determining its volume at 27°C. This is done by filling the measuring cylinder with water at 27°C such that no meniscus is present above the rim of

the container. The mass of the water in the container will give the volume of the measuring cylinder in liters.

RODDED OR COMPACTED BULK DENSITY

- 1) Fill the measuring cylinder with the aggregate sample in 3 layers of equal height, each layer being tamped with 25 strokes of the tamping rod.
- 2) Strike out the surplus aggregate using the tamping rod and weigh the container.
- 3) The bulk density in Rodded or compacted condition of aggregate is calculated in Kg/litre.

LOOSE BULK DENSITY

- 4) Fill the measuring cylinder with aggregate up to overflowing by means of trowel or scoop, the aggregate being discharged from a height not exceeding 50mm above the top, care should be taken to prevent segregation of the particle sizes of which the sample is composed.
- 5) The surface of the aggregate shall be then leveled with straight edge, and the net weight of aggregate in the measuring cylinder shall be determined and the bulk density in loose condition of aggregate is calculated in Kg/litre.

FORMULA

$$1) \text{ Bulk density} = \frac{\text{Mass of aggregate sample in measuring cylinder}}{\text{Volume of the measuring cylinder}}$$

$$2) \text{ Volume of cylinder} = \frac{\pi \times d^2 \times H}{4}$$

OBSERVATION AND CALCULATION

- 1) Diameter of cylinder $d =$ _____ m
- 2) Height of cylinder $H =$ _____ m
- 3) Volume of cylinder $= V =$ _____ m^3

FOR RODDED OR COMPACTED CONDITION

OBSERVATION	SAMPLE 1	SAMPLE 2
Mass of empty cylinder = W_1 Kg =		
Mass of cylinder + aggregate = W_2 Kg =		
Mass of aggregate sample in measuring cylinder = $(W_2 - W_1)$ Kg =		
Bulk density = $(W_2 - W_1) / V$ Kg/m ³		

FOR LOOSE CONDITION

OBSERVATION	SAMPLE 1	SAMPLE 2
Mass of empty cylinder = W_1 Kg =		
Mass of cylinder + aggregate = W_2 Kg =		
Mass of aggregate sample in measuring cylinder = $(W_2 - W_1)$ Kg =		
Bulk density = $(W_2 - W_1) / V$ Kg/m ³		



RESULTS

- 1) The bulk density of fine aggregate sample tested under Rodded or compacted condition is _____ Kg/m³
- 2) The bulk density of fine aggregate sample tested under loose condition is _____ Kg/m³

RELEVANT I.S. CODES AND SPECIFICATIONS

I.S.2386 (part III)-1963; Methods of test for aggregate for concrete

I.S:383-1970; Specification for coarse and fine aggregates obtained from natural sources for concrete.

Since the bulk density and voids ratio of aggregate depends on the size and shape of the aggregate, there is no specified limits for it.

PERMISSIBLE LIMITS

1. For fine aggregate =1440-1600 kg/m³
2. Ratio of loose condition to compacted condition for fine aggregate=0.87-0.96

SIGNIFICANCE OF THE TEST

For the purpose of mixture proportioning, it is important to know the space occupied by the aggregate particles, including the pores within the particles. The bulk density measures the volume that the graded aggregate will occupy in concrete, including the solid aggregate particles and the voids between them.

APPLICATION OF THE TEST

Bulk density or unit weight is required in estimating the quantities of a concrete mix proportion when batching is done by volumetric basis.

BULKING OF FINE AGGREGATES

AIM

To determine the bulking of the given fine aggregate sample

APPARATUS

Suitable graduated measuring glass cylinder of at least 250 ml, and 1000ml capacity, Metal tray and stirring rod, weighing balance having sensitivity accuracy equal to 0.5%(0.1gm) of weight of the test sample, trowel, steel scale.

THEORY

The free moisture content in fine aggregate results in apparent increase in the aggregate volume. This is due to the fact that free moisture forms a film around each particle. This film of moisture exerts surface tension, which keeps the neighboring particles away from it. Therefore there is no contact between the particles resulting in an apparent bulking in the volume of the sand. Bulking increases with moisture content up to a certain limit beyond which an increase in moisture content results in reduction in volume and when the moisture content reaches saturation point, the fine aggregate shows no bulking.

For the moisture content of 5% to 8%, this increase in the volume may be as much as 20% to 40% depending upon the grading of sand. The finer the material the more will be increase in volume for given moisture content. This phenomenon is known as “Bulking of Sand”

When moisture content is increased by adding more water, the sand particles pack near each other and amount of bulking of sand is decreased. Thus the dry sand and the sand completely flooded with water have practically the same volume.

The percentage of bulking of sand can be determined by a simple test in which the volume of moist sand is obtained and compared with the volume of the same sand in saturated form.

While proportioning of concrete mixes by volume, if bulking of sand is not accounted, the resulting concrete will be deficit of sand.

PROCEDURE

1. Sufficient quantity of oven dried sand sample is placed in the suitable graduated container (in 1000ml) until it is about $2/3^{\text{rd}}$ full.

2. Level off the top of the sand and pushing a steel rule vertically down through the sand at the middle to the bottom, measure the height of the sand sample inside the container “V” with respect to the graduation.
3. The sand is transferred in a clean metal tray without any loss.
4. 2% of water by weight of sand is added and water is thoroughly mixed with sand by hand.
5. The above steps are repeated for higher percentage of water say 4%, 6%, 8%..... etc. and so on increasing the percentages of water until bulking is maximum and suddenly starts falling down, and afterwards ultimately bulking is zero. This is the completely saturated sand or completely flooded with water which is equal to the same volume of dry sand.
6. Draw a graph of percentage bulking of sand along ordinate (Y-axis) versus percentage of water added along abscissa (X-axis).

OBSERVATIONS

Weight of oven dried sand sample W =.....gms.

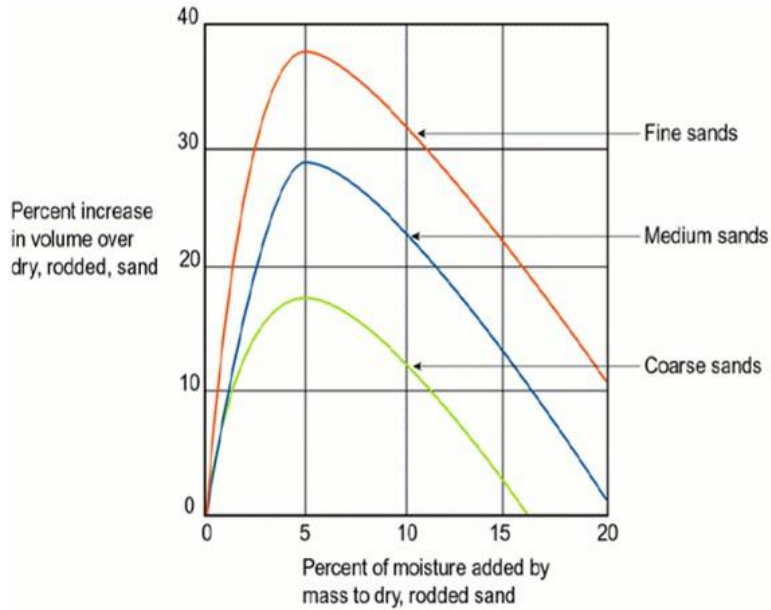
Initial volume of oven dried sand sample V=_____ml

TABULATION

SL. No	Percentages of water added	V ₁ in ml	V ₁ -V in ml	Percentage of Bulking of sand $\left[\frac{v_1 - v}{v} \times 100 \right]$
1	2			
2	4			
3	6			
4	8			
5	10			
6	12			
7	14			
8	16			
9	18			
10	20			
11	22			
12	24			

CALCULATIONS Percentage of Bulking of sand $\left[\frac{v_1 - v}{v} \times 100 \right]$

NATURE OF GRAPH



RELEVANT I.S. CODES AND SPECIFICATIONS / ACCEPTABLE LIMITS

1. Since the Percentage bulking of sand depends on the content of free moisture, there are no specified limits. Normally for sand obtained from river beds the percentage of bulking normally ranges from **3% to 30%**, depending upon the moisture content and particle size.
2. IS 2386 (part III)-1963; Methods of test for aggregate for concrete
3. IS 383–1970; Specifications for coarse and fine aggregate from natural source for concrete

APPLICATION OF THE TEST

The percentage bulking of sand is necessary in proportioning of concrete mixes by volume. It will be necessary to increase the volume of sand by the percentage of bulking in order that the amount of sand put in the concrete is in according to the mix proportion.

RESULTS AND DISCUSSIONS

1. The maximum bulking of the sand sample is _____% with _____% of water content.

CONCLUSION

1. The Percentage Bulking of the sand sample is within the normal range.

SILT CONTENT TEST ON FINE AGGREGATE

AIM

To find out the Silt content in sand

APPARATUS

A measuring cylinder (250ml), water, sand

THEORY

To check the quality of sand, silt content test should be conducted. Silt content stands for a fine material that is lower than 150 microns. It becomes unstable in the existence of water. Water at the bottom of a body of water does not freeze, and the silt provides some insulation, or warmth, for the animal. Silty soil is usually more fertile than other types of soil, meaning it is good for growing crops. Silt promotes water retention and air circulation

PROCEDURE

1. Firstly, a 50ml solution of 1% salt and water is prepared in the measuring cylinder. The addition of salt increases the settlement time of silt.
2. The sample of sand to be tested is then added to the cylinder until the level reaches 100ml.
3. 50ml of the solution of salt and water is again added to the measuring cylinder.
4. Close the open end of the measuring cylinder and shake it well.
5. After a period of 3-4 hours, you will notice a layer of silt settled over the sand.
6. Now note down the volume V1 of the silt layer settled over the sand.
7. Note down the volume V2 of the settled sand.
8. Repeat the procedure a couple more times to get the average.

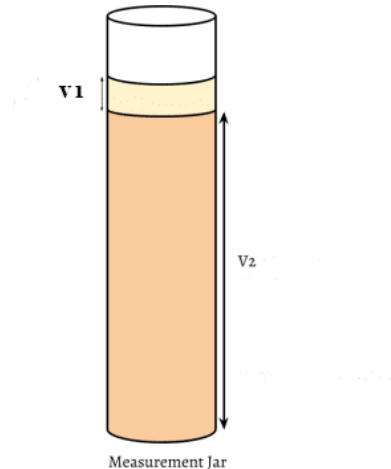
FORMULA

Percentage of Silt Content = $(V1/V2) \times 100$

V1 - Volume of silt layer

V2 - Volume of sand layer

DIAGRAM



OBSERVATION

S.No	Description	Sample 1	Sample 2
1	Volume of sample Sand (V2)		
2	Volume of silt layer (V1)		
3	Percentage of silt		
	Average		

RELEVANT I.S CODES AND SPECIFACATION

As per IS CODE **383-1970** The permissible value of silt content in Sand is **8%**

RESULT

Percentage of Silt content of given sample of sand = _____

SIGNIFICANE

The significance of knowing silt content in the sand is to ensure that the quality of sand is suitable for the work that it is going to perform.

APPLICATION

Silt content is a fine material that is unstable in the presence of water. Sand is an important construction material as it is used to increase the strength of plaster, mortar, and concrete. If there is more Silt content in the sand, the buildings won't be able to face any type of natural disaster. Silty soil is usually more fertile than other types of soil, meaning it is good for growing crops. Silt promotes water retention and air circulation. Too much clay can make soil too stiff for plants to thrive.

TEST ON COARSE AGGREGATE

PARTICLE SIZE DISTRIBUTION AND FINENESS MODULUS OF COARSE AGGREGATE

AIM

To determine the particle size distribution and fineness modulus of given sample of coarse aggregate.

APPARATUS

Balance, A set of sieves arranged in a following order of sizes 40mm, 37.5mm, 20mm, 16mm, 12.5mm, 10mm, 6.3mm, 4.75mm and pan.

THEORY

The Particle size distribution is an important physical property of the aggregate, which affects the mechanical properties of concrete. Aggregates are classified in to coarse aggregate and fine aggregate based on particle size. The aggregates higher than 4.75mm are considered as coarse aggregate and those passing through 4.75mm sieve are considered as fine aggregates.

Sieve analysis is conducted to determine the particle size distribution of an aggregate sample. Sieve analysis is a simple test consists of sieving a measured quantity of material through successively smaller sieves. The weight retained an each sieve is expressed as a percentage of the total sample.

Fineness modulus is an empirical factor indicating the relative coarseness or fineness of the aggregate sample & is obtained by adding the cumulative percentage of aggregate retained on each sieves & dividing by 100.

Minimum weight of the aggregate sample for sieving shall be as per the guidelines given in table 1V of IS: 2386 (part I)-1963 (appendix A). The set of sieve to be used for sieving is based on the maximum size of the aggregate present in the sample and type of aggregate (i.e. single sized/graded aggregate). The set of sieve shall be chosen as per table 2 of IS: 383-1970

PROCEDURE

- 1) Take 5kg of air dried coarse aggregate sample.

- 2) The sample of coarse aggregate before sieving should be brought to air dry condition by drying at room temperature.
- 3) The aggregate sample is weighed to an accuracy of 0.1 percent of its weight.
- 4) Choose the appropriate sieve set as per IS 383-1970 and arrange the sieves in order of sizes 40mm, 37.5mm, 20mm, 16mm, 12.5mm, 10mm, 6.3mm, 4.75mm and pan.
- 5) The weighed sample is placed on a largest appropriate sieve set & sieving is carried out with varied motion backward and forward, left and right, circular clockwise and anti clockwise. The period of sieving should not be less than 2 minutes. If sieving is done on a machine not less than 10 minutes sieving will be required for each test.
- 6) The fraction of the sample which passes the sieve is placed on the next successive sieve and sieving is done in the same manner.
- 7) On completion of sieving, the material retained on each sieve is weighed and recorded.
- 8) Calculate the percentage retained, percentage passing and cumulative percentage of weight retained.
- 9) Plot the graph of percentage passing versus IS sieve size on semi log graph.

OBSERVATION

Weight of coarse aggregate= _____ kg

TABULATION

SL.No	IS sieve No	Weight retained	% of Wt. retained	Cumulative % of Wt. retained	Cumulative Passing %
1)	40mm				
2)	37.5mm				
3)	20mm				
4)	16mm				
5)	12.5mm				
6)	10mm				
7)	6.3mm				
8)	4.75mm				
9)	PAN				
			TOTAL ΣC=		

DIAGRAM



Fig: IS Sieve for Coarse aggregate

FORMULA

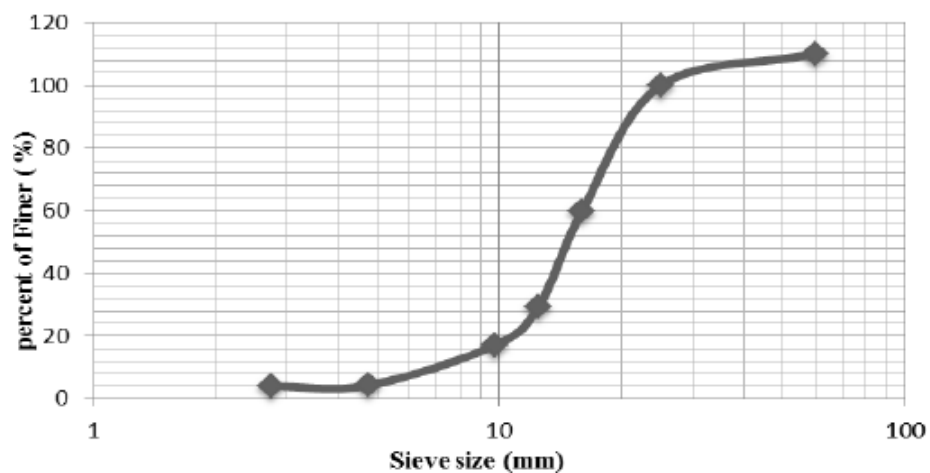
$$\text{Fineness Modulus} = \frac{\sum \text{Cumulative \% of wt. retained}}{100}$$

RESULT AND DISCUSSION

1. The particle size distribution of the aggregate sample is in accordance to IS 383-1970 for the given maximum size of the aggregate and testing is done according to I.S.2386 (part I)-1963
2. For coarse aggregate obtained from natural sources, fineness modulus lies between **5.5 - 8.0**
3. Fineness modulus of coarse aggregate is _____ and lies within the normal range.

NATURE OF GRAPH

GRAIN SIZE DISTRIBUTION (COARSE AGGREGATE)



SIGNIFICANCE

The sieve analysis determines the gradation (the distribution of aggregate particles, by size, within a given sample) in order to determine compliance with design, production control requirements, and verification specifications. Grading limits and maximum aggregate size are specified because these properties affect the amount of aggregate used as well as cement and water requirements, workability, pumpability, and durability of concrete.

APPLICATION OF THE TEST

This test is useful in concrete mix design. Sieve analysis test results help in combining of aggregate in required proportion so as to obtain the desired aggregate grading which is an important aspect of concrete mix design.

WATER ABSORPTION TEST FOR COARSE AGGREGATE

AIM

To determine the percentage of water absorption of given sample of coarse aggregate

APPARATUS

Weighing balance, Immersion tank and oven.

THEORY

Water absorption influences the behaviour of aggregate in concrete in several important aspects. A highly absorptive aggregate if used in dry condition, will reduce effective water cement ratio to an appreciable extent and may even make the concrete unworkable unless a suitable allowance is made. Hence determination of water absorption of aggregate is necessary to determine net water cement ratio.

PROCEDURE

- 1) Take 5 Kg of aggregate sample.
- 2) Wash thoroughly to remove dust or any other unwanted particles and immerse the sample for 24 hours in water.
- 3) Remove the aggregate from water and roll the sample on a large piece of cloth, so that surface moisture is removed and note down the mass of saturated surface dry sample as W_1
- 4) Keep the sample in an oven at a temperature of 100 to 110°C for $24 \pm \frac{1}{2}$ hours and note down the mass of the oven dry sample as W_2

FORMULA

Percentage of water absorption = $\{(W_1 - W_2) / W_2\} * 100$

TABULATION

SL. No	WET Wt. W1 gms	DRY Wt. W2 gms	% of water Absorption

RESULT

The % of water absorption is _____

RELEVANT I.S. CODES AND SPECIFICATIONS/ACCEPTABLE LIMITS

Permissible limit for water absorption of coarse aggregate should not exceed **3%** and testing of coarse aggregate is done as per I.S.2386 (part III)-1963.

SIGNIFICANCE

The water absorption of aggregate used for concrete has a significant effect on the required water content of the mix in order to produce concrete which is sufficiently workable in its fresh state and sufficiently strong in its hardened state.

APPLICATION

Water absorption gives an idea of strength of aggregate. Aggregates having more water absorption are more porous in nature and are generally considered unsuitable unless they are found to be acceptable based on strength, impact and hardness tests.

SPECIFIC GRAVITY OF COARSE AGGREGATE

AIM

To determine specific gravity of coarse aggregate.

APPARATUS

Spring Balance, Metallic wire Basket, Metal Tray, Tamping rod, Bucket.

THEORY

Specific gravity of an aggregate is the measure of its strength or quality of material. Aggregate having low specific gravity is generally weak in strength. Specific gravity is defined as the ratio of mass of given volume of aggregate sample to the mass of an equal volume of distilled water at the same temperature.

PROCEDURE

1. First take the empty weight of dry, clean metallic wire basket as W_1 kg.
2. Take 5 kg of aggregate sample, the basket along with the sample of aggregates is weighed as W_2 kg.
3. Immerse the basket in water, Remove the entrapped air by jolting the sample 25 times. The basket along with the aggregates is then weighed while suspended in water at a temperature of 22° to 32°C as W_3 kg
4. The aggregate sample is removed and mass of the empty basket immersed in water is taken as W_4 kg

OBSERVATION

- 1) Weight of empty dry, clean metallic wire basket = $W_1\text{Kg}$
- 2) Weight of basket + given sample of aggregate = $W_2\text{Kg}$
- 3) Weight of wire basket + sample in water = $W_3\text{Kg}$
- 4) Weight of empty basket immersed in water = $W_4\text{Kg}$

FORMULA

$$G = \frac{\text{Weight of coarse aggregate}}{\text{Weight of equal volume of water}}$$

$$G = \frac{(W_2 - W_1)}{(W_2 - W_1) - (W_3 - W_4)}$$

RESULT

Specific gravity of coarse aggregate is _____

DIAGRAM**RELEVANT I.S CODES AND SPECIFICATION /ACCEPTABLE LIMITS**

I.S: 2386(partIII)-1963: Methods of test for aggregates for concrete

I.S:383-1970; Specification for coarse and fine aggregates obtained from natural sources for concrete.

The specific gravity of aggregates used in construction ranges from about **2.5 to 3.0** with an average value of about **2.68**.

SIGNIFICANCE OF THE TEST

To determine the ratio of the weight of a given volume of aggregate to the weight of an equal volume of water. To know the strength or quality of material. Some deleterious particles are lighter than the good aggregates. Tracking specific gravity indicate a change of material or possible contamination.

APPLICATION OF THE TEST

Specific gravity of aggregates is required for calculation in concrete mixdesign. Knowing the specific gravity of each constituent and its mass, solid volume is calculated from which yield of the concrete is calculated.

MOISTURE CONTENT TEST FOR COARSE AGGREGATE

AIM

To determine the moisture content of a coarse aggregate by drying method.

APPARATUS

Weighing balance, oven etc.

THEORY

Determination of moisture content in aggregate is of vital importance in the control of the quantity of concrete particularly with respect to workability and strength. The aggregate will absorb a certain quantity of water depending on its porosity. The water content can be expressed in terms of the weight of the aggregate when absolutely dry, surface dry or when wet. Water content means the water held on the surface of the aggregate or the water held in the interior portion of aggregate particles.

The application of drying method is practically simple. Drying is carried out in an oven and the loss in weight before and after drying will give the moisture content of the aggregate. If drying is done completely at high temperature for a long time, the loss in weight will include not only the surface water but also some absorbed water. A practically quick result can be obtained by heating the aggregate quickly in an open pan.

PROCEDURE

1. Weigh the given wet coarse sample of aggregate with tray and take it as W_1
2. All moisture is removed from the aggregate by heating along with tray in an oven at 105 C to attain constant weight, all pores are empty. Weigh the oven dried aggregate with tray and take it as W_2
3. Take the empty weight of the tray W_3 .
4. Calculate the loss in moisture content of the aggregate in percentage.

FORMULA

Moisture content of the aggregate in percentage = $(W_1 - W_2 / W_2 - W_3) * 100$

OBSERVATION

SL. No	OBSERVATION	SAMPLE 1
1	Weight of given sample and tray = W_1	
2.	Weight of oven dried sample and tray= W_2	
3.	Weight of the empty tray= W_3	
4.	Weight of the water content = (W_1-W_2)	
5.	Weight of the dry sample= (W_2-W_3)	
6.	Moisture content in percentage = $(W_1-W_2/W_2-W_3)*100$	

RESULT

Moisture content of coarse aggregate sample is_____

The moisture content of coarse aggregate should be **nearest to 0.1%** as per I.S.2386 (part III)-1963; Methods of test for aggregate for concrete.

SIGNIFICANCE

The varying moisture contained on aggregates is one of the major causes of inconsistency in batching concrete from one batch to another. Moisture content can have dramatic effect on the concrete compressive strength and durability because it has a great influence on the water/cement ratio.

APPLICATION

The moisture content in aggregate is used to determine the binder content for hot Mix Asphalt HMA during production of the mixture in a plant. The procedure requires that a known amount of aggregate be obtained, the aggregate heated to remove the moisture, and the percentage of moisture determined

BULK DENSITY OF COARSE AGGREGATE**AIM**

To determine bulk density of coarse aggregate.

APPARATUS

- a) Measuring cylinder of appropriate capacity.
- b) Balance having sensitivity equal to 0.5% of the weight of test sample.
- c) Tamping rod

THEORY

The bulk density or unit weight is the weight of material in a given volume. The bulk density depends upon the particle size distribution, the shape of the aggregate particles and the manner in which the aggregates are filled into the measuring container. The bulk density of aggregate is measured by filling a container of known volume in a standard manner and weighing it. Based on the manner in which aggregates are filled into the measuring cylinder, bulk density is determined for the following conditions;

- 1) Rodded or compacted condition
- 2) Loose condition.

The aggregate sample giving maximum bulk density will have minimum voids and shall result in an economical concrete mix. The bulk density is expressed in Kg/liter. Knowing the specific gravity of aggregate sample the percentage of voids is calculated.

The nominal capacity of the measuring cylinder is based on the maximum nominal size of the aggregate and I.S.: 2386 stipulates as follows

Max nominal size of aggregate	Capacity of measuring cylinder
4.75mm	3 litre
4.75mm to 40mm	15 litre
Over 40mm	30 litre

PROCEDURE

The measuring cylinder is to be calibrated by determining its volume at 27°C. This is done by filling the measuring cylinder with water at 27°C such that no meniscus is present above the rim of the container. The mass of the water in the container will give the volume of the measuring cylinder in liters.

RODDED OR COMPACTED BULK DENSITY

- 1) Fill the measuring cylinder with the aggregate sample in 3 layers of equal height, each layer being tamped with 25 strokes of the tamping rod.
- 2) Strike out the surplus aggregate using the tamping rod and weigh the container.
- 3) The bulk density in rodded or compacted condition of aggregate is calculated in Kg/lit.

LOOSE BULK DENSITY

- 4) Fill the measuring cylinder with aggregate up to overflowing by means of trowel or scoop, the aggregate being discharged from a height not exceeding 50mm above the top, care should be taken to prevent segregation of the particle sizes of which the sample is composed.
- 5) The surface of the aggregate shall be then leveled with straight edge, and the net weight of aggregate in the measure shall be determined and the bulk density in loose condition of aggregate is calculated in Kg/lit.

FORMULA

- 1) Bulk density = $\frac{\text{Mass of aggregate sample in measuring cylinder}}{\text{Volume of measuring cylinder}}$
- 2) Volume of cylinder = $\frac{\pi \times d^2 \times H}{4}$

OBSERVATION AND CALCULATION

- 1) Diameter of cylinder d = _____ m
- 2) Height of cylinder H = _____ m
- 3) Volume of cylinder = V = _____ m³

FOR RODDED OR COMPACTED CONDITION

OBSERVATION	SAMPLE 1	SAMPLE 2
Mass of empty cylinder = W_1 Kg =		
Mass of cylinder + aggregate = W_2 Kg =		
Mass of aggregate sample in measuring cylinder = $(W_2 - W_1)$ Kg =		
Bulk density = $(W_2 - W_1) / V$ Kg/m ³		

FOR LOOSE CONDITION

OBSERVATION	SAMPLE 1	SAMPLE 2
Mass of empty cylinder = W_1 Kg =		
Mass of cylinder + aggregate = W_2 Kg =		
Mass of aggregate sample in measuring cylinder = $(W_2 - W_1)$ Kg =		
Bulk density = $(W_2 - W_1) / V$ Kg/m ³		



RESULTS

- 1) The bulk density of coarse aggregate sample tested under Rodded or compacted condition is _____ Kg/m³
- 2) The bulk density of coarse aggregate sample tested under loose condition is _____ Kg/m³.

RELEVANT I.S. CODES AND SPECIFICATIONS

I.S.2386 (part III)-1963; Methods of test for aggregate for concrete

I.S:383-1970; Specification for coarse and fine aggregates obtained from natural sources for concrete.

Since the bulk density and voids ratio of aggregate depends on the size and shape of the aggregate, there is no specified limits for it.

PERMISSIBLE LIMITS

1. For coarse aggregate =1600-1880 kg/m³
2. Ratio of loose condition to compacted condition for coarse aggregate=0.87-0.96

SIGNIFICANCE OF THE TEST

For the purpose of mixture proportioning, it is important to know the space occupied by the aggregate particles, including the pores within the particles. The bulk density measures the volume that the graded aggregate will occupy in concrete, including the solid aggregate particles and the voids between them.

APPLICATION OF THE TEST

Bulk density or unit weight is required in estimating the quantities of a concrete mix proportion when batching is done by volumetric basis.

COMPRESSION TEST ON WOOD

AIM

To determine the behaviour of the given specimen under static compression up to failure and to determine,

- 1) The crushing strength when loaded parallel to grain.
- 2) The crushing strength when loaded perpendicular to grains.

APPARATUS

Compression testing machine (CTM), vernier caliper, Test specimen (wood)

THEORY

When the material is subjected to compressive load, its length along the direction of the load decrease. If the length of the specimen is large compared to its lateral dimension, failure due to compressive load is termed as buckling. When the material is short, the failure due to compression is called crushing. As the applied load increases gradually, the compressive stress developed in the material increases. When the material reaches the ultimate load, cracks appear then the material is said to be failed.

Since brittle materials are unsuitable for tension test. These are usually used in compression test to evaluate the strength properties generally only compressive strength is determined. For brittle material with which the fracture occurs is the ultimate strength, which is the compressive strength. Some ductile materials will not fail in the compression test.

Timber specimen of cubical size is cut from logs for testing. The compressive strength of timber depends on whether the load is applied parallel to grain or perpendicular to grains. When loaded parallel to the grains, the grains act as cluster of columns hence resist greater load. Whereas when loaded perpendiculars to the grain, the grains are arranged like layers one above the other and weak grain layer will cause failure of the specimen at the smaller load value.

PROCEDURE

- 1) Measure the dimensions of the specimen at several sections with vernier caliper and obtain the mean.

- 2) Keep the specimen on top of bottom cross head either with grains parallel or perpendicular in the compression testing machine.
- 3) Bring down the adjustable upper cross head by rotating it manually till it just touches the specimen in the machine. Apply the load gradually at the rate of $0.5\text{kg/cm}^2/\text{sec}$.
- 4) Stop the application of load after the specimen has failed and note the crushing load.
- 5) Remove the specimen from the machine and study the failure pattern.



Fig 1: Compression testing machine (CTM)

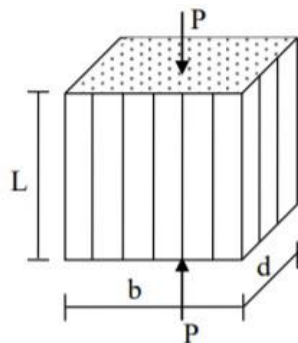


Fig. 1: Grains are parallel to the direction of loading

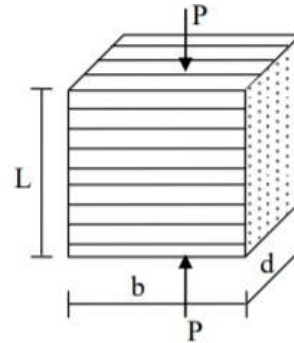


Fig. 2: Grains are normal to the direction of loading

Fig 1 and 2: Distribution of Grains in wood when load parallel and perpendicular

OBSERVATION

a) **Parallel to grains**

1. Length of the specimen = _____ mm
2. Breadth of the specimen = _____ mm

3. Original cross section of the specimen= L*B= _____ mm²

b) **Perpendicular to grains**

1. Length of the specimen = _____ mm

2. Breadth of the specimen = _____ mm

3. Original cross section of the specimen= L*B= _____ mm²

TABULATION

SL. No	Mode of loading	Cross sectional area (mm ²)	Maximum Load (kN)	Maximum Load (N)	Crushing strength (N/mm ²)
1	Load applied parallel to the grains				
2	Load applied perpendicular to the grains				

FORMULA

$$\text{Crushing strength} = \frac{\text{Maximum Load}}{\text{Cross sectional area}}$$

RESULT

- 1) Compressive strength of a given timber specimen when loaded parallel to the grains is _____ N/mm²
- 2) Compressive strength of a given timber specimen when loaded perpendicular to the grains is _____ N/mm²

SIGNIFICANCE

The purpose of compression test is to determine the behavior or response of a material while it experiences a compressive load by measuring fundamental variables such as strain, stress, and deformation.

APPLICATION

Measuring the strength of sheet construction materials, insulation boards and roofing panels. Penetration tests on plasterboard, pipes and shotcrete.

COMPRESSION TEST ON HYSD, CAST IRON

AIM

To Perform compression test of HYSD and cast iron on UTM.

APPARATUS

A UTM or A compression testing m/c, cylindrical or cube shaped specimen of cast iron, Vernier caliper, liner scale, dial gauge

THEORY

Several m/c 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. Several materials, which are good in tension, are poor in compression. Contrary to this, many materials poor in tension but very strong in compression. Cast iron is one such example. That is why determine of ultimate compressive strength is essential before using a material. This strength is determined by conduct of a compression test. 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 etc. But ductile materials like aluminum and mild steel which are strong in tension, are also tested in compression.

TEST SET-UP, SPECIFICATION OF M/C AND SPECIMEN DETAILS

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 shown in figure, it 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.

SPECIMEN

In cylindrical specimen, it is essential to keep $h/d \leq 2$ to avoid lateral instability due to buckling action. Specimen size = $h \leq 2d$.

PROCEDURE

1. Dimension of test piece is measured at three different places along its height/length to determine the average cross-section area.
2. Ends of the specimen should be plane for that the ends are tested on a bearing plate.
3. The specimen is placed centrally between the two compression plates, such that the centre of moving head is vertically above the centre of specimen.
4. Load is applied on the specimen by moving the movable head. The load and corresponding contraction are measured at different intervals. The load interval may be as 500 kg.
5. Load is applied until the specimen fails.

OBSERVATION

- Initial length or height of specimen $h = \text{-----}$ mm.
- Initial diameter of specimen $d_o = \text{-----}$ mm.

S.No.	Applied load (P) N	Recorded change in length (mm)

CALCULATION

1. Original cross-section area $A_o = \text{-----}$
2. Final cross-section area $A_f = \text{-----}$
3. Stress = -----
4. Strain = -----

For compression test, we can

1. Draw stress-strain (σ - ϵ) curve in compression,
2. Determine Young’s modulus in compression,

3. Determine ultimate (max.) compressive strength, and
4. Determine percentage reduction in length (or height) to the specimen.

RESULT

The compressive strength of given specimen = N/mm²

SIGNIFICANCE

The purpose of compression test is to determine the behavior or response of a material while it experiences a compressive load by measuring fundamental variables such as strain, stress, and deformation. Compression testing is a method that is used to establish the compressive force or crush resistance of a material and the ability of the material to recover after a specified compressive force is applied and even held over a defined period of time.

APPLICATION

Measuring the strength of sheet construction materials, insulation boards and roofing panels.
Penetration tests on plasterboard, pipes and shotcrete.

TENSION TEST ON MILD STEEL BARS

AIM

To determine the following strength by carrying out the tension test on mild steel specimen

1. Yield stress
2. Ultimate stress
3. Breaking stress
4. Young's modulus of a material at elastic point (from graph)
5. Percentage reduction in area
6. Percentage elongation in length

APPARATUS NEEDED

Universal testing machine (UTM), test specimen, extensometer Scale with least count of 0.01mm to measure elongation, steel scale, vernier caliper.

THEORY

A Steel rod of elastic material subjected to tensile loading for gauge length ' L_g ' and initial cross sectional area ' A_i '. As the load is increased the stresses at different loading are calculated and are plotted on Y- axis and similarly the elongation at different loading are noted down and strain at various loading are calculated and plotted on X-axis.

In steel, the length OA (Fig 3) is a straight line which indicates a stress is proportional to strain. Here material is perfectly elastic up to point 'A' and when load is removed at this stage the material regain its original shape and size. When load is further increased the material reaches point 'B' known as upper yield point and point 'C' is lower yield point.

PROCEDURE

1. Measure the initial diameter D_i of the given specimen with the help of vernier caliper, center point of specimen is located and value of the initial gauge length L_g on either side of it is marked using scale, punch mark are also made on the external surface of $2.5d$ for calculation of percentage elongation in length.
2. Fix the upper end of the specimen inside the shackles of the upper cross head and bring the shackles of the intermediate cross head into contact with the bottom of the specimen and the bottom end is fixed inside the shackles.
3. Bring the extensometer scale and the load dial gauge to zero reading.

4. Start the machine, and load is applied gradually, at regular interval of loads extension is measured. The elongation is noted from the extensometer scale.
5. When the load crosses the elastic point or yield point the further extension are noted from the extensometer scale.
6. When the maximum load is reached, the load dial indicator returns back rapidly and suddenly stops at the fracture of the specimen. Note down the maximum load and elongation.
7. Record the failure load and elongation at the failure load.
8. Take out the fractured specimen and measure the final diameter D_f at the fracture point and the final length L_f .
9. From the obtained values of load and elongation, stress- strain values are calculated and graph is plotted for stress Vs stain.

TABULATION

SL.No	LOAD (kN)	LOAD (N)	Elongation ΔL (mm)	Stress $\sigma = F/A_i$ (N/mm ²)	Stain $\epsilon = \Delta L/L_g$

OBSERVATIONS

- 1) Material: Mild steel
- 2) Least count of vernier = _____
- 3) Least count of extensometer = _____
- 4) Initial diameter (D_i) = _____ mm
- 5) Initial cross sectional area (A_i) = _____ mm²
- 6) Initial Length of the specimen (L_i) = _____ mm

- 7) Gauge length of the specimen (L_g) = $5D_i$ _____ mm
- 8) Final diameter of the specimen at neck (D_f) = _____ mm
- 9) Final cross-sectional area at neck (A_f) = _____ mm^2
- 10) Final Length of the specimen (L_f) = _____ mm

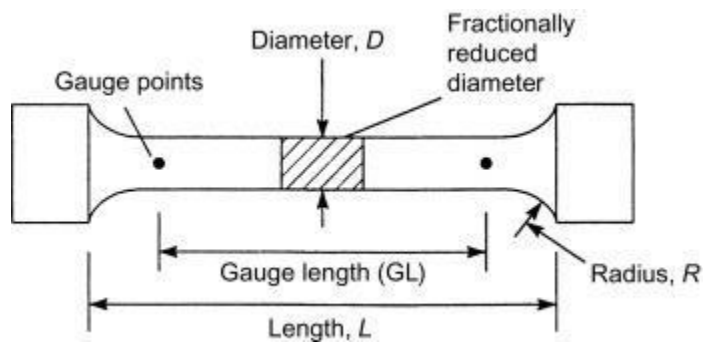


Fig 1: Typical Tensile test specimen.

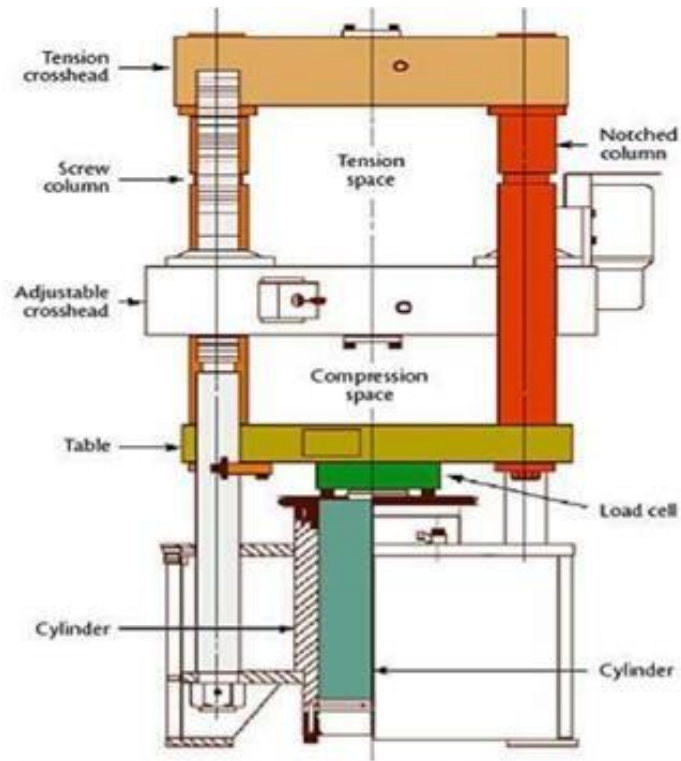
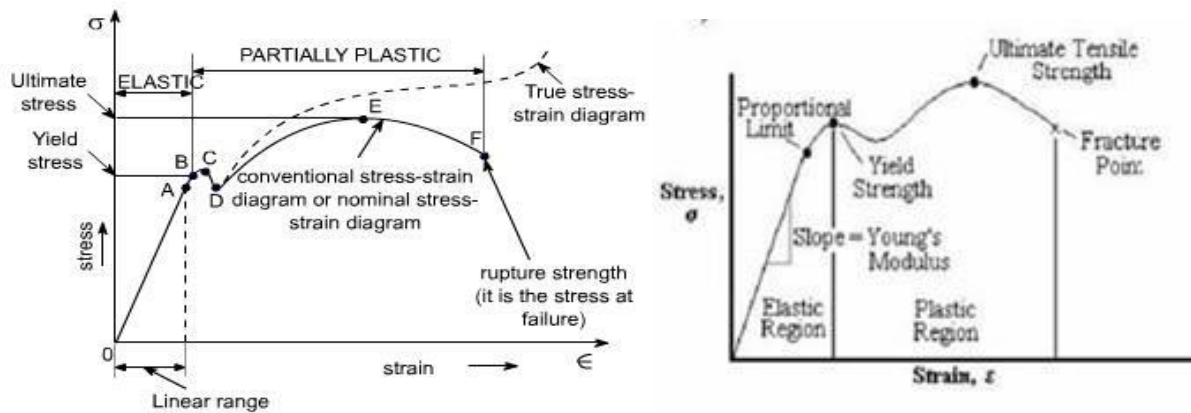


Fig 2: Universal testing machine (UTM) with Parts

GRAPH



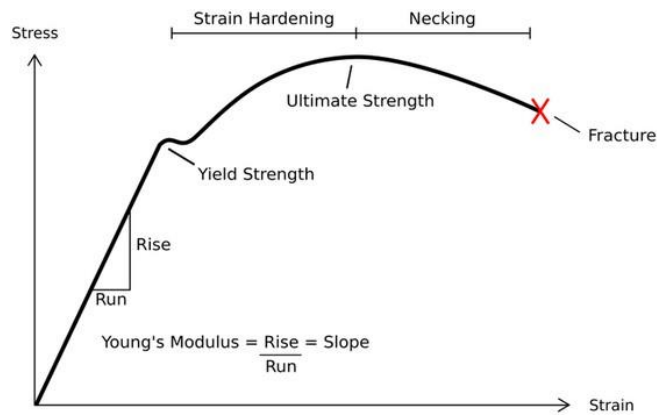


Fig 3: Typical stress strain curve for the mild steel

CALCULATIONS

- 1) Initial area (A_i)= $(\Pi/4)*D_i^2$ = _____ mm^2
- 2) Final area (A_f)= $(\Pi/4)*D_f^2$ = _____ mm^2
- 3) Stress(σ)= load /initial area = _____ N/mm^2
- 4) Stain(ϵ) =elongation /initial length = _____
- 5) Yield stress (σ_y)= yield load/initial area= _____ N/mm^2
- 6) Ultimate stress (σ_y) = Ultimate load/initial area= _____ N/mm^2
- 7) Breaking stress (σ_b) = Breaking load/initial area= _____ N/mm^2
- 8) Percentage elongation in length=

= (final length-initial length)/ (initial length)*100= _____ %

$$\frac{L_f - L_i}{L_i} \times 100$$

9) Percentage reduction in area=

$$= (\text{initial area} - \text{final area}) / (\text{initial area}) * 100 = \underline{\hspace{2cm}} \%$$

$$\frac{A_i - A_f}{A_i} \times 100$$

10) Young's Modulus (**E**) = stress/strain (value obtained from graph) = _____ N/mm²

RESULTS

1. Yield stress(from graph) = _____ N/mm²
2. Ultimate stress= _____ N/mm²
3. Breaking stress= _____ N/mm²
4. Young's modulus of a material at elastic point (from graph) = _____ N/mm²
5. Percentage reduction in area= _____ %
6. Percentage elongation in length= _____ %.

IS CODES

IS: 1608 (1972) - Method for tensile testing of steel products (First Revision), BIS, New Delhi. IS: 1786 (2008)- Specification for high strength deformed steel bars and wires for concrete reinforcement (Fourth Revision), BIS, New Delhi.

SIGNIFICANCE

The tensile strength of a metal is essentially its ability to withstand tensile loads without failure. The test is essential to perform to measure the quality of the materials under extreme tension forces during usage. This is an important factor in metal forming processes since brittle metals are more likely to rupture.

APPLICATION

The tension test or tensile test is widely used to assess the quality of the materials that are manufactured in different industries. The tension test helps to determine the strength of various metal products such as metal cables, construction angles, girders and other metal products that are used in different industries.

TORSION TEST ON MILD STEEL

AIM

To determine the behavior of ductile steel when subjected to torsion and obtain the following properties:

- 1) Modulus of rigidity
- 2) Modulus of toughness and ductility.

APPARATUS

Torsion testing machine, twist meter for measuring angle of twist, A steel rule and vernier caliper, test specimen.

THEORY

This test is performed either on cylindrical bar, tube or pipe. Suitable fixtures are used to prevent the collapse of the ends when testing the tube and pipe. A tubular specimen is preferred as the stress distribution will be uniform throughout the material cross section. In case of a cylindrical specimen, the stress will vary from zero at the axis to a maximum at its surface. The specimen is fixed rigidly at one end and other end is twisted. The torque or twisting moment applied is measured on a circular scale.

PROCEDURE

1. Measure the diameter 'd' of the specimen at several sections with vernier caliper to obtain the mean value and also measure the length of the specimen **L**.
2. Adjust the torsion machine to read zero and the specimen is fixed between the two grips of the machine.
3. Torque is applied at slow speed.
4. Take the readings of torque **M_t** and angle of twist **θ** simultaneously until failure occurs.
5. Note the torque at the yield **M_{ty}** and at fracture **M_{tu}**.
6. Plot the graph of torque **M_t** as ordinate (Y-axis) and angle of twist **θ** as abscissa (X-axis)

and calculate the G by using the relation $\frac{\Delta M_t L}{\Delta \theta J}$

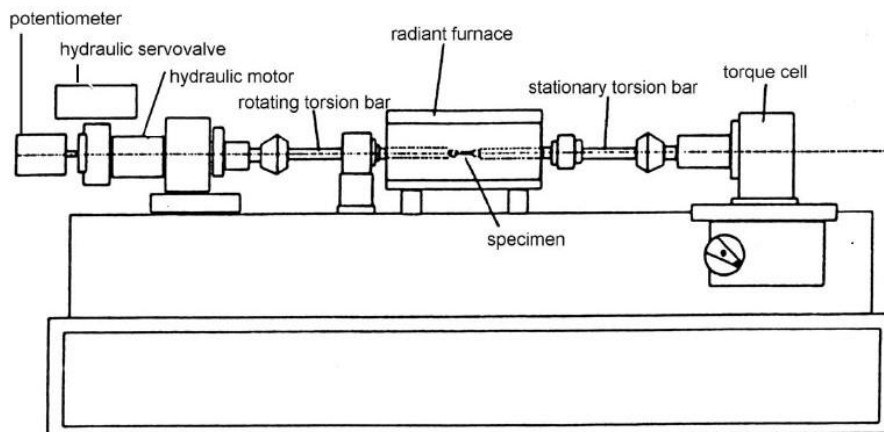
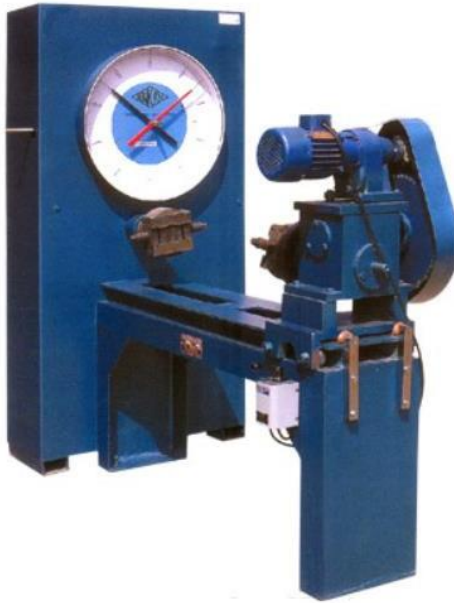


Fig 1: Torsion testing Machine

FORMULA

1. Torsional Equation: $\frac{T}{J} = \frac{q}{r} = \frac{G\theta}{l}$
2. Polar moment of Inertia $J = \frac{\pi d^4}{32}$

3. Shear stress $q = \tau = \frac{M_t d}{2J}$ (N/mm²)

4. Shear strain $\phi = \gamma = \frac{d\theta \left(\frac{\pi}{180} \right)}{2L}$

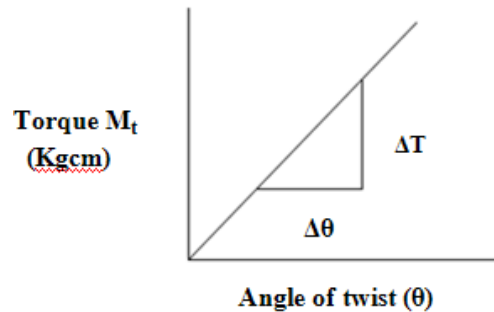
5. Modulus of toughness $T_o = \frac{M_u \theta \left(\frac{\pi}{180} \right)}{AL}$ (Nmm/mm³)

OBSERVATIONS

1. Diameter of solid circular specimen (d)= _____ mm
2. Length of the solid circular specimen(L)= _____ mm
3. Polar moment of Inertia (J)= _____ mm⁴

TABULATION

Angle of twist(θ)	Angle of twist $\theta \times \frac{\pi}{180}$	Torque M_t (Kg-cm)	Torque M_t (N-mm)

GRAPH**CALCULATIONS**

$$1. \text{ Modulus of rigidity (from graph)} = G = \frac{\Delta M_t L}{\Delta \theta J}$$

Where, L is the length of specimen

J is the Polar moment of Inertia

M_t is the Torque or Twisting moment in kg-cm

θ is the angle of twist in radian

RESULTS

1) Modulus of rigidity= _____ N/mm²

2) Modulus of toughness= _____ Nmm/mm³

IS CODE

IS 1717 (2012): Metallic Materials - Wire - Simple Torsion Test, Third Revision, 2012

SIGNIFICANCE

The purpose of a torsion test is to determine sample behaviour when twisted, or under torsional forces, as a result of applied moments that cause shear stress about the axis. Torsion testing is a type of mechanical testing that evaluates the properties of materials or devices while under stress from angular displacement.

APPLICATION

Torsion springs are used in torsion pendulum clocks. In such clocks, a torsion spring is used to suspend a wheel-shaped weight from the center of the clock. As the weight rotates around its axis, it twists the spring.

BENDING TEST ON WOOD WITH SINGLE POINT LOAD

AIM

To study the behavior of the given specimen under bending and to determine the following properties

- 1) Elastic strength
- 2) Modulus of elasticity
- 3) Bending stress
- 4) Modulus of rupture

APPARATUS

Universal testing machine, test specimen, steel scale, dial gauge, bending test arrangement support the specimen, knife edge load for applying a single concentrated load at the centre.

THEORY

If force act on piece of material in such way that they tend to introduce compressive stresses over the one part of the cross section of the piece and tensile stresses over the remaining part, the cross section of the piece is said to be in bending. In cross section of a beam, the line along which the bending stresses are zero is called neutral axis. In simple bending, the neutral axis passes through the centroid in bending. Stresses are proportional to the distance from the neutral axis within the proportional limit. Above the proportional limit bending stress do not vary linearly across the cross section. For this reason most of the members subjected to bending such as beams prefer usual laboratory test to determine bending, stress strain properties. When the beam is subjected to an external load the beam bend away from central line i.e. it deflects as the load increases, the beam goes on deflecting slightly. A stage is reached for a particular load the beam fails reaching its bending stress.

PROCEDURE

1. The dimensions of the wooden beam i.e. breadth, length and depth are measured.
2. Mark the midpoint of the specimen.
3. The test specimen is placed in UTM.
4. The beam is simply supported on two sliding blocks with rollers mounted at the top.

5. Deflection meter is attached to the center of the specimen and is adjusted to initial zero reading.
6. Now the single concentrated load is applied at the centre of the specimen.
7. Deflection is measured over the interval of load till the specimen break.
8. Plot the graph of load v/s deflection and determine the properties of the given specimen.

FORMULA

$$\text{Bending Equation} = \frac{M}{I} = \frac{f}{y} = \frac{E}{R}$$

Where,

M is Bending moment

I is Moment of Inertia

f is Bending stress

y is distance from neutral axis to top fibre or bottom fibre

E is Young's Modulus

R is Radius of curvature

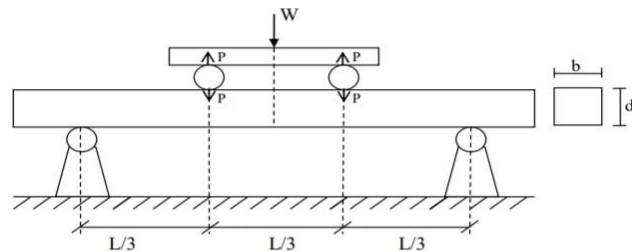
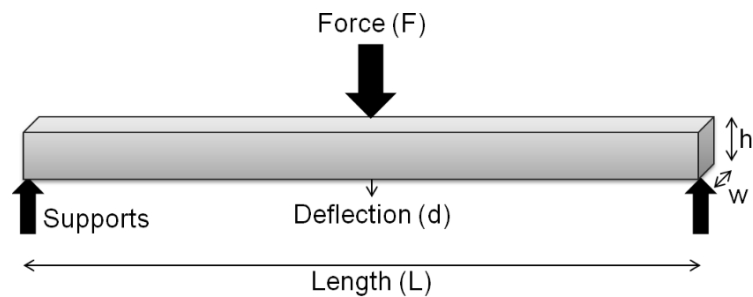


Fig 1: Bending test on Beam

OBSERVATION

Length of the specimen (L) = _____ mm

Breadth of the specimen (B) = _____ mm

Depth of the specimen (D) = _____ mm

TABULATION

SL No	Load(W) (kN)	Load(W) (N)	Deflection(δ) (mm)

GRAPH

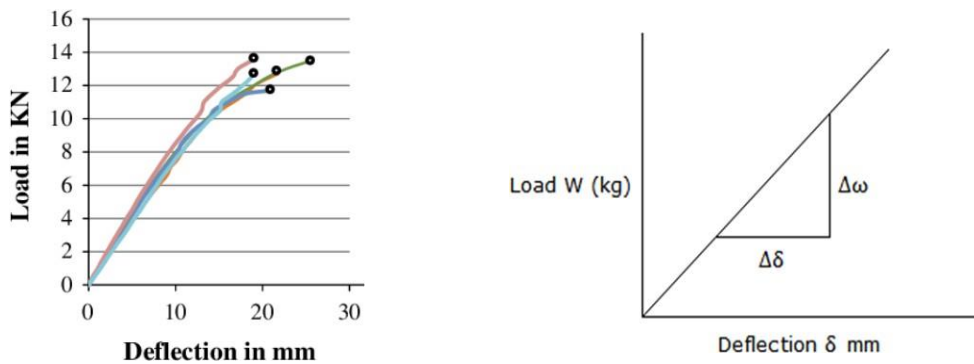


Fig 2: Load Vs deflection curve

CALCULATION

1. Area of the specimen = $B \cdot D = \text{_____ mm}^2$

2. Moment of Inertia (I) = $\frac{BD^3}{12} = \text{_____ mm}^4$

3. Bending moment for single concentrated load = $\frac{WL}{4} = \underline{\hspace{2cm}}$ N-mm

4. Modulus of elasticity of wood $E = \frac{\text{stress}}{\text{strain}}$

Take $\frac{\Delta w}{\Delta \delta}$ from the graph.

$$(E) = \frac{\left(\frac{\Delta W}{\Delta \delta}\right) \times L^3}{48I} = \underline{\hspace{2cm}} \text{ N/mm}^2$$

5. Modulus of rupture = $\frac{L^2}{8\delta} = \underline{\hspace{2cm}}$ mm

6. Bending stress = $\frac{3WL}{2D^3} = \underline{\hspace{2cm}}$ N/mm²

RESULTS

- 1) Modulus of elasticity of wood (E) = $\underline{\hspace{2cm}}$ N/mm²
- 2) Bending stress = $\underline{\hspace{2cm}}$ N/mm²
- 3) Modulus of rupture = $\underline{\hspace{2cm}}$ mm

IS CODE

IS 1734-Part 11(1983): Methods of Test to determine Bending Strength of Wood.

SIGNIFICANCE

Bending test on a wooden beam is to study the bending or flexural behavior of the wooden beam and to determine the Modulus of Elasticity and Modulus of Rupture of the wood. Wood and timber material undergo simple tension, compression and flexural testing to determine their suitability for a specific application.

APPLICATION

The flexure test method measures behavior of materials subjected to simple beam loading. Maximum fiber strain and maximum strain are calculated for increments of load. Used in Building Construction and railways work.

SHEAR TEST ON MILD STEEL (SINGLE AND DOUBLE SHEAR)**AIM**

To determine the shear strength of the given specimen in single and double shear.

APPARATUS

UTM, vernier caliper, shear attachments, test specimen.

THEORY

A force, which tends to make two adjacent parts of a member to slide relative to one another at their plane of contact, is called shear force. Shear force acts parallel to a plane. The member subjected to shear force undergoes deformation. The resistance against this deformation is called shear stress. Maximum shear stress which a material can withstand is called the shear strength. When there is only one cross section which resists the failure then the material is said to be in single shear and the average ultimate shear strength is equal to load divided by the area of the cross section. When two areas resist the failure of the material, then the material is said to be in double shear and the average ultimate shear strength will be equal to load divided by twice the area of the cross section.

There are two types of shear stress used in laboratory test. One is called direct or transverse shear stress and corresponds to the type of stress encountered in rivets, bolts and beams. The other type of shear stress is called pure or torsional shear and represents the kind of shear stress encountered in a shaft subjected to pure torsion. Direct test are usually conducted to measure shear strength and torsion test are usually conducted to evaluate the basic shear properties of a material.

PROCEDURE

1. Measure the diameter of the specimen using vernier caliper and average diameter is also calculated.
2. Place the specimen in the shear failure attachment such that specimen is in single shear and place the assembly in UTM.
3. Gradually apply the load until the specimen fails and note down the failure load at which the specimen fails.
4. Similarly, carryout the shear test for double shear.

5. Measure the diameter of another specimen using vernier caliper and calculate the average diameter.
6. Place the specimen in the shear failure attachment such that specimen is in double shear and place the assembly in UTM.
7. Gradually apply the load until the specimen fails and note down the failure load at which the specimen fails.
8. Calculate the shear stress of the material in single and double shear using formula.

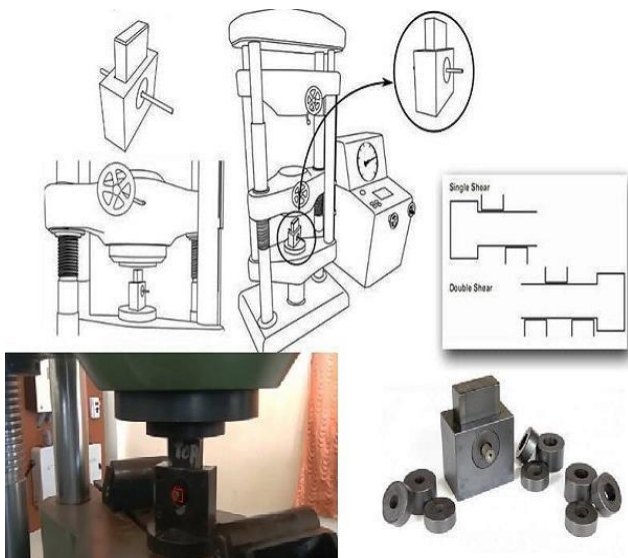


Fig 1

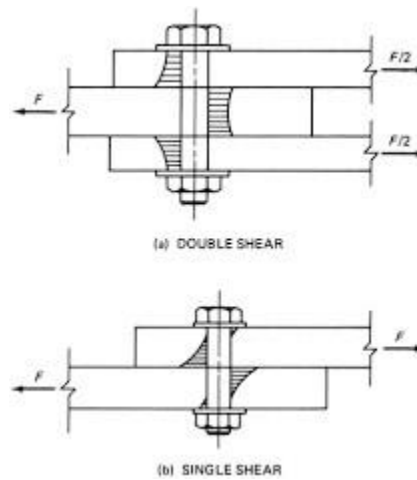


Fig 2

Fig 1: Shear attachments with specimen placed in UTM

Fig 2: Free Body diagram of Single and Double shear

FORMULAE

1. Shear strength= Failure load /Area
=F/A
2. Shear strength of a material in single shear =Failure load /Area of cross section.
=F/A _____(N/mm²)
3. Shear strength of a material in double shear = Failure load / (2*Area of cross section).
=F/ (2*A). _____(N/mm²)

TABULATION

Material	Type of shear	Diameter (mm)	Area = $(\pi/4) * d^2$	Failure load(F) (kN)	Failure load(F) (N)	Shear strength τ (N/mm ²)
Mild steel	Single					
	Double					

RESULT

1. Shear strength of the specimen in Single shear = _____ N/mm²
2. Shear strength of the specimen in Double shear = _____ N/mm²

IS CODE

IS 5242-1979: Method of test for determining shear strength of metals.

SIGNIFICANCE

The force that tends to produce a sliding failure on a material along a plane that is parallel to the direction of the force. Shear failure is important while designing any structures or machine components. Shear force causes the surface to go out of the alignment with each other and thus the material fails.

APPLICATION

In structural and mechanical engineering, the shear strength of a component is important for designing the dimensions and materials to be used for the manufacture or construction of the component (e.g. beams, plates, or bolts).

IMPACT TEST ON MILD STEEL

IZOD IMPACT TEST

AIM

To determine the IZOD impact resistance and specific impact factor of mild steel.

APPARATUS

Impact testing machine, Test specimen with V groove, Allen key for tightening the specimen in the clamping device with the help of clamping screw.

THEORY

Impact test is used to determine the behavior of the material under impact loading. Impact loading is one in which load or force is applied suddenly in shortest possible time. In reality there are many instances when loads are borne by engineering components suddenly rather gradually. Hence determining the impact value of any material is very important.

The principle employed in all impact testing procedure is that a material absorbs certain amount of energy before it breaks. The quantity of energy thus absorbed is characteristic of the physical nature of the material. If it is a brittle it breaks more readily i.e. quantity of energy absorbed is less. If the material is tough it needs more energy to break.

In testing, a swinging hammer is made to strike the specimen held firmly in vice. The hammer breaks the specimen on account of its energy. The height of the rise of the hammer on the other side indicates the residual energy of the hammer. The energy actually absorbed by the specimen in order to break, is given by the difference between the initial (before impact) and final energies (after sticking the specimen) of the hammer.

The specimen is square in cross section of 10mmx100mm having overall length of 75mm with 2mm deep V notch. It is held as vertical cantilever in a fixture such that the notch is on the tension side.

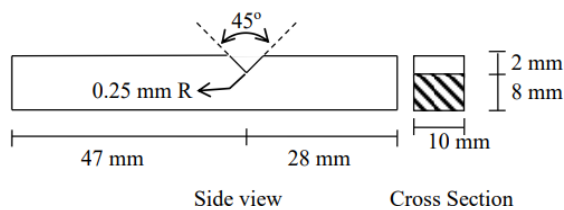
PROCEDURE

1. Fix the pendulum in the desired position and ensure the lock in holder.
2. Fix the striker in the pendulum hammer.

3. Adjust the pointer to the maximum value.
4. Release the pendulum by operating the lever and allow the pendulum to swing freely.
5. Note down the reading on scale which indicates the energy loss in overcoming the resistance like friction in the machine.
6. Now, fix the Izod specimen inside the clamping device (fixture). For this, hold the specimen in hand vertically such that the half of the V notch is just above the horizontal surface of the clamping device and V notch is facing the pendulum (tension side). Now insert the setting gauge such that the pointer edge of setting gauge correctly fits inside the V groove. Simultaneously tighten the clamping screw using the Allen key, so that the specimen is rigidly fixed. Check that there is no movement of specimen.
7. Release the pendulum by operating the lever so as to swing freely and the specimen will be smashed.
8. Stop the swinging pendulum by applying the pendulum break.
9. Note down the reading on the scale corresponding to the pointer which gives the impact value to break the specimen.
10. Repeat the procedure for two more samples and average value of the three readings is the impact energy required for the Izod specimen.

DIAGRAM

Standard specimen for IZOD test



OBERVATIONS

1. Type of material – Mild steel
2. Type of test- Izod test
3. Length of the specimen(L)= _____ mm
4. Width of the specimen(B)= _____ mm
5. Height of the specimen(H)= _____ mm
6. Depth below the notch (D)= _____ mm

7. Cross sectional area at notch $A=B*D= \underline{\hspace{2cm}} \text{ mm}^2$
8. Total impact energy of pendulum=16kgm
9. Total permissible frictional loss =0.5% of 16kgm= $\underline{\hspace{2cm}}$ kgm
10. Observed frictional loss= $\underline{\hspace{2cm}}$ kgm
11. Correction factor= Observed frictional loss – permissible frictional loss= $\underline{\hspace{2cm}}$ kgm
12. Energy absorbed by the specimen= $\underline{\hspace{2cm}}$ kgm
13. Total Izod Impact Energy of the specimen
 =Energy absorbed by the specimen– Correction factor
 = $\underline{\hspace{2cm}}$ kgm

CALCULATION

$$\begin{aligned} \text{IZOD Impact Strength of the specimen} &= \frac{\text{Impact Energy of the specimen}}{\text{Cross sectional area below the notch.}} \\ &= I / A \quad \underline{\hspace{2cm}} \quad (\text{Nm/mm}^2) \end{aligned}$$

RESULTS: IZOD Impact strength of the specimen= $\underline{\hspace{2cm}}$ Nm/mm²

RELEVANT IS CODES

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

SIGNIFICANCE

Impact test determines the amount of energy absorbed by a material during fracture. This absorbed energy is a measure of a given material's toughness and acts as a tool to study temperature-dependent brittle-ductile transition.

The Izod test is most commonly used to evaluate the relative toughness or impact toughness of materials and as such is often used in quality control applications where it is a fast and economical test. It is used more as a comparative test rather than a definitive test.

APPLICATION

Izod impact testing can be used to determine the sensitivity of notched plastics specimens. Impact resistance of plastic notched specimens measures how well a cracked plastic specimen will withstand an impact. Measuring notch sensitivity of plastics with the Izod test can be applied to plastic designs.

CHARPY IMPACT TEST

AIM

To determine the CHARPY impact resistance and specific impact factor of mild steel.

APPARATUS

Impact testing machine, Test specimen with U groove, Allen key for tightening the specimen in the clamping device with the help of clamping screw.

THEORY

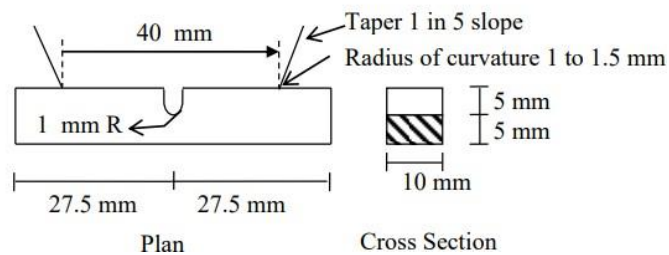
Charpy impact test (U Notch) consists of breaking by one blow from a swinging hammer under prescribed condition. The energy absorbed for failure of specimen is determined from which the impact value is obtained. A standard test piece is square in cross section of 10mmx10mm having overall length of 55mm with 5mm deep U notch.

PROCEDURE

1. Fix the pendulum in the desired position and ensure the lock in holder.
2. Fix the striker in the pendulum hammer.
3. Adjust the pointer to the maximum value.
4. Release the pendulum by operating the lever and allow the pendulum to swing freely.
5. Note down the reading which indicates the energy loss in overcoming the resistance like friction in the machine.
6. Now, place the Charpy specimen in the fixture such that the U notch is opposite to the tension side and hammer hits the simply supported specimen at the center.
7. Release the pendulum by operating the lever so as to swing freely and the specimen will be smashed.
8. Stop the swinging pendulum by applying the pendulum break.
9. Note down the reading on the scale corresponding to the pointer, which gives the impact value to break the specimen.
10. Repeat the procedure for two more samples and average value of the three readings is the impact energy required for the Charpy specimen.

DIAGRAM

Standard Specimen for Charpy test:



OBSERVATIONS

1. Type of material – Mild steel
2. Type of test- Charpy test
3. Length of the specimen(L)= _____ mm
4. Width of the specimen(B)= _____ mm
5. Height of the specimen(H)= _____ mm
6. Depth below the notch (D)= _____ mm
7. Cross sectional area at notch $A=B*D=$ _____ mm^2
8. Total impact energy of pendulum=30 kgm
9. Total permissible frictional loss =0.5% of 30kgm= _____ kgm
10. Observed frictional loss= _____ kgm
11. Correction factor= Observed frictional loss – permissible frictional loss= _____ kgm
12. Energy absorbed by the specimen= _____ kgm
13. Total Charpy Impact Energy of the specimen
 =Energy absorbed by the specimen– Correction factor
 = _____ kgm

CALCULATION

$$\text{CHARPY Impact Strength of the specimen} = \frac{\text{Impact Energy of the specimen}}{\text{Cross sectional area below the notch.}}$$

$$= I / A \quad \text{_____} \quad (\text{Nm}/\text{mm}^2)$$

RESULTS: CHARPY Impact strength of the specimen= _____ Nm/mm^2

RELEVANT IS CODES

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

SIGNIFICANCE

Impact test determines the amount of energy absorbed by a material during fracture. This absorbed energy is a measure of a given material's toughness and acts as a tool to study temperature-dependent brittle-ductile transition.

Charpy tests show whether a metal can be classified as being either brittle or ductile. This is particularly useful for ferritic steels that show a ductile to brittle transition with decreasing temperature.

The Charpy impact test is performed to evaluate the resistance of plastics to breakage by flexural shock according to standard test method. It indicates the amount of energy needed to break standard test specimens under specific conditions of specimen, mounting, notching and pendulum velocity at impact.

APPLICATION

The Charpy impact test measures the energy absorbed by a standard notched specimen while breaking under an impact load used as an economical quality control method to determine the notch sensitivity and impact toughness of engineering materials such as metals, composites, ceramics, and polymers.

HARDNESS TESTS ON FERROUS AND NON-FERROUS METALS**BRINELL'S HARDNESS TEST****AIM**

To find Brinell's hardness number (BHN) for the specimen like ferrous metal (mild steel) and nonferrous metal such as brass and aluminum.

APPARATUS

Brinell Hardness testing Machine, ball indenter having diameter 10mm, 5mm, 2.5mm, (1/16)" (1.58mm diameter), Test specimens of different materials such as Mild steel, Brass and Aluminum; travelling microscope.

THEORY

Hardness of a metal may be defined as its resistance against plastic deformation. It is also defined as the resistance of the material against indentation. Greater the hardness greater is the resistance towards deformation. Brinell hardness number is defined as the ratio of load to surface area of indentation. In this test, metal surface is indented by a hard steel ball of specified diameter under a specified load. The load is maintained for 30 seconds. The indentation diameter 'd' on the material is measured by traveling microscope and Brinell hardness number (BHN) is calculated using the formula.

PROCEDURE

1. Clean the surface of the material to be tested to clear off dirt, oil etc and the surface is rubbed with proper sand paper to facilitate.
2. Remove the trust piece from the sleeve and fix the suitable indenter with the trust piece inside the sleeve.
3. Select the appropriate load by rotating the load selector wheel.
4. Place the specimen on the anvil. Raise the anvil by rotating the hand wheel to apply a minor load (of 10kg) till the small pointer coincide with the 3rd division (red spot)
5. Now the specimen is brought in contact with the indenter by turning the hand wheel slowly in the clock wise direction

6. Wheel is turned slowly till the pointer on the graduated scale indicates '0' pointer on the outer scale and 'B-30' on the inner scale and the small pointer indicates 'Δ' mark with red dot on the small graduated arc.
7. Initially the operating lever for applying the load is towards the observer. Now, turn the lever away from the observer so that the entire load (major load) is applied on the specimen. The long pointer moves and when it comes to rest, wait for 10 to 15 seconds.
8. Now turn the lever slowly towards the observer i.e. to the original position so that entire the load is lifted off from the specimen.
9. Turn the hand wheel, lower the platform and take out the specimen.
10. Using traveling microscope measure the diameter of indentation 'd' made on the specimen.
11. Calculate the Brinell hardness number using the formulae. Repeat the test for different materials.

DIAGRAM

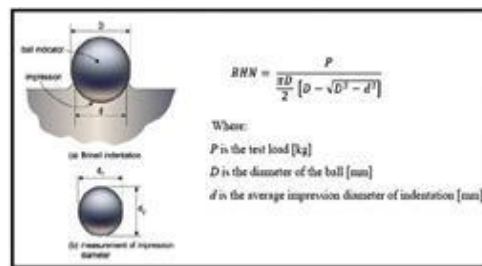
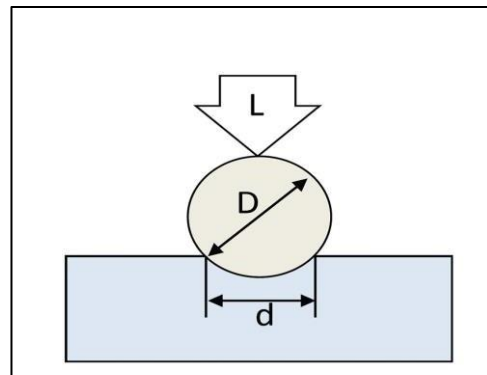


Fig: Hardness Testing Machine

FORMULA

Brinell hardness number (BHN) =
$$\frac{\text{Load in kg}}{\text{Area of indentation in mm}^2}$$

$$\text{BHN} = \frac{2P}{\pi D(D - \sqrt{D^2 - d^2})}$$

Where

P is applied load in Kg

D is diameter of the indenter ball in mm.

d is diameter of indentation in mm.

d is calculated as (MSR+ CVD* LC of microscope)

TABULATION

SL.No	Material	Diameter of the ball indenter 'D' (mm)	Load to be applied 'P'(kgf)	Diameter of indentation 'd' (mm)	BHN = $\frac{2P}{\pi D(D - \sqrt{D^2 - d^2})}$ (kgf/mm ²)
1	Mild steel				
2	Brass				
3	Aluminum				

RESULTS

1. BHN of mild steel is _____ kgf/mm²
2. BHN of Brass is _____ kgf/mm²
3. BHN of Aluminum is _____ kgf/mm²

RELEVANT IS CODES

IS: 1500 (1983):- Method of Brinell hardness test for metallic materials.

SIGNIFICANCE

Hardness testing enables us to evaluate a material's properties, such as strength, ductility and wear resistance, and so helps us to determine whether a material or material treatment is suitable for the purpose as per our requirement.

APPLICATION

Brinell hardness testing is typically used in testing aluminum and copper alloys (at lower forces) and steels and cast irons at the higher force ranges. As the Brinell test uses relatively high loads, and therefore relatively large indent, it is frequently used to determine the hardness in circumstances where the overall material properties are being ascertained and local variations in hardness or surface conditions make other methods unsuitable, such as forgings or castings of large parts.

ROCKWELL HARDNESS TEST

AIM

To determine the Rockwell hardness number (RHN) for hard material such as mild steel, cast iron and moderately hard material such as brass, aluminum and copper.

APPARATUS

Rockwell hardness testing machine, cone indenter of 120 degree apex angle for testing hard material (mild steel and cast iron), ball indenter of (1/16)" diameter (1.58mm) for moderately hard material (brass, aluminum and copper).

THEORY

The Rockwell test is a measure of the resistance of material, specifically metals, to permanent Indentation. The Rockwell test is the most popular indentation hardness test and is used in a wide variety of applications. In this test, the minor load is applied first and a SET position is established on the dial gauge of the Rockwell tester. Then the major load is applied. Without moving the piece being tested, the major load is removed and, with the minor load still applied, the Rockwell hardness number is automatically indicated on the dial gauge. The Rockwell test is based on measurement of the depth of penetration with the hardness number read directly from the dial gauge.

PROCEDURE

- 1) Clean the surface of the material to be tested to clear off dirt, oil etc and the surface is rubbed with proper sand paper to facilitate.
- 2) Remove the trust piece from the sleeve and fix the suitable indenter with the trust piece inside the sleeve.
- 3) Select the appropriate load by rotating the load selector wheel.
- 4) Place the specimen on the anvil. Raise the anvil by rotating the hand wheel.
- 5) Now the specimen is brought in contact with the indenter by turning the hand wheel slowly in the clock wise direction
- 6) Wheel is turned slowly till the pointer indicates the 'Δ' mark on the small graduated scale arc on the dial. The long pointer indicates '0' on the outer 'C' scale and "B-30" on the inner "B" scale. In this position minor load of 10kg is being applied on the specimen.

- 7) Initially the operating lever for applying the load is towards the observer. Now, turn the lever away from the observer so that the entire load (major load) is applied on the specimen. The long pointer moves and when it comes to rest, wait for 8 to 10 seconds.
- 8) Now turn the lever slowly towards the observer i.e. to the original position so that entire the load is lifted off from the specimen.
- 9) Note that reading on the outer black dial (B scale) for hard material and the inner red dial(C scale) for moderately hard material.

DIAGRAM

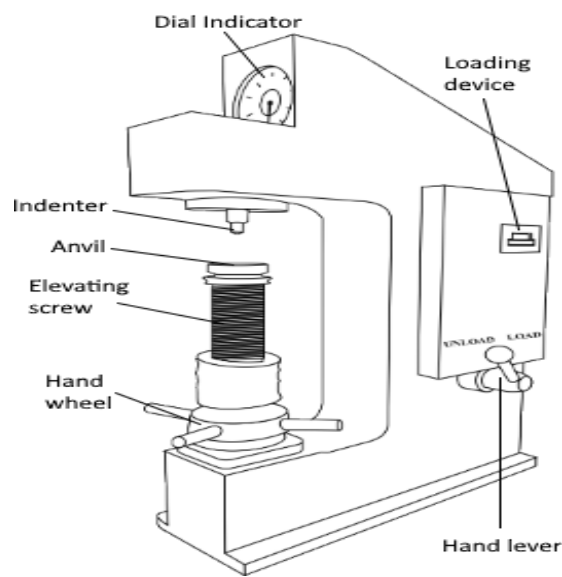


Fig: Hardness Testing Machine

TABULATION

SL. No	Material	Major load	Indentor	Dial	Scale	RHN
1	Mild steel					
2	Brass					
3	Aluminum					

RESULTS

1. RHN of Mild steel is _____
2. RHN of Brass is _____
3. RHN of Aluminum is _____

RELEVANT IS CODES

IS: 1586 (2000): - Method of Rockwell hardness test for Metallic materials.

IS 1586 (Part 1): 2012, Metallic materials - Rockwell hardness test: Part 1 Test method (scales A, B, C, D, E, F, G, H, K, N, T), Fourth revision, 2012.

IS 1586- (Part 2):2012 Metallic Materials - Rockwell Hardness Test, Part 2: Verification and Calibration of Testing Machines (scales A, B, C, D, E, F, G, H, K, N, T), Fourth revision,2012.

SIGNIFICANCE

Hardness testing enables us to evaluate a material's properties, such as strength, ductility and wear resistance, and so helps us to determine whether a material or material treatment is suitable for the purpose as per our requirement. Rockwell hardness testing is a method for measuring the bulk hardness of metallic and polymer materials.

APPLICATION

The Rockwell Hardness test is used to determine the hardness of a material by measuring the depth of penetration of an indenter on the material being tested. Rockwell hardness tester presents direct reading of hardness number on a dial provided with the machine. In heat treatment industries: used to check the hardness before and after hardening and also to check the quality of the material before and after treatment process. Casting industries: used to maintain the quality of their product.

DEMONSTRATION OF STRAIN GAUGES AND STRAIN INDICATORS

As the structure undergoes deformation or load, the strain gauges experience strain, which causes a change in their electrical resistance. These changes are then measured using a strain indicator, providing valuable information about the strain distribution within the structure.

Strain gauges are devices used to determine material strain due to static and dynamic loads coming from internal and external sources such as mechanical, thermal and pressure. During a given test, a gauge is attached to the specimen by an adhesive bond.

Strain gauges were created by utilizing the principle of strain. When a certain force is applied to a metal to make it expand or contract, the electrical resistance changes accordingly. The strain gauge measures the amount of strain by reading this electrical resistance and amplifying it to an electrical output.

Strain gauges are devices that are commonly used by engineers to measure the effect of external forces on an object. They measure strain directly, which can be used to indirectly determine stress, torque, pressure, deflection, and many other measurements.

The following different kind of strain gauges are available in the market:

- Linear strain gauges
- Membrane Rosette strain gauges
- Double linear strain gauges
- Full bridge strain gauges
- Shear strain gauges
- Half bridge strain gauges
- Column strain gauges
- 45°-Rosette (3 measuring directions)
- 90°-Rosette (2 measuring directions).

These strain gages are tailored for force, torque, pressure and displacement measurements within industrial, medical, aerospace and consumer industries. Applications range from medical devices, smart phones, commercial scales, tank and vessel weighing.



I) COMPRESSION TEST

OBJECTIVE- To determine the compressive strength of given sample

THEORY- A compression test is a method for determining the behavior of materials under a compressive load. Compression tests are conducted by loading the test specimen between two plates and then applying a force to the specimen by moving the crossheads together. The compression test is used to determine elastic limit, proportionality limit, yield point, yield strength and compressive strength.

Compressive Strength: - It is the maximum compressive stress that a material is capable of withstanding without fracture. Brittle materials fracture during testing and have a definite compressive strength value. The compressive strength of ductile materials is determined by their degree of distortion during testing.

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. Several materials, which are good in tension are poor in compression. Many materials poor in tension are good in compression. Cast iron is one such example. This strength is determined by conducting a compression test. During the test, the specimen is compressed and deformation Vs. the applied force is recorded.

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 etc. But ductile materials like Aluminium and mild steel which are strong in tension are also tested in compression.

PROCEDURE

1. Dimensions of test piece is measured at 3 different places along its height/length to determine the average c/s area.
2. Ends of the specimen should be plain. For that the ends are tested on a bearing plate.
3. The specimen is placed centrally between the two compression plates, such that the center of moving head is vertically above the center of specimen.

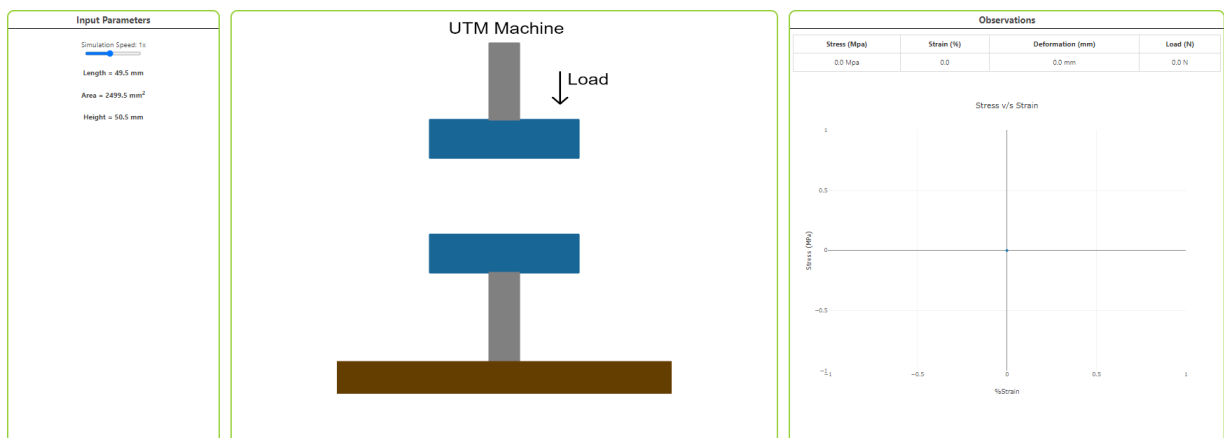
4. Load is applied on the specimen by moving the movable head.
5. The load and the corresponding contraction are measured at different intervals. The load interval may be as 500kg.
6. Load is applied until the specimen fails.
7. The values of stress and strain are calculated at several intervals and are plotted on a graph.
8. The resultant graph is the Stress-Strain curve which is the property of a material and is independent of the dimensions of specimen used.

VIRTUAL PROCEDURE

1. Start the Experiment by clicking the play button.
2. Observe the compression of the box in the simulation window.
3. As the simulation continues the different value of stress, strain and deformation is observed according to the increasing Load.
4. A Graph is plotted between the stress-strain values observed.
5. The Experiment allows you to pause/play/restart the simulation to view the values of different parameters at every stage of simulation.

SIMULATION

BEFORE APPLYING THE LOAD



AFTER APPYING THE LOAD

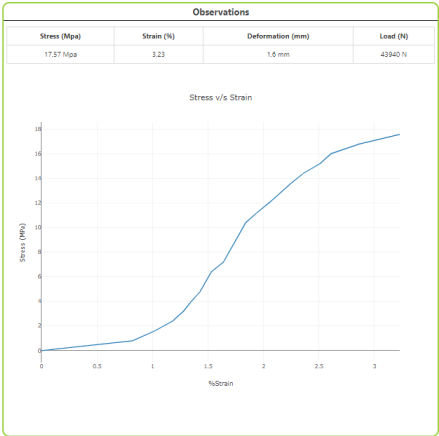
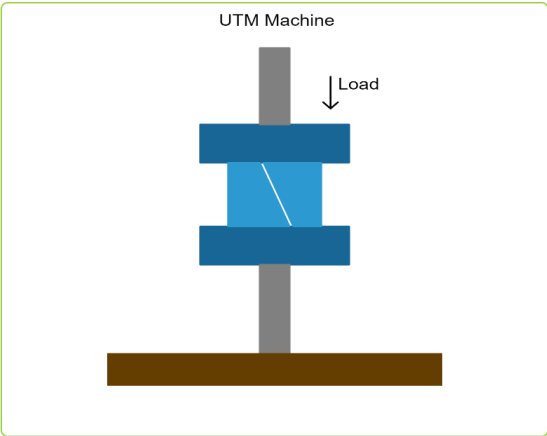
Input Parameters

Simulation Speed: 1x

Length = 49.5 mm

Area = 2499.5 mm²

Height = 56.5 mm





II) IMPACT TEST ON MILD STEEL

AIM - To determine the Impact toughness (strain energy) through Izod test

THEORY- In an impact test, a specially prepared notched specimen is fractured by a single blow from a heavy hammer. The energy required is the measure of resistance to impact. Impact load is produced by a swinging an impact weight W (hammer) from a height h .

Release of the weight from the height h swings the weight through the arc of a circle, which strikes the specimen to fracture at the notch.

PROCEDURE

1. Measure the dimensions of the specimen. Also, measure the dimensions of the notch.
2. Raise the hammer and note down initial reading from the dial, which will be energy used to fracture the specimen.
3. Place the specimen for test and ensure that it is placed center with respect to hammer. Check the position of notch.
4. Release the hammer and note the final reading. Difference between the initial and final reading will give the actual energy required to fracture the Specimen.
5. Compute the energy of rupture of specimen.

VIRTUAL PROCEDURE

1. Start the experiment by clicking the play button.
2. Observe the impact caused by the moving hammer on the test specimen.
3. The test specimen breaks into two pieces and the loss of energy is calculated.
4. An observation table is provided with different trials. Mean energy for failure of specimen is calculated.
5. The experiment allows you to pause/play/restart the simulation.

SIMULATION

BEFORE APPLYING THE LOAD

Input Parameters

Simulation Speed: 1x

Length of Rod = 80 mm

Diameter of Rod = 6 mm

Polar MOI = $1.272e-10 \text{ m}^4$

Modulus of Rigidity = 29.473 GPa

Izod Impact Tester

Observations

Trial	Loss of energy due to friction, E_f (J)	Total Loss of energy E_t during transit of hammer(J)	Energy for failure of specimen = KU / Impact Value = $E_t - E_f$ (J)
1	2	44	42
2	2	42	40
3	2	46	44
Average energy for failure of specimen = 42.00 J			

AFTER APPLYING THE LOAD

Input Parameters

Simulation Speed: 1x

Length of Rod = 80 mm

Diameter of Rod = 6 mm

Polar MOI = $1.272e-10 \text{ m}^4$

Modulus of Rigidity = 29.473 GPa

Izod Impact Tester

Observations

Trial	Loss of energy due to friction, E_f (J)	Total Loss of energy E_t during transit of hammer(J)	Energy for failure of specimen = KU / Impact Value = $E_t - E_f$ (J)
1	2	44	42
2	2	42	40
3	2	46	44
Average energy for failure of specimen = 42.00 J			

TENSION TEST ON HIGH STRENGTH DEFORMED STEEL

AIM

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

THEORY

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

APPARATUS

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

PROCEDURE

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

a) by the kickback of the live needle of the load indicating dial.

OR

b) by the rapid movement of extensometer dial needle at constant load reading.

Record the yield load(s), and remove the extensometer.

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

OBSERVATIONS AND CALCULATIONS BEFORE THE TEST

1. Material of the specimen : _____
2. Total length of the specimen = L = _____ cm
3. Mass of the specimen = m = _____ kg.
4. Gross cross sectional area = $A = \frac{m}{0.00785L} =$ _____ mm²
= _____ cm²

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

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

DATA SHEET FOR THE TENSION TEST ON HSD BAR

Load P, kg	Stress = $\sigma =$ P/A, kg/cm ²	Extensometer readings			Deformation dl, cm	Strain e = dl/L ₀	Remarks
		Left, div.	Right, div.	Average, div.			

OBSERVATIONS AND CALCULATIONS AFTER THE TEST

- Type of fracture : _____
 - Final gauge length = L_U = _____ cm
 - Percentage elongation = $\left(\frac{L_U - L_0}{L_0} \right) 100 =$ _____
 - Young's modulus of elasticity of the given high strength deformed steel = slope of the straight line portion of the stress-strain curve = E_t = _____ kg/cm²
= _____ GPa
 - (a) Upper yield stress = $\sigma_{yu} = \frac{\text{load at upper yield point}}{A} =$ _____ kg/cm²
= _____ MPa
 - (b) Lower yield stress = $\sigma_{yl} = \frac{\text{load at lower yield point}}{A} =$ _____ kg/cm².
= _____ MPa
- OR**
- Yield stress = $\sigma_y = \frac{\text{load at yield point}}{A} =$ _____ kg/cm².
= _____ MPa
- OR**
- 0.2% proof stress = $\sigma_{P0.2} =$ _____ kg/cm²
= _____ MPa
- Tensile strength (Ultimate strength) = $\sigma_{ult} = \frac{\text{Ultimate load}}{A} =$ _____ kg/cm²
= _____ MPa
 - Failure or breaking stress = $\sigma_f = \frac{\text{Load at failure}}{A} =$ _____ kg/cm²
= _____ MPa

RESULTS AND CONCLUSIONS

1. Young's modulus of elasticity of the material
2. Tensile strength
3. Percentage elongation
4. Percentage reduction.

RELEVANT IS CODES

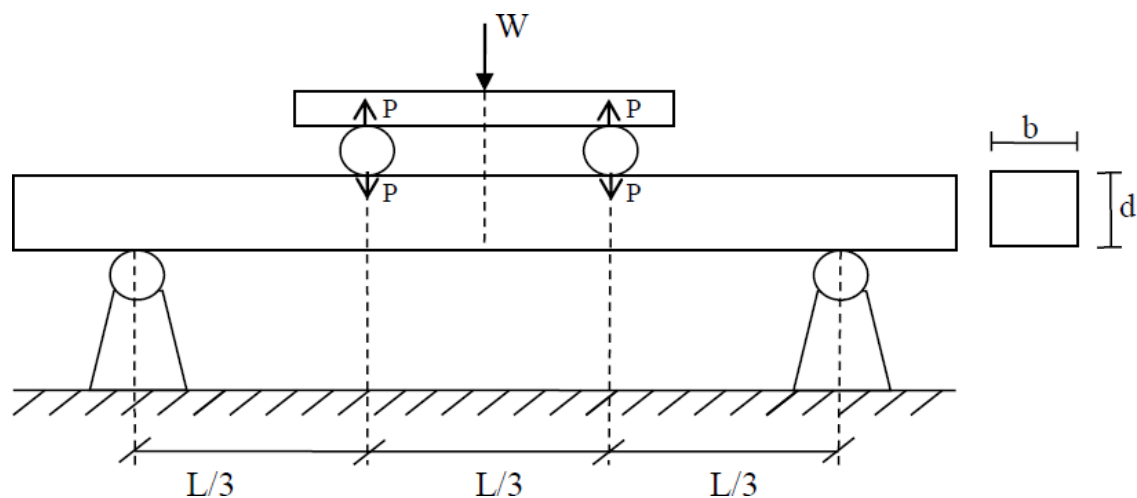
- i. IS: 1608 (1972), Method for tensile testing of steel products (First Revision), BIS, New Delhi.
- ii. IS: 1786 (2008), Specification for high strength deformed steel bars and wires for concrete reinforcement (Fourth Revision), BIS, New Delhi.

BENDING TEST ON WOOD UNDER TWO POINT LOADING**AIM**

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

APPARATUS

Universal Testing Machine, Dial gauge, M.S Plate, Wood Specimen, Rollers.

**PROCEDURE**

- Observe the specimen and measure its cross-sectional dimensions.
- Select a suitable span.
- Mark the mid span point and two-point loading locations at $1/3$ span distances. Mark the cross-section lines at these locations.
- Select a proper range of loading (i.e. 0 to 4 tonnes).
- Move the adjustable blocks and fix them at positions corresponding to selected span.
- Place the specimen over the roller supports. Place two more rollers at two-point loading positions and M.S. plate over them.
- Move the middle cross head to suitable position close to M.S. plate.
- Move the lower cross head and establish a slight contact between M.S. plate and the loading element fixed to the middle cross head.

- Fix the dial gauge suitably to measure the central deflection (i.e. maximum deflection) of the wooden beam. Adjust the dial gauge to read zero.
- Start applying the load gradually. Note down the dial gauge readings at regular load intervals of 40 kg. Remove the dial gauge after about 10 readings.
- Continue loading up to failure and record the load at failure. Switch off the machine and release the load. Remove the specimen and observe the type of failure.

OBSERVATIONS AND CALCULATIONS BEFORE THE TEST

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

TABULATION

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

OBSERVATIONS AND CALCULATIONS AFTER THE TEST

1. Type of failure : _____

2. Young's modulus of elasticity of given wood

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

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

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

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

where P_f is the load at failure.

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

RESULT

- Young's Modulus of given wood = ----- kg/cm²
- Maximum bending moment =-----kg-cm
- Modulus of rupture (bending) = -----kg/cm²

Lab Manual

GIS with Quantum GIS Laboratory

(BCVL456B)

CO's And PO's Mapping Chart

Sl. No.	Description	PO 1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO 10	PO 11	PO 12	PSO 1	PSO 2
1	Use open source software for civil engineering applications.					2									
2	Various tools in QGIS software.					1									
3	Create thematic layers with attribute data.		1											1	
4	Generate maps for decision making.	1					2								

Evaluation:

Non Integrated Lab		
CIE		
Particulars	Marks	Total
Performance	15	30
Journal	10	
Viva Voce	05	
Lab IA		
Particulars	Marks	Total
IA	100	20 (Reduced)
Total (CIE +Lab IA)		50

Mapping of Experiments with CO, PO and PSO

S.No.	Experiment Details	CO	PO	PSO
1	Installation and demonstration of open-source QGIS software, Useful commands for geo-processing, sample Vector and raster data.	1	5	
2	Creation of shape files with point features and practice in updating attribute table with necessary information	1	5	
3	Creation of shape files with line features and practice to update attribute table with necessary information	1	5	
4	Creation of shape files with polygon features and practice to update attribute table with necessary information	2	5	
5	Demonstrate vector data and raster data with examples	2	5	
6	Demonstrate the importance of map registration and projection. Discuss significance of ground control points.	2	5	
7	Demonstrate and discuss the importance of base maps and thematic maps with examples	3	2	1
8	Create shape file transport network for collection and disposal of waste from different sources like household, hotels, hospitals, etc.	3	2	1
9	Create a shape file for different types of roads using proper colour codes	4	1	
10	Create a shape file for formation of layout with complete layout features like road, waterline, sewage network, power supply network, etc.	4	1	

EXPERIMENT WISE LESSON PLAN

Experiment No.1	
Name	Installation and demonstration of open-source QGIS software, Useful commands for geo-processing, sample Vector and raster data.
Objectives	Students will able to understand how to install open source software and get use to it.
Experiment No.2	
Name	Creation of shape files with point features and practice in updating attribute table with necessary information
Objectives	Students will able to create shape with point features.
Experiment No.3	

Name	Creation of shape files with line features and practice to update attribute table with necessary information
Objectives	Students will able to create shape with line features.
Experiment No.4	
Name	Creation of shape files with polygon features and practice to update attribute table with necessary information
Objectives	Students will able to create shape with polygon features.
Experiment No. 5	
Name	Demonstrate vector data and raster data with examples
Objectives	Students will able to understand and prepare data attribute with vector and raster data
Experiment No. 6	
Name	Demonstrate the importance of map registration and projection. Discuss significance of ground control points.
Objectives	Students will able to understand the register map data with GIS.
Experiment No. 7	
Name	Demonstrate and discuss the importance of base maps and thematic maps with examples
Objectives	Students will able to create shape and preparation of base map.
Experiment No. 8	
Name	Create shape file transport network for collection and disposal of waste from different sources like household, hotels, hospitals, etc.
Objectives	Students will able to create shape with line feature and transport network.
Experiment No.9	
Name	Create a shape file for different types of roads using proper colour codes
Objectives	Students will able to create shape with line with colour codes.
Experiment No.10	
Name	Create a shape file for formation of layout with complete layout features like road, waterline, sewage network, power supply network, etc.
Objectives	Students will able to create shape with different feature.

LIST OF EXPERIMENTS

S. No.	Experiment	Page. No
1	Installation and demonstration of open-source QGIS software, Useful commands for geo-processing, sample Vector and raster data.	1
2	Creation of shape files with point features and practice in updating attribute table with necessary information	12
3	Creation of shape files with line features and practice to update attribute table with necessary information	14
4	Creation of shape files with polygon features and practice to update attribute table with necessary information	16
5	Demonstrate vector data and raster data with examples	18
6	Demonstrate the importance of map registration and projection. Discuss significance of ground control points.	19
7	Demonstrate and discuss the importance of base maps and thematic maps with examples	21
8	Create shape file transport network for collection and disposal of waste from different sources like household, hotels, hospitals, etc.	23
9	Create a shape file for different types of roads using proper colour codes	23
10	Create a shape file for formation of layout with complete layout features like road, waterline, sewage network, power supply network, etc.	24
11	Create a shape file for formation of layout with complete layout features like road, waterline, sewage network, power supply network, etc.	25
12	Virtual lab To extract the topographical features and delineate watershed from the Shuttle Radar Topographic Mission (SRTM) Digital Elevation Method.	26

LAB SAFETY & USAGE INSTRUCTIONS

1. Eating, drinking, or smoking is strictly prohibited inside the computer laboratory.
2. Do not bring liquids near computers, electrical connections, or peripherals.
3. Ensure proper handling of computers, keyboards, mouse, and UPS systems.
4. Students should maintain discipline and follow instructions given by the lab instructor.
5. Report any hardware, software, or network issues immediately to the instructor or lab staff.
6. Do not install, uninstall, or modify software settings without permission.
7. Use only authorized datasets and software provided for the laboratory exercises.
8. Save work frequently and maintain backup copies of files to avoid data loss.
9. Switch off systems properly after use and log out of user accounts.
10. Bags and personal belongings should be kept in designated areas.
11. Maintain cleanliness and ensure proper cable management around workstations.

EXPT. NO: 1

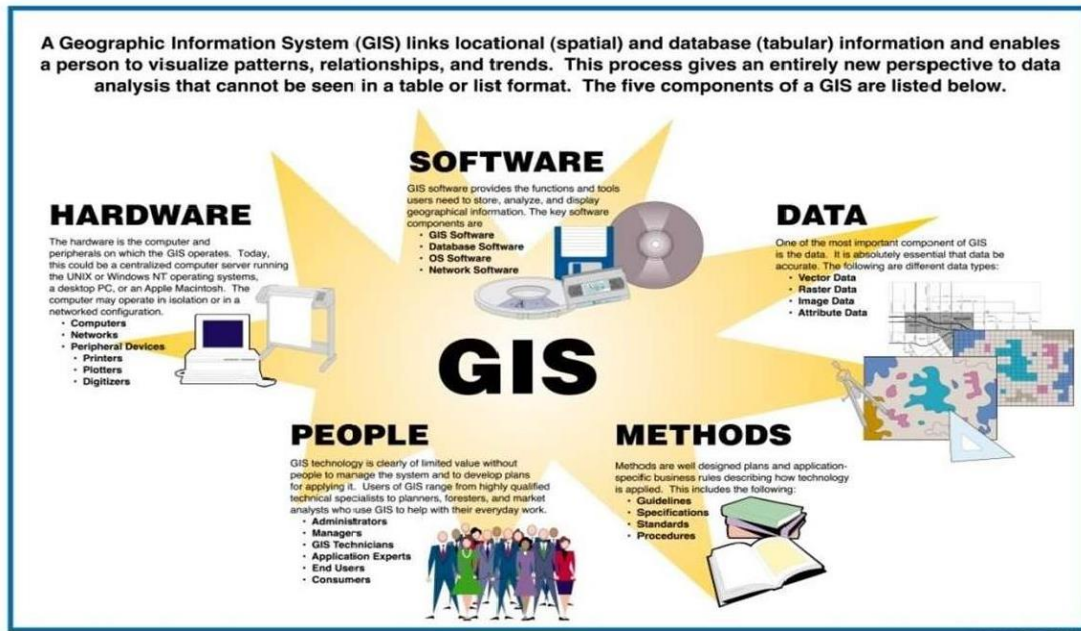
AIM: Installation and demonstration of open-source QGIS software, Useful commands for geo-processing, sample Vector and raster data.

Experiment 01

Pre-requisites to GIS Practical

What is a Geographic Information System (GIS)?

A Geographical Information System (GIS) is an organized collection of computer **hardware**, **software** and **data** used to link, analyze and display geographically referenced information.



The foundation of GIS is the ability to locate objects and events (streams, villages, disease cases) and link them with appropriate information in order to identify patterns and provide a basis for map making and analysis. Key types of geographical data, represented as separate map layers in a GIS, are outlined in the table below.

Sr. No	Data Type	Example	Layer on Map
1	POINT	Building, Hospital, City, Well.	Points
2	LINE	River, Road	Lines
3	POLYGON	Administrative Boundaries, Census tracts.	Areas
4	RASTER	Pixel or grid data	

Vector data: A representation of the world using points, lines, and polygons. Vector models are useful for storing data that has discrete boundaries, such as country borders, land parcels, and streets.

Point features: A map feature that has neither length nor area at a given scale, such as a city on a world map or a building on a city map.

Line features: A map feature that has length but not area at a given scale, such as a river on a world map or a street on a city map.

Polygon features: A map feature that bounds an area at a given scale, such as a country on a world map or a district on a city map.

Raster data: A representation of the world as a surface divided into a regular grid of cells. Raster models are useful for storing data that varies continuously, as in an aerial photograph, a satellite image, a surface of chemical concentrations, or an elevation surface.

With a GIS application you can open digital maps on your computer, create new spatial information to add to a map, create printed maps customized to your needs and perform spatial analysis.



Experiment Number 1

Installation and demonstration of open-source QGIS software, Useful commands for geo-processing, sample Vector and raster data.

11.1 Understanding qgis

What is Quantum GIS?

Quantum GIS (QGIS) is a user friendly Open Source GIS application licensed under the GNU General Public License. QGIS is an official project of the Open Source Geospatial Foundation (OSGeo). It runs on Linux, Unix, Mac OSX, Windows and Android and supports numerous vector, raster, and database formats and functionalities.

Like all GIS applications, QGIS provides a graphical user interface allowing display of map layers and manipulation of data for analyses and map-making.

A Geographical Information System (GIS) is a collection of software that allows you to create, visualize, query and analyze geospatial data. Geospatial data refers to information about the geographic location of an entity. This often involves the use of a geographic coordinate, like a latitude or longitude value. Spatial data is another commonly used term, as are: geographic data, GIS data, map data, location data, coordinate data and spatial geometry data. Applications using geospatial data perform a variety of functions. Map production is the most easily understood function of geospatial applications. Mapping programs take geospatial data and render it in a form that is viewable, usually on a computer screen or printed page. Applications can present static maps (a simple image) or dynamic maps that are customized by the person viewing the map through a desktop program or a web page.

Many people mistakenly assume that geospatial applications just produce maps, but geospatial data analysis is another primary function of geospatial applications. Some typical types of analysis include computing:

1. Distances between geographic locations
2. The amount of area (e.g., square meters) within a certain geographic region
3. What geographic features overlap other features?
4. The amount of overlap between features
5. The number of locations within a certain distance of another
6. and so on...

These may seem simplistic, but can be applied in all sorts of ways across many disciplines. The results of analysis may be shown on a map, but are often tabulated into a report to support management decisions. The recent phenomena of location-based services promises to introduce all sorts of other features, but many will be based on a combination of maps and analysis. For example, you have a cell phone that tracks your geographic location. If you have the right software, your phone can tell you what kinds of restaurants are within walking distance. While this is a novel application of geospatial technology, it is essentially doing geospatial data analysis and listing the results for you.

11.2 System Requirements

Windows OS:

Minimum: Pentium III / 256 MB RAM.

Recommended: 1GB of RAM and 1.6GHz processor.

Operation System: Platforms Windows and Linux (WinXP, Windows 7, Linux Suse 8.2/9.0/9.2, Linux Debian (Ubuntu))
MAC OS:
PC/Desktop with at least Pentium IV Tiger OS, Leopard OS.

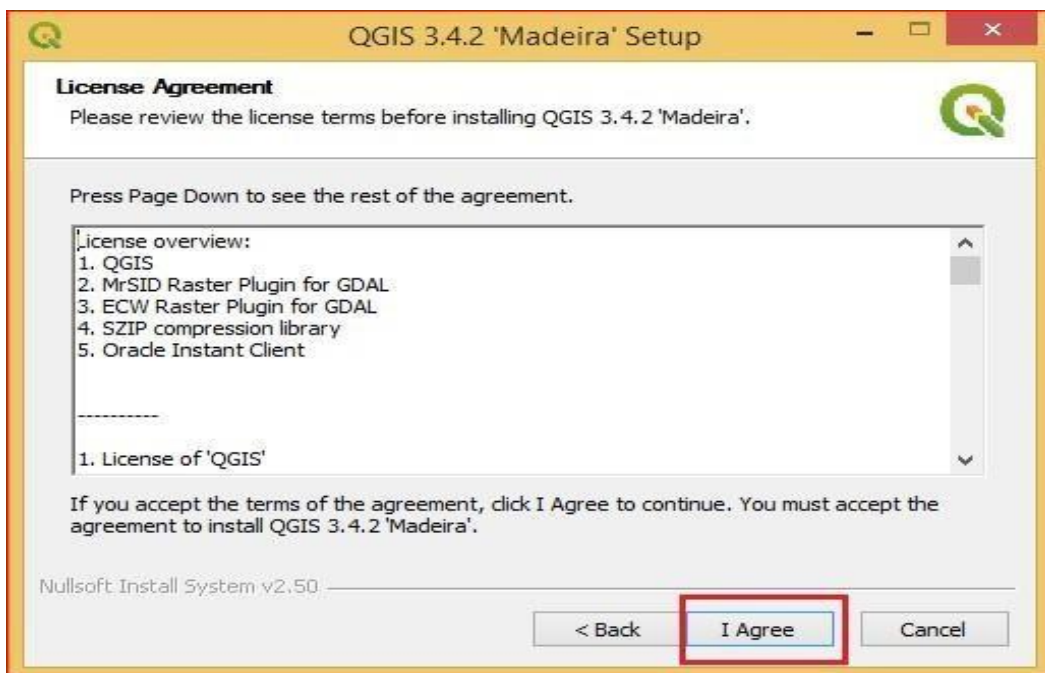
11.3 Installation of QGIS

Step By step procedure

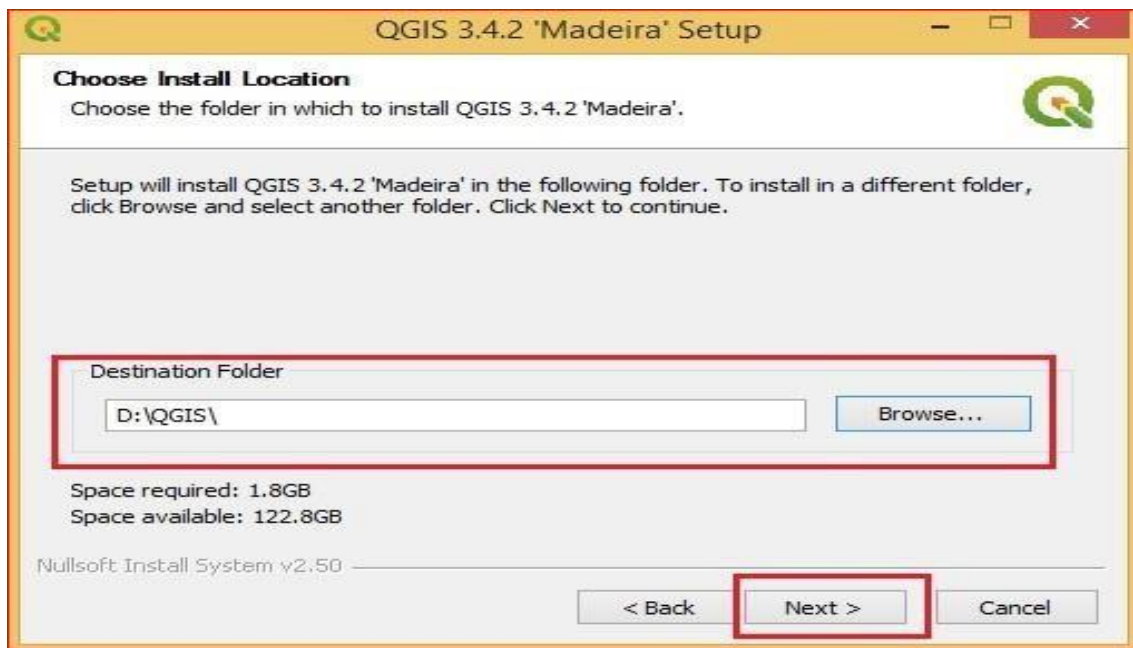
- 1) Create a folder on your D:/ drive on your computer called QGISlab by right clicking on the D: drive and navigating down to the New / Folder.
- 2) Go to the QGIS download page and download the latest 64 bit version of QGIS for windows which is QGIS 3.4 'Madeira' by clicking once.
- 3) If you have a 32 bit machine or using another operating system search the bottom of the page for your operating system and download the correct operating system version of QGIS.
<http://www.qgis.org/en/site/forusers/download.html>
- 4) Your browser will download the file to the browser's default download directory. By pressing the control key and the letter J at the same time a pop up window will show you the folder where the QGIS file has been downloaded. The QGIS file will be called:
[QGIS-OSGeo4W-3.4.2-1-Setup-x86.exe](#)
- 5) Move or copy the above file to your C:/QGISlab folder and double click on the file. You will get a pop up window with a security warning.
- 6) Hit the run button to start the installation process and follow the prompts. There is no need to install the data sets suggested by QGIS.



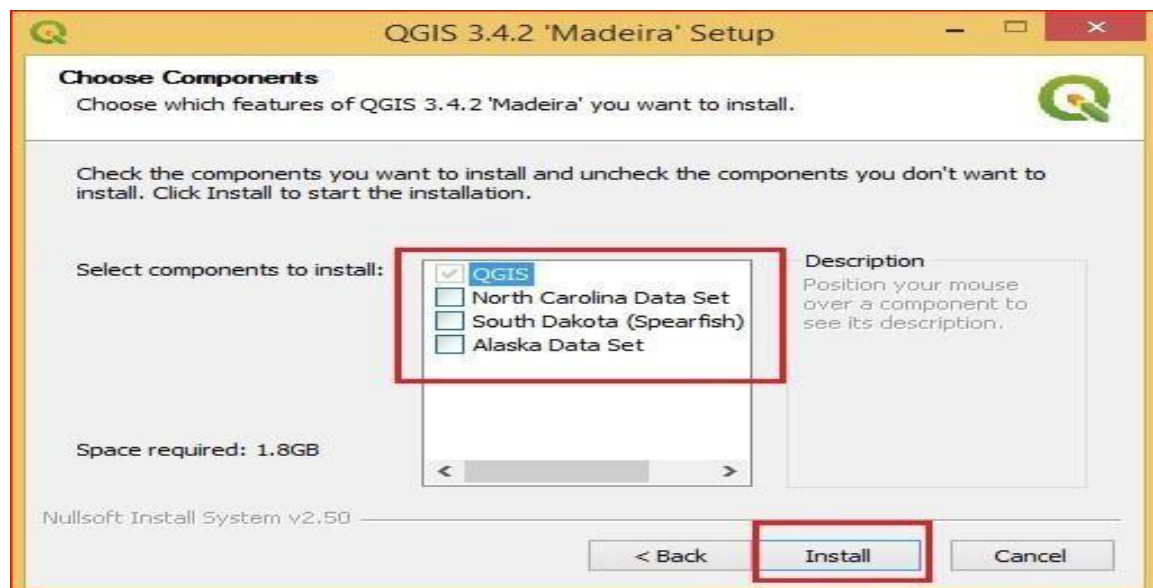
- 7) From the above window, click Next button and continue with the installation.
- 8) Please go through the license agreement and click on the button > I agree and proceed with the installation as shown in the screen.



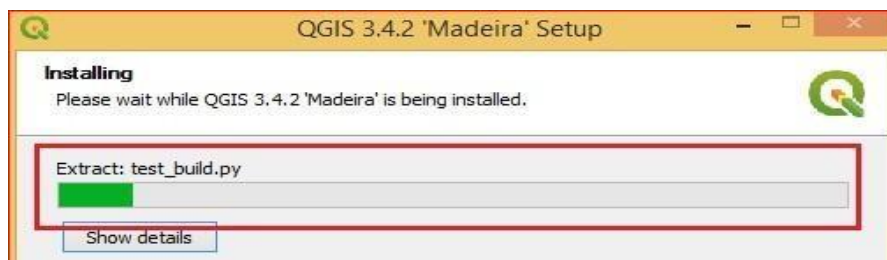
- 9) As the software is very heavy, it is advisable to install it in a different drive other than the windows drive. As per our example, we will be installing in QGIS folder on D:\ drive.



- 10) After browsing the folder click the Next button and proceed with the installation as shown in above figure.
- 11) By default QGIS component is selected. Do not install any other dataset at this point. Click Install to proceed with installation.



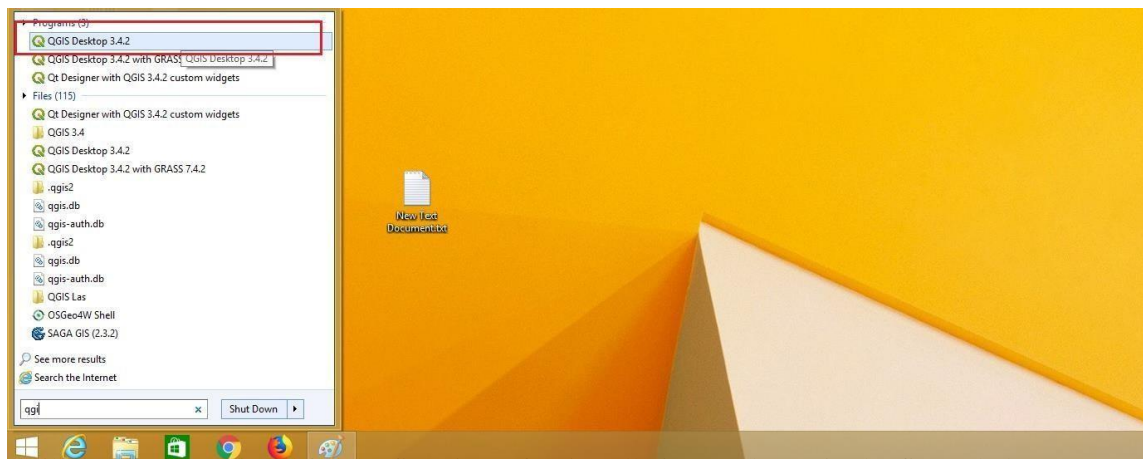
- 12) You will see the progress of the installation on the screen.



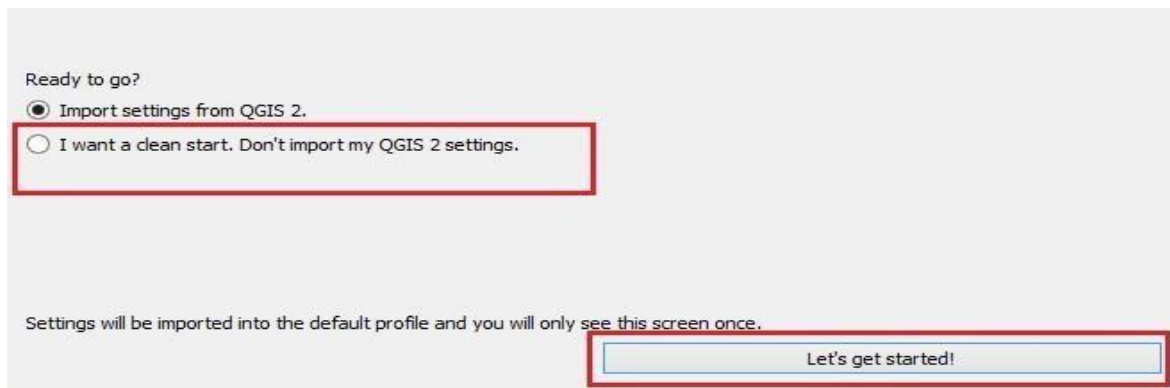
13) Please reboot your machine once the installation is completed. Click finish to complete the installation.



14) After machine is restarted, type QGIS on Run and open QGIS Desktop 3.4.2.

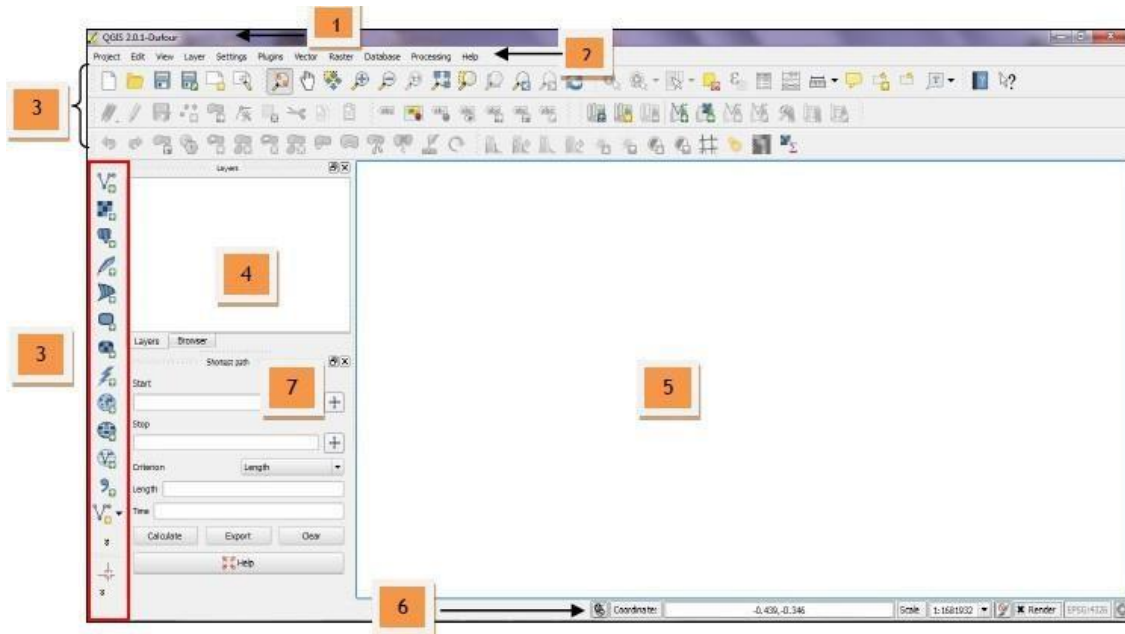


15) It will open a new wizard for the first time after installation as shown in the figure below.



16) Select I want a clean start. Don't import my QGIS 2 settings and click on let's get started button. You will be redirected now to the home screen of QGIS Desktop.

Understanding QGIS Desktop Environment.



Quantum GIS interfaces change from one project to another depending on the required interface of the project. Below are the basic menus that you will encounter in Quantum GIS during the practicals.

1. **Title of the Project** - Shows the title of the project that you are going to view.
2. **Menu Bar** - This provides access to various Quantum GIS features using a standard hierarchical menu.
3. **Toolbars** - These provide access to most of the same functions as the menus, plus additional tools for interacting with the map. It shows the command for zoom in, zoom out, pan, back to original view, go back to previous extent, go to next extent, object-information, coordinate read-out, measure, print and help.
4. **Table of Contents/Map Legend (TOC)** - Shows the layers that can be turned on or off and the legend, attributes symbols and query symbols available for the corresponding project.
5. **Display Window** - Shows the feature/s that you have to turn on from the TOC.
6. **Status Bar** - Shows you your current position in map coordinates (e.g. metres or decimal degrees) as the mouse pointer is moved across the map view. To the left of the coordinate display in the status bar is a small button that will toggle between showing coordinate position or the view extents of the map view as you pan and zoom in and out.
7. **Data sources browser** - In previous versions, QGIS browser was only provided as an external application which enables us to explore our spatial data sets. In QGIS 2.0.1-Dufour this application is also integrated in the QGIS framework as an additional panel just below the Table of Contents.

11.4 Quantum GIS tool bars and some other components

Toolbars are divided by thematic (greyed icons means they are inactive because the appropriate conditions to use them are not fulfilled). Some of them are included by default in QGIS and others can be added/removed from the interface:

Table of Contents. Menu

Turns layer on or off

Click the box to turn on or off the layer/s.



Folder icon in the TOC

This represents a group of layers in the TOC.



Grayed colour means only selected layers are visible in the group of layers.



Navigation toolbars

Zoom in

Click once in the map to zoom in or drag a box over the particular area.



Zoom out

Click once in the map.



Panning

Click in the map, hold down the mouse button, and drag in any direction.



Zoom to Full

Click to return to default view or view the full map layer/s.



Zoom to Selection

Click to view the selected part of map layer/s.



Zoom to Layer

Click to view a particular map layer.



Object Information

Identify Features

Click to activate and point to the layers you want to view the information.



Open Attribute Table

Click to open the attribute table of a layer.



Experiment 2

Creation of shape files with point features and practice in updating attribute table with necessary information

2.1 Aim:

To create shape file with point feature to identify the location of given map.

2.2 Requirement:

- QGIS Software 2.16.13
- Geo-referenced Map of Raichur Area 67/31

2.3 Procedure:

Once we have created the map, you may want to point people to specific locations that contain essential information. To do this, you must create a new layer. So, let's begin.

1. You'll have to create a new shapefile point layer with a name field as well.
2. Go to Layer > Create Layer > New Shapefile Layer.
3. Your "Point" type is already selected.
4. Add a name field.
5. Leave "Type" as the default: "Text data".
6. Leave the Length (as in character length) as the default: 80
7. Select the "Add to fields list" tab.
8. Select "OK".
9. Once the "Save layer as..." dialogue box appears, browse to the location where you want to save the new point shape file layer, which should be the same folder as the other layers for your map.
10. Once saved – use a name that makes more sense than "test" -- the layer should appear in your QGIS "Layers Panel" to the left.
11. Right click and choose Toggle Editing from the short-cut menu.
12. As you can see in the screen grab above and to the right, selecting Toggle Editing produces a pencil icon to the right of the "Layers Panel", which we're calling "Test".
13. Make sure your new layer is still highlighted, and in the toggle editing mode.
14. Click on the "Add Feature" points layer on the menu above the layers panel.
15. Once "Add Feature" is selected, click the area on the map where you want to add a point. You should see a dialogue box popup.
16. Fill in the "id" box with a number (not a letter), add a name – again, one the makes more sense than the one in the screen grab below -- in the "Test – Features Attributes" dialog box.
17. Fill out the box and select OK.
18. Your new layer contains one point. You can always add more by using the same process. But for now, let's stick to one point, which is the area on the map you want to highlight for the purposes of your story.

19. Right click the new layer and select Properties > Labels. Select Show labels for this layer and the name field for the point.
20. Select OK.
21. Right click the new layer to produce your short-cut menu.
22. Select the "Toggle Editing" option, a process also known as "toggling off".
23. This produces a "Stop editing" dialogue box.
24. Save your edits.
25. We're almost there. As we can see in step 20, our new layer is difficult to spot on the map, which means we want to increase the size and change the icon from a point to a symbol that stands out more.
26. To do this, right click on the layer in your "Layers Panel".
27. Right click on the layer to see the contents the attribute table.
28. The name in the "Test" column is what will appear on the map. But to make the new area easier to see, we'll have to go through a few more steps.
29. Choose the "Properties" option from the short-cut menu.
30. Choose the "Style" option.
31. You can increase the size, change the colour and obtain different icons.
32. Once you're satisfied with your choices, select the "Apply" tab to see how the result displays on the map. If you're happy with the result, select OK.
33. You've successfully created a new layer that points people to the exact area on the map that you want them to see.

2.4 Observation

Attribute table with necessary information

Sl. No	Point feature	ID	Details
01	Loc1	1	X: 74.45.32 Y: 15.32.45
02	Loc2	2	X: 75.45.32 Y: 16.32.45

2.5 Results/ conclusion

The given map Raichur feature created with point information and location were extracted using shape file.

Experiment 3

Creation of shape files with line features and practice to update attribute table with necessary information

2.1 Aim:

To create shape file with line feature to identify the location of given map.

2.2 Requirement:

- QGIS Software 2.16.13
- Geo-referenced Map of Raichur Area 67/31

2.3 Procedure:

Once we have created the map, you may want to line people to specific locations that contain essential information. To do this, you must create a new layer. So, let's begin.

1. You'll have to create a new shapefile line layer with a name field as well.
2. Go to Layer > Create Layer > New Shapefile Layer.
3. Your "Line" type is already selected.
4. Add a name field.
5. Leave "Type" as the default: "Text data".
6. Leave the Length (as in character length) as the default: 80
7. Select the "Add to fields list" tab.
8. Select "OK".
9. Once the "Save layer as..." dialogue box appears, browse to the location where you want to save the new line shape file layer, which should be the same folder as the other layers for your map.
10. Once saved – use a name that makes more sense than "test" -- the layer should appear in your QGIS "Layers Panel" to the left.
11. Right click and choose Toggle Editing from the short-cut menu.
12. As you can see in the screen grab above and to the right, selecting Toggle Editing produces a pencil icon to the right of the "Layers Panel", which we're calling "Test".
13. Make sure your new layer is still highlighted, and in the toggle editing mode.
14. Click on the "Add Feature" lines layer on the menu above the layers panel.
15. Once "Add Feature" is selected, click the area on the map where you want to add a line. You should see a dialogue box popup.
16. Fill in the "id" box with a number (not a letter), add a name – again, one the makes more sense than the one in the screen grab below -- in the "Test – Features Attributes" dialog box.
17. Fill out the box and select OK.

18. Your new layer contains one line. You can always add more by using the same process. But for now, let's stick to one line, which is the area on the map you want to highlight for the purposes of your story.
19. Right click the new layer and select Properties > Labels. Select Show labels for this layer and the name field for the line.
20. Select OK.
21. Right click the new layer to produce your short-cut menu.
22. Select the "Toggle Editing" option, a process also known as "toggling off".
23. This produces a "Stop editing" dialogue box.
24. Save your edits.
25. We're almost there. As we can see in step 20, our new layer is difficult to spot on the map, which means we want to increase the size and change the icon from a line to a symbol that stands out more.
26. To do this, right click on the layer in your "Layers Panel".
27. Right click on the layer to see the contents the attribute table.
28. The name in the "Test" column is what will appear on the map. But to make the new area easier to see, we'll have to go through a few more steps.
29. Choose the "Properties" option from the short-cut menu.
30. Choose the "Style" option.
31. You can increase the size, change the colour and obtain different icons.
32. Once you're satisfied with your choices, select the "Apply" tab to see how the result displays on the map. If you're happy with the result, select OK.
33. You've successfully created a new layer that lines people to the exact area on the map that you want them to see.

2.4 Observation

Attribute table with necessary information

Sl. No	Line feature	ID	Details	Length
01	Road	1	First X: 74.45.32 Y: 15.32.45 Last X: 75.45.22 Y: 16.35.45	2.3km
02	Power line	2	First X: 75.45.32 Y: 16.32.45 Last X: 75.46.32 Y: 16.33.45	5.2km

2.5 Results/ conclusion

The given map Raichur feature created with line information and location were extracted using shape file.

Experiment 4

Creation of shape files with polygon features and practice to update attribute table with necessary information

2.1 Aim:

To create shape file with polygon feature to identify the location of given map.

2.2 Requirement:

- QGIS Software 2.16.13
- Geo-referenced Map of Raichur Area 67/31

2.3 Procedure:

Once we have created the map, you may want to polygon people to specific locations that contain essential information. To do this, you must create a new layer. So, let's begin.

1. You'll have to create a new shapefile polygon layer with a name field as well.
2. Go to Layer > Create Layer > New Shapefile Layer.
3. Your "Line" type is already selected.
4. Add a name field.
5. Leave "Type" as the default: "Text data".
6. Leave the Length (as in character length) as the default: 80
7. Select the "Add to fields list" tab.
8. Select "OK".
9. Once the "Save layer as..." dialogue box appears, browse to the location where you want to save the new polygon shape file layer, which should be the same folder as the other layers for your map.
10. Once saved – use a name that makes more sense than "test" -- the layer should appear in your QGIS "Layers Panel" to the left.
11. Right click and choose Toggle Editing from the short-cut menu.
12. As you can see in the screen grab above and to the right, selecting Toggle Editing produces a pencil icon to the right of the "Layers Panel", which we're calling "Test".
13. Make sure your new layer is still highlighted, and in the toggle editing mode.
14. Click on the "Add Feature" lines layer on the menu above the layers panel.
15. Once "Add Feature" is selected, click the area on the map where you want to add a line. You should see a dialogue box popup.
16. Fill in the "id" box with a number (not a letter), add a name – again, one the makes more sense than the one in the screen grab below -- in the "Test – Features Attributes" dialog box.
17. Fill out the box and select OK.

18. Your new layer contains one line. You can always add more by using the same process. But for now, let's stick to one line, which is the area on the map you want to highlight for the purposes of your story.
19. Right click the new layer and select Properties > Labels. Select Show labels for this layer and the name field for the line.
20. Select OK.
21. Right click the new layer to produce your short-cut menu.
22. Select the "Toggle Editing" option, a process also known as "toggling off".
23. This produces a "Stop editing" dialogue box.
24. Save your edits.
25. We're almost there. As we can see in step 20, our new layer is difficult to spot on the map, which means we want to increase the size and change the icon from a polygon to a symbol that stands out more.
26. To do this, right click on the layer in your "Layers Panel".
27. Right click on the layer to see the contents the attribute table.
28. The name in the "Test" column is what will appear on the map. But to make the new area easier to see, we'll have to go through a few more steps.
29. Choose the "Properties" option from the short-cut menu.
30. Choose the "Style" option.
31. You can increase the size, change the colour and obtain different icons.
32. Once you're satisfied with your choices, select the "Apply" tab to see how the result displays on the map. If you're happy with the result, select OK.
33. You've successfully created a new layer that lines people to the exact area on the map that you want them to see.

2.4 Observation

Attribute table with necessary information

Sl. No	Polygon feature	ID	Details	Area
01	Pond	1	X: 74.45.32 Y: 15.32.45	1.35HA
02	Drainage basin	2	X: 75.45.32 Y: 16.32.45	4.2HA

2.5 Results/ conclusion

The given map Raichur feature created with polygon information and location were extracted using shape file.

Experiment 5

Demonstrate vector data and raster data with examples

5.1 Aim:

To demonstrate vector data and raster data with examples of shape file given map.

5.2 Requirement:

- QGIS Software 2.16.13
- Karnataka Map (Raster and Vector)

5.3 Procedure:

- Add raster and vector layer in QGIS.
- Set base map for the area.
- Select Karnataka map using KA_boudry
- Choose KA_dist for minimize the polygone the area.
- Select feature as selection for entire base.
- Using above icon select required area.
- Example selected in Belagavi district as polygone.
- Select option as identification features.
- Using layers select vector layer cut the area which is selected.
- Now paste the area which is selected for the demarking.
- Once the area is demarked save as different layer.
- Add raster layer in to selected basin examples Roads, Points.
- Use print composer prepare map according to the basin.
- Add XY, Legends, and Directions.

5.4 Observation

Attribute table with necessary information

Sl. No	Polygon feature	ID	Details	Area
01	Belagavi	1	X: 74.45.32 Y: 15.32.45	Polygon
02	Source road	2	X: 75.45.32 Y: 16.32.45	line
03	Zila panchayat office	3	X: 75.45.22 Y: 16.32.25 X: 75.45.45 Y: 16.32.48	Point

5.5 Results/ conclusion

The given map Karnataka feature created with polygon information and locations, Roads and district polygone were extracted using shape file.

Experiment 6

Demonstrate the importance of map registration and projection. Discuss significance of ground control points.

5.1 Aim:

To demonstrate map registration and projection

5.2 Requirement:

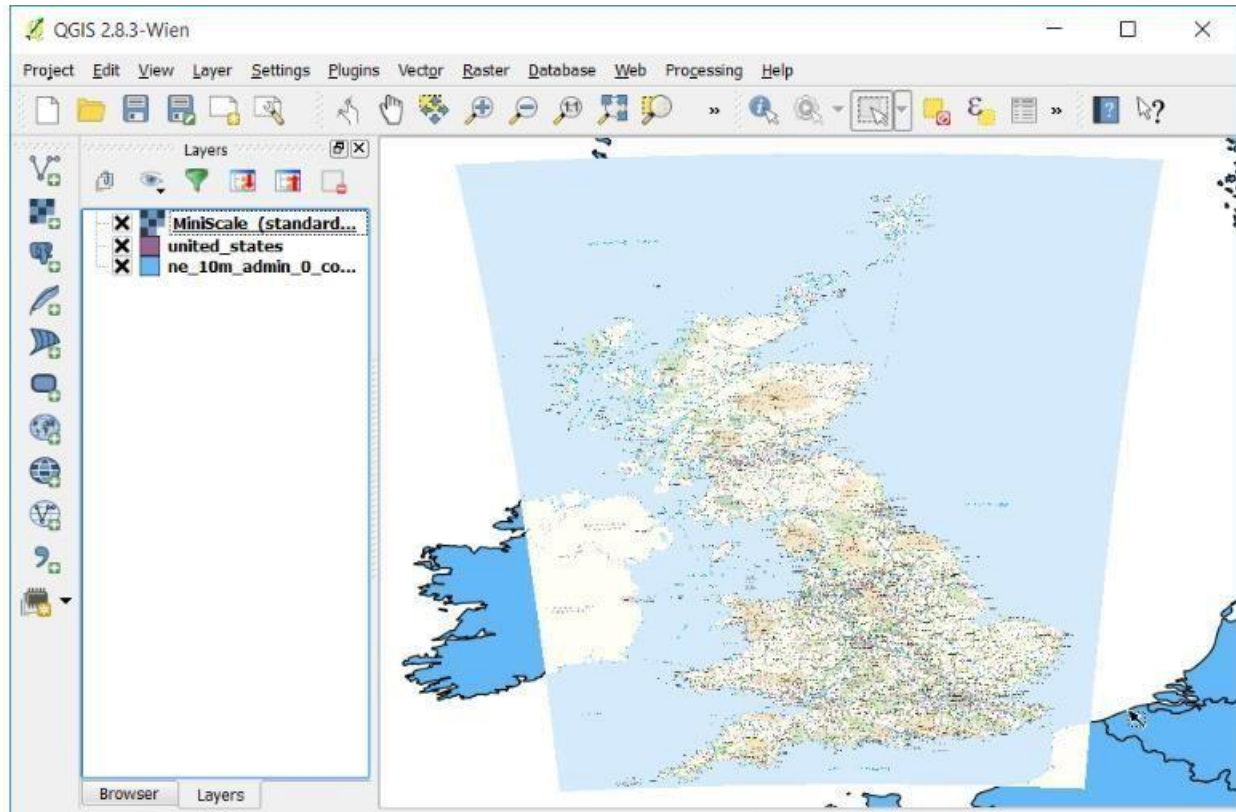
- QGIS Software 2.16.13
- India map with TOPOSHEET RAICHURU registration ID.

5.3 Procedure:

- Open QGIS. Go to Layer ▶ Add Layer ▶ Add Vector Layer
- Browse to the downloaded `ne_10m_admin_0_countries.zip` file and click Open.
- At the bottom of QGIS window, you will notice the label Coordinate. As you move your cursor over the map, it will show you the X and Y coordinates at that location. At the bottom-right corner you will see EPSG:4326. This is the code for the current CRS (Projection) for the project.
- As you will later see, the project's CRS may not match the layer's CRS. To determine a layer's projection, we can look into the metadata. Right click on `ne_10m_admin_0_countries` layer and select Properties.
- Switch to the Metadata tab in the Layer Properties dialog. Expand the Properties section. At the bottom, you will see the definition for the projection under Layer Spatial Reference System. This definition is in the [PROJ.4 format](#).
- Now let's see how we can change the layer's projection. This operation is called **Re-Projection**. Rather than re-projecting the entire layer, we can also re-project some features from the layer. Use the Select features by area or single click tool and click on United States feature to select it
- In the Save vector layer as... dialog, name the output layer as `united_states.shp`. Also check the Save only selected features box. This will ensure that only the selected feature gets re-projected and exported. Next, we choose the new projection for the layer. Click on the Select CRS button.
- Once the re-projected layer gets loaded, you will notice that the new INDIA layer overlays perfectly on top of `ne_10m_admin_0_countries` layer - even though they are in different projections. This is because QGIS has a feature called **On-the-fly CRS transformation**. The projection text at the bottom-right of QGIS now has the words **OTF** next the EPSG:4326. To learn more, let's explore the CRS option in QGIS.
- Switch to the CRS tab in the Options dialog. You will see that the default is Automatically enable „on the fly“ reprojection if the layers have different CRS. This means that when QGIS detects that you have loaded layers with different CRS, it will automatically re-project them back to a common CRS so they line up with each other. Click OK.
- In the Project Properties dialog, un-check the Enable „on the fly“ CRS transformation box and click OK.
- Back in the main QGIS window, you will see the nice World map disappear. This is because the Project CRS changed to **KARNATAK RAICHURE** and the coordinates and scale are different now. Right-click the **INDIA** layer and select Zoom to Layer
- Go to the `ESRI_TFW_FILES` folder within `georeferencing_files`. The `.tfw` files are plain text files. Open one of the `.tfw` files in a text editor.
- Copy the `MiniScale_(standard)_R17.tfw` file from the `georeferencing_files` folder to the `RGB_TIF_COMPRESSED` folder. This way the `.tfw` and the `.tif` files are in the same directory and QGIS can use the information.

- In the QGIS main windows, go to Layer ▸ Add Layer ▸ Add Raster Layer.... Browse to the **MiniScale_(standard)_R17.tif** file and click Open.
- Once the **MiniScale_(standard)_R17** layer is loaded, right-click on it and select Zoom to layer.

5.4 Observation



5.5 Results/ conclusion

The geo-referencing of the map is important to understand the levels of given data from the map where all the given data is precisely available with SCALE, COORDINATES and BLOOCK SYSTEMS.

Experiment 7

Demonstrate and discuss the importance of base maps and thematic maps with examples

7.1 Aim:

To demonstrate map base map and thematic map.

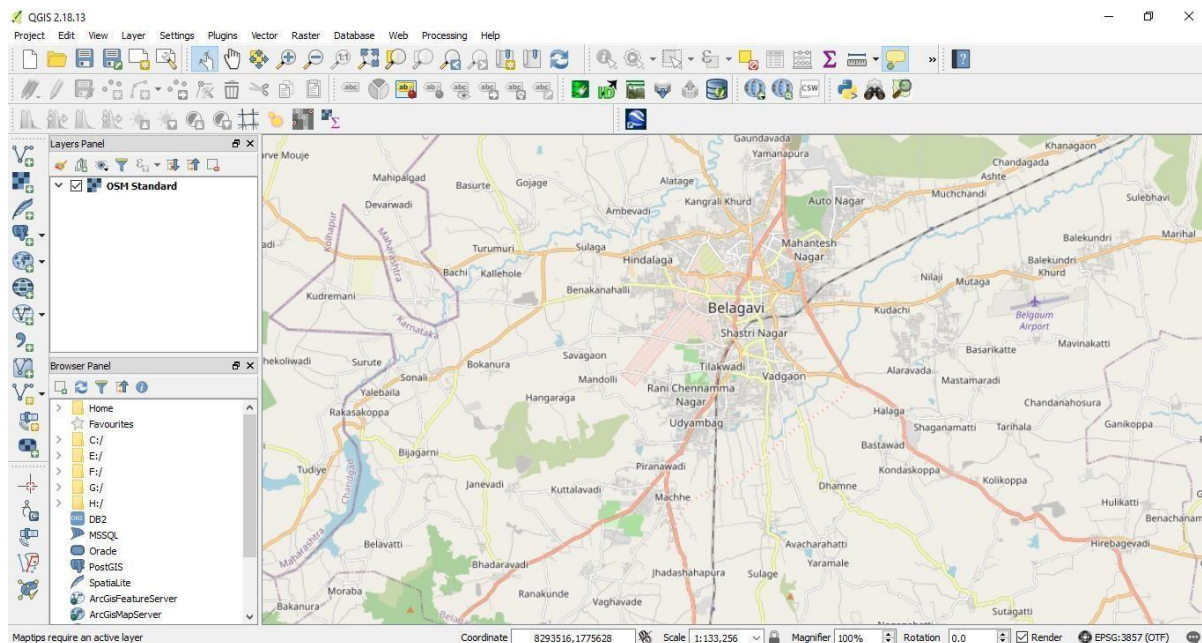
7.2 Requirement:

- QGIS Software 2.16.13
- PLUGINS QUICK MAP SERVICES.

7.3 Procedure:

- Open QGIS add download plug-in of quick map services.
- Install the quick map services.
- Select plug-in services
- Select OSM data map.
- Select OSM standard data.
- Select India in OSM data.
- In OSM data select google layer
- Extract maps as per the requirements of the area.
- Prepare point, Line and Polygone layers.
- Prepare print composer map of selected area.

7.4 Observation



7.5 Results/ conclusion

Base map in QGIS and Thematic data OSM standard maps are usefull to prepare the live data and preparation of the area.

Experiment 9

Create shape file transport network for collection and disposal of waste from different sources like household, hotels, hospitals, etc.

9.1 Aim:

To create shape file for given map and identify transport network.

9.2 Requirement:

- QGIS Software 2.16.13
- Karnataka Map (Vector)

9.3 Procedure:

- Add raster and vector layer in QGIS.
- Set base map for the area.
- Select Karnataka map using KA_boudry
- Choose KA_dist for minimize the polygone the area.
- Select feature as selection for entire base.
- Using above icon select required area.
- Example selected in Belagavi district as polygone.
- Select option as identification features.
- Using layers select vector layer cut the area which is selected.
- Now paste the area which is selected for the demarking.
- Once the area is demarked save as different layer.
- Add raster layer in to selected basin examples Roads, Points.
- Use print composer prepare map according to the basin.
- Add XY, Legends, and Directions.

9.4 Observation

Attribute table with necessary information

Sl. No	Polygon feature	ID	Details	Area
01	Belagavi	1	X: 74.45.32 Y: 15.32.45	Polygon
02	Source road	2	X: 75.45.32 Y: 16.32.45	line

9.5 Results/ conclusion

The given map Karnataka feature created with polygon information Roads and district polygone were extracted using shape file.

Experiment 10

Create a shape file for different types of roads using proper colour codes

10.1 Aim:

To create shape file for given map and identify different types of roads and colour codes.

10.2 Requirement:

- QGIS Software 2.16.13
- Karnataka Map (Vector)

10.3 Procedure:

- Add raster and vector layer in QGIS.
- Set base map for the area.
- Select Karnataka map using KA_boudry
- Choose KA_dist for minimize the polygone the area.
- Select feature as selection for entire base.
- Using above icon select required area.
- Example selected in Belagavi district as polygone.
- Select option as identification features.
- Using layers select vector layer cut the area which is selected.
- Now paste the area which is selected for the demarking.
- Once the area is demarked save as different layer.
- Add raster layer in to selected basin examples Roads, Points.
- Use print composer prepare map according to the basin.
- Add XY, Legends, and Directions.

10.4 Observation

Attribute table with necessary information

Sl. No	Polygon feature	ID	Details	Area
01	Belagavi	1	X: 74.45.32 Y: 15.32.45	Polygon
02	Source road	2	X: 75.45.32 Y: 16.32.45	line

10.5 Results/ conclusion

The given map Karnataka feature created with polygon information Roads and district polygone were extracted using shape file.

Experiment 11

Create a shape file for formation of layout with complete layout features like road, waterline, sewage network, power supply network, etc.

11.1 Aim:

To create shape file for given map and identify layout features.

11.2 Requirement:

- QGIS Software 2.16.13
- Karnataka Map (Vector)

11.3 Procedure:

- Add raster and vector layer in QGIS.
- Set base map for the area.
- Select Karnataka map using KA_boudry
- Choose KA_dist for minimize the layout of the area.
- Select feature as selection for entire base.
- Using above icon select required area.
- Example selected in Belagavi district as polygone.
- Select option as identification features.
- Using layers select vector layer cut the area which is selected.
- Now paste the area which is selected for the demarking.
- Once the area is demarked save as different layer.
- Add raster layer in to selected basin examples Roads, Points.
- Use print composer prepare map according to the basin.
- Add XY, Legends, and Directions.

11.4 Observation

Attribute table with necessary information

Sl. No	Polygon feature	ID	Details	Area
01	Belagavi	1	X: 74.45.32 Y: 15.32.45	Polygon
02	Source road	2	X: 75.45.32 Y: 16.32.45	line
03	drainage system	3	X: 75.45.32 Y: 16.32.45	line

11.5 Results/ conclusion

The given map Karnataka feature created with polygon information Roads and district polygone were extracted using shape file.

Virtual Lab

1.1 Aim:

To extract the topographical features and delineate watershed from the Shuttle Radar Topographic Mission (SRTM) Digital Elevation Method.

1.2 Theory:

An essential component of geological, geomorphological, hydrological, agricultural, and disaster planning and management is a landscape model of the planet. The Digital Elevation Models (DEM) give a digital representation of surface characteristics as elevation, slope, terrain relief, aspect, and curvature. The simplicity of use and excellent spatial resolution of open-source DEMs have demonstrated considerable promise as an alternative to conventional surveying techniques. The raster value in each cell indicates the elevation of the at particular location. The quality of a DEM is determined by the precision with which the elevation is represented at each pixel (absolute accuracy) and by the precision with which the morphology is represented (relative accuracy). A number of factors such as roughness of the landscape, the number of elevation samples taken, the size/resolution of the pixels, interpolation, will affect the quality of DEMs and terrain analysis algorithm used vertical resolution.

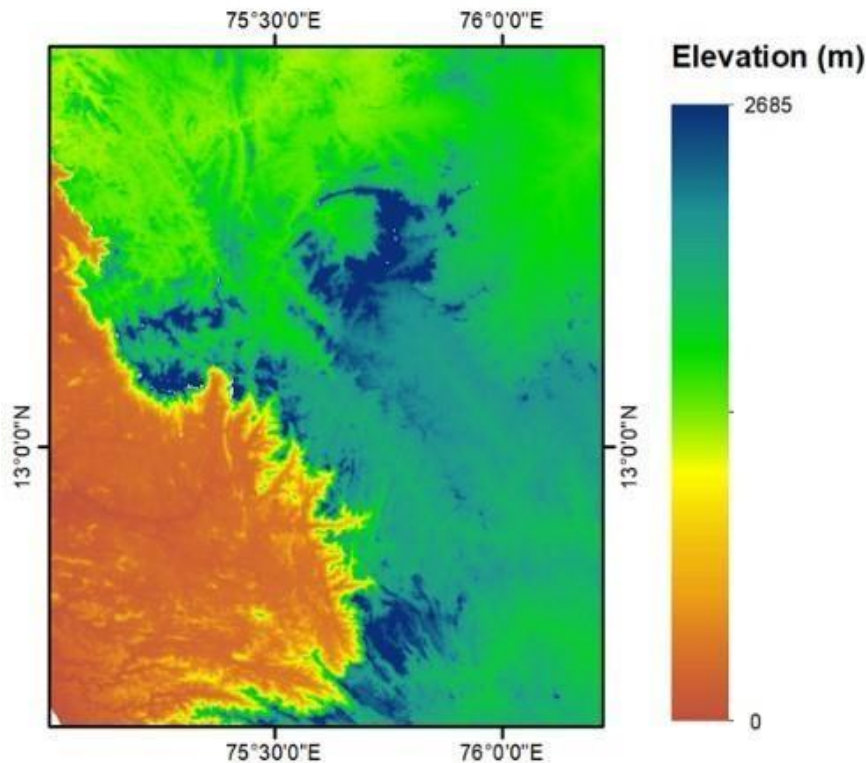


Figure: The DEM representing spatial variation in the elevation

The DTM is a DEM that represents the topography of the bare earth surface. Digital Surface Model (DSM) is a DEM of the shape of the surface, including vegetation, infra-structures etc on the earth surface. The difference in the DTM and DSM are shown in below figure.

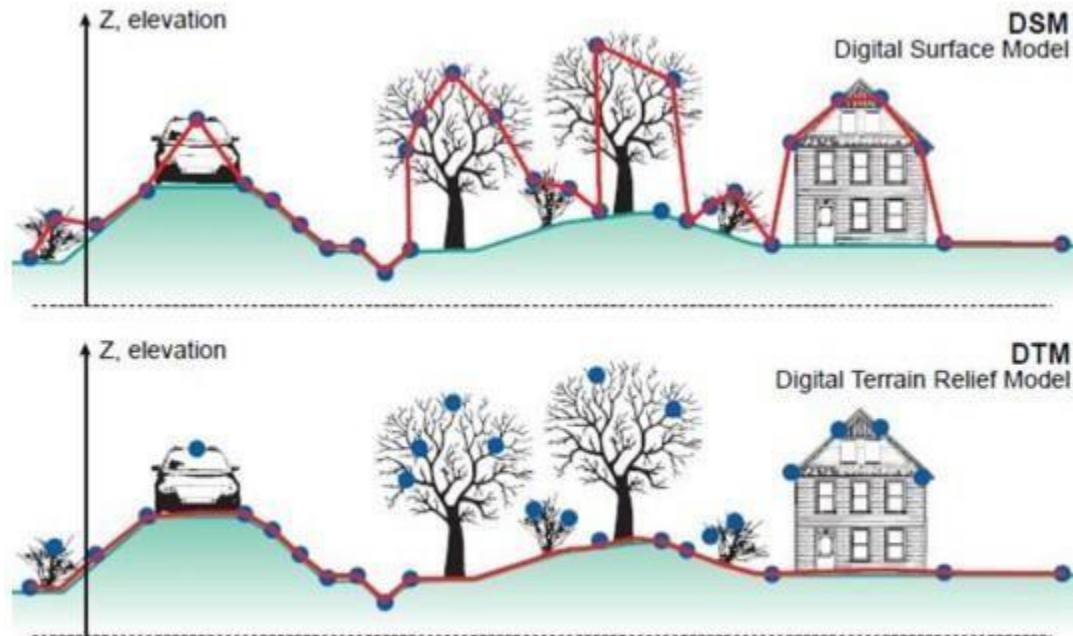


Figure: The representation of DTM and DSM

Shuttle Radar Topography Mission (SRTM) DEM of 30 m and 90 m <https://earthexplorer.usgs.gov/>, Advanced Space Borne Thermal Emission and Reflection Radiometer (ASTER)-Global DEM of 30 m <https://earthexplorer.usgs.gov/>, ALOS world-3D of 12.5m and 30 m <https://global.jaxa.jp/>, CARTOSAT-1 an Indian national DEM of 30 m resolution https://bhuvan.nrsc.gov.in/bhuvan_links.php, TanDEM-X of 90 m resolution <https://tandemx-science.dlr.de/> are freely available for the user community. From these the Elevation, Slope, Roughness, Aspect, Hillshade, Curvature, Contours can be derived. Also, the river basins can be extracted after carrying out the watershed delineation process. The detailed methodology to extract the below highlighted features are explained in the simulation.

- **Elevation:** Represents the height from the Mean Sea level for each raster cell.
- **Slope:** The degree of inclination of a terrain surface. It represents the rate of change of elevation.
- **Hillshade:** A technique used to visualize terrain as shaded relief.
- **Aspect:** The downslope direction of the maximum rate of change in value from each pixel to its neighbours, measured clockwise in degrees from 0 to 360.

1.3 Procedure

1. Click on the experiment, a window will open with objective. Click on description tab to understand the terminology in the experiment, click on the NEXT button to proceed.
2. Click on the Choose Map tab to select the map provided to proceed.
3. Click on the Color Ramp tab to select either of the colour ramp provided to proceed.
4. After selecting the Color Ramp click on the image to select the map then select a symbology.
5. Click on the DEM Derivatives, a subtab will be displayed. Select one of them, then click on the required symbology, hover on legend tab to view the legend.
6. To view the slope, Hillshade and Aspect select the data then give OK. Now click on the required symbology, hover on legend tab to view the legend.
7. To view the Fill, Flow Direction and Flow Accumulation, select the data then give OK. Now click on the required symbology, hover on legend tab to view the legend.
8. Click on the Stream Network to view the river Network flow.
9. Click on the watershed to view Basins.
10. Click on the selected map to view a subbasins.

1.4 Conclusion

