CIVIL ENGINEERING LABORATORY-II LAB MANUAL

SEMESTER-5TH

DEPARTMEMT OF CIVIL ENGINEERING
GOVERNMENT POLYTECHNIC
NABARANGPUR

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LABORATORY RULES AND REGULATIONS

General Rules

1. Be alert and proceed with caution at all times in the laboratory
2. Do not touch any equipment, other materials in the laboratory area until you are instructed to do so.
3. Do not operate machinery unless you have received instructions on their correct usage
4. Students are not allowed to do any load test on test frame, without supervision by the project supervisor
5. Clear away the rubbish and clean up the work area and apparatus provided for each experiment after use.
6. Clean up the machine after use.
7. Do not abuse the equipment and tools.
8. Any damage to equipment or apparatus must be reported immediately to the duty personnel.
9. Waste material should be disposed off properly.
10. Exercise extreme care when handling sharp-pointed or sharp-edged tools.
11. All accidents that occur in the laboratory must be reported.
12. Report all breakage, and tools and machines that are faulty.
13. Do not use tools that are blunt or in poor condition.
14. You must always concentrate/ focus on your work and know where the Emergency switch is located.

EXPERIMENT NO-1

DETERMINATION OF SPECIFIC GRAVITY OF SOISOLIDS BYPYCNOMETER METHOD

Aim: To determine the specific gravity of soil solids by Pycnometer bottle method

Specific gravity is the ratio of the mass of unit volume of soil at a statedtemperature to the mass of the same volume of gas-free distilled water at a stated temperature.

Specification:

This test is specified in IS: 2720 (Part 4) – 1985. A soil's specific gravity largely depends on the density of the minerals making up the individual soil particles. However, as a general guide, some typical values for specific soil types are as follows:

- The specific gravity of the solid substance of most inorganic soils varies between 2.60 and 2.80.
- Tropical iron-rich laterite, as well as some lateritic soils, usually have a specific gravity of between 2.75 and 3.0 but could behigher.
- Sand particles composed of quartz have a specific gravity ranging from 2.65 to 2.67.
- Inorganic clays generally range from 2.70 to 2.80.
- Soils with large amounts of organic matter or porous particles (such as diatomaceous earth) have specific gravities below 2.60. Some range as low as 2.00.

Equipments Required:

a) Pycnometer of about 1 litre capacity.

b) Balance accurate to 1g, glass rod, de-aired distilled water etc.

Theory:

Specific gravity of soil solids is defined as the weight of soil solids to weight of equal volume of water. In effect, it tells how much heavier (or lighter) the material is than water. This test method covers the determination of the specific gravity of soil solids that pass 4.75 mm sieve.

Equation for specific gravity, G:

$$G= (W_2-W_1)/((W_2-W_1)-(W_3-W_4))$$

Where, W_1=weight of Pycnometer in grams.

W_2=weight of Pycnometer + dry soil in grams.

W_3=weight of Pycnometer + soil+ water grams.

W_4=weight of Pycnometer + water grams.

Note: This method is recommended for coarse and fine grained soils

Procedure:

a) Clean and dry the pycnometer and weigh it along with the conical cap (W1 in gm).
b) Select about 300 gm of dry soil free of clods and put the same into the pycnometre. Weigh it (W2 in g) with cap andwasher.
c) Fill the pycnometer with de-aired water up-to half its height and stir the mix with a glass rod. Add more water and stir it. Fit the screw cap and fill the pycnometer flush with the hole in the conical cap and take the weight (W3 in g).
d) Remove all the contents from the pycnometer, clean it thoroughly and fill it with distilled water. Weigh it (W4 in g).
e) Now use the above equation for determiningG.
f) Repeat the same process for additionaltests.

Table:

Table 1: Weights of Pycnometer

Sl No	Particulars	Test No 1 (G1)	Test No 2 (G2)	Test No 3 (G3)
1	Weight of Pycnometer bottle (W_1), g			
2	Weight of Pycnometer + dry soil (W_2),g			
3	Weight of Pycnometer + soil + water, (W_3), g			
4	Weight of Pycnomerter + water (W_4), g			
5	Calculation of specific gravity, G			
6	Average G = (G1+G2+G3)/3			

Specimen calculations:

$$G= (W_2-W_1)/((W_2-W_1)-(W_3-W_4))$$

Result:

AVERAGE G=

Conclusion:

The experiment is conducted as per the procedure laid down. The specific gravity of soil solids obtained is______. This value falls in the range 2.6 to 2.75. Hence the type of soil ______________________.

EXPERIMENT-2

DETERMINATION OF SPECIFIC GRAVITY OF SOIL SOLIDS BYDENSITY BOTTLE METHOD

Aim: To determine the specific gravity of soil solids by Density bottle method.

Specific gravity G is defined as the ratio of the weight of an equal volume ofdistilled water at that temperature, both weights taken in air.

Specification:

IS 2720 (Part III) – 1980 is the standard recommended to determine specific gravity of fine grained soils. The value ranges are same as the previous experiment.The average of the values obtained shall be taken as the specific gravity of the soil particles and shall be reported to the nearest 0.01 precision. If the two results differ by more than 0.03 the tests shall berepeated.

Equipments Required:

1. 50 ml capacity density bottle withstopper
2. A constant temperature water bath (27°C)
3. Oven with a range of 105 to 110°C
4. Vacuum desiccators
5. Vacuum pump
6. Other accessories, such as, weighing balance accurate to 0.001g, trays,wooden mallet etc.

Theory:

Specific gravity of soil solids is defined as the weight of soil solids to weight ofequal volume of water.

Equation for specific gravity, G:

$$G= (W_2-W_1)/((W_2-W_1)-(W_3-W_4))$$

Where, W_1= weight of empty bottle W_2=
weight of bottle + dry soil W_3=
weight of bottle + soil + waterW_4=
weight of bottle + water

Note: This method is normally used for fine-grained soils. The method may also be used for medium and coarse grained soils, if the coarse particles are grained to pass 4.75-mm IS sieve before using.

Procedure:

a) Clean and dry the density bottle and weigh it along with the stopper (W_1 in g).
b) Select about 25 gm of dry soil free of clods and put the same into the density bottle.Weigh it with brass cap and washer (W_2 in g).
c) Fill the density bottle with de-aired water up to half its height and stir the mix with a glass rod. Add more water and stir it. Place the stopper on top and take the weight (W_3 in g).
d) Remove all the contents from the density bottle, clean it thoroughly and fill it with distilled water. Weigh it (W_4 in g).
e) Use above equation for determining G.
f) Repeat the same process for additional tests.

Table:

Table 2: Weights of density bottle

Sl. No	Particulars	Test No 1 (G1)	Test No 2 (G2)	Test No 3 (G3)
1	Weight of density bottle (W_1), g			
2	Weight of bottle + dry soil (W_2), g			
3	Weight of bottle + soil + water (W_3), g			
4	Weight of bottle + water (W_4), g			
5	Specific Gravity, G			
6	Average G, (G1+G2+G3)/3			

Specimen calculations:

$$G=(W_2-W_1)/((W_2-W_1)-(W_3-W_4))$$

Result:

AVERAGE G=

.

Conclusion:

The experiment is conducted as per the procedure laid down. The specific gravityof soil solids=____________________.The value falls in the range 2.6 to 2.75.The type of soil is _______as per the specification.

EXPERIMENT NO 3

DETERMINATION OF IN-SITU DENSITY BY CORE CUTTER METHOD

Aim: To determine the field density or unit weight of soil by Core cutter method.

Field density is used in calculating the stress in the soil due to its overburden pressure. It is needed in estimating the bearing capacity of soil foundation system, settlement of footing, earth pressures behind the retaining walls and embankments. Stability of natural slopes, dams, embankments and cuts is checked with the help of density of soil. It is the density that controls the field compaction of soils. Permeability of soils depends upon its density. Relative density of cohesionless soils is determined by knowing the dry density of soil in natural, loosest and densest states. Void ratio, porosityand degree of saturation need the help of density of soil.

Specifications:

This test is done to determine the in-situ dry density of soil by core cutter methodas per IS-2720-Part-29 (1975). Core cutter method in particular, is suitable for soft to medium cohesive soils, in which the cutter can be driven. It is not possible to drive the cutter into hard and boulder soils.

Equipments Required:

1) Cylindrical core cutter, 100mm internal diameter and 130mm long.
2) Steel dolley, 25mm high and 100mm internal diameter.
3) Steel rammer mass 9kg, overall length with the foot and staff about 900mm.
4) Balance, with an accuracy of 1g.
5) Palette knife, Straight edge, steel rule etc.
6) Square metal tray – 300mm x 300mm x40mm.
7) Trowel.

Theory:

Field density is defined as weight per unit volume of soil mass in the field at in- situ conditions. In the spot adjacent to that where the field density by sand replacement method has been determined or planned, drive the core cutter using the dolley over the core cutter. Stop ramming when the dolley is just proud of the surface. Dig out the cutter containing the soil out of the ground and trim off any solid extruding from its ends, so that the cutter contains a volume of soil equal to its internal volume which is determined from the dimensions of the cutter. The weight of the contained soil is found and its moisture content determined.

Equations are;

$\rho_d = \rho_t /(1+w)$ gm/cm³

Where, ρ_d = dry density in g/cm^3,
ρ_t = field moist density in g/cm^3,w
=water content %/100,
Υ_w = density of water = 1000

Procedure:

a) Measure the height and internal diameter of the core cutter to the nearest 0.25mm.
b) Calculate the internal volume of the core-cutter V_c in cm³.
c) Determine the weight of the clean cutter accurate to 1 g (W1 in g).
d) Select the area in the field where the density is required to be found out. Clean and level the ground where the density is to be determined.
e) Place the dolley over the top of the core cutter and press the core cutter into the soil mass using the rammer. Stop the pressing when about 15mm of the dolley protrudes above the soil surface.
f) Remove the soil surrounding the core cutter by digging using spade, up to the bottom level of the cutter. Lift up the cutter and remove the dolley and trim both sides of the cutter with knife and straight edge.
g) Clean the outside surface of the cutter and determine mass of the cutter with the soil (W2 in g).
h) Remove the soil core from the cutter and take the representative sample in the water content containers to determine the moisture content.
i) The field test may be repeated at other places if required.
j) The water content of sample collected is determined in the laboratory as per Experiment no 3 (*Determination of water content of soil solids by Oven Drying Method*).
k) Use the above equation, given the theory section, for determining density of soil (ρ_d).

Observations:

Length of core cutter l=-------------------- cm

Diameter of core cutter d= ---------------- cm

Volume of core cutter=Vc= --------------- cm

Table:

Table 5: Weights of core cutter

Sl.No.	**Particulars**	**Test nos.**		
		1 (ρ_{d1})	**2** (ρ_{d2})	**3** (ρ_{d3})
1.	Weight of empty cutter (W1), g			
2.	Weight of cutter + wet soil (W2), g			
3.	Volume of core cutter (V_c) cm^3			
4.	Weight ass of empty container (W3), g			
5.	Weight of container + wet soil (W4), g			
6.	Weight of container + dry soil (W5), g			
7.	Water content (w)=(W4-W5)/(W5-W3)			
8.	Field moist density ρ_t (kN/m^3) = (W2-W1)/Vc			
9.	Dry density ρ_d (kN/m^3) = ρ_t /(1+w)			
10.	Average density, Avg ρ_d			

Specimen calculations:

Avg $\rho_d = (\rho_{d1} + \rho_{d2+}\rho_{d3})/3$

Result:

Average in-situ field dry density: =--------------

Conclusion:

The value of dry density of the soil is _. The type of soil is.

EXPERIMENT NO-4

DETERMINATION OF PARTICLE SIZE DISTRIBUTION BYSIEVING (GRAIN SIZE ANALYSIS)

Aim: To determine the particle size distribution by sieving (Grain size analysis)and to determine the fineness modulus, effective size and uniformilty coefficient.

This test is performed to determine the percentage of different grain sizes contained within a soil. The mechanical or sieve analysis is performed to determine the distribution of the coarser, larger-sized particles. The distribution of different grain sizes affects the engineering properties of soil. Grain size analysis provides the grain size distribution, and it is required in classifying the soil.

Specifications:

This test is specified in IS: 2720 (Part 4) – 1985 – Method of test for soil (Part 4-Grain size analysis).

Equipments Required:

a) Sieves of sizes: 4.75 mm, 2.0 mm, 1.0 mm, 600 , 300□ , 150□ □ and 75 □. That is, I.S 460-1962 is used. The sieves for soil tests: 4.75 mm to 75 microns.
b) Thermostatically controlledoven.
c) Trays, sieve brushes, mortar with a rubber covered pestle,etc.
d) Mechanical sieve shakeretc.

Theory:

The grain size analysis is widely used in classification of soils. The data obtained from grain size distribution curves is used in the design of filters for earth dams and to determine suitability of soil for road construction, air field etc. Information obtained from grain size analysis can be used to predict soil water movement although permeability tests are generally used. The method is applicable to dry soil passing through 4.75 mm size sieve less than 10 % passing through 75-micron sieve.

Percentage retained on any sieve =(weight of soil retained / total weight)×100 Cumulative percentage retained = sum of percentages retained on any sieve on all coarser sieves.

Percentage finer than any sieve = 100 percent minus cumulative Size, Npercentage retained.

Procedures:

a) Take a representative sample of soil received from the field and dry it in the oven.
b) Use a known mass of dried soil with all the grains properly separated out. The maximum mass of soil taken for analysis may not exceed 500g.
c) Prepare a stack of sieves. Set the sieves one over the other with an ascending order (sieves having larger opening sizes i.e., lower numbers are placed above the one with smaller opening sizes i.e., smaller numbers). The very last sieve is #200 (75µ sieve). A pan is attached to the lowest 75µ sieve to collect the portions passing #200 sieve and fit the nest to a mechanicalshaker.
d) Make sure sieves are clean. If many soil particles are stuck in the openings try to poke them out usingbrush.
e) The whole nest of sieves is given a horizontal shaking for 10 min in sieve shaker till the soil retained on each reaches a constantvalue.
f) Determine mass of soil retained on each sieve including that collected in the panbelow.

Table:

The test results obtained from a sample of soil are givenbelow.Mass of soil taken for analysis W=_______________gm

Table 7: Sieve Analysis data sheet

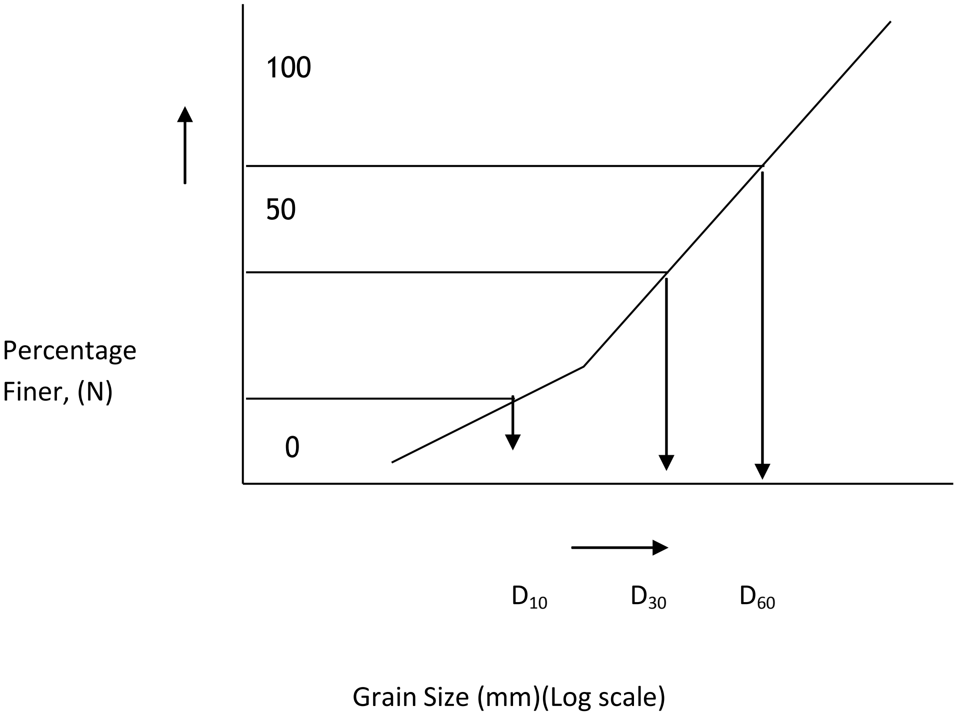
Sl No.	IS Sieves (mm)	Particle Size (mm)	Mass Retained (g)	Corrected Mass Retained (g)	Cumulative Mass Retained (g)	Cumulative % Retained	% Finer
1	4.75	4.75					
2	2.00	2.00					
3	1.00	1.00					
4	0.600	0.600					
5	0.300	0.300					
6	0.150	0.150					
7	0.075	0.075					
8	pan						

Cumulative Massretained W'= --------------------- gms

Graph (Grain Size in mm Vs Percentage Finer in %):

Draw graph of log sieve size vs % finer. The graph is known as grading curve. Corresponding to 10%, 30% and 60% finer, obtain diameters from graph these are D10, D30, D60, using these obtain Cc and Cu which further represent how well the soil is graded i.e whether the soil is well-graded, gap-graded or poorlygraded.

Graph1-Grain Size in mm Vs Percentage Finer in %



<u>Result:</u>

Uniformity coefficient, Cu=

Coefficient of curvature, Cc=

Percentage gravel=

Percentage sand=

Percentage silt=

Conclusion:

The uniformity coefficient,Cu=________and Cc=_______.

The value comes in the range of well gradedsoil.

EXPERIMENT NO -7

DETERMINATION OF LIQUID LIMIT OF FINE SOIL

AIM: To determine the liquid limit of fine soil by using Casagrande Apparatus

When water is added to dry soil, it changes its state of consistency from hard to soft. We can define liquid limit as the minimum water content at which the soil is still in the liquid state, but has a small shearing strength against flow. From test point of view we can define liquid limit as the minimum water content at which a pat of soil cut by a groove of standard dimension will flow together for a distance of 12 mm (1/2 inch) underan impact of 25 blows in the device.

Specifications:

This test is done to determine liquid limit of soil as per IS: 2720(Part 5)-1985. After receiving the soil sample it is dried in air or in oven (maintained at a temperature of 60^0C). If clods are there in soil sample then it is broken with the help of wooden mallet. The soil passing 425 micron sieve is used in thistest.

Equipments Required:

a) A mechanical liquid limit apparatus (casagrande type) with groovingtools.
b) Evaporating dishes, wash bottleetc.
c) Balance accurate to 0.01g.
d) Airtight container to determine watercontent.
e) Oven to maintain temperature at 105 to 110C.
f) Sieve (425micron).
g) Spatula
h) Desiccators and other accessories.

Theory:

Consistency of fine-grained soils may be defined as the relative ease with which a soil can be remoulded. Consistency limits may be categorized into three limits called Atterberglimits.

They are 1) Liquid limit 2) Plastic limit and 3) Shrinkage limit

Liquid limit is the moisture content that defines where the soil changes from a plastic to a viscous fluid state. Other limits will be discussed during corresponding experiments.

Procedure:

a) A representative sample of mass of about 120 gm passing through 425 µ IS sieve is taken for the test. Mix the soil in an evaporating dish with distilled water to form a uniformpaste.
b) Adjust the cup of the device so that the fall of the cup on to the hard rubber base is 10mm.
c) Transfer the portion of the paste to the cup of liquid limit device. Allow some time for the soil to have uniform distribution ofwater.
d) Level the soil topsoil so that the maximum depth of soil is 12 mm. A channel of11 mm wide at the top, 2 mm at the bottom and 8 mm deep is cut by the grooving tool. The grooving tool is held normal to the cup and the groove is cut through the sample along the symmetrical axis of the top.
e) The handle of the device is turned at a rate of about 2 revolutions per second and the number of blows necessary to close the groove along the bottom distance of 12 mm is counted. A sample of soil which closes the groove is collected.
f) The soil in the cup is re-mixed thoroughly (adding some more soil if required) some quantity of water which changes the consistency of soil, repeat the process. At least 4 tests should be conducted by adjusting the water contents of the soil in the cup in such a way that the number of blows required to close the groove may fall within the range of 5 to 40 blows. A plot of water content against the log of blows is made as shown in figure. The water content at 25 blows gives the liquid limit.

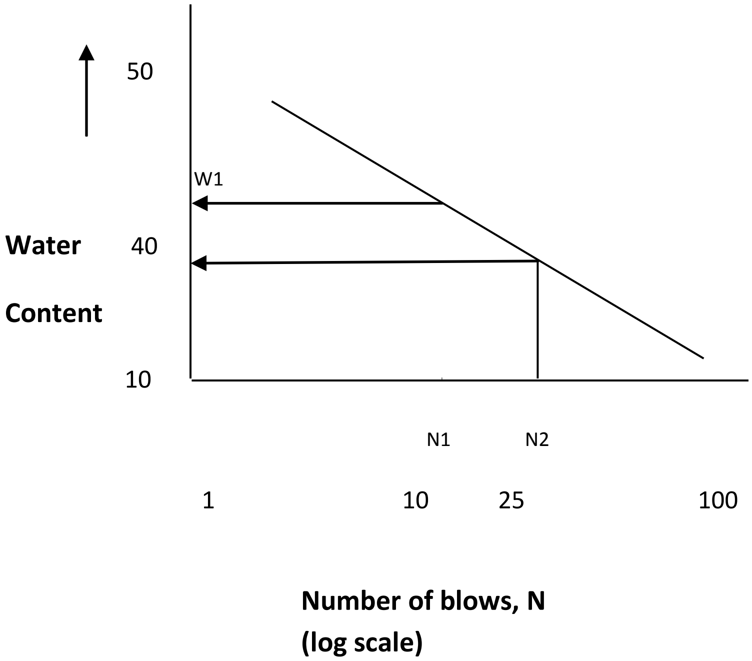
Table:

Table 8: Number of blows vs Water Content

Trial No	**1** (w1)	**2** (w2)	**3** (w3)	**4** (w4)
No of blows (N)				
Weight of Container (W1)				
Weight of Container + Wet soil (W2)				
Weight of Container + dry soil (W3)				
Water content w=(W2-W3)/(W3-W1)				
Water content, w = (w1+w2+w3+w4)/4				

Graph:

A semi-log plot of Number of blows Vs water Content is drawn from the table data.



Result:

From the graph drawn, flow index I_f=(w1-w2)/log (N2/N1)= ---------

And Liquid Limit= ----------- %

Conclusion:

As per the procedure the experiment is carried out. For 25 blows, water content is ______%.

EXPERIMENT N0-8

DETERMINATION OF PLASTIC LIMIT OF THE SOIL

AIM: To determine plastic limit of the soil.

The Plastic limit of fine-grained soil is the water content of the soil below which it cases to be plastic. It begins to crumble when rolled into threads of 3mm dia.

Specifications:

This test is done to determine the plastic limit of soil as per IS: 2720 (Part 5) – 1985. Take out 30g of air-dried soil from a thoroughly mixed sample of the soil passing through 425µm IS Sieve. Mix the soil with distilled water in an evaporating dish and leave the soil mass for 24hrs.

Equipments Required:

a) Porcelain evaporatingdish.
b) Flat glassplate.
c) Balance accurate to 0.01g.
d) Drying oven, maintained at 110 ± 5°C (230 ±9°F).
e) Weighing dishes, non-absorbent, withlids.
f) Flexible spatula, blade approximately 102 mm (4 in.) long × 19mm (0.75 in.)wide.

Theory:

The plastic limit is the moisture content that defines where the soil changes from a semi-solid to a plastic state. It may also be defined as that water content at which soil starts crumbling when rolled into threads of 3mm diameter. Use the paste from liquid limit test and begin drying. May add dry soil or spread on plate and air dry.

Procedure:

a) Select a representative sample of fine-grained soil of about 20 g or more passing through 420 µ IS sieve. Mix it with distilled water thoroughly on a glass plate suchthat the palm of the soil can be rolled into a thread of 3 mm diameter. Allow sometime for the proper distribution mixed withwater.
b) Take about 10 g of this wet sail and roll it into a thread on a glass plate with the palm of the hand. The rolling must be such that it forms a uniform thread of 3 mmdiameter. If the thread cracks before attaining 3 mm diameter, and add little morewater, knead it and roll again. If the rolling can be done to diameter less than 3 mm, mix some dry soil, knead it to remove same extra moisture in the soil. This process has to continue till the sample crumbles just at about 3 mm diameter. Collect the crumbled soil (at least 6 g) and measure its watercontent.

c) Repeat the process to get at least three water content determination (after they have been in the oven at least 16hours)..

d) The average of water content so obtained is the plastic limit of thesoil.

Table:

Table 9: Water content of 3 mm soil

Trail No	**1** **(w1)**	**2** **(w2)**	**3** **(w3)**	**4** **(w4)**
Weight of Container (W1), g				
Weight of Container + Wet soil (W2), g				
Weight of Container + dry soil (W3), g				
Water content w=(W2-W3)/(W3-W1), g				
Average water content, w = (w1+w2+w3+w4)/4				

Result:

The Plastic limit of soil (average water content)is______________________.

Plasticity index = $w_p - w_L$

Conclusion:

The plastic limit of the soil=_________and plasticity index= ________

The type of soil is________.

EXPERIMENT NO-9

DETERMINATION OF SHRINKAGE LIMIT

AIM: To determine the shrinkage limit of the soil.

The value of shrinkage limit is used for understanding the swelling and shrinkageproperties of cohesive soils. It is used for calculating the shrinkage factors which helps in the design problems of the structures made up of the soils or/and resting on soil. It gives an idea about the suitability of the soil as a construction material in foundations, roads, embankments anddams.

Specifications:

The test is specified in IS: 2720(Part 6)-1972. The 30 g soil passing 425 micron sieve isused for the test.

Equipments Required:

a) 2 numbers of porcelain evaporating dish, about 12 cm in diameter within aflat bottom.
b) 3 numbers of shrinkage dish made of non-corroding metal, having a flat bottom, 45mm diameter and 15 mm high.
c) A glass cup of about 50 mm diameter and 25 mmhigh.
d) Two numbers glass plates of size 75×75×3 mm, one plate of plane glass andthe other with three metalprongs.
e) Spatula balance accurate to 0.01 g, oven etc.
f) Mercury.
g) Desiccator and otheraccessories.

Theory:

As the soil loses moisture, either in its natural environment, or by artificial means in laboratory, it changes from liquid state to plastic state to semi-solid state and then to solid state. The volume is also reduced by the decrease in water content. But, at a particular limit the moisture reduction causes no further volume change. A shrinkage limit test gives a quantitative indication of how much moisture can change before any significant volume change and to also indication of change in volume. The shrinkage limit is useful in areas where soils undergo large volume changes when going through wet and dry cycles (e.g. earthdams).

Shrinkage limits are required to be determined on two types of soils, they are

i. Remoulded soil.
ii. Undisturbed soil.

Other shrinkage factors i.e. shrinkage ratio, volumetric shrinkage may also becalculated from the test data of shrinkage limit.

Shrinkage ratio is the ratio of a given volume change expressed as a percentage ofdry volume to the corresponding change in water content above the shrinkage limit.

Volumetric Shrinkage is the decrease in volume of a soil mass when the water content is reduced from given percentage to the shrinkage limit and which is expressed as percentage of dry volume of the soil mass.

Procedure:

a) Select a representative sample of soil of about 100 g passing through 425µ sieve.
b) Take 30 g out of it and place the same in an evaporating dish. Mix it thoroughly with distilled water and make it into a thin paste for readily filling into a dishfree from air bubbles.

Determination of mass and volume of shrinkage dish:

a) Take a shrinkage dish, clean it and find its mass correct to 0.1 gm (M3).= g
b) To determine its volume, place it in an evaporating dish. Fill the shrinkagedish with mercury till the excess overflows to the evaporating dish.
c) Coat the inside of the shrinkage dish with a thin layer of silicon grease orVaseline. Place a part of the soil paste prepared earlier at the centre of the dish so that it may occupy about one-third of its volume.
d) Find the mass of the wet soil with the dish immediately after filling(M1)= g
e) Keep the dish with soil exposed to air until the colour of the pat turns from black to light.
f) Select a glass cup with a flat bottom and keep ion an evaporating dish. Fill the cup with mercury and remove the excess mercury by pressing the glass plate with three prongs firmly over the top of thecup.
g) Remove the split over the mercury, take out the glass plate with theprongs, place the dry soil pat on the surface of the mercury.
h) Force the soil pat into the mercury by pressing with the same glass plate withthe prongs. Collect carefully the split over mercury and find its mass(Mm)=------- g

The volume of the dry soil p at Vd isVd

= Mm/ 13.6.

Where, 13.6 is the density of mercury in g/cm^3

Calculation of shrinkage limit, Ws

Mass of wet soil = $M_o = (M_1 - M_3)$= -----------------g

Mass of dry soil = $M_s = (M_2 – M_3)$= -----------------g

Volume of shrinkage dish = Volume of wet soil = V_o = ---------------

Volume of dry soil = V_d = ---------------

$V_d = M_m / 13.6$ where, 13.6 g/cm^3 is the density of mercury.

- **S**rinkage limit,W_s is

$W_s = ((M_o - M_s) - (V_o - V_d) \times \rho_w) / M_s$

Shrinkage ratio, $S_r = ((V_o - V_d) / V_o) \times 100$

Shrinkage limit of undistributed soil

In this case G is known in advance. The equation to be used for determining Ws is

$W_s = [(V_d / M_s) - (1/G)] \times 100$

For the undistributed soil we need to know only the volume of an undistributed dry pot of soil sample of diameter 45 mm and thickness 15 mm. Round off its edges to prevent the entrapment of air during mercury displacement. Air dry the sample initially and then dry over the same. Find its mass (Ms) after cooling it in a desiccator, and then its volume Vd by mercury displacement method. Ws may now be found out by use of equation

$$Ws = [(V_d/M_s)-(1/G)]\times 100.$$

Result:

The shrinkage limit W_s=------------------

Verification/Validations:

Value of shrinkage limit varies from 13 to 26.

Conclusion:

The shrinkage limit of soils _____________.

EXPERIMENT NO-10

DETERMINATION OF MAXIMUM DRY DENSITY AND OPTIMUM MOISTURE CONTENT BY MODIFIED PROCTOR COMPACTIONMETHOD

AIM: To determine moisture content- DRY DENSITY RELATIONSHIP BY MODIFIED PROCTOR TEST.

Compaction is the application of mechanical energy to a soil so as to rearrange its particle sand reduce the void ratio. It is applied to improve the properties of an existing soil or in the process of placing fill such as in the construction of embankments, road bases, runways, earth dams, and reinforced earth walls. Compaction is also used to prepare a level surface during construction of buildings. There is usually no change in the water content and in the size of the individual soil particles.

Specifications:

The experiment is conducted as per IS 2720-7(1980).

Equipment Required:

a) Typical equipment for proctor test is given in figure.
b) Other accessories are: Balance, oven, straight edge, sieves, metal hammer,etc.

Theory:

The objectives of compaction are:
a) To increase soil shear strength and therefore its bearing capacity.
b) To reduce subsequent settlement under working loads.
c) To reduce soil permeability making it more difficult for water to flow through

To assess the degree of compaction, it is necessary to use the dry unit weight, which is an indicator of compactness of solid soil particles in a given volume. The laboratory testing is meant to establish the maximum dry density that can be attained for a given soil with a standard amount of compactive effort.

1. Bulk density $\Upsilon_t = (M_2 - M_1)/V$
2. Dry density $\rho_d = \rho_t/(1 + w)$
3. Dry density ρ_d for zero air voidsline.

$$\rho_d = G\rho_w/(1 + (wG/S))$$

Where, M1 = mass of mould used for proctor testM2 =

mass of mould + compacted soil.

M = mass of wet soil.V

= volume of mould.

ρw = density of water.

G = Specific gravity of soils.W

= water content.

S = degree of saturation.

Procedure

a) Select a representative soil sample of about 25 kg. The material used for the test must be finer than 20 mm sieve. Air-dry sample.
b) Add sufficient water to the sample (about 7 % for sandy soils and 10 % for clay soils), which will be less than the estimated optimum moisture content. Mix the soil thoroughly and keep this in an airtight container for a period of 20hours.
c) Fix the mould to the base plate after cleaning its inside surface. Find the mass of the mould with the base plate (M1).
d) Attach the extension collar to the mould.
e) Take about 2.5 kg of soil in an air tight container and compact it in the mould in three equal layers each layer is compacted by giving 25 blows by the hammer weighing 2.6 kg and dropping from a height of 310 mm. The compaction must be uniform over the whole area, and a spatula scratches each layer before adding another layer. The filling must be such that the last layer projects into the collar by about 5 mm. After the completion of compaction, remove the collar and remove theexcess soil with the help of a straight edge. Find the mass of the mould with the base plate and the soil (M2). Remove the soil from the mould by making use of an ejector and take a representative sample for water content determination.
f) Carry out the tests 3 to 4 times by repeating the steps from (e) onwards. Each time use a fresh soil sample.

Observations and tabulation:

The following observations were made on the compaction of a soil by standard proctor test. Six tests were carried out on the selected samples of soil by varying the water content. Water contents of samples of each test were found out by the procedure explained earlier.

The test results are tabulated below.

Table 15: Weight of Soil for varying water content

Test No.	1	2	3	4	5	6

Mass of empty mould M_1g						
Volume of mould, cm^3						
Mass of mould + sample,M_2,g						
Mass of wet soil, M,g						
Wet density, ρ_t g/cm^3						
Water content, w%						
Dry density, ρ_d, g/cm^3						
W1 for calculation of saturation line %						
ρ_d, g/cm^3 for S=100%						
ρ_d, g/cm^3 for S=80%						

Note: Plot dry density vs. moisture content and find out the max dry density and optimum moisture for the soil. Also, mark the 100 % and 80 % saturation lines.

Result:

Maximum dry density ρd = g/cm3

Optimum moisture content, w=_______%

Conclusion:

The maximum density of the soil is___________with an OMC of__________. This indicates, after w%, any additional water addition, there is no gain in strength of soil.

EXPERIMENT NO-11

CALIFORNIA BEARING RATIO TEST

Aim: Determine the california bearing ratio by conducting a load penetration test in the laboratory.

Need and scope

The California bearing ratio test is penetration test meant for the evaluation of sub grade strength of roads and pavements. The results obtained by these tests are used with the empirical curves to determine the thickness of pavement and its component layers. This is the most widely used method for the design of flexible pavement.

This instruction sheet covers the laboratory method for the determination of c.b.r. Of undisturbed and remoulded /compacted soil specimens, both in soaked as well as unsoaked state.

Planning and organization

Equipment's and tool required are

1. Cylindrical mould with inside dia 150 mm and height 175 mm, provided with a detachable extension collar 50 mm height and a detachable perforated base plate 10 mm thick.
2. Spacer disc 148 mm in dia and 47.7 mm in height along with handle.
3. Metal rammers. Weight 2.6 kg with a drop of 310 mm (or) weight 4.89 kg a drop 450 mm.
4. Weights. One annular metal weight and several slotted weights weighing 2.5 kg each, 147 mm in dia, with a central hole 53 mm in diameter.
5. Loading machine. With a capacity of at least 5000 kg and equipped with a movable head or base that travels at an uniform rate of 1.25 mm/min. Complete with load indicating device.
6. Metal penetration piston 50 mm dia and minimum of 100 mm in length.
7. Two dial gauges reading to 0.01 mm.
8. Sieves. 4.75 mm and 20 mm i.s. Sieves.
9. Miscellaneous apparatus, such as a mixing bowl, straight edge, scales soaking tank or pan, drying oven, filter paper and containers.

Definition of CBR

It is the ratio of force per unit area required to penetrate a soil mass with standard circular piston at the rate of 1.25 mm/min. to that required for the corresponding penetration of a standard material.

C.B.R. = Test load/Standard load * 100

The following table gives the standard loads adopted for different penetrations for the standard material witha C.B.R. value of 100%

Tab 18.1 values of Penetration vs Standard load

Penetration of plunger (mm)	Standard load (kg)

2.5	1370
5	2055
7.5	2630
10	3180
12.5	3600

The test may be performed on undisturbed specimens and on remoulded specimens which may be compacted either statically or dynamically.

Preparation of Test Specimen

(A) Undisturbed specimen

Attach the cutting edge to the mould and push it gently into the ground. Remove the soil from the outside of the mould which is pushed in. When the mould is full of soil, remove it from weighing the soil with the mould or by any field method near the spot.

Determine the density

(B) Remoulded specimen

Prepare the remoulded specimen at Proctor's maximum dry density or any other density at which C.B.R. is required. Maintain the specimen at optimum moisture content or the field moisture as required. The material used should pass 20 mm I.S. sieve but it should be retained on 4.75 mm I.S. sieve. Prepare the specimen either by dynamic compaction or by static compaction.

Dynamic Compaction

1. Take about 4.5 to 5.5 kg of soil and mix thoroughly with the required water.
2. Fix the extension collar and the base plate to the mould. Insert the spacer disc over the base (SeeFig.38). Place the filter paper on the top of the spacer disc.
3. Compact the mix soil in the mould using either light compaction or heavy compaction. For light compaction, compact the soil in 3 equal layers, each layer being given 55 blows by the 2.6 kg rammer. For heavy compaction compact the soil in 5 layers, 56 blows to each layer by the 4.89 kg rammer.
4. Remove the collar and trim off soil.
5. Turn the mould upside down and remove the base plate and the displacer disc.
6. Weigh the mould with compacted soil and determine the bulk density and dry density.
7. Put filter paper on the top of the compacted soil (collar side) and clamp the perforated base plate onto it.

Static compaction

1. Calculate the weight of the wet soil at the required water content to give the desired density when occupying the standard specimen volume in the mould from the expression.

$$W = \text{desired dry density} * (1+w)\ V$$

2. Where W = Weight of the wet soil
3. w = desired water content
4. V = volume of the specimen in the mould = 2250 cm^3 (as per the mould available in laboratory)
5. Take the weight W (calculated as above) of the mix soil and place it in the mould.
6. Place a filter paper and the displacer disc on the top of soil.
7. Keep the mould assembly in static loading frame and compact by pressing the displacer disc till thelevel of disc reaches the top of the mould.
8. Keep the load for some time and then release the load. Remove the displacer disc.
9. The test may be conducted for both soaked as well as unsoaked conditions.
10. If the sample is to be soaked, in both cases of compaction, put a filter paper on the top of the soil and place the adjustable stem and perforated plate on the top of filter paper.
11. Put annular weights to produce a surcharge equal to weight of base material and pavement expected in actual construction. Each 2.5 kg weight is equivalent to 7 cm construction. A minimum of two weights should be put.
12. Immerse the mould assembly and weights in a tank of water and soak it for 96 hours. Remove the mould from tank.
13. Note the consolidation of the specimen.

Procedure for Penetration Test

1. Place the mould assembly with the surcharge weights on the penetration test machine.
2. Seat the penetration piston at the center of the specimen with the smallest possible load, but in nocase in excess of 4 kg so that full contact of the piston on the sample is established.
3. Set the stress and strain dial gauge to read zero. Apply the load on the piston so that the penetrationrate is about 1.25 mm/min

4. Record the load readings at penetrations of 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 4.0, 5.0, 7.5, 10 and 12.5 mm. Note the maximum load and corresponding penetration if it occurs for a penetration less than 12.5 mm.
5. Detach the mould from the loading equipment. Take about 20 to 50 g of soil from the top 3 cm layerand determine the moisture content.

Observations

For Dynamic Compaction

Optimum water content (%) :

Weight of mould + compacted specimen g :

Weight of empty mould g :

Weight of compacted specimen g :

Volume of specimen cm^3 :

Bulk density g/cc :

Dry density g/cc :

For static compaction

Dry density g/cc :

Moulding water content % :

Wet weight of the compacted soil, (W)g :

Period of soaking 96 hrs. (4days) :

For penetration Test

Calibration factor of the proving ring 1 Div. = 1.176 kg

Surcharge weight used (kg) 2.0 kg per 6 cm

constructionWater content after penetration test %

Least count of penetration dial 1 Div. = 0.01 mm

If the initial portion of the curve is concave upwards, apply correction by drawing a tangent to the curve at the point of greatest slope and shift the origin. Find and record the correct load reading corresponding toeach penetration.

$$\text{C.B.R.} = P_T/P_S * 100$$

Where P_T = Corrected test load corresponding to the chosen penetration from the load penetration curve.

P_S = Standard load for the same penetration taken from the table ⍰.

Tab 18.2 Tabulation for CBR test

Penetration Dial		**Load Dial**		**Corrected Load**
Readings	Penetration(mm)	Proving ringreading	Load (kg)	

Interpretation and recording

C.B.R. of specimen at 2.5 mm penetration:

C.B.R. of specimen at 5.0 mm penetration:

General Remarks

The C.B.R. values are usually calculated for penetration of 2.5 mm and 5 mm. Generally the C.B.R. value at 2.5 mm will be greater than value at 5 mm and in such a case/the former shall be taken as C.B.R. for design purpose. If C.B.R. for 5 mm exceeds that for 2.5 mm, the test should be repeated. If identical results follow, the C.B.R. corresponding to5 mm penetration should be taken for design

Specimen Calculations

EXPERIMENT – 12

DETERMINATION OF C AND Φ OF SOIL BY TRIAXIAL TESTING DEVICE

Aim: To find the shear parameters of the soil by undrained triaxial test.

Need and scope

The standard consolidated undrained test is compression test, in which the soil specimen is first consolidated under all round pressure in the triaxial cell before failure is brought about by increasing the major principal stress.

It may be performing with or without measurement of pore pressure although for most applications the measurement of pore pressure is desirable.

Knowledge of equipment

A constant rate of strain compression machine of which the following is a brief description of one is in common use.

a) A loading frame in which the load is applied by a yoke acting through an elastic dynamometer, more commonly called a proving ring which used to measure the load. The frame is operated at a constant rate by a geared screw jack. It is preferable for the machine to be motor driven, by a small electric motor.

b) A hydraulic pressure apparatus including an air compressor and water reservoir in which air under pressure acting on the water raises it to the required pressure, together with the necessary control valves and pressure dials.

A tri axial cell is to take 3.8 cm dia and 7.6 cm long samples, in which the sample can be subjected to an all round hydrostatic pressure, together with a vertical compression load acting through a piston. The vertical load from the piston acts on a pressure cap. The cell is usually designed with a non-ferrous metal top and base connected by tension rods and with walls formed of Perspex.

Apparatus for preparation of the sample

a) 3.8 cm (1.5 inch) internal diameter 12.5 cm (5 inches) long sample tubes.

b) Rubber ring.

c) An open ended cylindrical section former, 3.8 cm inside dia, fitted with a small rubber tube in its side.

d) Stop clock.

e) Moisture content test apparatus.

f) A balance of 250 gm capacity and accurate to 0.01 gm.

Experimental Procedure

1. The sample is placed in the compression machine and a pressure plate is placed on the top. Care mustbe taken to prevent any part of the machine or cell from jogging the sample while it is being setup,for example, by knocking against this bottom of the loading piston. The probable strength of the sample is estimated and a suitable proving ring selected and fitted to the machine.

2. The cell must be properly set up and uniformly clamped down to prevent leakage of pressure during the test, making sure first that the sample is properly sealed with its end caps and rings (rubber) in position and that the sealing rings for the cell are also correctly placed.

3. When the sample is setup water is admitted and the cell is fitted under water escapes from the beed valve, at the top, which is closed. If the sample is to be tested at zero lateral pressure water is not required.

4. The air pressure in the reservoir is then increased to raise the hydrostatic pressure in the required amount. The pressure gauge must be watched during the test and any necessary adjustments must be made to keep the pressure constant.

5. The handle wheel of the screw jack is rotated until the under side of the hemispherical seating of the proving ring, through which the loading is applied, just touches the cell piston.

6. The piston is then removed down by handle until it is just in touch with the pressure plate on the top of the sample, and the proving ring seating is again brought into contact for the begging of the test.

Observations

1. The machine is set in motion (or if hand operated the hand wheel is turned at a constant rate) to givea rate of strain 2% per minute.
2. The strain dial gauge reading is then taken and the corresponding proving ring reading is taken thecorresponding proving ring chart. The load applied is known.
3. The experiment is stopped at the strain dial gauge reading for 15% length of the sample or 15%strain.

Operator: Sample No:

Date: Job:

Location: Size of specimen:

Length: Proving ring constant:

Diameter: *Initial area L:*

Initial Volume: Strain dial gauge least count (const):

Tabulation sheet for tri axial test

Cell pressure kg/cm^2	**Strain dial**	**Proving ring reading**	**Load on sample kg**	**Corrected areacm^2**	**Deviator stress**
0.5	0 50 100 150 200 250 300 350 400 450				
0.5	0 50 100 150 200				

	250				
	300				
	350				
	400				
	450				
0.5	0				
	50				
	100				
	150				
	200				
	250				
	300				
	350				
	400				
	450				

Tab 16.2 Tabulation sheet for shear strength determination

Sample No.	**Wet bulk density gm/cc**	**Cell pressure kg/cm^2**	**Compressive stress at failure**	**Strain at failure**	**Moisture content**	**Shear strength (kg/cm^2)**	**Angle of shearing resistance**
1							
2							
3							

General Remarks

a) It is assumed that the volume of the sample remains constant and that the area of the sample increases uniformly as the length decreases. The calculation of the stress is based on this new area at failure, by direct calculation, using the proving ring constant and the new area of the sample. By constructing a chart relating strain readings, from the proving ring, directly to the corresponding stress.

b) The strain and corresponding stress is plotted with stress abscissa and curve is drawn. The maximum compressive stress at failure and the corresponding strain and cell pressure are found out.

c) The stress results of the series of triaxial tests at increasing cell pressure are plotted on a mohr stress diagram. In this diagram a semicircle is plotted with normal stress as abscissa shear stress asordinate.

d) The condition of the failure of the sample is generally approximated to by a straight line drawn as a tangent to the circles, the equation of which is $\tau = C + \sigma \tan\phi$. The value of cohesion, C is read of the shear stress axis, where it is cut by the tangent to the mohr circles, and the angle of shearing resistance (ϕ) is angle between the tangent and a line parallel to the shear stress.

Specimen Calculations

EXPERIMENT NO-13

DETERMINATION OF PERMEABLITY OF A SOIL SAMPLE BY CONSTANT- HEAD METHOD

AIM: To determine the coefficient of permeability of soil by constant-head method.

The rate of flow under laminar flow conditions through a unit cross sectional are of porous medium under unit hydraulic gradient is defined as coefficient of permeability. Water flowing through soil exerts considerable seepage force which has direct effect on the safety of hydraulic structures. The rate of settlement of compressible clay layer under load depends on its

permeability. The quantity of water escaping through and beneath the earthen dam depends on the permeability of the embankments and its foundations respectively. The rate of discharge through wells and excavated foundation pits depends on the coefficient of permeability of the soils. Shear strength of soils also depends indirectly on permeability of soil, as dissipation of pore pressure is controlled by itspermeability

Specifications:

IS 2720-17 (1986): Methods of test for soils, Part 17. This test is used to determine the permeability of granular soils like sands and gravels containing little or nosilt.

Equipments Required:

1. Permeameter mould of non-corrodible material having a capacity of 1000ml
2. The mould shall be fitted with a detachable base plate and removable extensioncounter.
3. Compacting equipment: 50 mm diameter circular face, weight 2.76 kg and height offall 310 mm as specified in I.S 2720 part VII1965.
4. Drainage bade: A bade with a porous disc, 12 mm thick which has the permeability10 times the expected permeability of soil.
5. Drainage cap: A porous disc of 12 mm thick having a fitting for connection to waterinlet oroutlet.

6. Constant head tank: A suitable water reservoir capable of supplying water to the permeameter under constanthead.
7. Graduated glass cylinder to receive the discharge.
8. Stop watch to note the time.
9. A meter scale to measure the head differences and length ofspecimen.

Theory:

The knowledge of this property is much useful in solving problems involving yield of water bearing strata, seepage through earthen dams, stability of earthen dams, and embankments of canal bank affected by seepage, settlement etc. Permeability of soil can be determined from Darcy's Law. The equation to determine the permeability of soil using constant head permeability test is given by:

$k = (Q \times L)/(A \times h \times t)$ Where, k = coefficient of permeabilityQ =
volume of water collected in time t
h = head causing flow
A = cross sectional area of sampleL =
length of sample

- A constant head permeameter shown schematically in the figure.
- For a typical setup the following dimensions areused
    - i. Internal diameter of the mould = 100mm.
    - ii. Effective height of the mould = 127.3mm.
    - iii. Detachable collar: 100 mm diameter and 60 mm height.
    - iv. Drainage base, having a porousdisc.
- Weighing balance, and other accessories.

Procedure:

a) A constant-head test assembly is as given in below figure.
b) Select a representative soil mass of about 2.5 kg properly mixed.
c) Fill the soil into the mould and compact it to the required dry density by makinguse of a suitable compacting device.
d) Set the assembly as shown in figure after saturating the porous stones.
e) The water supply is properly adjusted to maintain constant head.
f) Open the valve and saturate the sample by allowing water to flow through for a sufficiently long time to remove all air-bubbles.
g) When the whole setup is ready for the test, open the valve, allow the water to flow through the sample collect water in a graduated jar starting simultaneously astopwatch. Note the time to collect a certain quantity of water Q.
h) Repeat the test three times and determine the average of Q for the same time intervalt.
i) Measure the head h, length of sample L, and calculate the cross sectional area Aof the sample.
j) Calculate k by making use of equation

Observation:

Length of Soil sample L= ------------cm

Diameter of Soil sample D= --------- cm
Area of soil sample A=-----------

Constant head h=--------------cm

Sl.No	Quantity of water Q= ------ ml	Time t= -----sec	k=(QL)/(Ath) (cm/sec)
1			
2			
3			
4			

Result:

Coefficient of Permeability of soil k=-------------------------- cm/sec

Conclusion:

The type of soil tested is______as the permeability falls in the range as shown in the above table.

EXPERIMENT NO-14

VERIFICATION OF BERNOULLI’S EQUATION

Aim: To Verify the Bernoulli’s Theorem.

Theory

Considering friction less flow along a variable are duct, the law of conservation of energy states “for and Inviscid, incompressible, Irrotational and steady flow along a stream line the total energy(or Head) remains the same”. This is called Bernoulli’s equation. The total head of flowing fluid consist of a pressure head, velocity head and elevation head remain constant.

Mathematically, Bernoulli’s equation is given by

$$\frac{P}{\rho g} + \frac{v^2}{2g} + z = constant$$

where P, V and Z refer to the pressure, velocity and position of the relative to some datum at anysection.

Apparatus used

Inlet supply tank with overflow arrangement, outlet supply tank with means of varying flow rate,Perspex duct of varying cross-section and a series of piezometric tubes installed along its length.

Procedure

i) Open the inlet valve slowly and allow the water to flow from the supply tank.
ii) Now adjust the flow to get a constant head in the supply tank to make flow in and out flowequal.
iii) Under this condition the pressure head will become constant in the piezometer tubes.
iv) Measure the height of water level “h” (above the arbitrarily selected plane) in differentpiezometric tubes.
v) Compute the area of cross-section under the piezometer tubes.
vi) Note down the quantity of water collected in the measuring tank for a given interval oftime.
vii) Change the inlet and outlet supply and note the reading.
viii) Take at least three reading as described in the above steps.

Experimental set up of Bernoulli's theorem apparatus.

Observation

Area of collecting tank

(A)=Increase in depth=

Time =

Discharge=

Section	1	2	3	4	5
Cross-sectional area of pipe (a)					
Velocity of Flow (v=Q/a)					
$\frac{v^2}{2g}$					
Piezometer reading ($\frac{P}{\rho\rho\rho}$)					
$\frac{P}{\rho g}+\frac{v^2}{2g}+z$					

Sample calculation

Result

The total energy head is found to be . Hence the Bernoulli's theorem is verified

EXPERIMENT NO-15

DETERMINATION OF COEFFFICIENT OF DISCHARGE OF A RECTANGULAR NOTCH FITTED IN OPEN CHANNEL

Aim :

To Determine the Co-efficient of discharge of a flow through rectangular notch.

Theory:

A notch is a device used for measuring the rate of flow of liquid through a small channel (or) a tank. It is used to estimate discharge and velocity of flowing water. Notches are those overflow structure whose length of crest in the direction of low is accurately shaped. There may be rectangular, trapezoidal, V-notch etc. A rectangular notch, symmetrically located in a vertical thinplate, which is placed perpendicular to the side and bottom of a straight channel, is defined as a rectangular sharp-crested notch. The discharge coefficient C_d of a rectangular notch given by

$$C_d = \frac{Q_{act}}{Q_{th}}$$

In which Q_{act}=the actual discharge flowing in the pipe and QQ_{th}=theoretical discharge of rectangular notch is given by

$$Q_{th} = \frac{2}{3}\sqrt{2g}BH^{3/2}$$

Where Q=discharge over a rectangular notch, B=width of notch and H=head over the crest of thenotch.

Apparatus used

Approach channel with baffle plate fitted with notch, A Surface level gauge to measure head over notch, a measuring tank to measure flow rate and a constant steady supply of water with using pump.

Procedure

i) The notch under test is positioned at the end of the tank, in a vertical plane and with thesharp edge on the upstream side.

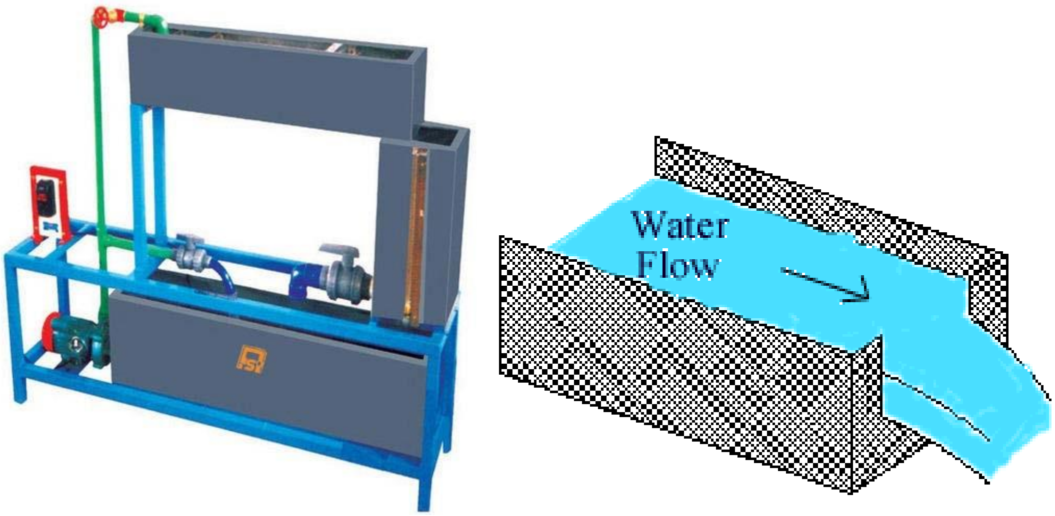
ii) The tank is filled with water up to crest level and subsequently note down the crest levelof the notch by the help of a point gauge.

iii) The flow regulating valve is adjusted to give the maximum possible discharge without flooding the notch.

iv) Conditions are allowed to steady before the rate of discharge and head H were recorded.

v) The flow rate is reduced in stages and the reading of discharge and H were taken.

vi) The procedure is repeated for other type of notch.



Experimental set up of rectangular notch apparatus.

Observation

Area of collecting tank (A)=

Width of notch (B) =

Crest Level of trapezoidal notch (H_0) =

Sl. No.	Rise of water level in collecting tank (h)	Δt	Discharge ($Q_{act} = \frac{Ah}{\Delta t}$)	Final Water level above notch (H_1)	Water head ($H=H_1-H_0$)	$Q_{th} = \frac{2}{3}\sqrt{2g}BH^{3/2}$	$C_d = \frac{Q_{act}}{Q_{th}}$

Sample calculation

$$Q_{act} = \frac{Ah}{\Delta t} =$$

$$Q_{th} = \frac{2}{3}\sqrt{2g}BH^{3/2} =$$

$$C_d = \frac{Q_{act}}{Q_{th}} =$$

Result

The average co-efficient of discharge of the rectangular notch is found to be_____.

EXPERIMENT NO-16

DETERMINATION OF COEFFICIENT OF DISCHARGE FOR VENTURIMETER

Aim:

To determine the coefficient of discharge of liquid flowing through venturimeter

Theory:

Venturimeter is a device consisting of a short length of gradual convergence and a long length of gradual divergence. Pressure tapping is provided at the location before the convergence commences and another pressure tapping is provided at the throat section of a Venturimeter. The difference in pressure head between the two tapping is measured by means of a U-tube manometer. On applying the Continuity equation & Bernoulli‟s equation between the two sections, the following relationship is obtained in terms of governing variables.

Theoretical Discharge (Q_{th}) is given by

$$Q_{th} = a_1 a_2 \sqrt{\frac{2gH_L}{a_1^2 - a_2^2}}$$

Where a_1 and a_2 are Area of inlet pipe and throat respectively,H=Head loss measured by the manometer is given by

$$H_L = x\left(\frac{}{S_{ww}} - 1\right) = 12.6x$$

In which *x*= manometric reading, S_m=Specific gravity of manometric liquid (=13.6), and S_{ww}= Specific gravity of water (=1).

The coefficient of discharge (C_d) of venturimeter is defined as the ratio of the actual discharge tothat theoretical discharge given by

$$C_d = \frac{Q_{act}}{Q_{th}} = \frac{Q_{act}}{a_1 a_2 \sqrt{\frac{2gH_L}{a_1^2 - a_2^2}}}$$

Apparatus used

Venturimeter, Pump and motor for steady supply of water, stopwatch, measuring tank.

Procedure

i) The pipe is selected for conducting experiment.

ii) The motor is switched on; as a result, water flows through pipes.

iii) The time taken for 10cm rise of water in collecting tank is noted.

iv) The experiment is repeated for different discharges in the same pipe.

v) Coefficient of Discharge is calculated

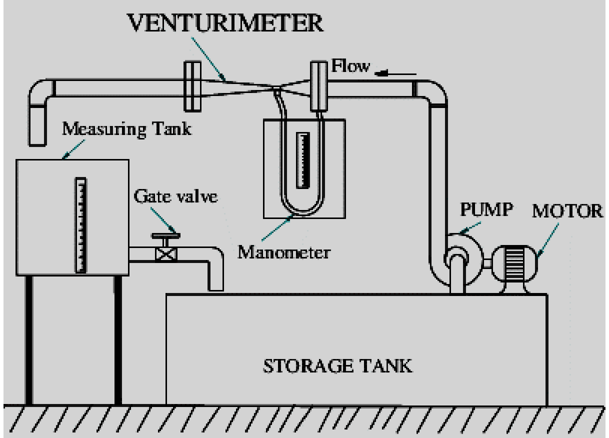


Fig. 6.1. Experimental set up of flow through venturimeter apparatus.

Observation

Diameter of the inlet pipe =

Diameter of the throat =

Area of collecting tank (A)=

Sl. No.	Rise of water level in collecting tank (h)	Δt	Discharge ($Q_{act} = \frac{Ah}{\Delta t}$)	Manometri creading (x)	Loss of head (H_L)	Q_{th}	$C_d = \frac{Q_{act}}{Q_{th}}$

Sample calculation For

observation Sl. No. _________

Area of inlet pipe (a₁)= Area

of throat (a₂)=

$H_L = 12.6x =$

$$Q_{th} = a_1 a_2 \sqrt{\frac{2\rho\rho H_0}{a_1^2 - a_2^2}} =$$

$$C_d = \frac{Q_{act}}{Q_{th}} =$$

Result

The average co-efficient of discharge of the venturimeter is found to be_______.

EXPERIMENT NO-17

FRICTION LOSS IN FLOW THROUGH PIPES

Aim: To determine the Co-efficient of friction in flow through pipes of various sizes.

Theory

When a fluid is flowing through a pipe, the fluid experiences some resistance due to which sme ofthe energy of fluid is lost. The major factor contributing to the energy loss in any pipe flow is through the boundary shear. Estimation of frictional losses is important from engineering point ofview as the design of pipe mains carrying water from any reservoir to the township over a long distance mainly depends upon the friction factors. Booster pumps at places are to be provided to add additional energy needed to maintain the required quantity of flow. The loss of energy due tofriction and it is calculated by the following Darcy-Weisbach formulae:

$$h_{ff} = \frac{4ffLv^2}{2gD}$$

Where, h_f = loss of head due to friction, f = co-efficient of friction., L = length of pipe

v = mean velocity of flow=Q/a, Q=Discharge, a= Cross-sectional area of pipe=$\pi D^2/4$

D = diameter of pipe, Discharge (Q) is measured as: $QQ = \frac{Ah}{\Delta\Delta t}$

In which A= Area of collecting tank

h= rise of water level in collecting tank in time interval Δt.

Actual head loss calculated using the manometer reading can be estimated as given by

$$h_{ff} = x\left(\frac{S_{H\rho\rho}}{S_{ww}} - 1\right) = 12.6x$$

Where x=manometer reading

Procedure

i) Switch on the pump and open the delivery valve.

ii) Open the corresponding ball valve of pipe under consideration.

iii) Keep the ball valve of other pipeline closed.

iv) Note down the differential head readings in the manometer. (Expel if any air is present byopening the drain cocks provided to the manometer).

v) Close the butterfly valve and note down the time taken for known water level rise.

vi) Change the flow rate and take the corresponding reading

vii) Repeat the experiment for different diameter of pipelines.

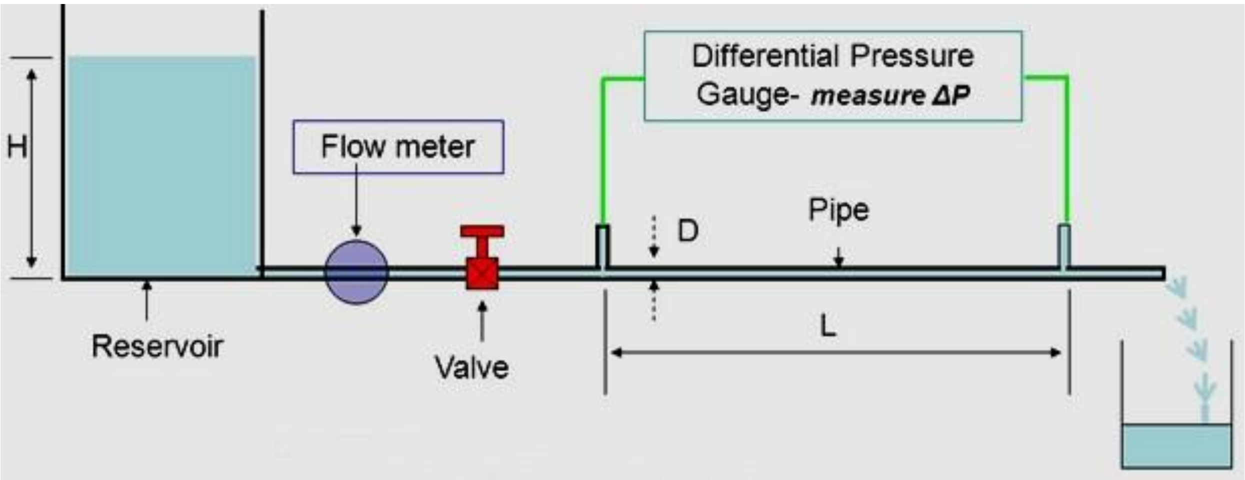


Fig. 8.1. Experimental setup of friction loss in pipe flow.

Observation

Length of the pipe, or the distance between the pressure tappings,

L=Diameter of the pipe (D)=

Cross-sectional area of pipe (a)=$\pi D^2/4$

Area of collecting tank (A)=

Sl. No.	Rise of water level in collecting tank (h)	Δt	Discharge $(QQ = \frac{Ah}{\Delta\Delta t})$	Velocity of flow, v=Q/a	Differential manometer reading (x)	$h_{ff} = 12.6x$	Co-efficient of friction $(ff = \frac{\rho\rho D h_{ff}}{2Lv^2})$

Sample calculation

For observation Sl. No. ____

Discharge, $QQ = \frac{Ah}{\Delta\Delta t} =$ __

Velocity of flow, v=Q/a=

Head loss, h_{ff} = 12.6x

Co-efficient of friction, $ff = \frac{\rho\rho D h_{ff}}{2Lv^2} =$

Result

The average co-efficient of friction of the pipe is found to be_______.

EXPERIMENT NO-18

DETERMINATION OF PENETRATION VALUE OF BITUMEN

Aim: To determine penetration value of bitumen.

Theory: The penetration test is widely used world over for classifying the bitumen into different grade. The ISI has standardized the penetration test equipment and the procedure, Figure 7.1. Even though is recognized that the empirical tests like penetration, softening point etc. can not fully qualify the – binder for its temperature susceptibility characteristic, the simplicity and quickness of operation of the test can not be ignored for common use.

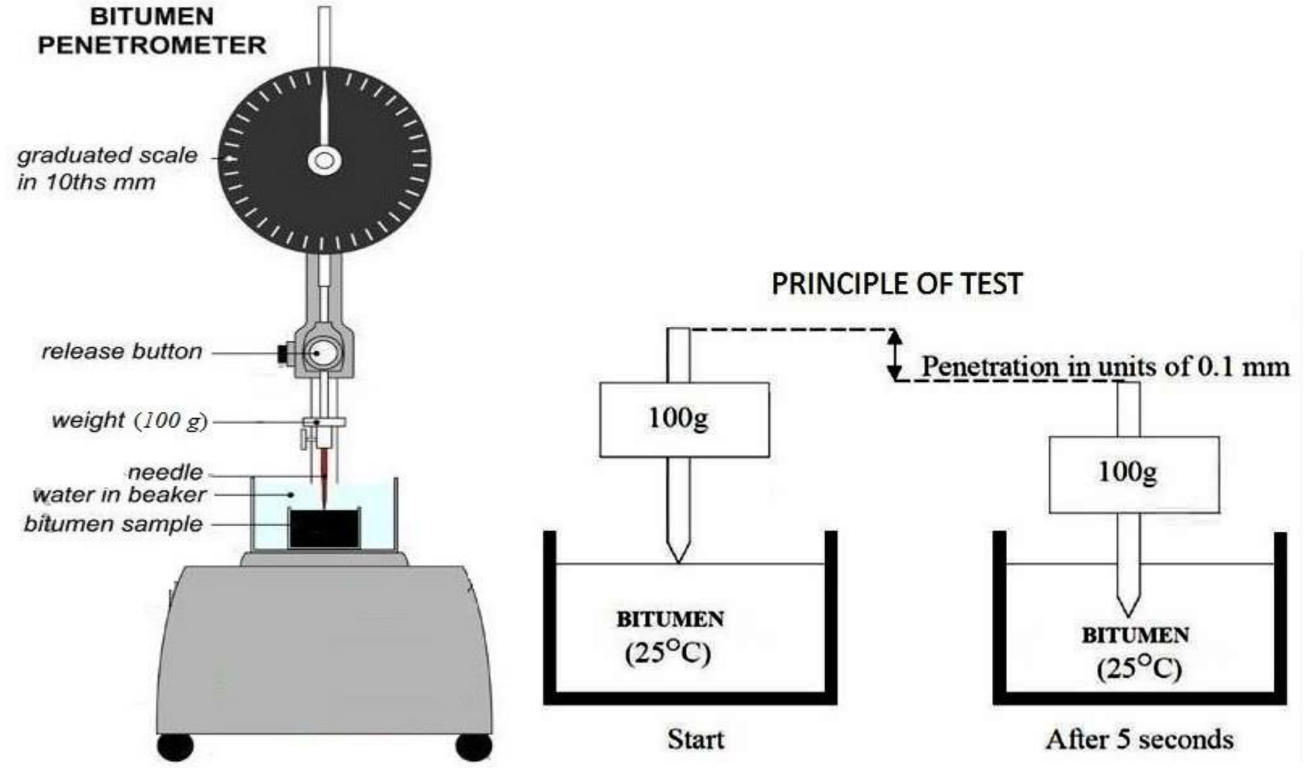


Figure 7.1: Penetrometer and test principle

Apparatus: It consists of items like container, needle, water bath penetrometer, stop watch etc. Following are the standard specifications as per ISI for the above apparatus.

(a) Container : A flat bottomed cylindrical metallic container 55 mm in diameter and 35mmor 57 mm in height.

(b) Needle : A straight, highly polished cylindrical hard steel needle with conical end, having the shape and dimensions. The needle is provided with a shank approximately 3.0 mm in diameter into which it is immovably fixed.

(c) Water-bath : A water bath is maintained at 25 ± 1^{0}C containing not less than 10 litres of water, the sampleis immersed to depth not les than 100 mm from the top and supported on a perforated shelf not less than 50 mm from the bottom of the bath.

(d) Penetrometer : It is an apparatus which allows the needle assembly of gross weight 100 g to penetrate without appreciable friction for the desired duration of time. The dial is accurately calibrated to give penetration value in units of one tenth of a mm. Electrically operated automatic penetrometers are also available.

(e) Transfer tray : A small tray which can keep the container fully immersed in water during the test.

Procedure: The bitumen is softened to a pouring consistency between 75^{0} and 100^{0}C above the approximate temperature at which bitumen softens. The sample material is thoroughly stirred to make it homogenous & free form air bubbles & water. The sample material is then poured into the container to a depth at least 15 mm more than the expected penetration. The sample containers are cooled in atmosphere of temperature not lower than 13^{0}C for one hour. Then they are placed in temperature controlled water bath at atemperature of 25^{0}C for a period of one hour. The sample container is placed in the transfer tray with water from the water bath and placed under the needle of the penetrometer. The weight of needle, shaft and additional weight are checked. The total weight of this assembly should be 100 g. 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; the needle assembly is clamped in this position. The contact of the tip of the needle is checked using the mirror placed on the rear of the needle. The initial reading of the penetrometer dial is either adjusted to zero or the initial reading is taken before releasing the needle. The needle is released exactly for a period of 5.0 secs by pressing the knob and the final reading is taken on the dial. At least three measurements are made onthis sample by testing at distance of not less than 100 mm apart. After each test the needle is disengaged and cleaned with benzene and carefully dried. The sample container is also transferred in the water bath before next testing is done so as to maintain a constant temperature of 25^{0}C. The test is repeated with sample in the other containers.

Observations:

Readings	Sample No.				Sample No.			
	Test 1	Test 2	Test 3	Mean value	Test 1	Test 2	Test 3	Mean value
1) Penetrometerdial reading (i) initial (ii) final 2) Penetrationvalue								

(in division)								

Mean penetration value =

Results : The difference between the initial and final penetration readings is taken as the penetration value. The mean value of three consistent penetration measurements is reported as the penetration value. The mean penetration value should not differ by more than the amount given below:

Penetration	Maximum Difference
0 to 49	2
50 to 149	4
150 to 249	6
250 and above	8

EXPERIMENT NO-19

DETERMINATION OF DUCTILITY VALUE OF BITUMEN

Aim: To determine ductility value of bitumen.

Theory: In the flexible pavement construction where bitumen binders are used, it is of significant that the binders form ductile thin films around the aggregates. This serves as satisfactory improving the physical interlocking of the aggregates. The binder material which does not posses ductility would crack and thus provide pervious pavement surface. Thus in turn results in damage to the pavement structure. It has been stated by some agencies that the penetration and properties, go together; but depending upon the chemical composition and the type of bitumen's, sometimes it has been observed that the above statement is incorrect. It may hence be that the bitumen may satisfy the penetration value, but may fail to satisfy the ductility Bitumen paving engineer would however want that both test requirements are satisfied in the Penetration or ductility can not in any case replace each other. The ductility is expressed as the in centimeters to which a standard briquette of bitumen can be stretched before the thread test is conducted at 27± 0.5^{0}C and a rate of pull of 50± 2.5 mm per minute. The test standardized by the ISI. The ductility test concept is shown in Figure 9.1

Apparatus: The ductility test apparatus consists of items like sample (briquette) moulds, water, trowel or putty knife sharpened on end and ductility machine. Standard specification .

(a) *Briquette mould :* Mould is made of bras metal with shape and dimeter as in fig 11.2 Bot ends calledclips possess circular holes to grip the fixed and mova – machine. Side pieces when placed together form thebriquette of the following dimessions.

Length	……	75 mm
Distance between clips	…..	30 mm
Width at mouth of clips	…….	20 mm
Cross section at minimum width	…….	10 mm × 10 mm

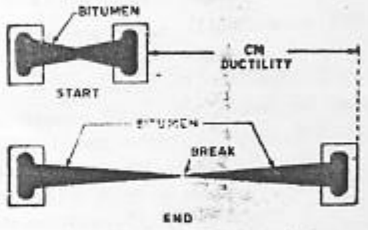


Fig. 18.1 Ductility Test Concept

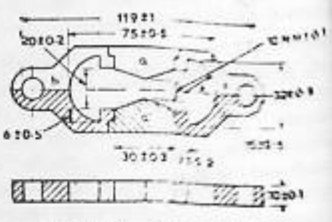


Fig. 18.2 Briquette Mould

(b) *Ductility machine:* It is an equipment which functions as constant temperature water bath and a pulling device at a precalibrated rate. The central rod of the machine is threaded and through a gear system provides movement to one end where the clip is fixed during initial placement. The other clip end is hooked at the fixed end of the machine. Two clips are thus pulled apart horizontally at a uniform speed of 50±2.5 mm per minute. The machine may have provision to fix to or more mould as to test these specimens simultaneously.

Procedure: The bitumen sample is melted to a temperature of 75^{0}C to 100^{0}C above the approximate softening point until it is fluid. It is strained through Is sieve 30, poured in the mould assembly and placed on a brass plate, after a solution of glycerine and dextrine is applied at all surfaces of the mould exposed to bitumen. Thirty to forty minutes after the sample is poured into the moulds, the plate assembly alongwith the sample is placed in water bath maintained at 27^{0}C for 30 minutes. The sample and mould assembly are removed from water bath and excess bitumen material is cut off by leveling the surface using hot knife. After trimming the specimen, the mould assembly containing sample is replaced in water bath maintained at 27^{0}C for 85 to 95 minutes. The sides of the mould are now removed and the clips are carefully booked 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. The pointer is set to read zero. The machine is started and the two clips are thus pulled apart horizontally. While the test is in operation, it is checked whether the sample is immersed in water at depth of at least 10 mm. The distance at which the bitumen thread of each specimen breaks, is recorded (in cm) to report as ductility value.

OBSERVATION SHEET – DUCTILITY TEST

Test Property	Briquette Number			Mean value
	(i)	(ii)	(iii)	
Ductility value (cm)				

Results: The ductility value of given bitumen sample =

EXPERIMENT NO-20

DETERMINATION OF VISCOSITY OF BITUMINOUS MATERIAL

Aim: To determine the viscosity of bituminous binder**.**

APPARATUS REQUIRED:

A orifice viscometer (one of 4.0mm diameter used to test cut back grades 0 and1 and 10mm orifice to test all other grades), water bath, stirrer and thermometer.

PROCEDURE:

1. Adjust the tar viscometer so that the top of the tar cup is levelled. Select the test Temperature . Heat the water in water bath to the temperature specified for the test and
   Maintains it within **±0.1°C** of the specified temperature throughout the duration of test. Rotate the stirrer gently at frequent intervals or perfectly continuously
2. Clean the tar cup orifice of the viscometer with a suitable solvent and dry thoroughly
3. Warm and stir the material under examination to **20°C** above the temperature specified for test and cool, while continuing the stirring.
4. When the temperature falls slightly above the specified temperature, pour the tar into the cup until the levelling peg on the valve rod is just immersed when the latter is vertical.
5. Pour into the graduated receiver **20ml** of mineral oil, or one percent by weight solution of soft soap, and place it under the orifice of the tar cup.
6. Place the other thermometer in the tar and stir until the temperature is **within ±0.1°C** of the specified temperature. When this temperature has been reached, suspend the thermometer coaxially with the cup and with its bulb approximately at the geometric center of the tar.
7. Allow the assembled apparatus to stand for five minutes during which period the thermometer reading should remain within **0.05° C** of the specified temperature. Remove the thermometer and quickly remove any excess of tar so that the final level is on thecentral line of the leveling peg when the valve is in vertical position.

8. Lift the valve and suspend it on valve support

9. Start the stop watch when the reading in the cylinder is **25ml** and stop it when it is **75ml.**
note the time in seconds

10. Report the viscosity as the time taken in seconds by **50ml** of tar to flow out at thetemperature specified for the test.

RECORD AND OBSERVATION:

Specification	**Test 1**	**Test 2**
Test temperature		
Time taken to flow 50cc of binder		
Viscosity	***Seconds***	***Seconds***

RESULT:

The Viscosity value of given bitumen is **Seconds.**

EXPERIMENT NO-22

DETERMINATION OF TURBIDITY OF WATER SAMPLE USING TURBIDIMETER/NEPHLOMETER

Aim: To determine the turbidity of the given sample

Theory:

Turbidity is a measure the extent to which light is either absorbed or scattered by suspendedmaterial present in the water. Surface waters results from the erosion of colloidal material such as clay, slit, rock fragments and metal oxides from soil, vegetable fibers and micro- organisms may also contribute to turbidity. Drinking water supplies requires special treatment by chemical coagulation and filtration before it may be used for public water supply.

This turbidity can be brought down to required level by adding coagulants. Coagulants when added to water it will form a geletaneous substance known as floc and this will arrest the fine suspended and colloidal particles. These arrested particles will settledown rapidly because of increase in their size.

Environmental Significance:

Turbidity water is displeasant and is accepted for domestic use. The colloidal matter associated with turbidity provides adsorption sites for chemicals and biological organisms that may be harmful or cause undesirable tastes and odour. Disinfection of the turbid waters is difficult and unsatisfactory, since the colloids partially shield organisms from the disinfectant. This IS values for drinking water is 10 to 25 NTU.

Apparatus:

Nephelo turbidity meter.

Reagents:

1. Turbidity free water: Pass distilled water through a lower turbidity than distilled water, discard the first 200ml, collected. If filtration does not reduce turbidity use distilled water.
2. Stock turbidity solutions:-

i) Solution 1: Dissolve 1.0 grams hydrazine suplate $(NH_2)_2.H_2So_4$ in distilled water anddilute it to 100 ml in a make up flask.

ii) Solution 2: Dissolve 10.0 grams hexamethylene tetramine $(CH_2)_6N_4$ in distilled water anddilute it to 100ml.

iii) Solution 3: In a 100ml flask, mix 5ml. each of solution 1 and 2. Allow it to stand 24 hours,then dilute it to 100ml and mix thoroughly. The turbidity of this solution is 400 NTU.

iv) Standard Turbidity Solution: Take 10.0ml of solution 3 in a 100ml make up flask anddilute it to 100ml. with turbid free water. The turbidity of this suspension is 40 NTU.

Procedure:

a) Calibration of Nephelometer:

i) Proper range of NTU on Nephelometer is selected.

ii) By placing distilled water in Nephelometer test tube, the Nephelometer reading to zero isset using the knobs.

iii) Using the standard turbid solution (i.e. 40 NTU), the Nephelemeter (i.e. adjust the Nephelemeter reading to 40 NTU using calibration knob) is calibrated.

b) Determination of turbidity of sample water:

Then the sample is thoroughly shaken so as to remove any air bubbles and poured it into meter cell. The turbidity of the sample is read out from the digital display.

Tabulation:

Sample	Turbidity(NTU)	Temp(°C)

Result: The turbidity of the given water sample is found to be

EXPERIMENT -23

DETERMINATION OF PH OF WATER SAMPLE USING (A) PH-METER (B) COLOUR COMPACTOR

Aim: To determine the pH of the given sample

Theory:

Measurement of pH is most frequently used in water chemistry. Practically, every phase of water supply and wastewater treatment, e.g. water softening, precipitation, coagulation, disinfection, acid-base neutralization is pH dependent. At a given temperature, the intensity of acidic or basic character of a solution is indicated by pH

Alkalinity and acidity are the acid- and base-neutralizing capacities of a water and usually are expressed as milligrams $CaCO_3$ per litre. pH as defined by the Sorenson is – log[H+], negative logarithm of hydrogen ion concentration. It is the intensity factor of acidity. Pure water is slightly ionized and at equilibrium, the product is

[H+] [OH^-] = 10^{-14} at 25 ^{0}C .... (1)

where [H+] = activity of hydrogen ions, moles/L

[O H^-] = activity of hydroxyl ions, moles/L and a logarithmic scale is convenient for expressing a wide range of ionic activities.

Apparatus:

The apparatus consists of a pH meter with glass and reference electrode with temperature compensation.

Procedure:

The pH meter is switched on and allowed it to warm for some period. Then the meter is standardized by dipping the electrode in pH 4.00 & 9 buffer. The temperature of water is measured and the temperature knob is kept at on that temperature. Now the instrument is calibrated and ready for measuring the pH of unknown solutions.

Tabulation:

Sample	Ph	Temp(°C)

Result: The pH of the given water sample is found to be

EXPERIMENT 24

DETERMINATION OF CHLORIDE CONTENT OF A WATER SAMPLE USING METHOD OF TITRATION

Aim: To determine the chloride content of the given sample.

Theory:

Chloride in the form of chlorine ion is one of the major inorganic anions. The salty taste produced by Chloride concentration is variable and dependent on the chemical composition of water. The Chloride is higher in wastewater than in raw water. Along the sea costal, Chloride may be present in high concentrations because of intrusion of salt water into the water and sewage system. In this method, slightly alkaline solution is used. Potassium chromate can indicate the end point of Silver nitrate titration of Chloride as quantitatively precipitated before red Silver chromate is formed.

In Mohr's method, the acidity of the water sample is removed by adding calcium carbonate. Potassium chromate acts as an indicator for titration. Preferential precipitation of white silver chloride over red silver chromate is the principle of this method. The change of colour from white to red indicates the end point. The reactions are:

$NaCl + AgN03 \sim AgCl + NaNO_3$

(white) Ag_2Cr0_4

$+2KNO_3$ (red)

Environmental Significance:

Chlorides associated with sodium (Sodium Chloride) exert salty taste when its concentration is more than 250 mg/L. These impact a salty taste to water. Chlorides are generally limited to 250 mg/L in water supplies intended for public water supply. In many areas of the world where water supplies are scarce, sources containing as much as 2000 mg/L are used for domestic purposes without the development of adverse effect, once the human system becomes adapted to the water.

It can also corrode concrete. Magnesium chloride in water generates hydrochloric acid after heating which is also highly corrosive and creates problem in boilers. Chloride determinations in natural waters are useful in the selection of water supplies for human use. Chloride determination is used to determine the type of desalting apparatus to be used andto control pumping of ground water from locations where intrusion of seawater is a problem.

Apparatus:

Titration Stand with Burette, Conical Flask, Beaker, Measuring Cylinder, Pipette, Funnel, Wash Bottle etc.

Reagents:

1. Standard silver nitrate solution, AgN03 (0.02 N)
2. 5 % Potassium chromate solution

Procedure:

50 mL of the given water sample is pipetted in a conical flask. Two drops of potassium chromate is added to the sample. The whole solution is titrated against standard silver nitrate solution with constant stirring. The red colour appearing at this stage does not persist and disappears on shaking. The titration is carried out till faint red colour persists. The procedure is repeated till three concordant readings are obtained.

Observation:

1. Titrant :
2. Indicator : Potassium Chromate Solution
3. End Point : Yellow to Brick Red

Tabulation:

sample	Volume of sample ml	Initial Burette reading of sample	Final Burette reading of sample	Volume of silver nitrate(mL)	Chloride(mg/l)

Calculations:

Initial Burette reading = X mL , Final Burette reading = Y mL

Total volume of $AgN0_3$= X - Y = V mL, Strength of $AgN0_3$ solution = y (N/50)1000

mL of 1 N $AgN0_3$ solution = 35.5 g of chloride

V mL ofy (N/50) $AgN0_3$ solution = (35.5 x V x y x 1000)/(50 x 1000) = 0.71 Vy mg ofchloride

50 mL of supplied water sample contains 0.71 Vy mg of chloride

1000 mL of supplied water sample contains (0.71 Vy x 1000) / 50 mg of chloride =
14.2Vy mg of chloride

Concentration of chloride in given water sample = 14.2Vy mg/L

Result:

The chloride concentration of the given water sample is found to be

EXPERIMENT NO-25

DETERMINATION OF OPTIMUM DOSE OF COAGULANT

Aim:

To determine the optimum coagulant dosage for clarifying the given sample of water by using alum as the coagulant and performing the jar test experiment.

Principle

Coagulants are used in water treatment plants

(i) to remove natural suspended and colloidal matter,

(ii) to remove material which do not settle in plain sedimentation, and

(iii) to assist in filtration.

Alum [Al2(SO4)3. 18H2O] is the most widely used coagulant. When alum solution is added to water, the molecules dissociate to yield SO2–4and Al3+. The +ve species combine with negatively charged colloidal to neutralize part of the charge on the colloidal particle. Thus, agglomeration takes place. Coagulation is a quite complex phenomenon and the coagulant should be distributed uniformly throughout the solution. A flash mix accomplishes this.

JAR TEST APPARATUS

Jar test is simple device used to determine this optimum coagulant dose required. The jar test, device consists of a number of stirrers (4 to 6) provided with paddles. The paddles can be rotated with varying speed with the help of a motor and regulator. Samples will be taken in jars or beakers and varying dose of coagulant will be added simultaneously to all the jars. The paddles will be rotated at 100 rpm for 1 minute and at 40 rpm for 20 to 30 minutes, corresponding to the flash mixing and slow mixing in the flocculator of the treatment plant. After 30 minutes settling, supernatant will be taken carefully from all the jars to measure turbidity. The dose, which gives the least turbidity,is taken as the optimum coagulant dose.

Apparatus:

1. Jar Test Apparatus
2. Glass Beakers
3. Pipette
4. Nephelometer
5. pH meter

Reagents

1. Alum solution (1mL containing 10 mg of alum)
2. Lime
3. Acid/alkali

Procedure

1. Take 1-litre beakers and fill them with sample up to the mark.
2. Keep each beaker below each paddle and lower the paddles, such that each one is about 1cmabove the bottom.
3. Find the pH of the sample and adjust it to 6 to 8.5.
4. Pipette 1, 2, 3, 4, 5, 6 mL of the alum solution into the test samples.
5. Immediately run the paddles at 100 rpm for 1 minute.
6. Reduce the speed to 30–40 rpm and run at this rate for 30 minutes.
7. Stop the machine, lift out the paddles and allow to settle for 30 minutes.
   Find the residual turbidity of the supernatant using
8. nephelometer.
9. Plot a graph with alum dosage along x-axis and turbidity along y-axis.
10. The dosage of alum, which represents least turbidity, gives Optimum Coagulant Dosage(O.C.D.).
11. Repeat steps 1–10 with higher dose of alum, if necessary.

OBSERVATION AND REPORTING:

Sample__________ pH___________ Date__________________

Location______________ Colour_____________ Temperature_____________________

Sample details	Volume of sample in liters	Does of coagulant	Rasidual turbidity	pH	Colour

Flash mixture, minutes____________
Slow mixspeed, rpm_____________
Slow mix time, inutes_________________, Temperature,°C_________________
Time of first floc formulation, minutes___________________

RESULTS:
Optimum dose of coagulant corresponding to maximum tubidity removal=______________.

EXPERIMENT NO: 26

DISSOLVED OXYGEN

AIM: TO DETERMINE DISSOLVED OXYGEN OF GIVEN SAMPLE.

PRINCIPLE:

DO rapidly oxidizes the divalent manganous to its higher valency which forms a brown hydrated oxide precipitate after addition of NaOH and KI. In the presence of iodide ions in an acidic solution the oxidized manganese reverts to the divalent state and liberates Iodine from KI equivalent to the original DO content.

The liberated Iodine is then titrated against Sodium thiosulphate solution with starch as an indicator. MnSO4 reacts with alkali to form white precipitate Mn(OH)2 thus indicating absence of oxygen in the sample.

REACTION:

$Mn^{++} + 2(OH) \rightarrow Mn(OH)_2$ (white)

$Mn^{++} + 2(OH) + 1/2\ O_2 \rightarrow MnO_2$

(brown)$+H_2O\ MnO_2 + 2I + 4H \rightarrow$

$Mn^{++} + I_2 + 2H_2O$

APPARATUS:

BOD bottles (capacity 300 ml), burette, pipettes, conical flask, burette stands, tile, measuring cylinder, weight balance,glass rod, beakers.

REAGENTS:

1. Winkler's A solution:

   Dissolve 48 gm tetra hydrate manganous sulphate in 100 ml distilled water. Filter if necessary.
2. Winkler's B solution:

   Dissolve 50 gm of NaOH and 15 gm of KI in 100 ml distilled water.
3. Starch indicator:

   Make a paste of 2gm L.R grade soluble starch powder in distilled water. Pour this solution in 100 ml distilledwater. Boil for few minutes. Cool the solution and then use.
4. Concentrated sulphuric acid
5. **Standard sodium thiosulphate solution:**

   Dissolve 24.82 gm $Na_2S_2O_3$ in distilled water and make up to 1 liter. It becomes 0.1N. Take 250 ml of thissolution and make up to 1 liter with distilled water to prepare 0.025N.

PROCEDURE:

1. Collect the sample in 300ml BOD bottle.
2. Add 2ml of Winkler’s A solution and 2ml of Winkler’s B solution well below the surface through the walls.
1. Stopper immediately to remove air bubbles and mix carefully by inverting bottle up and down.
2. Allow the brown precipitate to settle down leaving clear supernatant.
3. Add conc. Sulphuric acid drop by drop till precipitate digested.
4. Restopper the bottle and mix by inverting several times for complete dissolution.
5. A yellow colored solution appears.
6. Take 50 ml samples in conical flask.
7. Add few drops of starch indicator and titrate against 0.025N Na2S2O3 solution.
8. Note down the reading until the color changes from blue to colorless.

SOURCE:

1. Drinking water.
2. Tap water.

OBSERVATIONS:

1. In burette: 0.025 N sodium thiosulphate solution.
2. In conical flask: 50 ml sample + indicator.
3. Indicator: starch.
4. End point: blue to

OBSERVATION TABLE:

Sr no.	Source	Burette reading	Difference	Average

CALCULATION:

DO (mg/l) = (V x
70) / uWhere,
V= ml of titrant used for DO
determination (B.R.)u = ml of water

sample taken

70 = correction factor

RESULT:

The amount of dissolved oxygen determined from the given sample is   mg/l.

EXPERIMENT NO-27
TEST FOR COLIFORMS IN WATER

Aim: To find the Most Probable Number (MPN) of bacterial density by E.coli test**.**

Principle

Coliform group comprises of all the aerobic, facultative and anaerobic gram-negative non-spore forming rod shaped bacteria that ferment lactose with gas formation within 48 hours at 35°C. The standard test for this group may be carried out either by multiple tube fermentation technique or by membrane filter technique. The E.coli test by multiple tube fermentation technique consists of 3 phases – presumptive, confirmed and completed.

Escherichia coli (E.coli) for the purpose of sanitary examination of water, is defined as a gram- negative, nonspore forming rod which is capable of fermenting lactose with the production of acidand gas at 35°C in less than 48 hours, which produces indole peptone water containing tryptophan, which is incapable of utilising sodium citrate as its sole source of carbon, which is incapable of producing acetyl methyl carbinol, and which gives a positive methyl red test. The results are expressed in terms of MPN (Most Probable Number), which is based on certain probability formulae. The estimate may give a value greater than the actual number of coliform present. The accuracy of any single test depends on the number of tubes fermented. This method helps in describing the sanitary quality of water.

The safety of the water is generally judged from the knowledge of sanitary condition and mentioned by the number of samples yielding positive or negative results. If more than 95% should yield negative results, the safety is usually assured. The scheme of the MPN test is given as follows:

Apparatus

1. Fermentation tubes
2. Petri dishes
3. Autoclave
4. Incubator
5. Test tubes
6. Pipettes
7. Measuring jars
8. Inoculating equipments
9. Media preparation utensils etc.

Reagents

1. Lactose broth
2. Lauryl tryptose broth
3. Brilliant green lactose bile broth
4. Endo agar
5. Eosin methylene blue agar etc.

1. **Lactose broth:** Beef extract 3 g, peptone 5 g, lactose 5 g and reagent grade distilled water 1 litre. Add these ingredients to reagent grade distilled water, mix thoroughly and heat to dissolve. pH should be 6.8 7.0 after sterilisation.

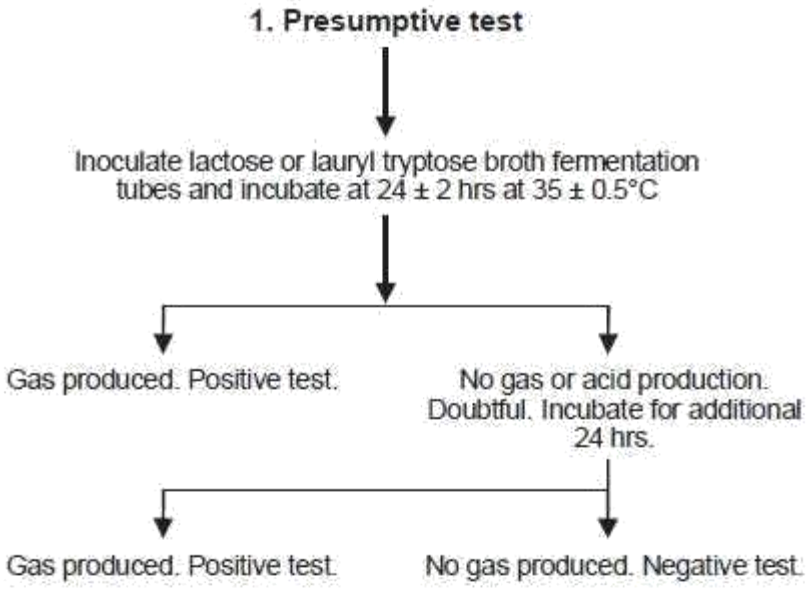
2. **Lauryl tryptose broth:** Tryptose 20 g, lactose 5 g, K_2HPO_4 2.75 g, KH_2PO_4 2.75 g, NaCl 5 g, sodium lauryl sulphate 0.1 g, reagent grade distilled water 1 litre, sterilise and use. Add dehydrated ingredients to water, mix thoroughly and heat to dissolve. pH should be 6.8 ±2 after sterilisation.

3. **Endo agar:** Peptone 10 g, lactose 10 g, K_2HPO_4 3.5 g, agar 15 g, sodium sulphite 2.5 g, basic fuchsin 0.5 g, distilled water 1 litre, pH 7.4 after sterilisation.

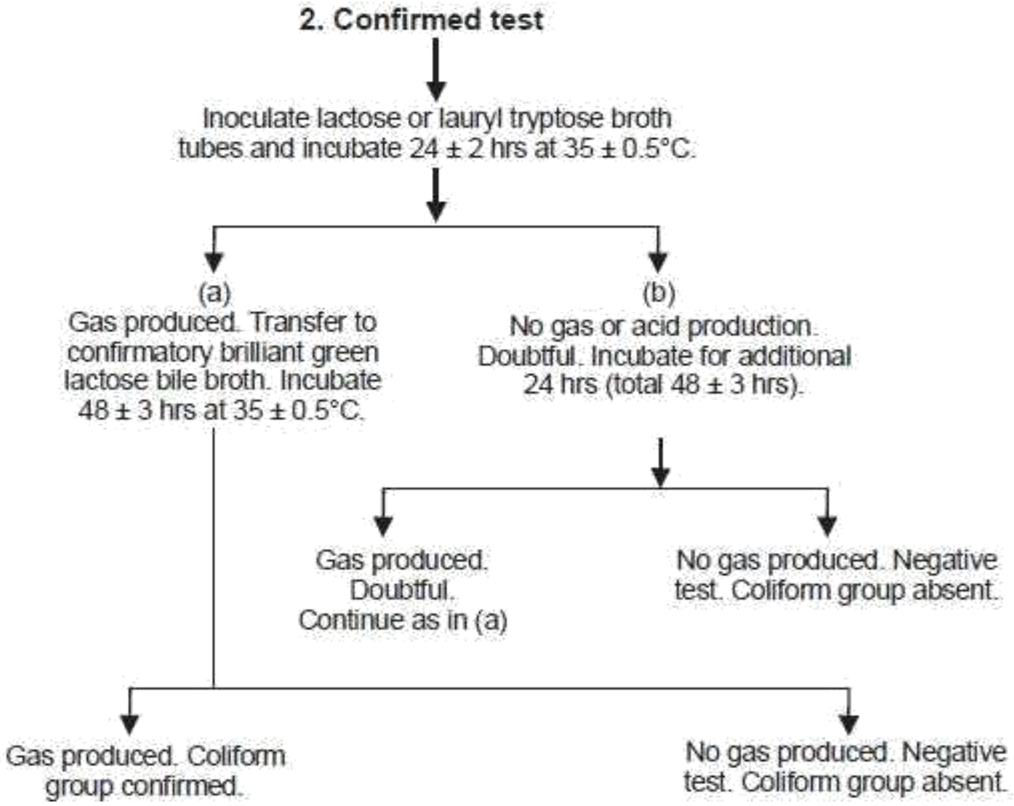
4. **EMB agar:** Peptone 10 g, lactose 10 g, K_2HPO_4 2 g, agar 15 g, eosin 0.4 g, methylene blue 0.065 g, distilled water 1 litre, pH should be 7.1 after sterilisation.

5. **Brilliant green lactose bile broth:** Peptone 10 g, lactose 10 g, oxgall 20 g, brilliant green 0.0133 g, distilled water 1 litre, pH should be 7.2 after sterilisation and is then ready for use. Store away from direct sunlight to extend the reagent stability to 6 months.

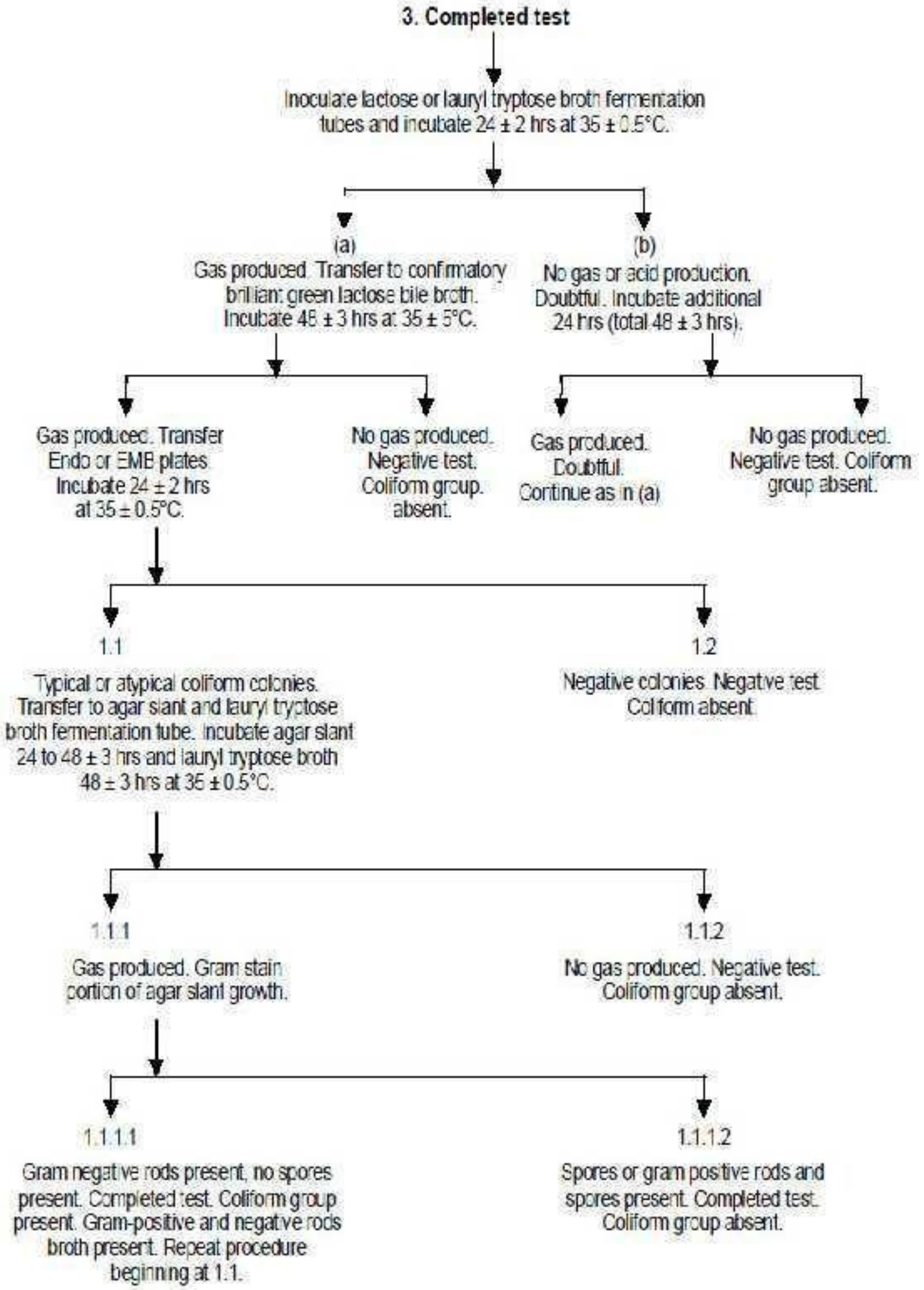
SCHEMATIC OUTLINES FOR THE E.COLI TEST PROCEDURE



Schematic outline of presumptive test for coliform detection.



Schematic outline of presumptive, confirmed and completed test for total coliform detection.



3. Completed test

Inoculate lactose or lauryl tryptose broth fermentation tubes and incubate 24 ± 2 hrs at 35 ± 0.5°C.

(a) Gas produced. Transfer to confirmatory brilliant green lactose bile broth. Incubate 48 ± 3 hrs at 35 ± 5°C.

(b) No gas or acid production. Doubtful. Incubate additional 24 hrs (total 48 ± 3 hrs).

Gas produced. Transfer Endo or EMB plates. Incubate 24 ± 2 hrs at 35 ± 0.5°C.

No gas produced. Negative test. Coliform group. absent.

Gas produced. Doubtful. Continue as in (a)

No gas produced. Negative test. Coliform group absent.

1.1 Typical or atypical coliform colonies. Transfer to agar slant and lauryl tryptose broth fermentation tube. Incubate agar slant 24 to 48 ± 3 hrs and lauryl tryptose broth 48 ± 3 hrs at 35 ± 0.5°C.

1.2 Negative colonies. Negative test. Coliform absent.

1.1.1 Gas produced. Gram stain portion of agar slant growth.

1.1.2 No gas produced. Negative test. Coliform group absent.

1.1.1.1 Gram negative rods present, no spores present. Completed test. Coliform group present. Gram-positive and negative rods broth present. Repeat procedure beginning at 1.1.

1.1.1.2 Spores or gram positive rods and spores present. Completed test. Coliform group absent.

Procedure

General

Clean and sterilize all the glass wares.

Presumptive Test

1. Inoculate a series of fermentation tubes with appropriate graduated quantities (multiples and sub-multiples of 10) of the water to be tested. The concentration of nutritive ingredients in the mixture of the medium should conform to the specifications. The partitions of the water sample used for inoculating lactose or lauryl tryptose broth fermentation tubes will vary in size and number with the character of the water under examination. Usually, decimal multiples and sub-multiples of 1mL of the sample are selected. Inoculate 10 mL portion of each water sample provided into different one of the three large tubes containing 10 mL of lactose or lauryl tryptose broth which has been prepared with twice the normal concentration of constituent to allow for dilution. Inoculate 1.0 mL and 0.1 mL of water into small tubes (two sets of three each) of single strength lactose or lauryl tryptose broth.
2. Incubate the inoculated fermentation tubes at 35±0.5°C. At the end of 24±2 hrs shake each tube gently and examine and if no gas is formed, repeat this test at the end of 48±3 hrs.
3. Record the presence or absence of gas formation at each examination of the tubes. Formation within 48±3 hrs of gas in any amount in the inverted fermentation tubes constitutes a positive presumptive test. Active fermentation may be shown by the continued appearance of small bubbles of gas throughout the medium outside the inner vial in the fermentation tubes. Presumptive test without confirmation should not be used routinely except in the analysis of heavily polluted water, sewage or other waste, which are not suitable for drinking purpose.

Confirmed Test

1. Lactose or lauryl tryptose broth may be used for primary fermentation in presumptive test to avoid false positive results.
2. Brilliant green lactose bile broth fermentation tubes are used in confirmed test.
3. Submit all primary fermentation tubes showing any amount of gas at the end of 24 hrs incubation to the confirmed test.
4. Gently shake primary fermentation tube showing gas formation and with a sterile metal loop, transfer one loop full of medium to a fermentation tube containing brilliant green lactose bile broth.
5. Incubate the inoculated brilliant green lactose bile broth tube for 48±3 hrs at 35±0.5°C.
6. The formation of gas in any amount in the inverted vial of the brilliant green lactose bile broth fermentation tube at any time within 48±3 hrs constitutes a positive confirmed test.
7. If no gas is formed, it is a negative confirmed test and E.coli is absent.

Completed Test

Completed test is the next step following the confirmed test. It is applied to the brilliantgreen lactose bile broth fermentation tubes showing gas in the confirmed test.

1. Streak one or more endo or Eosin Methylene Blue (EMB) agar plates (taken in Petri dishes) from each tube of brilliant green lactose bile broth showing gas.
2. While streaking it is essential to ensure the presence of some discrete colonies separated by at least 0.5 cm from one another.
3. Insert the end of the streaking needle into the liquid in the tube to a depth of5mm.
4. Streak the plate by bringing only the curved section of the needle in contact withthe agar surface so that the latter will not be scratched or torn.
5. Incubate the Petri dishes (inverted) at 35 ± 0.5°C for 24 ± 2 hrs.

6. The colonies developing on endo or eosin methylene blue agar may be typical (unnucleated, with or without metallic sheen) atypical (opaque, unnucleated, mucoid, pink after incubation for 24 hrs) or negative (all others).

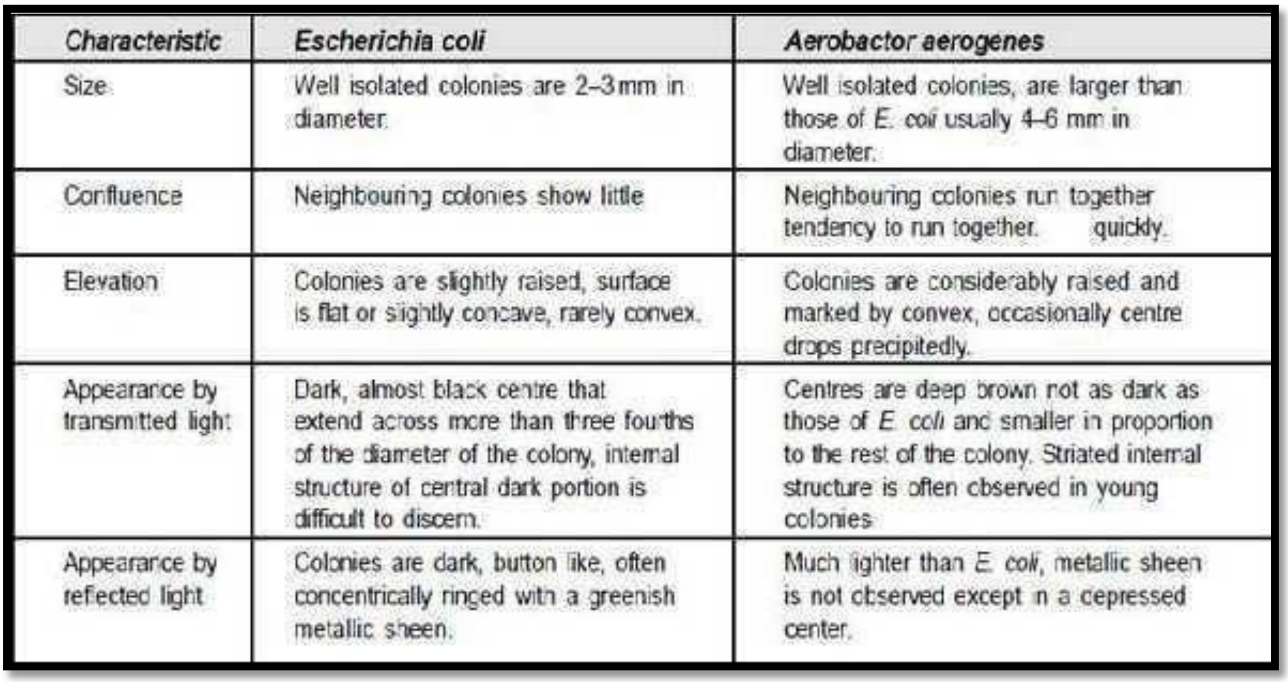
7. From each of these plates fish out one or two colonies and transfer to lauryl tryptose broth fermentation tubes and to nutrient agar slants.

8. Incubate the secondary broth tubes and agar slants at 35 ± 0.5°C for 24 ± 2 hrs or 48 ± 3 hrs and if gas is not produced in 24 hrs gram stained preparation from these agar slant cultures are made.

9. The gas formation in the secondary lauryl tryptose broth tubes and the demonstrationof gram-negative non-spore forming rod shaped bacteria in agar culture may be considered a satisfactory positive completed test.
10. If after 48 ± 3 hrs gas is produced in the secondary fermentation tubes and no sporeof gram positive rod are found on the slant, the test may be considered as positive completed test and this demonstrates the presence of coliform organisms.

Differentiation of *E. coli and A. aerogenes* on eosin or EMB agar can be done by referring the following table.

Differentiation of E.coli and A. aerogenes on eosin or EMB agar



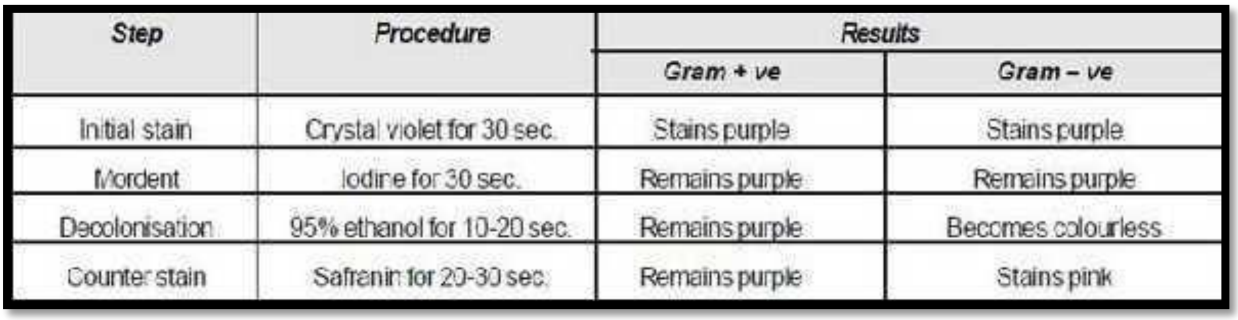
Characteristic	*Escherichia coli*	*Aerobactor aerogenes*
Size	Well isolated colonies are 2–3 mm in diameter.	Well isolated colonies, are larger than those of *E. coli* usualy 4–6 mm in diameter.
Confluence	Neighbouring colonies show little tendency to run together.	Neighbouring colonies run together quickly.
Elevation	Colonies are slightly raised, surface is flat or slightly concave, rarely convex.	Colonies are considerably raised and marked by convex, occasionally centre drops precipitedly.
Appearance by transmitted light	Dark, almost black centre that extend across more than three fourths of the diameter of the colony, internal structure of central dark portion is difficult to discern.	Centres are deep brown not as dark as those of *E. coli* and smaller in proportion to the rest of the colony. Striated internal structure is often observed in young colonies
Appearance by reflected light	Colonies are dark, button like, often concentrically ringed with a greenish metallic sheen.	Much lighter than *E. coli*, metallic sheen is not observed except in a depressed center.

1. Ammonium oxalate-crystal violet (Hucker's)
2. Lugol's solution
3. Counter stain
4. Acetone alcohol.

Procedure

1. Prepare a light emulsion of the bacterial growth on an agar slant in a drop of distilledwater on a glass slide.
2. Air-dry or fix by passing the slide through a flame and stain for 1minute with ammonium oxalate-crystal violet solution.
3. Rinse the slide in tap water and then apply Lugol's solution for 1minute.
4. Rinse the stained slide in tap water.
5. Decolorise with acetone alcohol till the stain is just removed.
6. Counter-stain with safranin for 15 seconds and then rinse with tap water.
7. Blot dry with blotting paper and view through the microscope.
8. Cells that decolorise and accept the safranin stain are pink and are defined as gram negative. Cells that do not decolorise but retain the crystal violet stain (deep blue) are defined as gram positive.

Steps in the gram staining are shown in the following table.



Step	Procedure	Results	
		Gram + ve	Gram – ve
Initial stain	Crystal violet for 30 sec.	Stains purple	Stains purple
Mordent	Iodine for 30 sec.	Remains purple	Remains purple
Decolonisation	95% ethanol for 10-20 sec.	Remains purple	Becomes colourless
Counter stain	Safranin for 20-30 sec.	Remains purple	Stains pink

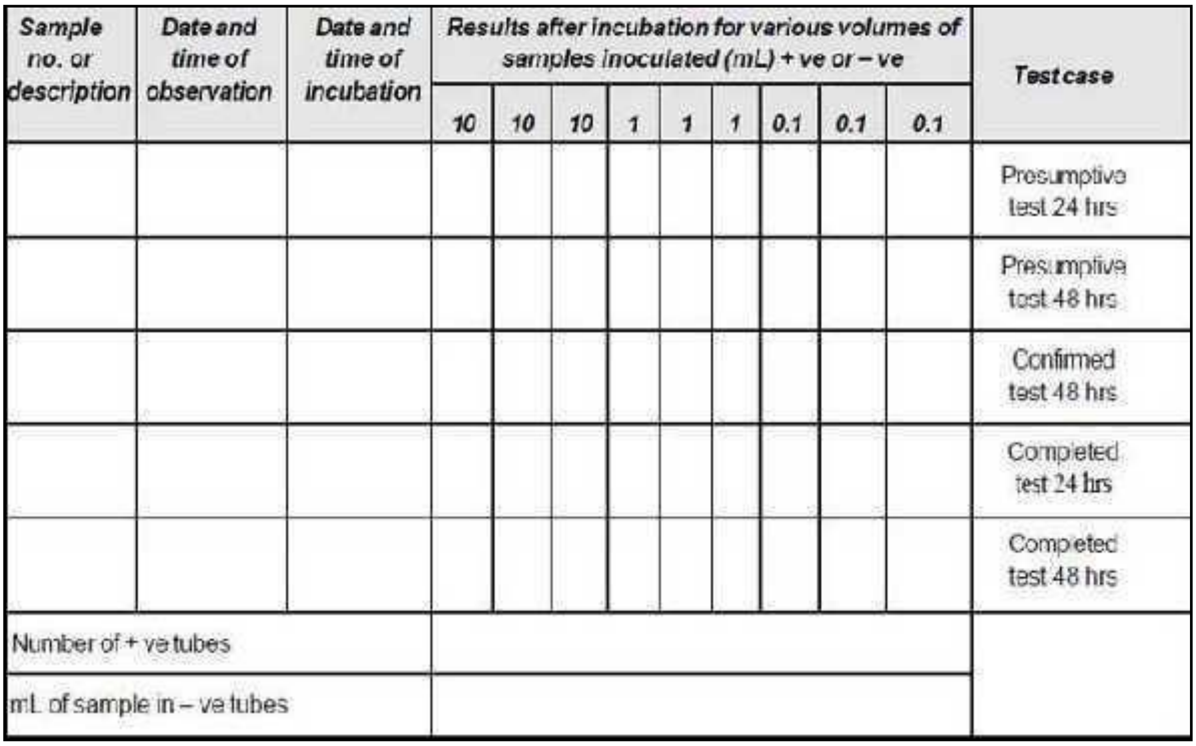
Computation of MPN

The number of positive finding of coliform group organisms resulting from the multiple portion decimal dilution planting should be computed as the combination of positives and recorded in terms of the Most Probable Number (MPN). The MPN for the variety of planting series are presented in table in Appendix III. The values are at the 95% confidence limit for the combination is 100,10,1 mL, the MPN is 0.1 times the value in the table. If on the other hand a combination corresponding to 1, 0.1, and 0.01 mL is planed, recprd MPN as 10 times the value shown in the table.

The MPN for combination not appearing on the table or for other combinations of tubes and dilutions, may be estimated by Thomas' simple formula:

$$\text{MPN/100 mL} = \frac{\text{No. of positive tubes} \times 100}{\sqrt{\text{mL sample in negative tubes} \times \text{mL sample in all tubes}}}$$

Observation



Sample no. or description	Date and time of observation	Date and time of incubation	Results after incubation for various volumes of samples inoculated (mL) + ve or – ve									Test case
			10	10	10	1	1	1	0.1	0.1	0.1	
												Presumptive test 24 hrs
												Presumptive test 48 hrs
												Confirmed test 48 hrs
												Completed test 24 hrs
												Completed test 48 hrs
Number of + ve tubes												
mL of sample in – ve tubes												

Calculation

Case (i)

For three each of 10 mL, 1 mL and 0.1 mL sample concentration combinationsMPN from the MPN table **(Appendix-III) =** ....

Case (ii)

For other combinations and dilutions

$$\text{MPN/100 mL} = \frac{\text{No. of positive tubes} \times 100}{\sqrt{\text{mL sample in negative tubes} \times \text{mL sample in all tubes}}} = \ldots\ldots\ldots$$

Result:

MPN/100 mL =........