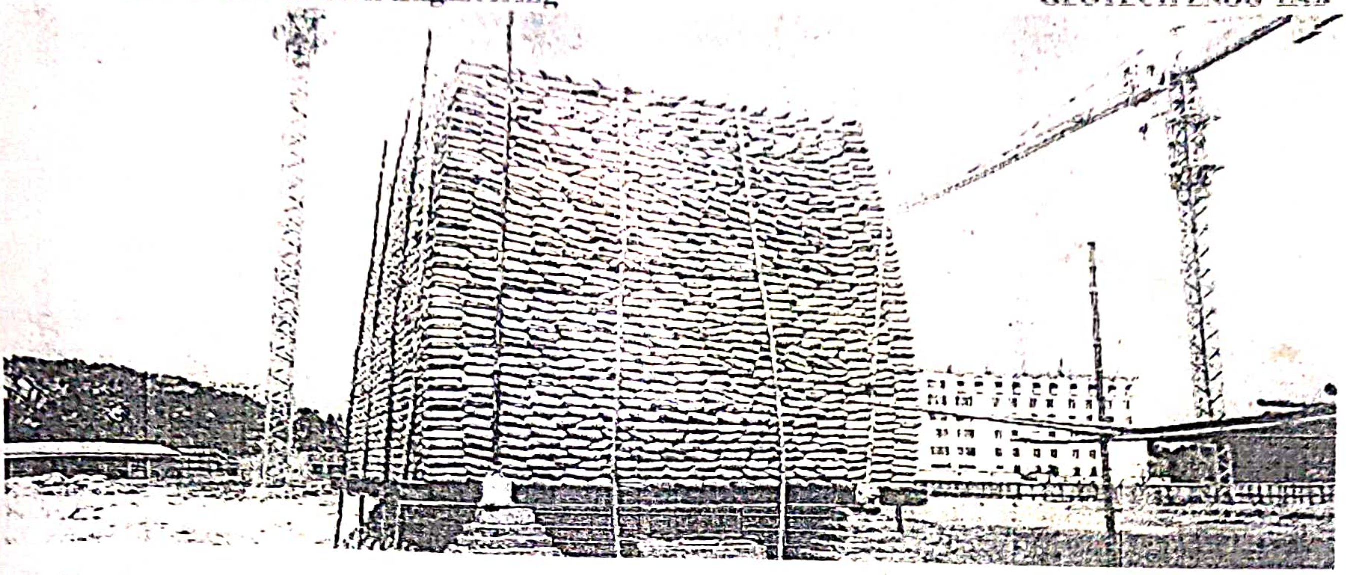


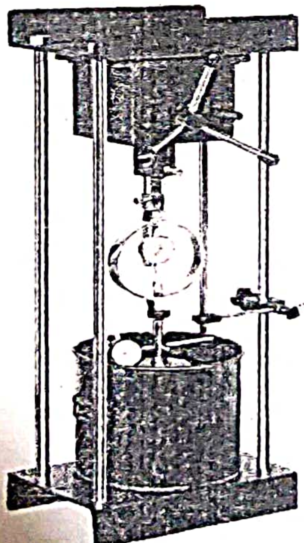
National Education Society ®

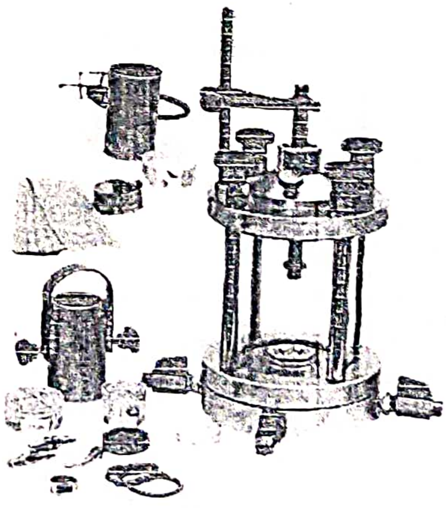
JAWAHARLAL NEHRU NATIONAL COLLEGE OF ENGINEERING SHIVAMOGGA

DEPARTMENT OF CIVIL ENGINEERING

LABORATORY MANUAL

GEOTECHNICAL ENGINEERING LABORATORY





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VISION OF THE INSTITUTE
To be a pace setting institute in technical & management education and research for producing highly competent engineers, managers & entrepreneurs to meet the needs of industry and society.

MISSION OF THE INSTITUTE	
M1	Impart quality education through flexible and innovative teaching learning process.
M2	Enable and Ignite young minds to excel in their career and life with entrepreneurial spirit, professional ethics and human values.
M3	Facilitate invention based research and collaborate with industries to address societal needs.

VISION OF THE DEPARTMENT
To become centre of academic excellence and place for learning professional skills to cater the technical challenges posed by the ever changing global environment and development.

MISSION OF THE DEPARTMENT	
M1	To impart quality education and advances in Civil Engineering to meet the changing global scenario.
M2	To assimilate the spirit of creativity, management and entrepreneurship in Civil Engineering and interdisciplinary field with ethical values
M3	To provide a healthy ambience for teaching, research, consultancy and industry interaction activities to solve engineering problems

V. Srinivasa
Staff In Charge

Professor & Head
Department of Civil Engineering
J.N.N. College of Engineering,
Shivamogga-577 204

ANNEXURE I:

(A) PROGRAM OUTCOMES(POs)

Engineering Graduates will be able to:

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

(B) PROGRAM SPECIFIC OUTCOMES (PSOs)

Program shall specify 2-4 program specific outcomes.

[illegible]

[illegible]

[illegible]

[illegible]	[illegible]
1.	Graduates will be able to pursue Civil Engineering profession [illegible] solutions.
2.	Graduates will be able to pursue [illegible] in their profession [illegible] modern tools and higher [illegible] teaching profession.
3.	Graduates will be able to exhibit good communication skills while working as [illegible] members and team leaders [illegible] leadership qualities.
4.	Graduates will be able to follow [illegible] professionalism, ethics, public policy, safety and sustainability [illegible] contributions to society [illegible] engineering problems and providing solutions.

Experiment no- 1

IDENTIFICATION OF SOILS:

AIM: To identify the given soil samples by their physical properties.

THEORY:

All "loose deposits" (a geological term) of weathered crust of the earth's rock mantle (lithosphere), both cohesion less and cohesive, in which the strength of bonds is only a small fraction of the strength of mineral particles, may be termed as soils. The upper layer of the natural earth crust altered by t he action of geological agents and enriched in humus is a specific structural mineral organic formation called the 'humus soil'.

The soils may be broadly classified as: (1) Fine grained soils (clay, silt).
(2) Coarse grained soils (sand, gravel).
Its difficult to identify silt from clay i.e. its difficult to distinguish between them.
1. Dialentency test and 2. Squeezing test are two tests to distinguish between clay and silt in the field. Soils may also be identified by their plasticity- character.

Under the property of cohesionless soil may be broadly divided into

1. cohesionless soil(sand)
2. cohesive soil (clay).

PROCEDURE:

Observe the given samples of soil for its color, odour, grain size, cohesive property, plasticity etc and perform the dialentency test if necessary.

Example:
Color: Grey.
Odour: No.
Grain size: Fine grained.
Cohesive in nature.
Shows plastic character.
Dialentency test shows no film of water.

RESULTS:

Sample no 1 is identified as 'clay'.

EXPERIMENT NO.2

DETERMINATION OF WATER CONTENT:

AIM: To determine the water content of the given sample of soil.

APPARATUS USED:0ven (110+/-5 deg c), soil specimen, balance, weight box, dessicator, steel cup, spatula etc.

OBJECT:

There is a definite relation between the weight of dry particles and the weight of water stored in the pores. Water content is one of the physical properties of soil, which plays an important role in soil mechanics. It leads us to determine the strength of the soil and inturn the bearing capacity. Hence it is necessary to determine the same.

THEORY:

Water content may be defined as the ratio of weight of water to weight of soil solids, expressed as a percentage and denoted by 'w'.

Mathematically $w = Ww / Ws * 100\ \%$

$= \text{Weight of water / weight of soil solids} * 100\ \%$

There are six methods to determine the water content.

1.Oven drying method (std. Method)
2.Sand bath method
3.Alcohol method
4.Infra red lamp torsion balance moisture meter method
5.Calcium carbide method
6.Pycnometer method.

Soil specimen: the soil specimen shall be representative of the soil mass .The size of the specimen selected depends on the quantity required for good representation, which is influenced by the gradation and maximum size of particles and on the accuracy of weighing .The following quantities are recommended for general laboratory use.

Size of particles more than 90 % passing	Minimum quantity of soil specimen to be taken for test massing
25 micron IS Sieve	25
2 mm IS Sieve	50
4.75 mm IS Sieve	200
10 mm IS Sieve	300
20 mm IS Sieve	500
40 mm IS Sieve	1000

PROCEDURE:

1. Clean the container and lid and weigh it (W1).
2. Take the required quantity of soil specimen in the container, crumbled and placed loosely and weigh it with lid. (W2).
3. Then keep it in oven with the lid removed, and maintain the temp.of the oven at 110 +/- 5 deg C.
4. Dry the specimen in the oven for 24 hours.

5. Take out the container, replace the lid and cool it in a dessicator.
6. Record the final weight (W3.) of the container with lid and dried soil sample.
   The water content is calculated using the formula:

$$w = (W2 - W3) / (W3 - W1) * 100 \%$$

where w = water content
W1 = mass of container with lid in g
W2 = mass of container with lid and wet soil in g
W3 = mass of container with lid and dry soil in g

RESULT:

DISCUSSIONS AND CONCLUSIONS:

APPLICATION: Engineering properties of soil depend upon the water content. Hence it is very important .on the design of structures.

CODE OF PRACTICE:
Method of test for soils.
Part II Determination of water content
IS 2720 (part II) 1973.

OBSERVATION:
1. Details of soil sample:
2. Method of test adopted:

TABULAR COLUMN: -

Description	1	2	3
Container number			
1. Mass of empty container (w1)g 2. Mass of container + wet soil (w2)g 3. Mass of container + dry soil (w3)g 4. Mass of water (w2-w3) = Ww g 5. Mass of solids (w3-w1)g = Ws g Water content (w) =(w2-w3) / (w3-w1) * 100			

EXPERIMENT NO.3

DETERMINATION OF SPECIFIC GRAVITY OF FINE GRAINED SOIL

AIM: To determine the specific gravity of the fine grained soil sample.

INSTRUMENTS USED: Density bottles of approximately 50 ml capacity with stoppers; A water bath maintained at a constant temperature (if std. Bottles is used this constant temp is 27 deg C), a vaccum dessicator , a balance capable of weighing accurate to 0.001g, vaccum pump, spatula, glass rod , 150 mm long and 3 mm dia , wash bottle etc.

OBJECT: Specific gravity is one of the important physical properties of soil.Determination of the same of a soil sample helps in knowing its degree of saturation and unit weigth of moist soils.It is used in computation of the results of several laboratory tests of soils. It is helpful in identification of soils.

THEORY: The specific gravity of soil is the ratio of the weight in air of a given volume of soil particles to the weight in air of an equal volume of distilled water at a temperature of 4 deg C . In other words it is the ratio of unit weight of soil solids to that of water .It is denoted by the letter 'G' .

PROCEDURE:

1. Take the density bottle with stopper which is cleaned , dried and weighed to the nearest 0.001 g (m1).
2. Take nearly about 20 g of sample and transfer it to the density bottle.
3. Weigh the bottle and contents together with the stopper to the nearest 0.001 g (m2).
4. Add sufficient air free distilled water till the soil in the bottle is just covered.
5. Entrapped air may be removed either by vaccum pumpor by heating in a water bath.or in sand bath.
6. To remove entrapped air by heating in water bath, fill the air free water till the neck of the bottleand insert the stopper. The bottle is then immersed in the bath till it attains the temperature of the bath.
7. Remove the bottle and contents and allow it to cool. Further add air free water until it is full. Then insert the stopper.
8. Again the bottle is kept in the bath and sufficient time is allowed to elapse. After this operation ensure that the water is free from entrapped air, as before. If not, repeat the process.
9. The stoppered bottle is then taken out of the bath and then allowed for cooling. The bottle is then wiped dry and the whole weighed to nearest 0.001 g.(m3).
10. The bottle is then cleaned out and filled completely with distilled water, free from entrapped air. The stopper is inserted and the whole is immersed in a constant temperature bath until it has attained the temperature of the bath.
11. If there is an apparent decrease in volume of the liquid, the stopper shall be removed, and further water is added to fill the bottle and the stopper inserted.

12. The stoppered bottle is then returned to the bath and sufficient time shall be allowed to elapse, till the water attains the constant temperature of the bath. If the bottle is not completely full repeat the process.
13. The bottle is then taken out of the bath and wiped dry and weighed to the nearest 0.001 g (m4).
14. Specific gravity 'G' can now be found out by using the formula:

$$G = (m2-m1)/[(m4-m1)-(m2-m3)] * GL$$

where,

m1 = mass of density bottle in g.
m2 = mass of bottle and dry soil in g.
m3 = mass of soil bottle and water in g.
m4 = mass of density bottle when full of water in g.

CORRECTION FOR TEMPERATURE:

The specific gravity is calculated at 27 degree C. If the room temperature is different from it the following correction is done.

G' = G*K

K = relative density of water @ room temperature / relative density of water @ 27 deg C.
G' = corrected specific gravity @ 27 deg C.

Specific gravity of water (GL)is taken as given in the chart, is used to get corrected specific gravity.

RESULT:

DISCUSSIONS AND CONCLUSIONS:

APPLICATION:

In the identification of minerals it is useful. This property is useful in finding out the degree of saturation and unit weight of moist soils.Indirectly this helps in calculation of pressure settlements and stability analysis.

CODE OF PRACTICE:

Method of test for soils
Part III Determination of specific gravity
Section I (Fine grained soils)
IS 2720 (Part III / Section I) – 1980.

OBSERVATION: -

1. Details of the soil sample:
2. Methods of test adopted:

TABULAR COLUMN: -

Determination number	1	2
Trial number	1	2
Temperature T °C		
Mass of bottle =(m1)g		
Mass of bottle + soil = (m2)g		
Mass of bottle + soil + water = (m3)g		
Mass of bottle + distilled water = (m4)g		
Mass of soil = (m2-m1)g		
Correction factor G2		

Specific gravity (G) = [(m2-m1)*G2] / [(m4-m1)-(m3-m2)]

EXPERIMENT NO 4

DETERMINATION OF SPECIFIC GRAVITY OF COARSE GRAINED:

AIM: To determine the specific gravity of coarse grained soil.

INSTRUMENTS USED: Pycnometer of about 900 ml capacity with conical cap, balance sensitive to 1g, glass rod , distilled water , wash bottle etc.

OBJECT: Specific gravity is one of the important properties of soil. Determination of specific gravity of a soil sample helps in knowing its degree of saturation, unit weight of soil solids etc.It is also used in computation of the results of several laboratorytests of soils. It is helpful in identification of soils.

THEORY: The specific gravity of a soil is the ratio of weight of soil sample at a given room temperature to the weight of an equal volume of distilled water at the same temperature. It is the ratio of unit weight of soil solids to that of water. It is denoted by the letter 'G'.

PROCEDURE:

1. Clean the Pycnometer and dry it.Find the weight of the pycnometer(m1) along with its cap and washer accurate to 1 g.
2. Take about 200 g to 400 g of oven dried sample and put it in the pycnometer. Weigh the pycnometer along with the soil etc (m2).
3. Fill the pycnometer to half its height with distilled water and mix it thoroughly with glass rod. Add more water and stir it. Replace the screw top and fill the pycnometer flush with hole in the conical cap and weigh it (m3) after drying the pycnometer from outside.
4. Empty the pycnometer , clean it thoroughly and fill it distilled water, to the hole of the conical cap and weigh it (m4).

   The specific gravity is calculated from the formula :

   $$G = (m2-m1) / [(m4-m1) - (m3-m2)] * GL$$

CORRECTION FOR TEMPERATURE:

The specific gravity is calculated for room temp at 27 deg C.If the room temperature is different then the following correction is applied.

$$G' = G*K$$

K = relative density of water at room temp/ relative density of water @27 deg C.

G' = corrected specific gravity at 27 deg C.

Specific gravity of water (GL) is taken as given in chart.

RESULT:

DISCUSSIONS AND CONCLUSIONS:

APPLICATION: In the identification of minerals , specific gravity is useful.This property is useful in finding out the degree of saturation and unit weight of soils. Indirectly this helps in pressure settlements and stability analysis.

CODE OF PRACTICE:

Methods of tests for soils
Part III Determination of specific gravity
Section II Coarse grained soil.
IS 2720 (Part III / Section II) – 1980.

TABULATION AND OBSERVATION:

1. Details of soil sample :
2. Method of test adopted :

Determination number	1	2	3
Bottle number	1	2	3
1.Temperature T ° c 2.Mass of pycnometer (m1) g 3.Mass of pycnometer + soil (m2) g 4.Mass of pycnometer + soil + water (m3) g 5.Mass of pycnometer + full water (m4) g Mass of soil = (m2 – m1) g correction factor G2 = specific gravity of soil sample (G) = [(m2 – m1) * G.L] / [(m4 – m1) – (m3 – m2)			

EXPERIMENT NO.5

DETERMINATION OF IN-SITU DRY DENSITY BY SAND REPLACEMENT METHOD

AIM: To determine the in-situ bulk density of soil and hence its dry density.

APPARATUS USED: Sand pouring cylinder , scrapper tool , bend spoon , dibber , cylindrical calibrating container , balance , metal tray with hole (300mm X 300mm and 100 mm dia hole in the center.) and clean , uniformly grounded natural sand passing through 1 mm IS Sieve and retained on the 600 micron IS Sieve .

OBJECT: Density of soil is a very important physical property.This is useful for checking up the degree of compaction in the field. It is related to voids ratio , porosity and other qualities which are helpful in the design of foundation when we use soil as a structural material as on reservoir embankment, this property is very essential. Hence it is an important property to be determined.

THEORY: Density of unit weight of soil mass is defined as its weight per unit volume. The different types of densities are :

(1) Bulk density – It is the ratio of total weight of soil per unit total volume of soil.
Mathematically $(\gamma_b) = W / V$ g/cc
(2) Dry density – It may be defined as the ratio of total weight of dry soil solids to the total volume of soil .
$(\gamma_d) = W_d / V$ g/cc
(3) Saturated density – is the total weight of saturated soil per unit total volume of the soil.
$(\gamma)_{sat} = W_{sat} / V$ g/cc.
(4) Submerged density – It may be defined as the ratio of total weight of submerged soil to the total volume of soil .
$(\gamma') = W_{sub} / V$ g/cc

PROCEDURE:

There are three parts :

(a) Calibration of the cylinder
(b) Measurement of soil density
(c) Determination of dry density.

(a).Calibration of the cylinder

1. The pouring cylinder is filled with sand, so that the level of the sand within the cylinder is about 10 mm from the top . Its total initial weight W1 is found and should be maintained constant throughout the test for which the calibration is used .(The shutter of the cylinder should be closed.)

2. Place the cylinder on the glass plate , open the shutter and allow the sand to run out . When no further movement of sand takes place within the cylinder , the shutter is closed and the cylinder is removed carefully.
3. The sand that has filled the cone of the pouring cylinder is collected and weighed ,to the nearest gram (W2).Repeat step two and three for at least two or three times and the mean weight is calculated.
4. Sand poured on the glass plate is again filled to the cylinder , so that the weight of the cylinder with sand is again W1 .The shutter should remain closed during the operation .
5. The pouring cylinder is placed concentrically on top of the calibrating cylinder .
6. The shutter is opened and sand is allowed to run out .
7. When no further movement of sand takes place within the cylinder , the shutter is closed.
8. The pouring cylinder is removed and weighed to the nearest gram (W3).
9. Again pour back the sand to the pouring cylinder so that its weight is again W1.
10. Repeat steps 5 to 9 three times and mean value of W3 is taken.
11. The weight of calibration cylinder is found out (m1) g.
12. The calibration container is filled with clean water upto the brim and weighed again (m2) g .
13. The volume of calibration container is the difference of m2 and m1.Hence volume of calibration container V ml is found out. Also volume can be measured by the dimension of the container .
14. The bulk density = (W1 – W3 – W2) / V g/cc.

(b). <u>Measurement of soil density:</u>

15. A flat area , approximately 450 mm sq of the soil to be tested is exposed and trimmed down a lvel surface preferably with the aid of the scrapper tool .
16. The metal tray with center hole is placed on the prepared surface of the soil with the hole over the portion of the soil to be tested .
17. The soil in the hole is then to be excavated .The depth of the layer to be tested being upto a maximum of 150 mm .
18. Remove the metal tray ,place the pouring cylinder concentrically over the hole and open the shutter . Allow the soil to run into the hole.
19. The excavated soil is carefully collected , leaving no loose material in the hole .
20. When no further movement of sand is seen , close the shutter and remove the pouring cylinder .
21. The excavated soil collected is weighed accurately to the nearest gram (Ww) .
22. Weigh the pouring cylinder with remaining sand accurately .(W4).
23. The bulk density = W_w / (W1 – W4 – W2) x (γ_b) g/cc

(d) .<u>Determination of dry density:</u>

24. Weigh accurately the container (W5).
25. Take some representative soil in this container and weigh it accurately.

26. Keep the container and wet soil in the oven for 24 hours maintaining 105 to 110 deg C .
27. Cool the container and soil and weigh it accurately (W7) .
28. The water content is determined using ,

$$w = (W6 - W7) / (W7 - W5) * 100\%$$

29. The dry density = $(\gamma_b) / (1 + w)$ g/cc

RESULT :

DISCUSSIONS AND CONCLUSIONS :

APPLICATION : The in – situ density of natural soil is needed for the determination of bearing capacity of soils , for the purpose of stability , analysis of natural slopes for the determination of pressures on the underlying strata and for calculation of settlement etc.In compacted soils the in – situ density is needed to check the amount of compaction that the soil has undergone for comparison with design data .

CODE OF PRACTICE :

Method of test for soils

Part XXVIII – Determination of dry density of soils in – place by sand replacement method .

IS 2720 (Part XXVIII) – 1974.

OBSERVATION:

A.Determination of weight of sand in cone

Mass of sand + pouring cylinder (m1) g =
Mean of sand in cone (m2) g =

etermination of bulk density of sand

Mean Mass of sand + cylinder after pouring (m3) g =
Mass of sand filling calibrating container = m1 – m2 – m3 =
Volume of calibrating container (V) =
Bulk density of sand = (m1 – m2 – m3) / V

C.Determination of bulk density of soil

Mass of soil from the hole m =
Mass of sand + cylinder after pouring in the hole (m4) g =
Mass of sand in hole = m1- m2 – m4 =
Bulk density of soil (γ_b) =

EXPERIMENT NO 6

DETERMINATION OF DRY DENSITY OF SOILS IN PLACE BY CORE CUTTER METHOD.

AIM: To determine the in- situ bulkdensity of soil.and hence dry density of soil.

APPARATUS USED: Cylindrical core cutter of steel, steel dolly, steel rammer, pellete knife, steel nail, spade, straight edge, balance etc.

OBJECT:Density of soil is a very important physical property.This is useful for checking the degree of compaction in the field.It is related to voids ratio,porosity,and other qualities which are helpful in the design of foundation. When we use soil as a structural material as in reservoir embankment , this property is very much essential.

THEORY: The density of unit wt of soil mass is defined as its weight per unit volume. The different types of densities are:

1. Bulk density.
2. Dry density.
3. Saturated density
4. Submerged density.

PROCEDURE:

1. Measure the inside dimensions of the core cutter and calculate its volume. V cc
2. Weigh the core cutter to accurate to 1 g. (W1).
3. A flat area , approximately 300 m m sq of the soil to be tested is exposed and trimmed down to a level surface.
4. Put the dolly on top of the core cutter , and drive the assembly into the soil with the help of the rammer until the top of the dolly projects above 1.5 cm above the surface.
5. Remove the surrounding soil and allow some soil to project from the level end of the cutter and take out the assembly .
6. Using the straight edge ,from the flat edge of the cutter, remove the dolly and trim flat the other end of the cutter.
7. Weigh the core cutter with full soil. (W2).
8. The bulk density of soil = (W2- W1)/ V g/cc.
9. Weigh the empty container (W3) g.
10. Take some representative soil sample in the container and weigh it.(W4) g.
11. Keep the container and wet soil in the oven at 105 +/- 5 degree C for 24 hours.
12. Weigh the container and dry soil accurately (W5).

    Water content , w = (W4-W5)/(W5-W3) x 100 %.
13. The dry density of the soil (γ_d) = (γ_b)/(1+w) g/cc.

RESULTS:

DISCUSSIONS AND CONCLUSIONS:

APPLICATIONS: The in place density of natural soil is needed for the determination of bearing capacity of soils , f or the purpose of stability , a nalysis of natural slopes, for determination of pressures on the underlying strata , for calculation of settlement etc. In compacted soils the in place density is needed to check the amount of compaction that the soil has undergone for comparison with design data.

CODE OF PRACTICE:

Method of test for soils
Part XXIX Determination of dry density of soils in place by the Cure Cutter method.
IS 2720 (Part XXIX) – 1975.

OBSERVATION:

Mass of core-cutter = m1 =
Mass of core-cutter + soil = m2 =
Mass of wet soil = m2 – m1 =
Inside diameter of core cutter =
Volume = $V = (\pi * d^2 * l) / 4$ =
Bulk density = $\gamma_b = (m2 - m1) / V$

TABULATION:

DESCRIPTION/CONTAINER NO.	Steel cup number	Steel cup number	Steel cup number
Mass of steel cup (W1) g			
Mass of steel cup + wet soil (W2) g			
Mass of steel cup + dry soil (W3) g			
Water content (w)			

CALCULATION:

Dry density = $\gamma_d = \gamma_b / (1 + w)$

Water content = $w = (W2 - W3) * 100 / (W3 - W1)$

EXPERIMENT NO 7

GRAIN SIZE ANALYSIS [SIEVE ANALYSIS, MECHANICAL ANALYSIS, DRY ANALYSIS].

AIM: To determine the particle size distribution in the soil. (particle size between 4.75 mm and 75 micron)

APPARATUS USED: Balance, IS sieves, oven, trays or bucket, brushes, mechanical sieve shakers.

OBJECT: Soil is also classified based on grain size. The analysis of this type exposes, mainly the proportions by must, of various sizes of particles present in the soil.Therefore it is an important charachteristics of soil. Hence determination of particle size distribution in the soil is necessary.

THEORY: The soil is classified based on grain size as gravel , sand, silt and clay depending upon the quantity of particles absent in the soil, the soil is classified as sandy silt , s ilty sand , s ilty clay, clayey silt etc. Gravel and sand are cohessionless coarse grained soils . Silts and clays are fine grained soils.

Gravel	4.75 mm
Sand	4.75 to 0.075 mm
Silt	0.075 mm to 0.002 mm
Clay	0.002 mm

The soil is well graded or poorly graded can be found out by making a semi – logarithmic plot of % finer as ordinate (natural scale) and particle size as abssica. (log scale). Also from the graph effective diameter , mean size , uniformity co-efficient Cu and co-efficient of curvature Cc, can be found out.

D_{10} - effective size (diameter corresponding to 10 % finer)

D_{60} - mean size (diameter corresponding to 60 % finer)

Uniformity co- efficient, $Cu = D_{60}/ D_{10}$.

Co- Efficient of curvature ,$Cc = (D_{30})^2 / (D_{10} \times D_{60})$.

The following are IS sieves.

Designation	Apperture (mm)
4.75 mm	4.750
2.36 mm	2.360
1.18 mm	1.180
710 microns	0.710
600 microns	0.600
425 microns	0.425
300 microns	0.300
250 microns	0.250
212 microns	0.212
150 microns	0.150
75 microns	0.075

PROCEDURE:

1. The soil fractions retained on 75 microns IS sieve and passing through 4 .75 mm IS sieve is taken for analysis .
2. To separate the clay portions , the soil is washed as per IS standards.
3. The soil retained on 4.75 mm and 0.075 mm IS sieve is taken for analysis.
4. Arrange all the sieves in descending order of diameter, the least at the bottom and highest at the top.
5. Take some soil and weigh it (W1) g.
6. Place the soil in the 4.75 mm sieve.
7. The set of sieves arranged one above the other is fitted into a mechanical sieve shaker.
8. Set the timer for 10 minutes and put on the switch and sieve for 10 minutes.
9. Remove the set of sieves from the sieve shaker.
10. The soil fraction retained on each sieve is carefully collected in containers and weight of each fraction is determined and recorded.
11. Percentage finer is calculated and a plot is made with % finer as ordinate (natural scale) and particle diameter as abssica (log scale).
12. Calculate uniformity coefficient (Cu), coefficient of curvature(Cc), % of gravel, % of sand , %age of silt and clay, mean size and effective size (Hazon's coefficient).

RESULTS:

DISCUSSIONS AND CONCLUSIONS:

APPLICATION: The results of grain size analysis are widely used in soil classification obtained from grain size distribution curve is used in the design.

CODE OF PRACTICE:

Method of test for soils
Part IV - Grain size analysis
IS 2720 (Part IV) – 1975.

OBSERVATION:

1. Colour:
2. Odour:
3. Grain size:

TABULATION:

I S Sieve Designation	Weight Retained in g	Cumulative Weight retained	% Cumulative Weight retained x	% Finer (100 – x)
4.75 mm				
2.36 mm				
1.18 mm				
600 micron				
300 micron				
150 micron				
75 micron				
Pan				

CALCULATION:

Co-efficient of curvature = $Cc = (D_{30})^2 / (D_{10} * D_{60})$

Uniformity Co-efficient = $Cu = D_{60} / D_{10}$

CONSISTENCY OF SOIL:

The relative ease with which a soil sample can be deformed is termed as co nsistency. The degree of firmness of soil is expressed by its consistency as soft, firm, stiff or hard. Fine grained soil may be mixed with water to form a plastic paste which can be moulded into any form by pressure.Addition of water reduces the cohesion and on further addition the soil fails to retain its shape under its own weight, but flows as a liquid.
In 1911, the Swedish agriculturist Mr. Atterburg derived the entire range from liquid to solid state into four states of consistency: (I) the liquid state, (II). The plastic state, (III) the semi solid state,(IV). The solid state.Accordingly arbitrary limits known as consistency limits or Atterberg limits , expressed in terms of % water content were put forward to divide these into three stages. They are:

I. The liquid limit.
II. The plastic limit.
III. The shrinkage limit.

EXPERIMENT NO 8:
DETERMINATION OF LIQUID LIMIT AND PLASTIC LIMIT

AIM: To determine the liquid limit and plastic limit of given soil sample.

APPARATUS USED: Casagrande's apparatus(mechanical device or liquid limit device) grooving tool of standard size (Casagrande's BS tool), large glass plate, spatula, drying oven, evaporating dishes, steel containers, weight box and balance etc.

OBJECT: The liquid limit and plastic limit are both dependent on amount and type of clay in the soil. Hence it forms the basis for soil classification in cohesive soils and inturn to identify the particular type of soil.
The plasticity test will provide information regarding cohesive properties of soil and the amount of capillary water it can hold. The index properties are also related to these limits.

THEORY:
Liquid limit (w_L) with reference to standard liqid limit device may be defined as the minimum water content at which a part of soil cut by a groove of standard dimensions,will flow together for a distance of 12mm under an impact of 25 blows in the device.
Plastic limit (w_P) may be defined as the minimum water content at which soil will just begin to crumble when rolled into a thread approximately 3 mm in diameter.
Plasticity index (I_p) is defined as the numerical difference between liquid limit and plastic limit of a soil. It indicates the plastic range i.e the range between which the soil exhibits plastic properties.
Consistency Index (I_c) [Relative Consistency] is defined as the ratio of difference of liquid limit and natural water content to the plasticity index of the soil.
Liquidity Index (I_L) [Water plasticity ratio] is the ratio expressed as percentage of natural water content of the soil minus its plastic limit to its plasticity index.

PROCEDURE:
Determination of liquid limit:

1. Adjust the height of the fall of the cup to 1 cm.
2. Take about 120 g of soil sample passing through 425 micron sieve and mix thoroughly with distilled water to form a uniform paste.
3. Take portion of the so formed paste into the cup of Casagrande device, squeeze down and spread into position.
4. Make a groove in the paste using a standard dimensional grooving tool.
5. Turn the crank at the rate of 2 rps and count the no of blows required to close the groove in the soil for a distance of 12 mm. The closing should occur by flow of the soil and not due to the soil sliding on the surface of the cup.
6. Mix the sample in the cup and repeat the steps 4 and 5 until the no of blows required to close the gap is nearly the same (a difference of two or three blows indicates the poor mixing of the sample.

7. When consistent value between 10 to 40 blows is obtained, take a portion of the soil (nearly 10 g) near the closed groove for water content determination.
8. By changing the water content of the soil , 4 t o 5 values of no of blows corresponding to various water contents should be obtained.
9. For some soils it is more convenient to start with soil drier than liquid limit and obtain values by increasing the water content which is a quicker method for fine grained clays.
10. Plot a graph of no of blows as abscissa on logarithmic scale and the corresponding water content as ordinate on a semi-log sheet.The curve so obtained is called flow curve which is a straight line given by ,$w1-w2 = If \log (n2 /n1)$
    Where w1 and w2 are water contents corresponding to blows n1 a nd n2 respectively. If is the slope of the curve and is known as flow index.
    The water content corresponding to 25 blows is taken as liquid limit .

Determination of plastic limit :

1. Mix thoroughly 15 g of soil with distilled water ,on a flat glass or a in an evaporating dish till the soil mass becomes plastic enough to the easily moulded with fingers.Leave the plastic soil mass for enough time to allow water to permeate through the soil mass.
2. Form a ball of about 10g of this plastic soil mass and roll it between the finger and glass plate with just sufficient pressure to roll the mass into a thread of uniform diameter throughout the length .
3. When a diameter of 3 mm is reached remould the mass into a ball.
4. Repeat the process of rolling and remoulding until the thread just starts crumbling at a diameter of 3 mm.
5. The crumbled threads are kept for water content determination
6. Repeat the procedure and the plastic limit is taken as the average of five trials.

RESULTS :

DISCUSSIONS AND CONCLUSIONS :

APPLICATIONS :

Liquid limit and plastic limit help in
1.determining the different index properties of soil.
2.determining the strength of the soil.
3.classifying the soils
4.determining the cohesiveness of soils.

CODE OF PRACTICE :

Method of practice for soils
Part V Determination of liquid limit and plastic limit
IS 2720 (Part V) – 1970.

OBSERVATION & CALCULATION OF LIQUID LIMIT:

Details of the sample:

Colour :
Odour :
Grainsize:

TABULAR COLUMN:

Determination No.	I			II			III		
Number of blows									
Container No.									
Weigtht of empty container (w1) g									
Mass of container + wet soil (w2) g									
Mass of water + dry soil (w3) g									
Mass of water (Ww) = (w2 – w3) g									
Mass of dry soil (Wd) = (w3 – w1) g									
Water content w = (Ww * 100) / Wd %									
Average water content									

Flow Index = $I_f = (w1 - w2) / \log_{10} (n2/n1)$ =

OBSERVATION OF PLASTIC LIMIT:

Details of soil sample:

Colour:
Odour:
Grainsize:

EXPERIMENT NO .9 :
DETERMINATION OF SHRINKAGE LIMIT

AIM : To determine the shrinkage limit of the given soil sample.

APPARATUS USED : Evaporating dish ,spatula ,shrinkage dish , straight edge , glass plate , oven , sieve , balance , weight box , mercury , dessicator etc.

OBJECT : It has been recognized that shrinkage on dr ying is an indication of the structure of the soil , the greater the shrinkage the more dispersed is the structure.Hence its determination is of high importance.

THEORY: shrinkage limit is defined as the maximum water content beyond which a reduction in the water content will not cause a decrease in the volume of the soil mass. It is the lowest water content at which the soil can still be completely saturated.
Shrinkage index is the numerical difference between plastic limit and shrinkage limit.
Shrinkage ratio: is defined as the ratio of a given volume change expressed as the percentage of dry volume to the corresponding change in water content above the shrinkage limit expressed as a percentage of the weight of the oven dried soil.
Volumetric shrinkage (Vs) is the decrease in the volume of the soil mass , expressed as the percentage of dry volume of the soil mass ,when the water content is reduced from the given percentage to the shrinkage limit.
Linear shrinkage (Ls) is defined as t he decrease in one dimension of the soil mass expressed as the percentage of the original dimension when water content is reduced from the given value to the shrinkage limit.

PROCEDURE :

1. Take a sample weighing 100g from the thoroughly mixed portion of the material passing through 425 micron IS sieve .
2. Place about 30g of soil sample in the evaporating dish and thoroughly mix with an amount of distilled water in an amount sufficient to fill the soil voids completely and to make the soil pasty.Fill it to the shrinkage dish without entrapping air bubbles. Water is added slightly more than the liquid limit.
3. Determine the weight of the clean empty shrinkage dish (W1)g.
4. Coat the inside of the shrinkage dish with the layer of grease or Vaseline to prevent the adhesion of soil to the dish.
5. Place the soil paste which is equal to one third the volume of the shrinkage dish at the center of the dish.
6. Allow the paste to flow to the edges by tapping the shrinkage dish on firm surface cushioned by several layers of blotting paper, rubber sheet or similar material.
7. Add an amount of soil approximately equal to the first portion and tap the shrinkage dish as before, until the paste is thoroughly compacted and all the air voids are brought to the surface.
8. Add more soil paste and continue tapping until the shrinkage dish is completely filled and excess soil paste stands out of its edge

9. Strike of all the excess soil paste using straight edge and wipe off all the soil adhering to the outside of the shrinkage dish.
10. Weigh immediately the shrinkage dish with the wet soil pat (W2)g.
11. Allow soil pad to dry in air until the color of the pat turns from dark to light.
12. Oven dry the pad in shrinkage dish to constant weight at 105 +/- 5 deg C .Cool in air.
13. Record the weight of shrinkage dish and dry soil (W3)g.
14. To find the volume of the wet soil pad, fill the shrinkage pit with mercury and allow it to overflow.
15. Remove the excess mercury by pressing the plane glass firmly over the top shrinkage dish in such a way that the plate flushes with the top of the shrinkage dish and no air is entrapped.
16. Weigh the mercury held in the shrinkage dish to an accuracy of 0.1g (W4)g.
17. Volume of wet soil pad = weight of mercury / 13.6 = W4/13.6

    13.6 = unit weight of mercury
18. To find the volume of the wet soil pad ,fill the glass cup with mercury and remove excess mercury by pressing with the glass plate ,with the three prongs firmly over the top of the cup.
19. Carefully wipe off any mercury which is adhering to the outside of the cup.
20. Place the cup filled with mercury in the evaporating dish ,taking care not to spill any mercury from the glass cup.
21. Place the oven dried soil pad on the on the surface of the mercury in the glass cup.
22. Then carefully push the dry soil pat under mercury by means of glass plate until the plate flushes firmly over the top of the cup.
23. Collect the displaced mercury in the evaporating dish without spilling it.
24. Care is taken to see that no air is entrapped under the soil pad.
25. Weigh the mercury so displaced by the soil pad ,accurate to 0.1g (W5)g.
26. The volume of dry soil pad can be calculated by dividing the weight of displaced mercury with unit weight of mercury.

    Volume of dry soil pat = Vd = displaced mercury / 13.6 = W5 /13.6 g
27. Calculate the moisture content of the soil pat as a percentage of dry weight of the soil .

    $$W = (W2 - W3)/(W3 - W1) \times 100$$
28. Calculate shrinkage limit as

    $$Ws = W - [(V1 - Vd)\, \gamma_w / Wd] \times 100$$
29. Shrinkage ratio (R) = Wd / Vd =(W3 – W1) /Vd = [(V1- Vd)/Vd x 100] / W – Ws
30. Volumetric shrinkage (Vs) = (W- Ws) SR.
31. Linear shrinkage (Ls) = 100[1- (100/Vs+100)^1/3]

RESULTS :

DISCUSSIONS AND CONCLUSIONS :

TABULATION:

Determination No.	I	II
Container No.		
Mass of container (w1) g		
Mass of container + wet soil (w2) g		
Mass of container + dry soil (w3) g		
Mass of water Ww = (w2 – w3) g		
Mass of dry soil = Wd = (w3 – w1) g		
Water content w = (Ww * 100) / Wd %		
Average water content		

CALCULATION:

Assume natural water content of soil =

1.Plastic Limit = w_p =

2.Plasticity Index = $w_l - w_p$ = Ip =

3.Liquidity Index = $(w - w_p)$ / Ip =

4.Consistency Index = Ic =($w_l - w$) / Ip =

5.Flow Index = I_f =

6.Toughness Index = It = Ip / I_f =

APPLICATIONS :

Shrinkage limit is an important property which helps in designing foundations overlying soil strata subjected to alternate dry and wet conditions.

CODE OF PRACTICE :

Method of test for soils.
Part VI – Determination of shrinkage factors.
IS 2720 (Part VI) – 1972.

OBSERVATION & TABULATION:

I S sieve no. :
Type of soil :
Natural water content (assume) Ww =

A . Water content of wet soil pat:

1.Mass of shrinkage dish = w1 g =
2.Mass of shrinkage dish + wet soil pat = w2 =
3.Mass of shrinkage dish +dry soil pat = w3 =
4.Mass of dry soil pat = (w3 – w1)g =Wd =
5.Mass of water =(w2 – w3) g =
6.Water content of soil pat w = (w2 – w3) * 100 / (w3 – w1)

B. Volume of wet soil pat:

1.Mass of evaporating dish =
2.Mass of evaporating dish + shrinkage dish = w'
3.Mass of mercury in shrinkage dish + evaporating dish = w''
4.Mass of mercury in shrinkage dish (w'' - w')g = w4 =
5.Volume of wet soil pat = (w4 / 13.6) cm^3

C. Volume of dry soil pat:

1.Mass of evaporating dish = w5 g =
2.Mass of mercury displaced by dry soil pat + Mass of evaporating dish =w6 g =
3. Mass of mercury displaced by dry soil pat = w7 = (w6 – w5) g
4. Volume of dry soil pat = w7 / 13.6 cm^3

CALCULATION:

1. Shrinkage limit = [w – (V1 – Vd) * γ_w / Wd] * 100
2. Shrinkage limit = (Sr) = Wd / Vd
3. Volumetric shrinkage =(Vs)= (V1 –Vd) * 100 / Vd

EXPERIMENT NO.10

CO-EFFICIENT OF PERMEABILITY –USING CONSTANT HEAD PERMEAMETER

AIM: To determine the coefficient of permeability of the given soil sample using constant head permeameter.

APPARATUS REQUIRED : Permeameter ,constant head filter tank ,specimen compaction equipments ,balance , weights ,stop watch ,ruler etc.

OBJECTS OF TEST : To determine the coefficient of permeability of granular soils by constant head method and under laminar flow conditions of water. The method is suitable for disturbed granular soil containing less than 10% of soil passing 75 micron IS sieve,the type of materials used for construction of embankments and base courses under pavements.

THEORY : Permeability is the rate of flow of water ,under laminar conditions through unit cross-sectional area of porous medium,under unit hydraulic gradient and standard temperature conditions.

PROCEDURE :

1. Connect the specimen through the top inlet to the constant head reservoir and bottom outlet shall be opened.
2. When steady state flow has been established ,the quantity of flow for convenient time interval is collected and the same measured.

RESULT :

DISCUSSIONS AND CONCLUSIONS :

APPLICATIONS :

The determination of permeability is essential to calculate leakage through and under dams ,rate of consolidation and related settlement ,infiltration into deep excavations ,stability of slopes ,embankments ,hydrostatic uplift etc.

CODE OF PRACTICE :

Method of tests for soils.

IS 2720 – (Part XXXV)

OBSERVATION & CALCULATION:

Diameter of the mould (D) =
Length of the mould (L) =
Volume of the mould (V) =
Area of the mould (A) =
Constant head (h) =
Mass of empty mould (w1) g =
Mass of mould + soil (w2) g =
Mass of specimen (w2 – w1) g =
Bulk density (γ b) = (w2 – w1) / V

TABULAR COLUMN:

TRIAL NO.	Q in ml	Time (t) in secs	K = (Q*L) / (h*A*t) In cm/sec
1.			
2.			
3.			

EXPERIMENT NO. 11

COEFFICIENT OF PERMEABILITY USING VARYING HEAD PERMEAMETER

AIM: To determine the permeability of the given soil sample by us ing varying head permeameter.

APPARATUS REQUIRED:

1. Permeamter
2. Compaction equipment
3. Drainage bank
4. Set of stand pipes
5. IS sieve, mixing pan, graduated cylinder, stopwatch, 75 micron wire gauze, thermometer, etc.

OBJECT: Laboratory determination of coefficient of permeability of soils using falling head method. This test is recommended for soils with coefficient of permeability in the range of 10^{-3} to 10^{-7} cm per second.

PROCEDURE:

Preparation of test specimen (disturbed soil sample)

1. Take thoroughly mixed air dried or oven dried soil about 2.5 kgs.
2. Determine the moisture content of the soiil sample, the sample shall be placed in air tight container . The quanity of water to be addede to the stored sample shall be computer and spread evenly over the sample, after thoroughly mixing the material. The material is again stored in the storage container. The moisture content of the sample is again determined and the entire process is repeated till the moisture content is 0.5% of that desired.
3. The permeameter should be weighed to the neartest gram. It is clamped between the copaction base plate and the extension collar.
4. The mould with specimen is weighed and then assembled to the draingage base.
5. The specimen is connected to the top inlet of the seleced stand pipe.
6. The bottom outlet shall be opened and the time interval required for water level to fall from initial head h1 to final head h2 as read above the center of the outlet is recorded.
7. The stand pipe is refilled with water and the test repeated, till three successive observations give the same time interval.
8. The time intervals are recorded for drop in head from the same initial to final values as in the first determination.
9. Alternatively after selecting suitable initial and final head h1 and h2, time intervals shall be noted for the head fall from h1 to h2.

RESULTS:

DISCUSSIONS AND CONCLUSIONS:

APPLICATIONS:

At the site, the determined permeability is essential to calculate leakage through and under dams, rate of consolidation and related settlement, infiltration into deep excavations. Stability of slopes, embankments, hydrostatic uplift etc.

CODE OF PRACTICE:

Method of test for soils
IS 2720 – (Part XXXVI)

OBSERVATION & CALCULATION:

Mass of empty mould (w1) g =
Mass of empty mould + soil sample (w2) g =
Mass of soil sample = (w2 – w1) g =
Diameter of the mould (D) =
Area of the mould = $(\pi * D^2) / 4$ =
Length of the mould = L =
Volume of the mould = V =
Bulk density = (w2 – w1) / V =
Diameter of the stand pipe (d) =
Area of the standpipe (a) = $(\pi * d^2) / 4$ =

TABULAR COLUMN:

Serial No.	Time taken in secs (t)	Initial head In cm (h1)	Final head In cm (h2)	$Log_{10}(h1/h2)$ In cm/sec	K= [2.3log(h1/h2)*a*l] / (A * t)

EXPERIMENT NO. 12
COMPACTION TEST
HEAVY COMPACTION TEST
DETERMINATION OF WATER CONTENT – DRY DENSITY RELATION USING HEAVY COMPACTION TEST. .

AIM: To bring out the relationship between water content and dry density and to determine optimum moisture content.

APPARATUS USED:
Cylindrical metal mould, metal rammer, balance, oven, steel straight edge, minimizing tools etc.

OBJECT:
Many types of earth constructions such as dams, retaining walls, highways, airports require man placed soil or refill. If the soil is compacted in optimum moisture content, the achieved density will be maximum and it decreases permeability; increases shear strength and decreases further settlement. Hence it is necessary to bring out the relation between water content and dry density.

THEORY:
Compression of soil taking place by the expulsion of air with the compressive stress is called compaction. Artificially, rearrangement of soil particles is done to decrease the porosity and to increase the dry density. Compaction is achieved by rolling, tempering or vibrating; when water is added to dry soil, the soil particles absorb a film of water. With the addition of more water, these films get mixed and permits soil particles to slide over each other more easily. This process is called lubrication. Because of lubrication, the addition of a small amount of wather to dry soils aid the compaction process upto a certain limit. Addiont of water replaces air from the voids, but after a relatively high degree of saturation is reached, the water occupies the space which could be occupied by soil particles. The amount of entrapped air remains constant. There there is an optimum amount of mixing water for a given soil and compaction process will give maximum weight of soil per unit volume.

PROCEDURE:
1. A representative sample passing through 4.75 mm IS sieve and weighing 20 kg or more is taken and air dried.
2. Mix some water to bring the moisture content to about 7% and ensure that the soil is thoroughly mixed.
3. The empty mould is cleaned, dried and weighed to the nearest gram Wm and also the dimensions are noted to calculate the volume.
4. The inside of the mould may be slightly greased. The mould with collar is filled to the base plate and placed on the solid base.
5. The soil sample is divided into equal 8 parts.
6. The soil is compacted into the mould in five equal parts (layers).

7. Each layer is given 25 blows using 4.89 kg ha mmer dropping from a height of 450 mm. The blows are uniformly distributed over the surface of each layer.
8. Each layer of the compacted soil is scrapped with the spatula before filing the soil for next layer. Ensure a free fall of the rammer and the lump of soil sticking to the rammer at any stage is removed.
9. Care ist aken to keep the sleeve free from soil to ensure a free fall and the lump of soil sticking to the rammer is removed at any stage.
10. The amount of soil used is just sufficient to fill the mould leaving about 5 mm to be struck off when the collar is removed.
11. The collar is removed and the compacted layer of soil is carefully levelled off at the top of the mould using straight edge.
12. The mould and soil is again weighed to the nearest gram.
13. The soil is removed off the soil cut in the middle and representative soil specimen is taken in an airtight container from the surface for water contenet determination.
14. Break the soil and increase the water content by 2 to 4 % and repeat the procedure for different water contents.
15. The wet density of the compacted soil is calculated:

$$\gamma_b = \frac{W - Wm}{Vm}$$

γ_b = wet density of soil (g/cm^3)
W = mass of mould + moist compacted soil.
Wm = mass of empty mould
Vm = volume of mould

16. The dry density of the compacted soil is computed as follows:

$$\gamma_d = \frac{\gamma_b}{1 + w}$$

γ_b = bulk density of compacted soil
γ_d = dry density of soil
w = water content

17. The voids ratio (e) is calculated as:

$$e = \frac{G \cdot \gamma_w}{\gamma_d}$$

G = specific gravity of soil
γ_w = unit weight of water

18. The Porocity (n) is calculated as:

$$n = 1 - \frac{\gamma_d}{\varepsilon \gamma_w}$$

19. A curve showing the relationship between dry density and water content is plotted. The water content corresponding to maximum dry density gives the optimum water content.
20. Zero voids line is also plotted using the following equation:

$$\gamma_d = \frac{G \cdot \gamma_w}{H G w}$$

21. Different voids line can be plotted using:

APPLICATIONS:

At the site, the determined permeability is essential to calculate leakage through and under dams, rate of consolidation and related settlement, infiltration into deep excavations. Stability of slopes, embankments, hydrostatic uplift etc.

CODE OF PRACTICE:

Method of test for soils
IS 2720 – (Part XXXVI)

OBSERVATION & CALCULATION:

Mass of empty mould (w1) g =
Mass of empty mould + soil sample (w2) g =
Mass of soil sample = (w2 – w1) g =
Diameter of the mould (D) =
Area of the mould = $(\pi * D^2) / 4$ =
Length of the mould = L =
Volume of the mould = V =
Bulk density = (w2 – w1) / V =
Diameter of the stand pipe (d) =
Area of the standpipe (a) = $(\pi * d^2) / 4$ =

TABULAR COLUMN:

Serial No.	Time taken in secs (t)	Initial head In cm (h1)	Final head In cm (h2)	$Log_{10}(h1/h2)$ In cm/sec	K= [2.3log(h1/h2)*a*l] / (A * t)

STANDARD PROCTOR TEST - 14

DETERMINATION OF DRY DENSITY WATER CONTENT RELATION USING LIGHT COMPACTION TEST

AIM:
To bring out the relationship between water content and dry density and to determine optimum moisture content.

APPARATUS USED:
Cylindrical metal mould, metal rammer (2.6 kg with 310 mm drop), balance, oven, steel, straight edge, mining tools etc.

OBJECT:
Many types of earth constructions such as dams, retaining walls, highways, airports require man placed soil or refill. If the soil is compacted in optimum moisture content, the achieved density will be maximum and it decreases permeability, increases shear strength and decreases further settlement. Hence it is necessary to bring out the relation between water content and dry density.

THEORY:
Compression of soil taking place by the expulsion of air with the compressive stress is called compaction. Artificially, rearrangement of soil particles is done to decrease the porosity and to increase the dry density. Compaction is achieved by rolling, tempering or vibrating; when water is added to dry soil, the soil particles absorb a film of water. With the addition of more water, these films get mixed and permits soil particles to slide over each other more easily. This process is called lubrication. Because of lubrication, the addition of a small amount of wather to dry soils aid the compaction process upto a certain limit. Addiont of water replaces air from the voids, but after a relatively high degree of saturation is reached, the water occupies the space which could be occupied by soil particles. The amount of entrapped air remains constant. There there is an optimum amount of mixing water for a given soil and compaction process will give maximum weight of soil per unit volume.

PROCEDURE:
1. Sample of soil passing through 4.75 mm IS sieve and weighing about 8 kg or more is taken and air dried.
2. Mix some water to bring the moisture content to about 7% and ensure that the soil is thoroughly mixed.
3. The empty mould is cleaned, dried and weighed to the nearest gram Wm and also the volume Vm is noted.
4. The inside of the mould is slightly greased. Themould with collar is fixed to the base plate and fixed on the solid base.
5. The soil sample is divided into 6 equal parts.
6. The soil is compacted into the mould in 3 layers.
7. Each layer is given 25 blows using 2.6 kg hammer dropping from a height of 310 mm. These blows are uniformly distributed over the surface.

8. Each layer of the compalcted soil is scrapped with the spatula before filling in the next layer.
9. Care is taken to see that there is free fall of the hammer, and the lump of soil sticking ot the rammer is removed at any stage.
10. The amount of soil used is just sufficient enough to fill the mould having about 5 mm to be struck off when the collar is removed.
11. The collar is removed, and the soil at the top of the mould is levelled off using a straight edge.
12. The mould and the soil is again weighed to the nearest gram.
13. The soil is removed and cut and representative specimen is taken in an airtight container from the surface for water content determination.
14. Break the soil and increase the water content by 2 to 4 %. Repeat the procedure for different water contents.
15. The wet density of compacted soil is calculated:

$$\gamma_b = \frac{W - Wm}{Vm}$$

γ_b = bulk/wet density of soil
W = mass of mould + moist compacted specimen of soil
Wm = mass of empty mould
Vm = volume of mould

16. The dry density of compacted soil is computed as follows:

$$\gamma_d = \frac{\gamma_b}{1 + W}$$

γ_d = dry density of the compacted soil
W = water content

17. The voids ratio (e) is computed as:

G = specific gravity of soil
γ_w = unit weight of water

18. The porosity (n) is calculated as:

$$n = 1 - \frac{\gamma_d}{\varepsilon \gamma_w}$$

19. A curve showing the relationship between dry density and water content is plotted. The water content corresponding to maximum dry density is called optimum moisture content.
20. Zero voids line is also plotted using the following equation:

$$\gamma_d = \frac{G.\gamma_w}{1 + G W}$$

21. Different voids line may be plotted using:

$$\gamma_d = \frac{(1 - n_a)\,G.\gamma_w}{(1 + G.W)}$$

RESULTS:

$$\gamma_d = \frac{(1 - n_a)\, G\, \gamma_w}{(1 + G w)}$$

n_a = percentage air voids

RESULTS:

DISCUSSIONS AND CONCLUSIONS:

APPLICATIONS:

The purpose of the laboratory compaction test is to determine the proper amount of mixing water to be used when compaction soil in the field and the resulting degree of decrease in volume which can be expected from compaction at optimum water content. To accomplish this, a laboratory test which will give a degree of compaction comparable to that obtained by the field method used is necessary.

CODE OF PRACTICE:

Method of test for soils
Part VI – Determination of Dry density – water content relationship – using heavy compaction
IS:2720 (Part VI) – 1974

OBSERVATION:

Length of mould = l =
Diameter of mould = d =
Volume of mould = V = $(\pi * d^2 * l) / 4$ =
Assume specific gravity of soil sample = G =

TABULAR COLUMN:

Determination Number	I	II	III	IV
Mass of the mould (m1) g				
Mass of the mould + compacted soil (m2) g				
Mass of compacted soil (m2 – m1) g				
Bulk density (γ_b) = (m2- m1) / V g/cm^3				
Water content (w)				
Dry density (γ_d) = γ_b / (1 + w) g/cm^3				
Zero air voids line= γ_d = (G * γ_w) / (1+w*G) g/cm^3				
5% air voids line (γ_d) = [(1 – n_a)*G* $\sqrt{w}$] / (1+w*G)				

EXPERIMENT NO. 13

EXPERIMENT NO. 15
UNCONFINED COMPRESSION TEST

AIM:
To determine the unconfined compressive strength of the soil and shear parameter (cohesion) under controlled strain.

APPARATUS USED:
Mould for preparing the soil specimen, dial gauge, proving ring, weighing box, steel rule, loading pan, spanner etc.

OBJECT:
The load coming any structure ultimately transfers to the soil through the structural foundation. The underlying soil or rock undergo shearing deformations or compressibility due to load. So we must know the strength of the soil, whether it can withstand the load or not. Hence unconfined compressive strength gives the bearing capacity and bearing capacity is used in design of foundation structure.

THEORY:
Unconfined compression test is an indirect method of determining strength of soil; by subjecting a cylindrical specimen of soil to axial compression load. The specimen fails by shear in spite of the compressive load. The shear strength comprises due to friction and cohesion. But in cohesive soils, cohesion plays an important role in the development of shear strength. This test is called unconfined compression test, since only vertical load is applied with no lateral pressure.

The unconfined compression test is a special case of triaxial compression test in which $\sigma_1 = \sigma_3 = 0$. The cell pressure in the triaxial cell is also called confining pressure. Due to the absence of such a confining pressure, the axial specimen of soil is subjected to major principal stress σ_1 till the specimen fails due to shearing along a cricitcal plane of failure. When the break occurs, the proving ring dial indicates a definite maximum load, which drops rapidly with further increase of strain. In plastic failure, no definite maximum load is indicated. In such a case, the load corresponding to 20% strain is arbitrarily taken as the failure load.

$\sigma_1 = 2C \tan(45 + \phi/2)$

$\sigma_3 = 0$ } ; $\sigma_1 = 2C$

$\phi = 0$ } ; $C = \sigma_1/2$

Axial strain $\varepsilon = \Delta L/L$ for cohesive soils

σ_1 = major principal stress

ΔL = change in length; L = initial length

Corrected area $A_c = \dfrac{A_o}{1 - \varepsilon}$

A_o = initial area of specimen

Compressive strength $\sigma = P/A$

P = compressive force

PROCEDURE:
1. Remould specimen is directly prepared in the soil mould by compacting the soil at desired water content and dry density.
2. Measure the initial length, diameter and weight of the specimen.
3. Place the specimen on the bottom plate of the loading pad. The upper plate is adjusted to make contact with the specimen.
4. Set the dial gauge and adjust to zero.
5. Before this the loading ring is fixed between the upper plate and loading arm.
6. Apply axial compressive load in such a way that axial strain is at 0.5 to 2.0% /min.
7. Note the proving ring readings and dial gauge readings at suitable intervals.
8. The specimen is compressed until failure.
9. Note the dial gauge and proving ring reading and repeat the experiment.
10. The graphs are plotted.

RESULTS:

DISCUSSIONS AND CONCLUSIONS:

APPLICATIONS:
Portable, unconfined compression tests are now used abroad for strength determination at construction sites, to find the bearing capacity of the soil and hence to design foundations.

CODE OF PRACTICES:
Method of test for soils
Part X – Determination of unconfined compression strength
IS 2720 – (Part X) – 1973.

OBSERVATION & CALCULATION:

Initial diameter = D_o =
Initial length = L_o =
Initial Area = A_o =
Initial density = d_o =
Rate of strain = 1.25 mm/min

DISCUSSIONS AND CONCLUSIONS:

APPLICATIONS:

The purpose of the laboratory compaction test is to determine the proper amount of mixing water to be used when compaction soil in the field and the resulting degree of decrease in volume which can be expected from compaction at optimum moisture content. To accomplish this, a laboratory test which will give a degree of compaction comparable to that obtained by the field method used is necessary.

CODE OF PRACTICE:

Method of test for soils
Part VII – Determination of water content
Dry density – water content relation using light compaction
IS: 2720 (Part VII) – 1974

OBSERVATION & TABULATION:

Length of mould = l =
Diameter of mould = d =
Volume of mould = V = $(\pi * d^2 * l) / 4$ =

Assume specific gravity of soil sample = G =

Trial No.	I	II	III	IV
Mass of mould (m1) g				
Mass of mould + compacted Soil (m2) g				
Mass of compacted soil (m2 – m1) g				
Bulk density (γ_b) = (m2 – m1) / V g/cm³				

Water content determination:

TABULAR COLUMN:

Proving ring reading	Force in kg	Dial gauge reading	Deformation in cm	Strain $\epsilon = \Delta l / l$	Correction factor $1 / (1-\epsilon)$	Corrected area $A_c = A_o / (1-\epsilon)$

CODE OF PRACTICE:
Method of test for soils
Part XVI – Laboratory determination of C.B.R.
IS: 2720 – (Part XVI) – 1974.

EXPERIMENT NO. 14

DIRECT SHEAR TEST

AIM:
To determine the shear parameter such as C and ϕ of the soil.

APPARATUS USED:
Shear box, grid plates, porous stones, base plate, loading frames, weights, proving ring, micrometer dial gauge.

OBJECT:
The load coming any structure is ultimately transferred to the soil through the structural foundation. The underlying strata undergo shearing deformations. So we are supposed to know the strength of the solids whether it can stand the load or not. The direct shear test gives the shear parameters, which helps in the design of foundations.

THEORY:
Measurement of shear strength can be done by conducting direct shear test. This is a commonly used test and is performed in a shear apparatus. The soil held between the metal grid and porous stone is sheared by applying shear force. The shear resistance is developed due to normal load. As the latter increases, the shear resistance also increases. In this test, the failure plane is fixed, i.e. horizontal.

PROCEDURE:
1. Take out the specimen using the culting ring.
2. Arrange the shear box in such a way that the porous stone is at the bottom and above the porous stone, the grids are perpendicular to the direction of shear. Placc the sample and again place the grid plate as before and then place the loading pad. The locking pin must be put before arrangements.
3. Weigh the shear box assembly before placing the sample.
4. Weigh the shear box assembly after placing the sample.
5. Note down the dimensions of the shear box.
6. Fix the shear box assembly on the shear frame.
7. Fix the dial gauge and proving ring and set them to read zero.
8. Place some normal load through the hanger.
9. Remove the locking pins so that the upper and lower parts are freed to move against each other.
10. By turning the spacing screws, raise the upper part slightly above the lower part by 1 mm.
11. The rate of strain may vary from 1 to 205 mm/minute.
12. Note down the proving ring and dial gauge reading at regular intervals of time.
13. Repeat the same procedure for different values of normal load.
14. The stress can be calculated as follows:

$$\text{Shear stress} = \frac{\text{Load}}{\text{Corrected Area}} = \frac{P}{Ac}$$

Corrected Area = Ac = Ao (1 - δ/3)
δ = displacement
Ao = initial area

15. Plot the graph between the normal stress and the shear stress. From the cu rve, the ordinate intercept gives the cohesion and slope of the curve gives the angle of internal friction.

RESULTS:

DISCUSSIONS AND CONCLUSIONS:

APPLICATIONS:
From the graph of shear stress versus direct stress it is found that the specimen has no value of cohension. The resistance offered to shearing is completely contributed due to internal friction increases, the shear resistance increases.

CODE OF PRACTICE:
Method of test for soils
Part XIII – Direct Shear Test
IS 2720 – (Part XIII) – 1972.

TABULAR COLUMN:

Normal Load in kg / cm^2	Displacement DGR x divisions	Deformation δ in cm x * 0.001	Area correction (1 - δ/3)	Corrected Area(m^2) Ac = Ao(1-δ/3)	Proving ring reading	Shear force in kg	Shear stress In Kg/cm^2

OBSERVATION:

Soil specimen dimensions =
Thickness of soil =
Initial area of the specimen =
Volume of the specimen =

SUMMARY OF RESULTS

Test No.	Normal stress kg /cm^2	Shear stress at failure kg/cm^2	Shear displacement at failure cm
1.			
2.			
3.			

EXPERIMENT NO. 16
TRIAXIAL TEST

AIM:
To determine the shear parameters C and ϕ of the soil by triaxial compression test (confined compression test).

APPARATUS USED:
Triaxial cell, loading frame, split mould, metal scale, rubber membrane, membrane stretcher , O. rings, platform, proving ring, leg-pump, porous stone, dummy plate, dial gauge, soil sample, mould for preparing soil sample, weight box etc.

OBJECT:
The object of this test is to determine the shear parameters of undisturbed soil specimen in the triaxial compression apparatus, by unc onsolidated undrained test, without the measurement of pore pressure.
The load coming on any structure ultimately transfers to the soil through the structural foundation. The underlying soil or rock undergo shearing deformation or compressibility due to load. So we must know the strength of the soil, whether it can withstand the load or not.

THEORY:
To determine shear parameters and shear strength of disturbed or undisturbed soil sample. Triaxial compression test gives accurate results, due to stimulation of field conditions to a certain extent. Hence it is an internal test and most useful than any other test results. In this the specimen is subjected to axial force and confined pressure all round the specimen. Therefore it is called triaxial compression test. Depending on drainage conditions, there are four types of shear tests.

(a) Undrained or quick test
(b) Consolidated undrained test
(c) Drained test

The shear parameters depend on the drainage conditions.

PROCEDURE:

1. Obtain the sample from the samples.
2. Place the sample centrally on the padasteel of the triaxial cell. Depending on the drainage conditions, place the dummy plate below and above the specimen.
3. Fix the membrane to the membrane stretcher, suck the air through the tube and lock it.
4. Place the membrane stretcher with membrane in such a way that the soil is inside the membrane stretcher and release the air through the tube.
5. Slowly membrane fixed to the top and bottom of the soil.
6. Put rubber rings to the membrane stretcher. Again insert such a way that soil and membrane is inside the membrane stretcher, put the perapex cell and fix the screws.

7. The assembled cell is kept on the loading frame.
8. Fix the mould inside the cell and close the valve.
9. Fix the proving ring and dial gauge and set them to zero.
10. Apply cell pressure through the lateral pressure assembly or leg pump.
11. Apply axial load through the loading frame and note down the axial deformation and proving ring reading till specimen fails.
12. Remove the specimen and observe the mode of failure.
13. For different cell pressure, repeat the whole experiment.
14. Plot the graphs.

RESULTS:

DISCUSSIONS AND CONCLUSIONS:

APPLICATIONS:

To find the shear parameters and thus making it helpful in structural design of foundations, retaining walls, embankments etc.

CODE OF PRACTICE:

Method of test for soils
Part XI – Determination of shear strength parameters, of a sp ecimen tested in consolidated undrained triaxial compression, without the measurement of pore water pressure.
IS 2720 – (Part XI) – 1971.

OBSERVATION:

Confined compression test without the measurement of pore pressure

1. Initial diameter of the specimen = Do =
2. Initial length of the specimen = Lo =
3. Initial weight of specimen =
4. Cell pressure = σ_3 = 1 kg/cm^2
5. Description of sample =
6. Mode of failure =
7. Bulk density =
8. Rate of strain = 3 mm/min

TABULAR COLUMN:

Proving ring reading	Load in kg	Dial gauge reading	Deformation in cm	Strain $\epsilon = \Delta l/lo$	Correction Factor $(1/1 - \epsilon)$	Corrected area $Ac = Ao/(1 - \epsilon)$	Deviator stress σ_d	Corrected stress $\sigma_1 = \sigma_3 + \sigma_d$

EXPERIMENT NO. 14
DETERMINATION OF C.B.R.

AIM:
To determine the C.B.R. value of the given soil in the laboratory.

APPARATUS USED:
Moulds (150 + 0.1 mm inside diameter) and 175 + 0.1 height and 50 mm inside height extension collar, detachable perforated base plate 10 mm thick (the perforations on the base plate is 1.5 mm in diameter) steel cutting collar, circular metal spacer disc, metal rammer, weight (weight 2.5 kg a nd 147 metric diameter with a central hole 53 mm in diameter) loading machine, metal penetration plunger proving ring, dial gauge, sieves etc.

OBJECT:
Based on C.B.R. value, the pavement design is made and it gives the geometric strength of the soil; hence the determination is necessary.

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

PROCEDURE:
1. The density of the remoulded soil is taken as the field density or maximum dry density. (IS-2720 Part VII or Part VIII – 1974) to consider the O.M.C. or field moisture.
2. Sieve the soil sample in 20 mm IS sieve.
3. Take about 5 kg of the soil and thoroughly mix with water. (OMC – Part VII or VIII – 1974)
4. Compact the soil with the rammer following heavy compaction test.
5. The mould with the extension collar attached is clamped to the base plate.
6. The spacer disc is inserted over the base plate and a disc of coarse filter paper is placed on top of the spacer disc.
7. The soil water mixture is compacted into the mould in accordance with the methods applicable to the 150 mm ϕ mould specified in IS 2720 – (Part VII) – 1974 or IS 2720 – (Part VIII) – 1974.
8. Remove the collar and trim the compacted soil carefully at the top by means of straight edge.
9. Remove the perforated base plate and spacer disc.
10. Note down the mass of compacted soil specimen and mould.
11. Place the filter paper on the perforated base plate.
12. The compacted soil and mould is inverted and the perforated base plate clamped to the mould with the compacted soil specimen in contact with the filter paper.
13. Place the compacted soil and mould on the testing machine.
14. Place the surchage weight which represents the intensity of loading equal to the weight of the base material of pavement.
15. Plunger is seated on the soil specimen and an initial load of 4 kg is applied to ensure the full contact between surface of plunger and specimen.
16. Set the dial gauge reading as zero and treat the initial load on the proving ring as zero.
17. Apply the load to the penetration plunger, such that the penetration is approximately 1.25 mm/min.
18. Record the load at penetrations of 0.0 mm; 0.5 mm; 1.0 mm; 1.5 mm; 2.0 mm; 2.5 mm; 4.0 mm; 5.0 mm; 7.5 mm; 10.0 mm and 12.5 mm.
19. The maxium load and penetration occurs for a penetration reading less than 12.5 mm.
20. The plunger is raised and the mould detached from the loading equipment.
21. About 20 to 50 g of soil is taken from the top for water content determination. The penetration test may be repeated as check test for the reverse end of the sample.
22. The load versus penetration is plotted with load as ordinate and penetration as abcissa.
23. A correction is applied by dr awing a tangent to upper curve at point of contraflexure.
24. The corrected curve may be taken to be this tangent plus the original position of the curve with the origin of strains shifted to the point where the tangent cuts the horizontal axis.
25. Corresponding to the penetration value at which C.B.R. is desired corrected load value is taken from the load penetration curve and:

$$C.B.R. = \frac{Pt}{Ps} \times 100$$

Pt = corrected unit test load corresponding to the chosen penetration from the load penetration curve
Ps = unit standard load for the same depth of penetration as for Pt taken from the table.
as for Pt taken from the table.

RESULT:

DISCUSSIONS AND CONCLUSIONS:

APPLICATIONS:
The test is arbitrary and the results give the empirical strength number. This may not be directly related to the fundamental properties governing the strength of soils, such as cohesion and angle of friction. However, it should be noted that attempts have been made to correlate C.B.R. values to certain properties such as bearing capacity, and the plasticity index.

Water content determination:

Trial No.	I			II			III			IV		
Container No.												
Mass of container (w1)g												
Mass of container +wet soil (w2) g												
Mass of container+dry soil (w3) g												
Mass of water = (w2 – w3) g												
Mass of dry soil = (w3 – w1) g												
Water content = (w2 – w3) / (w3 – w1) *100%												
Average												
Dry density = $(\gamma_b)/\ 1+w$ g/cm^3												

1 T + Gift + Ea Dec + Platform (includes d.J)
(OR)
+ Photo booths