NRI INSTITUTE OF INFORMATION SCIENCE & TECHNOLOGY BHOPAL

DEPARTMENT OF CIVIL ENGINEERING

LAB MANUAL
GEOTECH LAB

NIIST BHOPAL	NRI INSTITUTE OF INFORMATION SCIENCE & TECHNOLOGY DEPARTMENT : CIVIL ENGINEERING	FORM NO	NIIST/A/10
BRANCH CIVIL	LIST OF EXPERIMENTS	REV. NO	0
SESSION		REV. DT	30/06/2011

SUBJECT NAME: Geotechnical Engg. SUBJECT CODE: CE701

1	Determination of water content by Oven drying method.
2	Determination of water content by Pycnometer
3	Determination of soil field density by core cutter method
4	Determination of soil field density by sand replacement method
5	Determination of Specific Gravity By Pycnometer.
6	Determination of Consistency Limits (i) Liquid Limit (ii) Plastic Limit (iii) Shrinkage Limit
7	Determination of liquid limit of soil by cone penetrometer.
8	Grain size analysis by sieve shaking method
9	Grain size analysis of fine grained soil by sedimentation using (i)pipette (ii) hydrometer.
10	Determination of coefficient of permeability of soil by- (a) constant head method (b) variable head method
11	Determination of compaction parameters by- (a) light compaction, (b) heavy compaction.
12	Direct Shear test
13	Triaxial Test
14	Unconfined Compression Strength Test

GEOTECHNICAL ENGINEERING

LO	LAB OUTCOMES
LO1	Students will be familiar with soil properties like OMC , DD, MC, density, PL,LL, plasticity index , color of soil
LO2	Specific gravity , grains texture and composition and classification of the soil can be done after the lab test
LO3	Permeability, porosity , compaction , and shear of soil can be found
LO4	Angle of cohesion and friction parameters cab be found
LO5	Liquid state and particle properties can be studies as per IS codes

EXPERIMENT NO 1

DETERMINATION OF WATER CONTENT BY OVEN DRYING METHOD

Aim:

To determine the water content of soil solids by Oven Drying method.

The water content (w) of a soil sample is equal to the mass of water divided by the mass of solids.

Specifications:

This test is done as per IS: 2720 (Part II) – 1973. The soil specimen should be representative of the soil mass. The quantity of the specimen taken would depend upon the gradation and the maximum size of the particles. For more than 90% of the particles passing through 425 micron IS sieve, the minimum quantity is 25g.

Equipments Required:

a) Non-corrodible airtight containers.
b) Balance weighting to accuracy of 0.04% of the weight of the soil taken for test.
c) Desiccators with suitable desiccating agent.
d) Thermostatically controlled oven to maintain temperature 110 °C ± 5 °C.
e) Other accessories.

Theory:

In almost all soil tests natural moisture content of the soil is to be determined. The knowledge of the natural moisture content is essential in all studies of soil mechanics. To sight a few, natural moisture content is used in determining the bearing capacity and settlement. The natural moisture content will give an idea of the state of soil in the field. Water content, w of a soil mass is defined as the ratio of mass of water in the voids to the mass of solids:

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

Where, W1 = Weight of empty container in grams
W2 = Weight of container + wet soil in grams
W3 = Weight of container + dry soil in grams

Precautions:

- Ensure that soil samples are between 350 to 400g. Larger samples take too long to dry, while smaller samples lead to inaccurate results.
- Ensure that the oven temperature is maintained at 110° C ± 5° C. Do not allow the oven door to stay open for too long, as it takes a while for the oven to regain the drying temperature.
- Do not put moist samples in the oven on a shelf below dry samples. Moist samples should be placed on the top shelf and all partially dried samples placed on the lower shelf.
- Do not over-load the oven, as this will create a much longer drying time.
- Do not allow dried samples to pick up moisture after they are removed from the oven. Weigh them immediately after drying.
- Soils and aggregates may contain bacteria and/or organisms which can be harmful for one's health. Wearing dust masks and protective gloves when handling materials is advised. The use of heat resistant gloves/mitts or pot holders to remove samples from the ovens is recommended.
- Prior to handling oven, testing or disposing of any waste materials, students are required to read do's and don'ts of the Geotechnical engineering laboratory.

Procedure:

a) Clean the container with lid and find the mass (W1 in g).
b) Select the required quantity of moist soil sample, place it in the container, place the lid on it, and weigh it (W2 in g).
c) Keep the container in the oven with lid removed and dry it for at least 24 hr. at a temperature of 110 °C till the mass remains constant.
d) Remove the container from the oven, replace the lid, and cool it in desiccators. Find the mass (W3 in g).
e) Determine the water constant w by using the above equation.
f) Repeat the experiment with other test samples

Table: Weights of container

Sl No	Particulars	Test No1 (w1)	Test No2 (w2)	Test No3 (w3)
1	Weight of empty container (W1), g			
2	Weight of container + wet soil (W2), g			
3	Weight of container + dry soil (W3), g			
4	Water content, w			
5	Average water content, w = (w1+ w2 + w3)/3			

Specimen calculations:

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

Result:

AVERAGE w=

Verification/ Validation:

Soil mass is generally a three phase system. It consists of solid particles, liquid and gas. The phase system may be expressed in SI units either in terms of mass-volume or weight volume relationships. Water content value is 0% for dry soil and its magnitude can exceed 100%.

Conclusion:

The experiment is conducted as per the procedure laid down. The water content of the soil sample is determined. Water content, w =_____%. The value is verified and the three phase system is sketched.

EXPERIMENT NO 2

DETERMINATION OF WATER CONTENT BY PYCNOMETER METHOD

Aim:

To determine the water content of soil solids by Pycnometer bottle Method.

To determine water content by this method, the value of G should have been determined prior.

Specifications:

This test is done as per IS: 2720 (Part II) – 1973. This method is suitable for coarse grained soils from which the entrapped air can be easily removed.

Equipments Required:

1. Pycnometer of 1000 ml capacity with a brass conical cap.
2. Balance accurate to 1 g.
3. Glass rod other accessories.

Theory:

A Pycnometer is a glass jar of about 1 liter capacity, fitted with a brass conical cap by means of a screw type cover. The cap has a small hole of about 6mm diameter at its apex. For many soils, the water content may be an extremely important index used for establishing the relationship between the way a soil behaves and its properties. The consistency of a fine-grained soil largely depends on its water content. The water content is also used in expressing the phase relationships of air, water, and solids in a given volume of soil.

Water content, w of a soil mass is defined as the ratio of mass of water in the voids to the mass of solids:

$$\text{Water content, } W\% = [((W2-W1)/(W3-W4))\times(((G-1)/G)-1)]\times 100$$

Where, W1= Weight of empty pycnometer in grams
W2 = Weight of pycnometer + wet soil in grams
W3 = Weight of pycnometer + dry soil in grams
W4 = Weight of pycnometer + water in grams

Procedure:

a) Clean and dry the pycnometer and weigh it (W1 in g).
b) Select a mass of wet soil of about 300 gm and place the same in pycnometer and weigh it (W2 in g).
c) Fill the pycnometer with distilled water up-to half its height and stir the mix with a glass rod. Keep on adding more water till the mix is flush with the hole in the conical cap. Dry the pycnometer outside and find the mass (W3 in g).
d) Remove the contents of PM and clean it. Fill with clean water up-to the top level of the hole in the cap weigh it (W4 in g).

e) Now use the above equation for determining water content, where, G value is taken from Experiment No 1 (Determination of specific gravity by pycnometer method) for the given soil.

Table : Weights of pycnometer

Sl No	Particulars	Test No1 (w1)	Test No2 (w2)	Test No3 (w3)
1	Weight of empty pycnometer (W1), g			
2	Weight of pycnometer + wet soil (W2), g			
3	Weight of pycnometer + soil + water (W3), g			
4	Weight of pycnometer + water (W4), g			
5	Water content, w			
6	Average water content, Avg w			

Specimen calculations:

$$w\% = [((W2-W1)/(W3-W4))\times(((G-1)/G)-1)]\times100$$

Average water content, $w = (w1+w2+w3)/3$

Result:

Average water content, w =______%

Verification/ Validation:

Soil mass is generally a three phase system. It consists of solid particles, liquid and gas. The phase system may be expressed in SI units either in terms of mass-volume or weight volume relationships. Water content value is 0% for dry soil and its magnitude can exceed 100%.

Conclusion:

Pycnometer method is a simple method to determine the water content of a soil. Experiment is carried out using the soil specimen collected from the college itself. All foreign matters are removed, clods broken and water content we got for the soil specimen is_________.

Comparing with the oven drying method, the value is___________.

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, porosity and 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 method as 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 x 40mm.
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 dolly over the core cutter. Stop ramming when the dolly 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;

$$\rho_d = \rho_t/(1+w) \ \text{gm/cm}^3$$

OR

$$\gamma_d = \gamma_t/(1+w) \ \text{kN/m}^3$$

Where, ρ_d = dry density in g/cm³,
γ_d = dry unit weight in g/cm³,
ρ_t = field moist density in g/cm³,
γ_t =field moist unit weight in g/cm³,
w =water content %/100,
γ_w = unit weight of water = 9.81 kN/m³

Precautions:

1. Core cutter method of determining the field density of soil is only suitable for fine grained soil (Silts and clay). That is, core cutter should not be used for gravels, boulders or any hard surface. This is because collection of undisturbed soil sample from a coarse grained soil is difficult and hence the field properties, including unit weight, cannot be maintained in a core sample.
2. Core cutter should be driven into the ground till the steel dolly penetrates into the ground half way only so as to avoid compaction of the soil in the core.
3. Before lifting the core cutter, soil around the cutter should be removed to minimize the disturbances.
4. While lifting the cutter, no soil should drop down.

Procedure:

a) Measure the height and internal diameter of the core cutter to the nearest 0.25 mm.
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 (γ_d OR ρ_d).

Observations:

Length of core cutter l= __________ cm

Diameter of core cutter d= __________ cm

Volume of core cutter=Vc= __________ cm

Table: Weights of core cutter

Sl.No.	Particulars	Test nos.		
		1 (ρ_{d1})	2 (ρ_{d2})	3 (ρ_{d3})
1.	Weight of empty cutter (W1), gms			
2.	Weight of cutter + wet soil (W2), gms			
3.	Volume of core cutter (V_c) cm^3			
4.	Weight ass of empty container (W3), gms			
5.	Weight of container + wet soil (W4), gms			
6.	Weight of container + dry soil (W5), gms			
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: = ------------

Verification/ Validation:

The dry density of most soils varies within the range of 1.1-1.6 g/cm^3. In sandy soils, dry density can be as high as 1.6 g/cm^3; in clayey soils and aggregated loams, it can be as low as 1.1 g/cm^3.

Conclusion:

The value of dry density of the soil is ____. The type of soil is____.

EXPERMENT NO 4

DETERMINATION OF IN-SITU DENSITY BY SAND REPLACEMENT METHOD

Aim:

To determine in-situ density of natural or compacted soil using Sand replacement Method.

The in-situ density of natural soil is needed for the determination of bearing capacity of soils, for the purpose of stability analysis of slopes, for the determination of pressures on underlying strata for the calculation of settlement and the design of underground structures. Moreover, dry density values are relevant both of embankment design as well as pavement design.

Specifications:

This test is done to determine the in-situ dry density of soil by core cutter method as per IS-2720-Part-28 (1975). In order to conduct the test, select uniformly graded clean sand passing through 600 micron IS sieve and retained on 300 micron IS sieve.

Equipments Required:

a) Sand pouring cylinder of about 3 litre capacity (Small pouring cylinder as per IS 2720 Part 28)
b) Cylindrical calibrating container 10 cm internal diameter and 15 cm depth
c) Glass plate, trays, containers for determining water content
d) Tools for making of a hole of 10 cm diameter and 15 cm deep, knife and other accessories
e) Metal container to collect excavated soil
f) Metal tray, 300mm square and 40mm deep with a hole of 100mm in diameter at the centre
g) Weighing balance
h) Moisture content cans
i) Glass plate about 450 mm/600 mm square and 10mm thick
j) Oven
k) Dessicator

Theory:

By conducting this test, it is possible to determine the field density of the soil. The moisture content is likely to vary from time and hence the field density also. So it is required to report the test result in terms of dry density. In sand replacement method, a small cylindrical pit is excavated and the weight of the soil excavated from the pit is measured. Sand whose density is known is filled into the pit. By measuring the weight of sand required to fill the pit and knowing its density, the volume of pit is calculated. Knowing the weight of soil excavated from the pit and the volume of pit, the density of soil is calculated. Therefore, in this experiment there are two stages, namely

1. Calibration of sand density
2. Measurement of soil density

Field density is defined as weight per unit volume of soil mass in the field at in-situ conditions. Equations are:

$$\rho_d = \rho_t/(1+w) \text{ gm/cm}^3$$

OR $\gamma_d = \gamma_t/(1+w) \text{ kN/m}^3$

Where, ρd = dry density,
γd = dry unit weight,
ρt = field moist density,
γt =field moist unit weight,
w =water constant,
γw = unit weight of water = 9.81 kN/m³

The basic equations in determination of density using sand replacement method are:

$$V_h = W_s / (G \times \rho_w)$$

$$\rho_t = M / V_h$$

$$\rho_d = \rho_t/(1+w)$$

Where, V_h = Volume of hole made in the field.
W_s = weight of the sand that fills the hole.
W = weight of moist soil removed from the hole.
w = moisture content of soil removed from the hole.
ρ_t = moist soil in-situ density.
ρ_d = dry density of the soil.
G = specific gravity of the solids.
ρ_w = density of the water.

Precautions:

- If for any reason it is necessary to excavate the pit to a depth other than 12 cm, the standard calibrating can should be replaced by one with an internal height same as the depth of pit to be made in the ground.
- Care should be taken in excavating the pit, so that it is not enlarged by levering, as this will result in lower density being recorded.
- No loose material should be left in the pit.
- There should be no vibrations during this test.
- It should not be forgotten to remove the tray, before placing the SPC over the pit.

Procedures:

Stage1 –Determination of mass of sand that fills the cone

a) Measure the internal dimensions (diameter, d and height, h) of the calibrating can and compute its internal volume, $V_c = \pi d^2 h/4$

b) With the valve closed, fill the cylinder with sand
Weight of sand filled in the cylinder+cylinder W'=------- gms.

c) Keep the cylinder on a glass plate, which is kept on a horizontal surface.

d) Open the valve and allow the sand to fill the cone completely. Close the valve.
Weight of sand in the cylinder +cylinder W"= ----gms

e) Determine the mass of the sand left in the cylinder.
Weight of sand fills the conical portion=W_1=W'-W"

f) The difference between the mass of sand taken prior to opening of the valve and the weight of sand left in the cylinder after opening the valve gives the weight of sand that fills the cone. Let the mass be W_1.

Determination of bulk density of sand

a) Measure the internal dimensions of the calibrating container and find its volume.
Length of calibrating container l= --------cm

Diameter of calibrating container d= --------cm

Volume of calibrating container V_c= -------- cm^3

Let this volume be V_c

b) Place the pouring cylinder concentrically on the top of the calibrating container with the valve closed. Fill the cylinder with sand up to about 1 cm below the top.
Weight of cylinder W1= -----g

Weight of cylinder +sand in the cylinder W2= ------g

Weight of sand filled in the cylinder Wo=W2-W1= ------g

Let the weight of sand filled be Wo.

c) Open the valve of the cylinder and allow the sand to flow into the container. When no further movement of sand is seen, close the valve. Find the weight of the sand left in the cylinder
Weight of cylinder +sand after filling the calibrating container W3= gms.

Determine the weight of sand that fills the calibrating container Wc=W2-W3=-----

d) The bulk density of sand ρs is

$$\rho s = Wc/ Vc.$$

Stage 2 - Determination of in-situ density:

a) Level the area where the density is required.

b) Place the metal plate on the surface, which is having a circular hole of about 10 cm diameter at the centre. Dig a hole of this diameter up to about 15 cm depth collect all the excavated soil in a container.
Let the weight of the soil removed = W2=-------- g

c) Remove the plate and place the sand-pouring cylinder concentrically on the hole. Fill the cylinder with sand up to a constant level mark with the shutter valve closed. Open the valve and allow the sand to run into the hole till no movement of the sand is noticed. Close the valve and determine the mass of sand that is left in the cylinder
Weight of cylinder+sand after filling the hole completely W4= g

Weight of sand filling only the hole in the field Ws=W2-W4-Wc= g

Volume of the hole, $V_h = W_s/ \rho_s$ where ρ_s = bulk density of sand.

d) Bulk density of soil in-situ, ρ_t, is

$$\rho_t = W/ V_h = (W/ W_s)\times \rho_s$$

Determination of Water content of soil collected from the hole:

Weight of empty container (W5) = --------g

Weight of container + wet soil (W6) =----- g

Weight of container + dry soil (W7) = -----g

Water content (w) = (W6-W7)/(W7-W5)

Dry density of sand $\rho d = \rho_t/(1+w)$= --------g/cm³

Result:

1) Weight of wet soil from the hole, W =______gm
2) Water content of the soil, w =____%
3) Weight of sand that fills the hole =_____gm
4) Volume of the hole $Vh=Ws/\rho s$ =______cm³
5) Bulk density of the soil $\rho t = W/Vh$ =______gm/ cm³
6) Dry density $\rho d = \rho t/(1+w)$ =_____gm/ cm³

a) Dry density of soil =__________g/cm³
b) Water content of the soil =________%

Verification and Validations:

Sand replacement method is an indirect method of finding the density of soil. The basic principle is to measure the in-situ volume of hole from which the material was excavated from the weight of sand with known density filling in the hole. The in-situ density of material is given by the weight of the excavated material divided by the in-situ volume. The dry density of most soils varies within the range of 1.1-1.6 g/cm³. In sandy soils, dry density can be as high as 1.6 g/cm^3; in clayey soils and aggregated loams, it can be as low as 1.1 g/cm^3.

Conclusion:

The dry density of the soil is________g/cc. Comparing with the in-situ density by core cutter method, more or less the same value is achieved. The type of soil is silty-clay.