Practical Manual

SOIL PHYSICS

APS-501 3(2+1)

For

M.Sc. (Ag.) Soil Science

2023

Department of Soil Science

College of Agriculture
Rani Lakshmi Bai Central Agricultural University
Jhansi-284003

Practical manual

SOIL PHYSICS

APS-501 3 (2+1)

M.Sc. (Ag.) Soil Science

DR Y BIJILAXMI DEVI
DR SANDEEP UPADHYAY
DR ANUSUIYA PANDA

Department of Soil Science

College of Agriculture
Rani Lakshmi Bai Central Agricultural University
Jhansi-284003

Contents

Exercise No.1

Objective: Determination of Bulk Density

Principle: Known volume of sample will be taken to collect soil sample using core sampler and the dry weight will be estimated and bulk density can be calculated.

Requirements: Core sampler, spade, aluminium can box, oven, weighing balance

Procedure:

1. Collect soil sample using core sampler and transfer it to a moisture can box.
2. Keep it in the oven to dry the soil for 24 hrs at 105^oC.
3. Take dry weight of the sample and calculate volume of the core sampler *i.e* cylinder using the formula $\pi r^2 h$

Observation and Calculation

1. Weight of empty moisture box = W1 g
2. Weight of moisture box + oven dry soil = W2 g
3. Weight of oven dry soil = (W1-W2) g
4. Volume of the soil or Volume of core sampler = V ml = $\pi r^2 h$
5. Calculate Bulk Density by using formula BD (g cm^{-3} or Mg m^{-3}) = Oven dry weight of soil/Volume of soil
6. Interpret the result

Exercise No.2

Objective: Determination of Particle Density

Principle: The mass of unit volume of soil solid is called particle density. It can be determined by measuring the mass and volume of soil solid.

Requirements: Pycnometer, Hot Plate, Hot air oven, Weighing balance

Procedure:

1. Weigh the dry empty pycnometer of known volume and fill it water completely and close it with stopper
2. Wipe out all the moisture from outside and find its weight
3. Weight 10 g soil and put it in pycnometer, add 15-20 ml of water and boil it for a short time in order to expel all air
4. Cool the pycnometer at room temperature and fill completely by adding water and fit stopper
5. Wipe out all the moisture from outside and find its weight.

Observation and Calculation

1. Weight of empty pycnometer = W1 g
2. Weight of pycnometer + water = W2 g
3. Weight of pycnometer + water + oven dry soil = W3 g
4. Weight of oven dry soil = W4g
5. Volume displaced by soil = Y ml = (W2 +W4) – W3
6. Calculate Particle Density by using formula

   PD (g cm^{-3} or Mg m^{-3}) = Weight of oven dry soil/Volume ofwater displaced by soil

7. Interpret the result

Exercise No.3

Objective: Determination of Porosity of soil

Principle: Porosity of soil is the fraction of soil volume not occupied by soil particle (solids)

Requirements: Core sampler, spade, aluminium can box, oven, weighing balance, pycnometer, hot plate

Procedure:

1. Determine Bulk density and particle density by following the previous experiment's exercise.
2. Following the principle, Porosity can be derived from BD and PD

$$BD = Ws/V$$
$$PD = Ws/Vs$$
$$Ws = BD \times V$$
$$Ws = PD \times Vs$$
$$Ws = Ws$$
$$BD \times V = PD \times Vs$$
$$BD/PD = Vs/V$$

3. Percentage of solid space = Vs/V x 100

= BD/PD x 100

= 100 – (BD/PD)x100

Observation and Calculation

1. Calculate % Porosity = 100 – (BD/PD) x 100

Exercise No.4

Objective: Mechanical analysis by hydrometer method

Principle: The hydrometer method is based on the principle that the density of the particles at a given depth decreases as a homogeneously dispersed suspension settles. The rate of decrease in density at any given depth is related to the settling velocities of the particles, which in turn are related to their sizes. The time required to settle the particles of a given size can be calculated by using Stock's equation:

$$V = \frac{2\ r^2 g\ (\rho s - \rho f)}{9\ \quad \eta}$$

where

v – settling velocity (cm/sec or m x 10^{-2}/sec)
r – equivalent spherical radius of the particles (cm or m)
η – viscosity of the suspending fluid (g/cm sec or kg/m sec)
g – acceleration due to gravity (cm/sec^2 or m/sec^2)
ρs and ρf are the densities of the solid particles and of fluid (g/cm^3 or Mg/m^3) respectively

Thus, in a time 't', all particles having settling velocities greater than h/t, would be located below depth 'h' and the particles, having settling velocities < h/t, would be retained above this depth.

Requirements: Hydrometer, thermometer, Glass rod, 1000 ml beaker, 1000 ml measuring cylinder, 500 ml conical flask,weighing balance

Chemicals: 0.5% Sodium hexametaphosphate, Hydrogen peroxide, H_2O_2 (30%), Tap water (use distilled water if tap water is too hard)

Procedure:

1. Take 50g oven-dry soil (ground and sieved through a 2 mm sieve) in a 1000 ml beaker
2. Add 25 ml H_2O_2 and swirl the contents well. Allow the reaction to take place for 5-10
3. minutes
4. Place the beaker on a water bath (to allow heat from steam of water bath).
5. Add H_2O_2 and then let cool the contents
6. Next, add 150 ml of 0.5% sodium hexametaphosphate (1:3, Soil: Solution) in it
7. Shake the contents of the beaker with an electric stirrer for 10 minutes
8. Transfer the contents of the beaker in a 1000 ml cylinder and make up the volume of the suspension by adding more distilled water
9. Note down the temperature of the suspension immediately
10. Shake the contents of the cylinder by moving up and down gently for one minute and then place on the table for settling of finer particles and note down the time immediately
11. Take the first reading (Rh1) carefully by lowering down the hydrometer into the suspension at 4 minutes when the particles larger than 0.02mm in diameter have settled out. Insertion of hydrometer should be started 10 seconds in advance of reading time

12. Remove the hydrometer carefully after reading and wash using distilled water
13. Allow the suspension to remain undisturbed
14. Take second reading (Rh2) at 2 hours from the time shaking was stopped, where particles larger than 0.002 mm in diameter have settled out

Temperature correction:

The hydrometer is calibrated at 68 ^{0} F. If the working temperature is > 68 ^{0} F, then the correction factor (r) needs to be added and if the working temperature is < 68 ^{0} F, then the correction factor (r) needs to be subtracted. r = 0.2 × (observed temperature in 0 F - 68 ^{0} F)

Observation and Calculation

First reading = Clay + Silt

Second reading =

Exercise No.5

Objective: Mechanical analysis by International Pipette Method

Principle: Texture is an important property of soils because particle size determines the surface area of solids per unit volume or mass of soil. Texture also influences the pore size distribution in soil. A sandy soil isdominated by large individual soil particles and, therefore, has a relatively small total surface areaand large pore spaces between soil particles. At the other extreme, a clay soil consists of tinyindividual particles and has a large total surface area but small pore spaces.

Soil particles suspended in solution settle out at a rate that depends on the size of the particles, The larger the particle, the faster it settles. Settling rate is given by Stokes= Law

$$V = \frac{2\, r^2 g\, (\rho s - \rho f)}{9\ \eta}$$

where

v – settling velocity (cm/sec or m x 10^{-2}/sec)
r – equivalent spherical radius of the particles (cm or m)
η – viscosity of the suspending fluid (g/cm sec or kg/m sec)
g – acceleration due to gravity (cm/sec^2 or m/sec^2)
ρs and ρf are the densities of the solid particles and of fluid (g/cm^3 or Mg/m^3) respectively

Requirements: Thermometer, Glass rod, 1000 ml beaker, 1000 ml measuring cylinder, 500 ml conical flask, weighing balance

Chemicals: 0.5% Sodium hexametaphosphate, Hydrogen peroxide, H_2O_2 (30%), Tap water (use distilled water if tap water is too hard)

Procedure:

1. Weigh out 20 g (to nearest 0.01 g) of soil and transfer to a shaker cup.
2. Fill with water to a depth of 10 cm and add 5 mL Na hexametaphosphate. Stir for 5minutes.
3. Pour contents into a 500 mL graduated cylinder. Use a stream of water from a wash bottle to transfer soil remaining in cup. Bring volume to 500 mL.
4. Cover top of cylinder with parafilm. Put palm of hand over top, grasp bottom of cylinder and invert several times to resuspend soil.
5. Set on bench top, begin timing, gently remove parafilm and take a 25 mL aliquot from the upper 10 cm of suspension at 48 s. A mark on the pipette at 10 cm from the tip serves as a good guide for depth.
6. Transfer aliquot to a weighed (record mass in Table 1) evaporating dish and put inoven at 105° C. Higher temperature than boiling is needed due to presence of solutes. Label evaporating dish Asilt + clay. Also, write your lab group number on the evaporating dish. Since it takes 8 h for all silt size particles to settle 10 cm, a mechanical analysis by the pipette method cannot be completed within the

time allowed for this lab. However, the steps in this procedure can be followed and approximate results obtained in shorter time.

7. Take the second 25 mL aliquot after only 40 min but from upper 5 cm of the suspension. Mark pipette 5 cm above tip.
8. Transfer aliquot to weighed, labeled evaporating dish and put in oven at 105° C.
9. After 40 min, all silt greater than 0.005 mm diameter will be settled to below 5 cm. Thus, the second aliquot contains some silt (0.005 to 0.002 mm diameter) as well as clay.
10. To demonstrate flocculation, add 5 mL of CaCl2 solution to the suspension after taking second aliquot. Cover the top of cylinder with parafilm, invert several times, then set on bench top. Observe what happens.
11. Dispose of suspension and soil into waste bucket.
12. At the beginning of the next lab, remove evaporating dishes from oven, cool and weigh. Record the net weight of the first evaporating dish as combined silt and clayin 1/20th of the soil-water suspension. The net weight ofthe second is assumed to be1/20th of the clay.
13. Calculate percentages of each of the separates as

$$\% \text{ clay} = (20 \times \text{mass of clay in aliquot} / \text{total mass of soil}) \times 100 \%$$

$$\% \text{ silt} = (20 \times [\text{mass of silt + clay - mass of clay}] / \text{total mass of soil}) \times 100\%$$

$$\% \text{ sand} = 100 \% - (\% \text{ silt} + \% \text{ clay})$$

The 20 g sample of soil used, even though air-dry, contained adsorbed water from the atmosphere. Depending on fineness of texture and organic matter content, adsorbed wateraccounts for up to several percent oftotal air-dryweight ofsoil. You should use the oven-dry mass ofsoil in the above calculations. Convert air-dry mass to oven-dry by

$$\text{oven-dry mass} = \text{air-dry mass} / (1.00 + [\text{moisture } \% / 100 \%])$$

14. Use the textural triangle to assign a textural class name.

Exercise No.6

Objective: Measurement of Atterberg Limits

Principle: The Atterberg limits are a basic measure of the critical water contents of a fine-grained soil, such as its shrinkage limit, plastic limit, and liquid limit.

Requirements: Liquid limit device, Porcelain (evaporating) dish, Flat grooving tool with gauge, eight moisture cans, Balance, Glass plate, Spatula, Wash bottle filled with distilled water, Drying oven set at 105°C

Procedure:

Liquid Limit:

a) Take roughly 3/4th of the soil and place it into the porcelain dish. Assume that the soil was previously passed through a No. 40 sieve, air-dried, and then pulverized. Thoroughly mix the soil with a small amount of distilled water until it appears as a smooth uniform paste. Cover the dish with cellophane to prevent moisture from escaping.

b) Weigh four of the empty moisture cans with their lids, and record the respective weights and can numbers on the data sheet.

c) Adjust the liquid limit apparatus by checking the height of drop of the cup. The point on the cup that comes in contact with the base should rise to a height of 10 mm. The block on the end of the grooving tool is 10 mm high and should be used as a gage. Practice using the cup and determine the correct rate to rotate the crank so that the cup drops approximately two times per second.

d) Place a portion of the previously mixed soil into the cup of the liquid limit apparatus at the point where the cup rests on the base. Squeeze the soil down to eliminate air pockets and spread it into the cup to a depth of about 10 mm at its deepest point. The soil pat should form an approximately horizontal surface.

Use the grooving tool carefully to cut a clean straight groove down the center of the cup. The tool should remain perpendicular to the surface of the cup as groove is being made. Use extreme care to prevent sliding the soil relative to the surface of the cup.

f) Make sure that the base of the apparatus below the cup and the underside of the cup is clean. Turn the crank of the apparatus at a rate of approximately two drops per second and count the number of drops, N, it takes to make the two halves of the soil pat come into contact at the bottom of the groove along a distance of 13 mm (1/2 inch). If the number of drops exceeds 50, then go directly to step eight and do not record the number of drops, otherwise, record the number of drops on the data sheet.

g) Take a sample, using the spatula, from edge to edge of the soil pat. The sample should include the soil on both sides where the groove came into contact. Place the soil into a moisture can and cover it. Immediately weigh the moisture can containing the soil, record its mass, remove the lid, and place the can into the oven. Leave the moisture can in the oven for at least 16 hours. Place the soil remaining in the cup into the porcelain dish. Clean and dry the cup on the apparatus and the grooving tool.

h) Remix the entire soil specimen in the porcelain dish. Add a small amount of distilled water to increase the water content so that the number of drops required for closing the groove decrease.

i) Repeat steps six, seven, and eight for at least two additional trials producing successively lower numbers of drops to close the groove. One of the trials shall be for a closure requiring 25 to 35 drops, one for closure between 20 and 30 drops, and one trial for a closure requiring 15 to 25 drops. Determine the water content from each trial by using the same method used in the first laboratory. Remember to use the same balance for all weighing.

Plastic Limit:

a) Weigh the remaining empty moisture cans with their lids, and record the respective weights and can numbers on the data sheet.

b) Take the remaining 1/4 of the original soil sample and add distilled water until the soil is at a consistency where it can be rolled without sticking to the hands.

c) Form the soil into an ellipsoidal mass. Roll the mass between the palm or the fingers and the glass plate. Use sufficient pressure to roll the mass into a thread of uniform diameter by using about 90 strokes per minute. (A stroke is one complete motion of the hand forward and back to the starting position.). The thread shall be deformed so that its diameter reaches 3.2 mm (1/8 in.), taking no more than two minutes.

d. Gather the portions of the crumbled thread together and place the soil into a moisture can, then cover it. If the can does not contain at least 6 grams of soil, add soil to the can from the next trial. Immediately weigh the moisture can containing the soil, record it's mass, remove the lid, and place the can into the oven. Leave the moisture can in the oven for at least 16 hours.

e) Repeat steps three, four, and five for at least two more times. Determine the water content from each trial by using the same method used in the first laboratory. Remember to use the same balance for all weighing.

Observation and Calculation

Liquid Limit:

1. Calculate the water content of each of the liquid limit moisture cans after they have been in the oven for at least 16 hours.
2. Plot the number of drops, N, (on the log scale) versus the water content (w). Draw the best-fit straight line through the plotted points and determine the liquid limit (LL) as the water content at 25 drops.

Plastic Limit:

1. Calculate the water content of each of the plastic limit moisture cans after they have been in the oven for at least 16 hours.
2. Calculate the plasticity index, PI = LL - PL. Report the liquid limit, plastic limit, and plasticity index to the nearest whole number, omitting the percent designation.

Moisture Content

Moisture content is calculated with the following formula:

$$MC = \frac{W_{wt} - W_{dt}}{W_{dt} - W_t} \times 100$$

where,

MC = moisture content
W_{wt} = weight of the moisture specimen with tare
W_{dt} = weight of the dried specimen with tare
W_t = weight ofthe container

Exercise No.7

Objective: Dry Aggregate Analysis

Principle: Stable aggregates will be determined depending upon its ability to withstand shaking and sizes. Different aggregates will be calculated based on the stability with different sizes.

Requirements: Brush, weighing balance, Sieves of appropriate sizes, Jars, Kraft paper

Procedure:

1. Lay the soil samples out on brown paper or newspaper and leave them until dry. Paper can also be used to cover the samples to prevent contamination. Drying times vary depending on how wet the samples were when taken and ambient humidity. If needed, the samples may be gently broken up by hand along natural fracture lines. This procedure may be repeated during the first few days of drying, but do not force the soil to break apart. Most samples will be dry within one week. To make sure that they samples are dry, check to see if the weights change with further drying. To do this, make the following measurements:
   a) weigh a subset of three to five samples from the various treatments when you think that they are dry;
   b) leave these samples to dry either by incubating overnight (at least 8 hours) at room 1 temperature or drying on a slide warmer or in an oven at less than 40o C for at least 2 hours; and
   c) weigh the samples again and compare weights.
2. Dry soil may be weighed at this point for a total soil weight (WT) or the sum of the weights in each aggregate size class may be used for the WT value.
3. Air-dried soil is gently poured onto a sieve with a screen size matching the largest sized aggregates in a size class. The soil should be added to the sieve until all the sample is used or soil just covers the entire screen, whichever comes first. If a large amount of soil is being sieved, you may have to repeat the sieving process until the whole sample is completed.
4. The sieve is held in one hand above a piece of brown paper or newspaper and tapped with the other hand (use work gloves to protect hands and mask and other personal protective equipment to protect from dust) at least 25 times for very small samples and up to 150 or more times for samples that cover the entire screen. Soil aggregates and particles smaller than the mesh screen will pass through and be collected on the paper below.
5. Gently pour the material on the paper into a sieve with a screen size matching the smallest aggregates in the size class and repeat step 3.
6. Gently pour the aggregates collected on top of the screen into a plastic bag, tube, or jar for storage and repeat steps 3-4 on the material that has passed through the screen.
7. Repeat step 3-5 until all the aggregate size classes of interest are collected.
8. Repeat steps 2-6 until all of the soil has been sieved. You can combine aggregates of the same size class and sample together even if they were sieved in different repeated fractions.
9. Weigh the total amount of aggregates in each size class (W_A). Use these values plus the total sample weight (W_T) value described in step 1 and the proportion of the aggregate weight that is in the coarse

fraction (i.e. the average coarse material weight (W_c) divided by original wet sieved sample weight (W_o) from the wet sieving process and multiplied by W_A) to calculate the proportion of the total sample that is in each aggregate size class (P_{awi}).

$$P_{awi} = \frac{[W_A - \{ W_c / W_o) \times W_A\}]}{W_T}$$

where P_{awi} = proportion of aggregate weight for each size class i; W_A = weight of total material in each size class i; W_c= weight of coarse material in size i as measured after weight sieving; W_o = weight of aggregates placed on the sieve prior to wet sieving size i; W_T = total sample weight.

Observation and Calculation

Agg Size	Weight	Proportion sand weight from WSA	Proportion Agg weight from WSA	Proportion Sand	Proportion Agg	Proportion Total Sum	Proportion Total calc	Summed Total
>2, <0.053								
1-2								
0.25-1								
0.053-0.25								

Agg size	Aggregate size class description
Weight	Total weight of aggregates in a size class
Proportion sand weight from Water Stable Aggregate (WSA)	Ave coarse weight (from WSA data sheet) ÷ Ave original weight (from WSA data sheet)
Proportion agg weight from WSA	[Ave original weight (from WSA data sheet) - Ave coarse weight (from WSA data sheet)] ÷ Ave original weight (from WSA data sheet)
Proportion sand	(Weight * Proportion sand weight from WSA) ÷ Total weigh of soil sample (or sum of aggregate weights)
Proportion agg	(Weight * Proportion agg weight from WSA) ÷ Total weigh of soil sample (or sum of aggregate weights)
Proportion total sum	Proportion sand + Proportion agg
Proportion total calc	Weight ÷ Total weigh of soil sample (or sum of aggregate weights)
Summed total	Sum for all four aggregate size classes of (Proportion total sum)

Exercise No.8

Objective: Wet aggregate Analysis

Principle: Soil samples are air-dried to a constant weight to make sure samples from all treatments are at the same moisture content. Samples are dry sieved by hand to collect aggregate size classes one size class at a time rather than using a rotary sieve or sieve shaker with stacked sieves. This will reduce mechanical shearing of aggregates and keeps larger aggregates from impacting and breaking up smaller aggregates. Collecting each size class individually allows for each size class to be wet sieved or analyzed individually.

Requirements: Brush, weighing balance, Sieves of appropriate sizes, Jars, Kraft paper, Hot Air Oven

Procedure:

1. Pre-weigh and label weigh boats to transfer aggregates and coarse material into for drying. [The same weigh boat may be used for both the aggregates (collected after wet sieving, step 5) and the coarse material (collected after treating with sodium hexametaphosphate, step), but pre-weighing the boats will allow you to subtract the boat weight from the air-dried samples without having to remove the samples to tare the boat.]
2. Transfer 1-4* g of air-dried soil in each aggregate size classes into sieves with a screen size ¼ of the size of the smallest aggregates in the size class. For example, if you are sieving 1 to 2 mm aggregates, use a screen with mesh openings of 0.25 mm (¼ of 1 mm). The screens are placed in the pre-weighed weigh boats to collect dust that passes through the screen during weighing and for capillary rewetting (Step 3).
3. Samples are capillary rewetted from underneath by adding Milli-Q (or double distilled) water to the outside of the sieve in the weigh boat and allowing water to wick up from underneath.
4. Incubate on bench top for 10 min.
5. Place sieves into an apparatus described by Kemper and Koch (1966) for mechanical wet sieving. Sieves are moved up and down in a column of water at a rate of approx. 40 cycles per minute for 5 min. The bottom of the sieve is never allowed to break the surface of the water.
6. Material collected on the sieve was washed gently into pre-weighed weigh boats, dried at 70 to 90^{o} C, and weighed.
7. The coarse material was removed by adding 0.5% sodium hexametaphosphate and shaking periodically (3 to 4 times) over a 5 min period to disrupt the aggregates
8. The disrupted aggregates are washed through a screen matching the smallest aggregate size in the class using forced water. For smaller aggregate sizes, a rubber policeman or similar device may be used help break up aggregates and push them through the screen. The coarse material is collected on the screen, washed into pre-weighed weigh boats, dried between 70 to 90^{o}C, weighed, and subtracted from the amount of aggregates collected after wet sieving
9. The formula for calculating the percentage WSA for each size class is:

$$WSA_i = [(W_a - W_c) \div W_o] \times 100$$

where WSA$_i$= water stable aggregation for each size class i; W_a = weight of material on the sieve after wet sieving size i; W_c = weight of coarse material in size i; W_o = weight of aggregates placed on the sieve prior to wet sieving size i.

Observation and Calculation

Agg Size	Sieve ID	Orig. stab. sample wght (g)	Ave orig. wght	Boat wght	Dried agg. wght + boat	Agg. wght	Dried coarse wght + boat	Coarse wght	Ave coarse wght	Propor. coarse	Propor. aggreg	WSA	Ave
2-1	AA												
2-1	BB												
2-1	CC												
2-1	DD												

Agg size	Aggregate size class description
Sieve ID	ID on sieve used for WSA
Orig. stab. sample wght (g)	Weight of sample in sieve for WSA
Ave orig. wght	Average weight of duplicate samples in sieves for WSA
Boat wght	Weight of pre-weighed weigh boat
Dried agg. wght + boat	Weight of material left on sieve after wet sieving and drying at 70-90oC and without tarring the weigh boat
Agg. wght	(Dried aggreg weight + boat) – (Boat weight)
Dried coarse wght + boat	Weight of material left on sieve after treating dried aggregates with sodium hexametaphosphate, washing disrupted aggregates through the sieve and drying at 70-90oC and without tarring the weigh boat
Coarse wght	(Dried Nahexa coarse material weight + boat) – (Boat weight)
Ave coarse wght	Average weight of coarse material from duplicate WSA samples
Propor. coarse	(Ave coarse weight) ÷ (Ave original weight)
Propor. aggreg	[(Ave original weight) - (Ave coarse weight)] ÷ (Ave original weight)
WSA	[(Aggreg weight) – (Coarse material wght)] ÷ (Original stability sample wght (g))
Ave	Average WSA values for duplicate samples
SE	Standard Error of WSA values for duplicate samples

Exercise No.9

Objective: Gravimetric Method of soil moisture determination

Principle: Weighted soil sample is placed in oven at 105^{o}C and it is dried to constant weight. The weight difference is considered to be water present in soil sample.

Requirements: Auger, spade, aluminium can box, oven, weighing balance

Procedure:

1. Take weight of moisture box
2. Take sample of about 100 g from required depth with help of Auger/Spade
3. Put the moist soil sample in the moisture box and close the box to prevent loss of water moisture by evaporation
4. Put the moist soil sample in the moisture box and close the box to prevent loss of water by evaporation
5. Bring the moisture box containing the moist soil to the lab and weigh immediately
6. Place the moisture box in hot air oven till a constant weight at 105^{o}C temp. for 24-48 hrs
7. Allow the sample to cool for some time in hot air oven. Then close the moisture box and put into the desiccator for further cooling
8. Now weigh the sample closed moisture box with oven dry soil.

Observation and Calculation

1. Weight of empty moisture box = X g
2. Weight of moisture box + fresh soil = Y g
3. Weight of moisture box + oven dry soil = Z g
4. Weight of moisture in soil = Y-Z g
5. Weight of oven dry soil = Z-X g

$$\text{Moisture \%} = \frac{\text{Fresh weight} - \text{Dry weight}}{\text{Weight of oven dry weight soil}} \times 100$$

Exercise No.10

Objective: Neutron Probe method of soil water content analysis

Principle: Neutrons emitted from a radioactive source (usually Radium-Beryllium) upon collision with a particle having mass nearly equal to its own, like hydrogen atom in the soil and release their energy and gets thermalized. The thermalized neutrons are detected by a detector and recorded on a scaler.

Requirements: Neutron Probe, Detector, Scaler, Cable, Access tube of Aluminium or steel of 20 gauze with 1.9 inch internal and outer diameter, Soil auger

Procedure:

1. Prepare a plot measuring 1 m x 1m in the field
2. Drill a hole with the help of auger and insert the access tube in the soil with little disturbances such that no bulge is created in the access tube. Keep the access tube 10-20 cm above the soil and cover with inverted can or close its opening with a rubber cork to prevent entry of trash. In order to prevent water entry into the tube, close the lower end of the access tube with rubber stopper.
3. Turn on the scaler and allow it to warm up for few minutes.
4. Place the probe on the top of the access tube and measure the counts, called standard counts. The normal counting time is one minute. The background' count thus obtained should not be much more than 100 counts per minute. Approximately, a 15 cm soil layer is characterized by a single measurement.
5. Take readings at successive depth intervals starting at least 18-25 cm from the soil surface.
6. Lower the probe in the access tube to a depth at which water content is to be determined and note the counts.
7. Calculate the count ratio by dividing the observed counts at a depth by the standard counts.
8. Determine the water content of that layer of soil gravimetrically and convert to volumetric water content by multiplying it with bulk density of the soil.
9. Construct a calibration curve by filling a linear relation ($\theta_v = a + bCR$) between volume water content (θ_v) and the count ratio (CR)

Observation and Calculation

1. Standard Count = SC
2. Actual Count = AC
3. Count Ratio = AC/SC
4. Constants of calibration curve = a and b
5. Volumetric water content

$$\theta_v = a + bCR \ m^3m^{-3}$$

Exercise No.11

Objective: Determination of soil moisture content by tensiometer

Principle: Soil water potential may be considered as the "Energy status" of the water in the soil pores, relative to some standard reference condition or datum. Soil water potential is defined along with the units of measurement now in common practice. Soil water potential is used primarily for determining the direct ion and rate of water flow between locations with differing potentials. The potential of soil pore water varies over several orders of magnitude, ranging from positive values in saturated soil to extremely negative values in dry soil. Direct measurement of soil water potential involves determining water pressure or water surface elevation relative to a datum (e.g., pressure transducer, standpipe water level, etc.), while indirect measurement involves measuring some surrogate property that correlates with water potential (e.g., electrical resistance or conductivity, water vapor pressure, water content, plant xylem potential, etc.).
Requirements: Tensiometer, Field, Reading book

Procedure:

1. When buried in the soil, the ceramic tip of the tensiometer allows water to move freely in or out of the tube. As the soil dries out, water is sucked out through the porous ceramic tip, creating a partial vacuum inside the tensiometer which is read on the vacuum gauge.
2. When the soil is wetted by sufficient rainfall or irrigation, water flows back into the tensiometer, the vacuum decreases and the gauge reading is lowered.
3. Tensiometer measures how tightly water is held to the soil particles and not how much water is left in the soil. A sandy soil will reach a high tension sooner than a clay loam
4. Tensiometers do not operate in dry soil because the pores in the ceramic tip drain and air is sucked in through them breaking the vacuum seal between the soil and the gauge on top of the tensiometer.

Observation and Calculation

$$\text{Potential} = \text{Force x Distance} = mgl = rwVgl\ (Nm)$$

Soil water potential can be expressed in three different units:
a) Potential per unit mass (m): m = potential/mass = gl (Nm/kg)
b) Potential per unit volume (y): y = potential/volume = rwVgl / V = rwgl (N/m^2, water pressure units)
c) Potential per unit weight (h): h = potential/weight = mgl / mg = l (m, head unit) = equivalent height of water

Exercise No.12

Objective: Determination of available water holding capacity of soil

Principle: Available Water Capacity (AWC) is the amount of water available to plants from the time the soil stops draining water to the time the soil becomes too dry to prevent permanent wilting. Available water capacity is the amount of water that a soil can store that is available for use by plants.

Water holding capacity is the total amount of water a soil can hold at field capacity. Sandy soils tend to have low water storage capacity. Subsoil constraints (acidity, hardpans etc.) can prevent crops accessing water in the subsoil.

Field capacity is the amount of water held in a soil after gravitational water drainage stops. This is water contained in a soil a few hours to a day after a soaking rain or irrigation. Field capacity includes plant unavailable water held at or below the permanent wilting point. Plant available water holding capacity is the amount of water held between wilting point and field capacity

Requirements: Pressure plate apparatus and 50 mL burette. Beakers, Soil sample, Butter paper, Funnel keep

Procedure:

This procedure determines the soil water content at Permanent Wilting Point (PWP) and Field Capacity (FC) and calculates AWC as the difference between PWP and FC.

1. Place the sample-retainer rings on the porous plate. Using a teaspoon or small scoop, take a random, grab sample of soil <2 mm diameter, and dump the whole sample into the ring taking care to avoid particle size segregation. Level the soil. Carry out duplicate samples.
2. Add distilled water to the surface of the porous plate until it reaches halfway up the outside of the rings. Cover the plate and allow to stand overnight, adding more water as required to maintain the level.
3. When the soils are saturated, carefully transfer the plate to the pressure chamber and connect the outlet tube. Connect the outflow tube from the pressure chamber to the bottom of 50 mL burette. Apply the appropriate pressure.
4. When equilibrium has been reached (minimum 24 hrs) as shown by no change in volume in the draining burette, close the burette tap and release the pressure in the chamber. Transfer the soil from each ring to a weighing tin and determine the moisture content according to the Soil Moisture Content.
5. Repeat the procedure for other required pressures.

Observation and Calculation

The AWC therefore can be calculated as

$$AWC = \theta_{FC} - \theta_{PWP}$$

where θ_{FC} is the water content at FC and θ_{PWP} is the water content at the PWP. The wilting point has originally been determined as the matrix potential at which sunflower seedlings wilt irreversibly.

Exercise No.13

Objective: Determination of soil moisture characteristic curve

Principle:A soil moisture characteristic (SMC) curve describes the functional relationship between soil water content and its energy status in terms of its matric potential under equilibrium conditions. The SMC is an important property of a given soil controlled by soil pore size distribution which is strongly affected by texture, structure and organic matter content. Pressure plate apparatus is used to measure soil water potential and with the help of this knowledge, soil moisture can indirectly be correlated by drawing a moisture characteristic graph.

A curve showing relationship between matric suction and volumetric water content is known as SMCC. This curve states that water retention is a continuous function of the soil matric suction and it decreases with increase in suction

Requirements: Pressure Plate Apparatus, Water, Weighing balance, Hot Air Oven

Procedure:

1. Soil samples are filled in rubber ring and kept in ceramic plate of the pressure plate apparatus.
2. Soil samples are saturated with water, excess water will be collected in a beaker through an outlet.
3. Specific potential has been kept and water has been suctioned out. After the water has been suction out depending on potential fixed in the apparatus, gravimetric soil moisture content should be estimated. Repeat the procedure for different potentials viz. 1, 5, 10,15 bar.
4. Moisture content between suction values 1 to 15 bar can usually be measured by this instrument
5. The instrument is very good for preparing soil moisture characteristics curves in the higher suction range *i.e*> 1 bar to 15 bars or even more
6. Ceramic plates are unable to held pressure more than 20 bars
7. Draw the soil moisture characteristic curve using the information of soil moisture content against different potential.

Observation and Calculation

1. Soil moisture content at 1 bar =
2. Soil moisture content at 5bar =
3. Soil moisture content at 10bar =
4. Soil moisture content at 15bar =
5. Draw moisture characteristic curve in X and Y axis by joining different soil moisture content values in the graph.

Exercise No.14

Objective: Determination of saturated hydraulic conductivityby constant head permeameter

Principle: The saturated hydraulic conductivity is a measure of readiness with which a saturated soil transmits water through its body and is expressed as length per unit time. Hydraulic conductivity is of a considerable importance for irrigation, drainage and evaporation studies. It depends upon properties of water / fluid and on the porosity, pore size distribution and continuity of soil pores. It is generally assumed to be a constant physical property of a soil for any given positioning the field at any given time varying only with respect to water content or water potential. Since viscosity and density of water passing through the soil affect the hydraulic conductivity, this soil property varies for different quality of waters. The hydraulic conductivity of soil varies from 0.001 cm/hr in a fine clay to over 25.0 cm/hr. on coarse sand. In principle the hydraulic conductivity of soil is calculated from Darcy's Law after measuring the soil water flux and hydraulic gradient. Darcy's law is used for determining the hydraulic conductivity of soil samples in the laboratory. In saturated flow the gradient is of positive pressure potential gradient.

Requirements: Permeameter, Graduated cylinders, stop watch etc.

Procedure:

8. Place a filter paper disc on the screen of the permeameter.
9. Take 200 gm of 2 mm sieved air-dry soil.
10. Dump the entire sample in one lot into the permeameter and pack it by tapping the permeameter 15 to 20 times on a wooden block from a height of 2 to 3 cm.
11. Place the filter paper disc on the top of the soil.
12. Place the permeameter in a tray filled with water, keeping the water level slightly above the bottom of the sample and allow it to soak overnight (14 –16 hrs) or longer till fully wet at the surface.
13. Raise the water level in the tray to coincide with the top of the soil in the permeameter for complete saturation.
14. Place the permeameter on the stand and start the siphon to maintain a constant head (2 – 3 cm) on the top of the soil (do not allow the water to flow over the top of the permeameter).
15. Keep at least 4 to 6 replications (if different students are using the same soil, then their data can be used as replicates).
16. Note down the time when the water head on soil sample becomes constant and as steady flow is obtained.
17. Collect the percolate in a graduated cylinder and measure the volume at pre-decided interval of time.
18. Record a few consecutive readings till the flux becomes constant and measure the exact water head on the soil and then discontinue the experiment. Measure the length of soil column with the measuring scale.

Observation and Calculation

1. Diameter of the permeameter = d cm
2. Cross sectional area of the permeameter= A cm^2
3. Depth of water above the soil = h cm.
4. Length of soil column = L cm
5. Time for which percolate collected = T min.
6. Volume of percolate collected = Q cm^3 or ml
7. Hydraulic gradient = (L + h) / L
8. Saturated hydraulic conductivity = QL / At (L + h) cm./min

$$Q = -K\, iA$$

$$i = H2 - H1 / L$$

Exercise No.15

Objective: Determination of saturated hydraulic conductivity by falling head permeameter

Principle: Darcy's law is used for determining the hydraulic conductivity of soil samples in the laboratory. In this method, drop in water level in a narrow tube is measure instead of flow. This method is better adopted for slowly permeable soils.

Requirements: Special apparatus consists of a galvanized iron cylinder (40 cm in length and 30 cm in diameter) with a conical top to which a vertical glass tube of small diameter is attached, Permeameter, Graduated cylinders, stop watch etc.

Procedure:

1. Push the cylinder into the soil to a depth for which determination is to be made and assemble the whole apparatus.
2. Wet the sample from below by water supply through a three way stop cock and lower porous plate.
3. Fill the space above the sample by introducing water with pipette or syringe at the top of the sample until it overflows.
4. Record the time for water level to fall from h1 to h2. Make additional 2 – 3 such measurements.

Observation and Calculation

1. Diameter of stand pipe = d cm
2. Cross sectional area of stand pipe = a cm^2
3. Length of the sample = L cm
4. Diameter of the sample = D cm
5. Cross sectional area of the sample (A) = Πr^2 cm^2
6. Initial hydraulic head = h1 cm
7. Final hydraulic head = h2 cm
8. Time taken for change in head = t sec
9. Saturated hydraulic conductivity = (al / At) ln (h1/h2) cm/sec

Exercise No.16

Objective: Determination of infiltration rate of soil using double ring infiltrometer

Principle: Infiltration is the process of penetration of water into the ground surface and the intensity of this process is known as infiltration rate. The infiltration rate is expressed in terms of volume of water poured per ground surface per unit of time. Soil erosion, surface runoff & ground water recharge are affected by this process. At a certain moment the maximum infiltration rate can be indicated by the infiltration capacity of soil. Infiltration of water into the soil can be determined by a simple instrument called Double ring Infiltrometer. The cylindrical ring Infiltrometer consist of single metal cylinder. These cylinders are partially inserted into the ground and water is filled up to a margin inside the cylinder and after that the speed of penetration of water is measured with respect to the time and depth of penetration of water inside the cylinder. Four types of cylinders are taken for this experiment of diameter 15cm, 30cm, 45cm & 60cm and they are experimented as 15-45cm & 30-60cm double ring Infiltrometer. To spread the water vertically after infiltration we use double ring Infiltrometer. Double ring Infiltrometer is better than single ring Infiltrometer. In single ring Infiltrometer the water will spread horizontally & vertically both..

Requirements: Four numbers of cylindrical ring Infiltrometers (height = 60cm, diameter 15cm, 30cm, 45cm, and 60cm),wooden piece (to drive the cylinder inside the soil), hammer (to dig the cylinder inside the soil without any disturbance in the soil surface), measuring bucket of three numbers (12 lt, 13 lt, and 20 lt), measuring jar (2 lt),metal plate, long pipe, stopwatch (to know the time interval in which infiltration has to be measured), tape & scale (the amount of water penetrating inside the soil within a specific time interval), cover & plastic sheet, stationary use, wash cloths. Experimental Field, Shovel/hoe, Hammer (2 kg), Watch or clock, 5 litre buckets, Timber (75 x 75 x 400), Hessian (300 x 300) or jute cloth, At least 100 litres of water.

Procedure:

Before beginning your experiment, practice driving the ring Infiltrometer into the soil without disturbing the soil surface. Using the graduated cylinder, pour water into the Infiltrometer and note that the water "ponds" within the ring. You will need to select a penetration depth and ponding level that you will maintain for each experiment.

a) Hammer the 30 cm diameter ring at least 15 cm into the soil. Use the timber to protect the ring from damage during hammering. Keep the side of the ring vertical and drive the measuring rod into the soil so that approximately 12 cm is left above the ground.

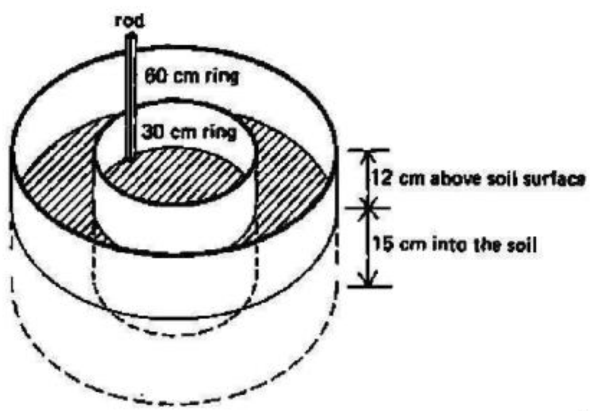
Hammer the 60 cm ring into the soil or construct an earth bund around the 30 cm ring to the same height as the ring and place the hessian inside the Infiltrometer to protect the soil surface when pouring in the water.

c) Start the test by pouring water into the ring until the depth is approximately 70-100 mm. At the same time, add water to the space between the two rings or the ring and the bund to the same depth. Do this quickly. The water in the bund or within the two rings is to prevent a lateralspread of water from the Infiltrometer.

d) Record the clock time when the test begins and note the water level on the measuring rod.

e) After 1-2 minutes, record the drop in water level in the inner ring on the measuring rod and add water to bring the level back to approximately the original level at the start of the test. Record the water level. Maintain the water level outside the ring similar to that of inside.

f) Continue the test until the drop in water level is the same over the same time interval. Take readings frequently (e.g. every 1-2 minutes) at the beginning of the test, but extend the interval between readings as the time goes on (e.g. every 20-30 minutes).



Note: Water volume for the experiment is measured in milliliters. 1ml = 1 cm^3

Observation and Calculation

$$F = \frac{k\{ho - (-v - L)\}}{L}$$

Where v is wetting from soil suction head
ho is the depth of ponded water above the ground surface;
K is the hydraulic conductivity;
L is the total depth ofsubsurface ground in question

Diameter of the Infiltrometer (d) = cm
Radius ofthe Infiltrometer (r = d/2) = cm
Infiltrometer surface area ($A = \pi r^2$) = cm

Exercise No.17

Objective: Determination of Air-filled porosityof soil

Principle: The air-filled soil porosity is the portion of the total porosity of soil containing air. This value is calculated by subtracting the water-filled porosity from the total soil porosity. Recommended Air-filled porosity is 30-50% for proper aeration in soil.

Requirements: Aluminium can box, Hot Air oven, weighing balance etc.

Procedure:

1. Fill the soil in a beaker of 100 ml mark and weigh it using weighing balance
2. Slowly add water until it reaches 100 ml mark in the beaker. Wait for 5 minutes to allow the air bubbles to come out
3. Record the wait of the water by subtracting the two weights
4. Calculate using the formula and interpret the result

Observation and Calculation

1. Weight of beaker + soil =A g
2. Weight of water + soil + beaker = B g
3. Weight of water = B – A = W g
4. Air filled Porosity = (W/100) x100 =   %

Exercise No.18

Objective: Determination of soil temperature by thermocouple method

Principle: Soil temperature refers to the intensity of heat expressed as degree centigrade. The main processes influenced by soil temperature are seed germination, root and shoot growth, absorption and transport of water and nutrient by plants, decomposition of organic matter, microbial and enzymatic activities and weathering processes**.**There are number of thermometers that can be used for measuring soil temperature e.g. mercury or liquid in glass, bourdon and electric resistance thermometers.

Thermocouple method: The precise measurement of soil temperature can be made with thermocouple which are made by joining two dissimilar metals at two different places to form two junctions. If entire circuit is composed of only two metals, the total e.m.f. in the circuit is proportional to the difference in temperature of the two junctions. One junction is called measuring junction (hot) and the other is the reference junction (cold). To measure temperature, the reference junction is kept at constant temperature at 00C (with melting ice). However, some commercially available potentiometers have a built-in correction for the temperature of the reference junction.

Requirements:copper wire (20-30 gauge), constantan wire (20-30 gauge), sleeves, material for soldering, wax, metal, potentiometer, hot bath thermometer, stirrer

Calibration of thermocouple

The output recorded by potentiometer gives the difference of temperature of the two junctions and is 40 micro volts for each degree celsius for copper-constantan thermocouple. Calibration is done by measuring e.m.f. with water in the hot water bath at different temperatures and calibration curve is made for e.m.f. and temperature.

Procedure:

1. Make a hole in the soil with an auger to the depth at which temperature is to be measured.
2. Place one junction (measuring) at that depth and re-pack the soil to ensure proper contact.
3. Dip the other end in the melting ice (reference junction).
4. Measure the e.m.f. with micro voltmeter(potentiometer)
5. Calculate the temperature from the calibration curve.
6. Interpret the temperature result

Thermocouples can be joined in series or parallel. In series they are called thermopiles and output will be sum of e.m.f. of all the thermocouples. Mostly these are joined in series as they increase the sensitivity of the system.