भारतीय मानक

मृदा कणों में पानी रोकने की क्षमता ज्ञात करना – परीक्षण विधि

Indian Standard

DETERMINATION OF WATER RETENTION CAPACITY IN SOILS — METHOD OF TEST

ICS 13.080

BUREAU OF INDIAN STANDARDS
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI 110002

January 2000 **Price Group 1**

Soil Quality and Improvement Sectional Committee, FAD 27

FOREWORD

This Indian Standard was adopted by the Bureau of Indian Standards, after the draft finalized by the Soil Quality and Improvement Sectional Committee had been approved by the Food and Agriculture Division Council.

The ability of soil to store water is called its water retention capacity. This depends upon the quantity and arrangement of various sized particles, namely, sand, silt and clay. Since water is retained in the pores created by the arrangement of these primary particles, it is more appropriate to define water retention in terms of size, number and arrangement of pores rather than of particles. The porosity is more for clay than sandy soil. In swelling soils porosity can not be precisely defined. Similarly, the presence of high organic carbon content and sodium in the exchange complex modify the water retention capacity of soils. The use of the term 'capacity' is, however, misleading as the soil-water system is not static but dynamic. The water movement does not begin or cease at a particular value of soil-water content but is a continuous process. For this reason the use of soil-water constants such as hygroscopic coefficient point is not preferred as these represent some arbitrary values. More important is the energy with which water is held in the soil, also termed as the 'intensity' parameter. The energy of water in a saturated soil is nearly the same as that of pure free water at the same temperature and elevation. However, with the decrease in water content of soil, adsorptive and capillary forces become increasingly important and consequently decrease the potential energy (capacity to do work) of soil water. The total potential energy of water in soil is divided into four components, namely, (i) the matric potential, due to attraction of soil matrix for water, (ii) the osmotic potential due to dissolved salts, (iii) the gravitational potential due to position, and (iv) the pressure potential due to external gas pressure or water column. In saturated soil the matric potential is negligible, while for unsaturated soils the pressure potential is negligible.

Matric potential results from forces associated with the coloidal matrix and includes forces associated with adsorption, capillarity, and curved air-water interfaces. This is defined with respect to a free water at the same elevation temperature and pressure. It has a negative sign which is often expressed as matric suction or soil moisture tension. Since the suction and tension terms are themselves negative these are used with a positive sign.

The soil-water is not equally available to the plants in the entire soil-moisture range from saturation to any value in the dry range. As the matric potential decreases so is the decrease in water availability. The range of water potential of agricultural significance is usually from -1/3 (or -1/10 for coarse textured soils to -15 bar under aerable soil conditions, and between positive heads -15 bar under unaerobic conditions). The particle and pore-size distributions are reflected in the relationship between water content and water potential of a soil. The curves showing the relationship are known as 'soil moisture characteristic curves'. These curves are not unique in character as they exhibit certain amount of hysteresis due to their dependency on soil structure but do provide useful information on available water storage capacity of soils, moisture depletion at a particular suction and basic information regarding soil-water relationships.

Indian Standard

DETERMINATION OF WATER RETENTION CAPACITY IN SOILS — METHOD OF TEST

1 SCOPE

This standard prescribes method for determination of water retention capacity in soils.

2 DETERMINATION OF WATER RETENTION CAPACITY IN SOILS

2.1 Principle

In a saturated soil at equilibrium with free water at the same elevation, the actual pressure is atmospheric, and hence the hydrostatic pressure and the suction or tension are zero. As suction is increased or water pressure becomes higher than atmospheric the largest pores which can not retain water against this exceeding pressure begin to empty. This critical suction is called the air-entry suction. Its value is generally small and distinct in coarse-textured and well aggregated soils. If suction is further increased, more water is drawn out of the soil and more of the relatively large pores will drain cut. In other words as each increment of water is lost from the soil, the work that must be done to remove the next increment increases (or soil will release water at higher applied suctions). The influence of suction to remove a small increment of water is different for each soil as the amount of water retained in soil at equilibrium is a function of the sizes and volumes of the water-filled pores and hence it is a function of the matric suction or matric potential. This function is determined experiementally and represented graphically by a curve known as soil-moisture retention curve, or soil-moisture characteristic.

2.2 Apparatus

a) *Tension Table* — Consisting of sintered disc glass buchner funnel of diameter about 6 cm and height 10-12 cm, connected to an over-flow system by means of flexible transparent plastic tubing. The plate of the funnel is of sufficiently fine porosity (G-4) to preclude air-entry over the range of desired suction.

b) *Pressure Plate* — (1) Pressure plate apparatus complete with all fittings including air compressor, and with a range of ceramic plate cells (at least one each for 1 and 15 bar), (2) Brass soil retaining rings 3 cm high and about 6 cm in diameter (as per specifications of the soil sampling auger to take undisturbed soil samples), (3) Balance, (4) Drying oven, (5) Moisture cans, (6) Syringe or pipette, (7) Sieve (2 mm size to prepare disturbed soil samples), (8) Rubber rings 1 cm high and about 6 cm diameter to contain disturbed soil samples, (9) Soil sampling augers to draw disturbed and undisturbed soil samples, (10) Vacuum desiccator, (11) Motor operated suction pump.

2.3 Procedure

a) *Tension Table* — In tension table the flexible plastic tubing is filled with distilled water without any air bubble. It is then placed on a movable arm of a stand having a scale. The desired suction is created by varying the difference in the levels of the fixed Buchner funnel at the middle of sample soil core and the point of outflow in the flexible tubing. The undisturbed soil sample is placed on the saturated sintered disc glass funnel and a good contact between the soil and sintered plate ensured. The soil is fully saturated from underneath by raising the point of outflow of the flexible water hanging column. After saturation, cover the buchner funnel to prevent evaporation and lower the point of outflow until the desired suction is obtained. The suction may be kept 0, 20, 50, 100, 150 and 200 cm to determine soil water retention corresponding to 0 (saturation), 0.20, 0.05, 0.10, 0.15 and 0.20 bar. At each equilibrium, when the water flow ceases through the outflow tube of the hanging column, soil sample is weighed, over-dried and reweighed to ascertain the water retention capacity of the soil at that suction. Usually water retention up to 0.2 bar is determined by this method and beyond this suction it is determined by pressure plate apparatus.

b) *Pressure Plate Apparatus* — Put desired number of rubber rings on the ceramic plate cell. About 12 such rings are accommodated in one plate cell. Prepare soil samples after grinding and passing through a 2 mm round-hole sieve. Pour a representative soil sample slowly with the help of a spoon into the rubber ring. It is better to run a duplicate sample for each soil type. Level the samples in the rings and note down the layout of samples placed on the ceramic plate cell. Put excess of water slowly on the plate cell and allow samples to saturate at least for 16-20 hours in the presence of free water. After this period, remove the excess water from the ceramic plate with a pipette or syringe. Mount the cell in the extractor and connect up the outflow tubes. Use the plastic spacers if there are more than one plate cells to be put inside the extractor. Close all unused outlet ports with the plug bolts that are provided. Check that 'o' ring is in place. Mount lid and screw down clamping bolts. Build up the desired pressure in the extractor to the equilibrium value somewhat slowly. At this point water will start flowing out of the outlet tube and continues to flow till equilibrium is reached inside the extractor. After the equilibrium has been attained, the samples can be removed. Most soils will approach hydraulic equilibrium in one or two days depending upon the soil type. Slowly permeable soils like alkali soils may take longer time. At the close of the run the pressure regulator is shut off and the pressure exhausted from the extractor. The clampling bolts and lid are removed and soil samples transferred immediately to the moisture boxes. The moisture boxes containing soil samples are weighed in the balance and fresh weight is recorded. The moisture boxes are put in the drying oven. The temperature in the oven is maintained at 105-110°C and samples are dried to a constant weight at least for 12 hours and reweighed after cooling in a desiccator. Determine the tare weight of the moisture cans.

The procedure is repeated for determining water retention at other equilibrium pressures to construct the curve over the entire soil-moisture range. It is desirable to determine soil-water retention at equilibrium pressures of 0, 1/50, 1/20, 1/10, 1/3, 1/2, 1, 5, 10 and 15 bar. A plot of soil moisture content (on the X-axis) *versus* suction (on the Y-axis) is drawn. Such curves can be drawn for different soil types and water retention at any given suction can be obtained from these curves.

It is better to make these determinations on undisturbed soil samples as grinding and sieving alter the pore-size distribution, particularly of larger pores, and the water retention in the low suction range with disturbed samples may not reveal the true information. The undisturbed samples are taken with the help of specially designed core-sampler where there is a provision to accommodate small rings, 3 cm high and of about 6 cm in diameter. The core sampler is slowly pushed into the soil to the desired depth through repeated droppings of the hammer on the sampler. This way representative samples from a given depth in the soil profile are obtained. The core containing rings is disconnected and the rings are slowly pushed out. The excess soil protruding from the rings is trimmed off and the soil samples along with rings are wrapped in the polyethylene envelopes and may be stored in the refrigerator for use. Rest of the procedure for determining water retention capacity is the same as described for disturbed soil samples. In compact and slowly permeable soils the time required for saturating the soil samples may be extended. It is also desirable to saturate the soil samples in the vacuum desiccator. In that case the ceramic plate cell along with soil samples is put in the vacuum desiccator connected with motor operated suction pump assembly for about 10 minutes before placing in the extractor.

2.4 Calculations

The moisture content in the soil sample, after it has been equilibrated against the applied pressure and oven dried, is calculated as follows:

Percent soil moisture content by weight (w)

$$= \frac{(\text{Weight of wet soil + tare}) - (\text{Weight of dry soil + tare})}{(\text{Weight of dry soil + tare}) - (\text{tare})} \times 100$$

$$W\ (\text{Percent}) = \frac{\text{Loss in weight on drying } (M_w)}{\text{Weight of oven dry soil } (Ms)} \times 100$$

Percent soil moisture content by volume (O)

$$= \frac{w \times \text{bulk density } (P_b) \text{ for the soil depth}}{\text{Density of water } (P_w)}$$

Also, $0 = w \times p_b$

Here $Pw = 1 \text{ g cm}^{-3}$

Depth of water in the soil – 0 × soil depth.

Bureau of Indian Standards

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This Indian Standard has been developed from Doc : No. FAD 27 (107).

Amendments Issued Since Publication

Amend No.	Date of Issue	Text Affected

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Printed at : Prabhat Offset Press, New Delhi-2