A SIMPLE METHOD FOR THE SIMULTANEOUS DETERMINATION OF PARTICLE DENSITY AND BULK DENSITY OF A SOIL CLOD

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A simple method based on volume-weight relationships in soil was developed for the simultaneous determination of the particle density of soil and bulk density of a soil clod. The dry clod is weighed in air before and after saturation with a non-polar liquid. It is then weighed under the same liquid. Both particle density and bulk density are computed from these weights using simple equations. Volume of the entrapped air on submergence of the clod in kerosene oil was computed. The soil sample in a Keen's box should be preferred over a natural soil clod for determination of soil bulk density.

INTRODUCTION

Several methods have been reported for the determination of bulk density of soil clods (Blake 1965). The volume of the given clod has been determined by displacement of a non-wetting liquid like mercury (Haines 1923). But mercury may enter some of the lager pores (Vershinin *et al.* 1966) and may not always surround some of the depressions in the clod (Abrol and Palta 1968). In the Kerosene saturation method (McIntyre and Stirk 1954) the assumption that only excess of kerosene is drained at 10 cm tension is not entirely valid. It was found that some of the larger pores and holes were also drained at this tension (Palta *et al.* 1969). The saturation method of Prihar and Hundal (1971) ignores the volume changes associated with swelling of soils.

Generally the natural soil clod is waterproofed by coating with a suitable material and volume measured by displacement method. Many materials (Abrol and Palta 1968; Brasher *et al.* 1966; Perry 1942; Remy 1964) have been used for coating the clods but every material has certain drawbacks (Abrol and Palta 1968; Palta *et al.* 1969). Sometimes air gaps are left between the clod depressions and the coating, and sometimes coating material enters pores in the surface resulting in an increase in observed volume of the clod. The main limitations of the coating procedure are the difficulty in obtaining the completely impermeable initial coating and the chances of increasing the thickness of surface films from repeated coating of the clod. Moreover, the clod must be sufficiently stable to cohere during coating, weighing and handling. It may be difficult to collect such clods in sandy soils

This paper describes a simple method for the determination of the bulk density of a soil clod which eliminates the necessity of coating. It also permits the computation of particle density of the soil.

Materials and Methods

Principle

Volume of soil solids and total volume of a dry clod can be computed by saturating it with a non-polar organic liquid and then weighing the saturated clod in air and in the same organic liquid.

Volume 'V' of an oven-dry soil clod of weight 'W' is the sum of the volume of solids (V_s) and the volume of soil air (V_a).

$$V = V_s + V_a \quad \ldots \quad (1)$$

$$W = V_s D_p \quad \ldots \quad (2)$$

Where D_p is the particle density of the soil. When this clod is saturated in an organic liquid of density 'd' (g/ml) and weighed in air, its weight, W_1, can be written as

$$W_1 = V_s D_p + V_a d \quad \ldots \quad (3)$$

The loss in the weight of this saturated clod on submergence in the same organic liquid will be equal to the weight of the volume of the liquid displaced (Archimede's principle).

Hence

$$W_1 - W_2 = Vd \quad \ldots \quad (4)$$

Where W_2, the weight of the saturated clod in organic liquid, is given by

$$W_2 = V_s(D_p - d) \quad \ldots \quad (5)$$

Equations (2) and (5) yield

$$V_s = (W - W_2)/d \quad \ldots \quad (6)$$

Therefore, D_p, particle density, of the soil is given by

$$D_p = Wd/(W - W_2) \quad \ldots \quad (7)$$

Similarly, D_b, bulk density, of the clod, from Eqn. (4), is given by

$$D_b = Wd/(W_1 - W_2) \quad \ldots \quad (8)$$

Thus the bulk density and particle density of an uncoated oven-dry clod can be computed from three weights only, i.e. (i) weight of the uncoated clod in air, (ii) weight of the saturated clod in air, and (iii) weight of saturated clod on submergence.

Procedure

Clods were obtained from lower horizons of soil profiles at the College of Agriculture Farm at Palampur, India. Since the clods were collected from thin horizontal layers several centimeters below the plough layer, it is presumed that all clods had nearly same bulk density.

The natural soil clods were oven dried and weighed. These clods were equilibrated on kerosene saturated sand columns (Prihar and Hundal 1971) and individual clods were weighed in air. A kerosene saturated clod was placed in a Keen's box that served as a pan of the balance. Earlier additional weights had been added to this box

so that the balance was counterpoised when the box alone was immersed in kerosene. Then the saturated clod was weighed in kerosene.

The bulk density was computed from Eqn. (8) and particle density from Eqn. (7).

Results and Discussion

The results obtained by this method and the rubber solution method (Abrol and Palta 1968) are summarised in Table 1. That the proposed method compares favourably with the existing methods is seen from the standard deviation values for the two methods. But the waterproofing procedures are tedious whereas the proposed method is very simple. Moreover, it is very difficult to coat the surface of clods with big pores. The present method is advantageous under these conditions.

In many studies (Abrol and Palta 1968; McIntyre and Loveday 1968; Palta *et al.* 1969) the volume of the clod measured by displacement method, to an accuracy of 0.05 ml (Abrol and Palta 1968; Palta *et al.* 1969) introduced considerable error in bulk density values especially of small clods. But this was attributed to non-inlcusion of inter aggregate space in small clods (McIntyre and Loveday 1968; Shipp and Matelski 1965). Consequently clods of volume 50 to 200 ml were recommended (Brasher *et al.* 1966) for bulk density determination. In the present study the volume was measured, by weighing, to an accuracy exceeding 0.001 ml and it was found that bulk densities for small clods were within the experimental error of the bulk densities computed for big clods.

McIntyre and Loveday (1968) found that bulk density was less for clods which were wetted rapidly. According to them this decrease in bulk density was the result of incipient failure (Quirk and Panabokke 1962) of the clods. But air may get entrapped when a dry clod is wetted rapidly. The present method was employed for evaluating the volume of entrapped air and the resulting effect on bulk density and particle density values. The given oven dry clod was equilibrated on kerosene saturated sand columns. It was weighed in air and in kerosene. The same clod was oven dried, submerged in kerosene and weighed. It was observed that the weights needed to counterpoise the balance increased with time. From this increase in weight of the submerged clod one may compute the decrease in the volume of the entrapped air with increase in submergence time. The weight of the submerged clod was recorded after the steady state was reached and the clod was again weighed in air. The volume of soil solids, computed from Eqn. (6), for submerged clods was always more than that for the equilibrated clods. This difference in the volume of the soil solids is the volume of the entrapped air. As expected, the entrapped air introduced more error in particle density values than in bulk density values (Table II).

For bulk density determination the recommended clod volume is 50 to 200 ml but in many soils it is difficult to get such clods and maintain them during transport and handling. To overcome this limitation Keen's box was employed for collecting the soil samples. A blotting paper pad was placed at the bottom of this box and the box was lightly pressed at the spot, preferrably moistened, and the sample was removed with a hand hoe. The soil surface in the box was not smoothened to ensure minimum disturbance of the soil fabric. The sample was of an unknown volume

TABLE I

Average bulk density and particle density values as determined by two different methods on Palampur soils

Soil	Horizon depth (cm)	Bulk density (g/cm³)		Particle density (g/cm³)	
		Proposed method	Ruber solution	Proposed method	Pycnometer
Sandy clay loam	0–12	1.669 ± 0.0510	1.760 ± 0.0589	2.541 ± 0.0571	2.501 ± 0.0682
	12–48	1.737 ± 0.0323	1.707 ± 0.0847	2.510 ± 0.0365	2.535 ± 0.0287
	48–85	1.766 ± 0.0402	1.718 ± 0.0368	2.545 ± 0.0369	2.603 ± 0.0412
	85–97	1.710 ± 0.0514	1.691 ± 0.0444	2.576 ± 0.0342	2.554 ± 0.0259
	>97	1.528 ± 0.0309	1.567 ± 0.0355	2.648 ±0.0216	2.617 ± 0.0197
Loam		1.503 ± 0.0408	1.582 ± 0.0509	0.496 ±0.0224	2.546 ± 0.0212
Sandy loam		1.637 ± 0.0373	1.601 ± 0.0251	2.488 ± 0.0480	2.522 ± 0.0269
Silty clay loam		1.465 ± 0.0427	1.421 ± 0.0372	2.562 ± 0.0294	2.504 ± 0.0366

TABLE II

Comparison of bulk density and particle density values from equilibrated clods and rapidly wet clods

Soils	Equilibrated clods		Rapidly wet clods		Volume of entrapped air (per cent of porosity)
	Bulk density (g/cm³)	Particle density (g/cm³)	Bulk density (g/cm³)	Particle density (g/cm³)	
Loamy sand	1.650 ± 0.0321	2.564 ± 0.0551	1.632 ± 0.0420	2.293 ± 0.1235	9
Loam	1.582 ± 0.0427	2.571 ± 0.0143	1.554 ± 0.0531	2.251 ± 0.0454	18

and the purpose of the box was to facilitate collection and handling of the sample. Moreover, in Keen's box inter-aggregate space is included and therefore these samples are better representatives of the field conditions than are the clods.

The values of particle density obtained with this method compare well with the values obtained with the pycnometer (Table I). But the present method is simpler than the pycnometer method as it eliminates the necessity of cleaning and drying the pycnometer. The proposed method is very useful for studying the effect of organic matter on soil particle density. Moreover, in this method determination of particle density does not involve additional measurements when the bulk density of the soil has to be determined.

This method involves minimum handling of the clod and thus can be employed for soils in which very stable clods are not available. The use of Keen's box overcomes fully this limitation of the clod method. The present method can be employed for studying moisture-volume relationships of swelling coils.

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