SECTION II

LABORATORY INVESTIGATIONS

SUB-SECTION II b

IDENTIFICATION TESTS

II b 2 THE LABORATORY DETERMINATION OF THE VOLUME WEIGHT AND AIR SPACE OF STONY SOILS

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There are a number of reasonably good methods available for determining the volume weight and the volume of voids, or the air space, in stone-free soils if they are soft enough or moist enough to allow a sample of pre-determined volume being taken with a suitably designed sampling tube or cylinder. These methods, however, fail, or become very inaccurate, for soils containing even quite small proportions of stones, for the sampling tube is bound to affect the packing of the soil inside the tube if the cutting edge meets a stone of appreciable size. For such soils it is preferable to take an undisturbed sample of soil, of irregular shape and unknown volume, and determine its volume after sampling. This can be easily done for very porous non-cohesive soils, such as gravels and coarse sands, by fixing the soil in a cement before removing the sample, as for example by pouring molten paraffin wax on to it and cutting out the block of impregnated soil.

There are no technical difficulties in taking an undisturbed sample from the superficial layers of a cohesive soil, and it is always possible, if it is necessary, to get undisturbed samples from the subsoil, though this may be expensive. In this paper it will be assumed that an undisturbed sample has in fact been obtained, and this paper is concerned with determining the volume weight and air content of such samples.

There are clearly three separate quantities that can be measured in this connection, namely
1) the volume of the soil particles plus the water plus the air in the clod. This volume, divided by the weight of the clod, gives its volume weight;
2) the volume of soil particles plus the water;
3) the volume of the air space in the clod. This volume is the difference between the first and second of these volumes.

There appear to be no accurate methods in general use for determining the first volume, i.e. the volume weight, in cohesive stony soils, such as the clay-with-flints soil that occurs over a large area of country around Rothamsted. The second volume - the volume of soil plus water - can be determined in an air pycnometer for any type of soil. The general practice has been to determine the volume of air from the difference between these two volumes, but this is only possible if the first volume can be accurately obtained.

The outline of the method described here is as follows. A clod of as large a volume as is convenient to handle is taken from the field, weighed (weight I), immersed in a suitable oil that is immiscible with water and evacuated to remove all the air, and weighed in this liquid (weight II), then taken out of the oil and allowed to drain, then weighed in air (weight III). At the same time the specific volume, σ x), of the oil is determined. Then

Volume of clod $= \sigma$(weight III - weight II)
Volume of soil plus water $= \sigma$(weight I - weight II)
Volume of air $= \sigma$(weight III - weight I).

The moisture content of the clod can then be determined by putting it in a flask containing toluene, and determining its moisture content by the Dean and Stark method xa) ; or the clod can be put in a soxhlett apparatus, have the oil extracted with petroleum ether, then dried in an oven.

The points of technique that require examination are
1) the choice of a suitable impregnating oil;
2) the possibility of displacing the air in the clod by the liquid, without removing appreciable quantities of the water in the clod;
3) the possibility of being able to determine accurately the weight of the impregnated drained clod in air.

The requirements the impregnating oil must fulfil are very stringent, so the choice of liquid is limited. The oil must not affect the volume of the clod on impregnation; the water in the clod must be immiscible with the liquid; the liquid must have a low vapour pressure at room temperature and a moderate viscosity, so that the weight of the impregnated well-drained clod can be accurately determined. Many liquids were tried, and of these three appear to be satisfactory: tetrahydronaphthalene (tetralin), decahydronaphthalene (decalin) and commercial lamp oil paraffin or kerosene. However if paraffin is used, and it is the liquid we have used most extensively, it must be cleaned and dried by shaking up either with a good clay free from organic matter, or with activated silica gel.

Direct tests showed that clods impregnated with paraffin changed their length by less than 0.03 per cent. on the average, so that impregnation caused a swelling of less than 0.1 per cent.

The technique of displacing all the air in the clod by paraffin can be easily tested for dry clods in a laboratory containing suitable high vacuum apparatus. It was found that putting a dry clod in paraffin, and putting the beaker containing the paraffin in a desiccator, and evacuating for half an hour on a

x) The specific volume is defined as the reciprocal of the density or specific gravity. If the density of the oil is d, = 1/d.
xa) This method is described in A.S.T.M.D. 95-40, The Institute of Petroleum 74/45 and BSF 598. The principle is to reflux the wet soil with toluene or xylene and collect in a suitable trap the water distilled off.

good water pump gave satisfactory displacement of all the air. But since a hyvac pump was available, this was in fact always used for such clods. After the evacuation, air is let into the desiccator and the clod left in the paraffin overnight, as it appears the paraffin takes a little time to penetrate into the finer pores of the clod, even in the absence of air.

The technique could not be so definite for damp clods, since the process of displacing the air automatically involves an evaporation of some of the water. It was found for damp clods, weighing up to 500 gm., that if they were put in paraffin and the desiccator was only just large enough for the beaker containing the paraffin, 5 minutes evacuation on a good water pump for wet, and 10 minutes for damp, clods appeared to give the best compromise between removing too little air and too much water. As with the dry clods, air is let into the desiccator shortly after the evacuation has ceased and the clod is left in the paraffin overnight.

The three difficulties encountered in weighing the drained impregnated clod in air were the difficulty of removing paraffin from the cradle carrying the clod, the difficulty of preventing evaporation of paraffin during drainage, and the difficulty of ensuring that the air spaces in the clod were full of paraffin but that the films of paraffin around the outside of the clod had a negligible volume compared with the air space.

The cradle finally used consists of a large ring of wire suspended by three finer wires which are attached to a single fine wire. When the clod is being weighed in paraffin, the paraffin is deep enough for this single wire only to be in the paraffin-air interface. Across the stout wire ring three finer wires are fixed forming an equilateral triangle in the ring, and the clod sits on this triangle. Just before weighing the impregnated clod in air, it is easy to touch all the wire junctions with a filter paper to remove any films or drops of paraffin they may be holding.

Evaporation during draining was minimised in two ways, by letting the drainage take place by suspending the cradle in a beaker covered at the top with a wet cloth, and by allowing drainage to take place for as short a time as possible. It was found that 10 minutes' hanging was usually long enough for the smaller and 20 minutes' for the larger clods. Before weighing the bottom of the clod was lightly touched with a piece of filter paper to remove the last drop of oil.

The results obtained using this technique have been compared with the results obtained by using other available techniques on the same clods. This restriction of having to make several measurements on the same clod is necessary, at least at Rothamsted, because there can be a very large variation between the volume of the air spaces of different clods taken from the same field at the same time.

One comparison can be made very easily, and that is the determination of the volume of the soil plus water by the air pycnometer and by this method. The clods were first put in a suitable air pycnometer and were afterwards impregnated with paraffin. During the course of this work it was found that the air pycnometer is sensitive to changes in the relative humidity of the air, so it was used in two conditions: with the air dry when dry clods were used, and with the air saturated when wet or damp clods were used. Taking this precaution, it was found that for 30 clods, with a volume of soil plus water between 50 and 70 c. cm, and of variable moisture content, the mean value of this volume was 0.020 ± 0.019 c. cm larger by the pycnometer method. Using 24 clods, whose soil plus water volume varied between 190 and 240 c.cm, and a larger but less accurate design of air pycnometer, the volume was 0.56 ± 0.42 c.cm larger by the pycnometer method. Obviously these two methods agree very closely, which shows that weighing II must be reasonably accurate, that is, the evacuation technique employed must be satisfactory, even for moist or wet clods.

The goodness of this evacuation, or of weighing II, can be checked another way. After the volume of the soil plus water has been determined, the paraffin can be removed with petroleum ether in a soxhlett apparatus, the soil put in an oven, so its moisture content can be determined. From this, the volume of the soil particles can be calculated, assuming the density of the water is the same as water in bulk. Now the density of the soil particles can be determined on the oven-dry sample by breaking up the clods, putting some of the soil in a specific gravity bottle, and adding water to the soil under vacuum. It is essential to determine its density in water, if the clod was originally wet, for the density of the water in the clod is somewhat greater than of free water. Now the assumption that all the water in the specific gravity bottle is the same as water in bulk is an integral part of the specific gravity calculation, but the divergence of the specific gravity of the water close to the surface of the soil particles will affect each calculation to the same extent. In a small series of comparisons, the soil density as calculated from the weighing in paraffin and from the weight of oven dry soil after all the manipulations the clods had to suffer was 2.622, whilst that of the oven-dry soil particles in water as determined directly in specific gravity bottles was 2.623, that is, the discrepancy was less than 0.1 per cent. The specific gravity of these same soil particles if paraffin was used in the specific gravity bottle instead of water was 2.607. Naturally, if this test is to be made with initially dry clods instead of initially moist clods, the density of the soil particles in the specific gravity bottles must be determined in paraffin and not in water.

It has been much more difficult to make an independent check on the air space in the clods, that is to check the validity of weighing III. It has only been done for dry clods. The method used for comparison is based on determining the volume of the clod, that is of the soil plus water, by impregnating and waterproofing the surface of the clod with a resin or wax. A technique was developed for sealing the surface by impregnating it either with a bakelite resin (V.5124 and R.4697 were both used) or with wax (Seekay wax mixed with Alloprene dissolved in carbon tetrachloride was used. It was not possible to prove that all the impregnation was on the inner surface of the clod and none outside the surface, but various indirect tests indicated that the proportion on the outside of the surface was very small. The clod volumes as determined by this wax and resin impregnation method and the paraffin method agreed to within 0.05 c.cm for dry clods having volumes between 10 and 250 c.cm. Since it is not possible to bring independent proof about the limits of accuracy of either method, this agreement cannot be used to prove the accuracy of eiter method, but the agreement does suggest that they are both measuring what is intended.

SUMMARY DESCRIPTION OF THE METHOD DESCRIBED FOR DETERMINING THE VOLUME OF A CLOD AND ITS AIR CONTENT.

1) Wet Clods. The clod, which can weigh up to 500 gm., is placed on a suitable wire platform, is weighed in air and then immersed in a beaker of paraffin, put in a small desiccator and evacuated for 5-10 min. using a good water pump. The desiccator is then gently bumped to remove any large bubbles around the clod, air is let in and the clod left in the paraffin overnight. It is then weighed in the paraffin, taken out and left to drain hanging in a beaker which is covered with a piece of wet cardboard. After 20 min. the thick layer of paraffin at the bottom of the clod is removed by touching it with a piece of filter paper, particular care being taken to remove the paraffin from the wire in contact with the clod. It is then weighed in air, replaced in the beaker, and after a further 10 min. draining is touched again with filter paper and reweighed. If the weight has changed by more than about 0.02-0.03 gm., the process is repeated.

2) Damp clods. The only difference from the wetter clod is that the time of evacuation on the water pump should be lengthened somewhat, probably to about 15-20 min.

3) Dry clods. The differences between this and the preceding ones are that dry paraffin must be used, at least 30 min. on the water pump should be given, and during draining the cardboard on the beaker should be saturated with paraffin and not water.

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NOTES ON SOME CANADIAN "SILTS"

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One half of the area of the Dominion of Canada consists of one of the most interesting geological phenomena of the world, the Canadian Shield. This vast area of 1,825,000 square miles, taking its name from the shape of its outline, consists of rocks of Precambrian age. It is part of a continental mass which, in Precambrian time, extended far beyond present limits. During succeeding geological periods, these ancient rocks were covered by sedimentary deposits which still remain as the surface rocks outside the Shield but which have been almost completely eroded from the entire area of the Shield itself by repeated glacial action. The resulting topography is remarkably uniform in general, although exhibiting great irregularity in local detail. Low relief is an almost universal feature of the shield, the smooth flat-topped character of the rolling hills being similar across almost the whole continent. An unusually large proportion of the Shield is covered by water - the lakes and rivers of which have made canoe travel in the Canadian North almost legendary.

Vegetation falls into two divisions, the southern wooded belt constituting Canada's great coniferous forest resource, and the northern area which is commonly called The Barren Lands, lacking trees but covered largely by "muskeg" and similar organic deposits, usually overlying permanently frozen soil ("permafrost") or solid rock at shallow depths. As would be expected, the soils found in the Canadian Shield are all glacial or glacio-fluvial deposits, in view of the geologically recent retreat of the last ice sheet. The sands and gravels are found in typical glacial deposition formations such as moraines, eskers and drumlins. Fine grained soils are also found, some deposits extending over relatively large areas. This paper presents some notes on progress in a study of typical examples of these somewhat unusual soils.

These fine grained soils of the Canadian North are found in many different types of deposit. Some are quite extensive, the well known "Clay Belt" of northern Ontario and Quebec covering several thousand square miles. Many of the deposits can be linked directly with the known locations of glacial lakes, the outlines of some of which have been traced in great detail by Pleistocene geologists, frequently by detailed study of their old shore lines which can sometimes be followed for miles even by the untrained eye. Other deposits may be correspondingly small in extent, occurring at outlets from existing lakes and in eroded stream beds. Engineering operations are revealing still other deposits, as cuttings are made for roads and railways and excavations for building operations. The development of Canada's greatest iron mine has revealed one of the most unusual deposits in the bed of a large lake which had to be drained in order to gain access to high-grade iron ore, located beneath its surface by geophysical exploration carried out on the ice during winter.

The soils have the common appearance and feel of clays; they have been and still are described by all but such investigators as "clays", even in official geological reports. The productivity of the resulting surface soil has resulted in extensive agricultural development in some locations (such as the "Clay Belt") and the "clayey" character of the resulting agricultural land, especially after rain, is a matter of more than local comment. Certain unusual effects of engineering operations in such soils, however, have given some indication that the soils are not clays of the ordinary sort. Pile driving, for example, has been found to reduce bearing capacity; some disastrous slides have been even more potent indicators of uncommon soil conditions. And the known geological history of the deposits points in no uncertain manner to soils which are most certainly not true clays, despite all that the