Experimental Application of the Phenomenon of Neutrons Scattering for Determining the Soil Porosity

Application Expérimentale du Phénomène de la Dispersion des Neutrons à la Détermination de la Porosité des Sols

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Summary

The theoretical assumptions for measuring soil porosity by means of neutrons scattering and the results of experiments on gravels and sands are given in this paper.

Sommaire

Le rapport contient des considérations théoriques pour mesurer la porosité des sols à l'aide de la dispersion des neutrons et les résultats des essais sur des graviers et des sables.

During the past few years the phenomenon of the scattering of neutrons has been used for the determination of moisture content of various tested materials. Among the studies in this field there is a method worked out by JANIK and SZKATULA (1955) for the determination of moisture content of brick walls by using the scattering of neutrons. This method uses the following procedure.

A source of fast neutrons is put beside the tested wall and close to it a counter of slow neutrons is placed. The neutrons flowing out from the source penetrate into the wall and are scattered on its atomic nuclei, being slowed down on the hydrogen nuclei. A very small percentage of neutrons is slowed down in the case of a dry wall and the counter (reacting on the slow neutrons only) registers a small number of counts per time unit. In the case of a damp wall a much bigger percentage of neutrons is slowed down on the hydrogen nuclei of water molecules and the counter registers a much larger number of counts per time unit.

In the quoted method the scurce of neutrons consisted of 200 mg of radium embedded in 1 kg of powdered beryllium (in this arrangement the neutrons are obtained in reaction $^{9}Be(\gamma, n)^{8}Be$ as a result of bombardment of beryllium nuclei by the gamma rays of radium).

A spark counter adjusted for counting the slow neutrons was used as a detector of neutrons. A detailed description of the construction of the counter, the source of neutrons and the registering electronic apparatus was given by JANIK and SZKATULA (1955) and in another paper by the same authors (1956).

Using the above mentioned method, a study of the applicability of the phenomenon of neutrons scattering for determining the porosity of soil by measuring its moisture content when fully saturated was carried out. The tests were on uncohesive soils, i.e. gravel and sand, and are described below.

The tested gravel or sand was completely dried and put in a cylinder of about 40 cm diameter and 30 cm high. The mass of tested gravel or sand (dry and later moist) was measured exactly by weighing. A spark counter was placed on the surface of the tested sample near to the source of neutrons (Fig. 1). The number of counts per time unit was measured by the counter: the number for the dry gravel was subtracted afterwards from that received for the moist gravel. The tested gravel was then wetted to the water content which could be retained on the surface of the particles (moisture content 3 to 5 per cent)* and afterwards it was fully saturated with water (moisture content about 15 to 20 per cent). In both cases the number of counts per time unit was measured by the counter; thus the relationship between the number of counts and moisture content of the tested gravel was found. The tests were carried out for gravels and sands containing the following particle sizes: 10 to 20 mm, 4 to 10 mm, 4 to 8 mm, 1 to 2 mm, 0 to 0·5 mm. In the case of sand, 0 to 0·5 mm, the tests were carried out when such an amount of water was added to it that the moisture content amounted to about 10 per cent and 17 per cent.

The average number of counts per time unit for the dry gravel and sand (afterwards subtracted from the results for the moist gravel) was 33 counts per 6 minutes. This number is very close to the number of counts for the dry bricks which was obtained formerly (JANIK and SZKATULA, 1955) and amounted to 36 counts per 6 minutes.

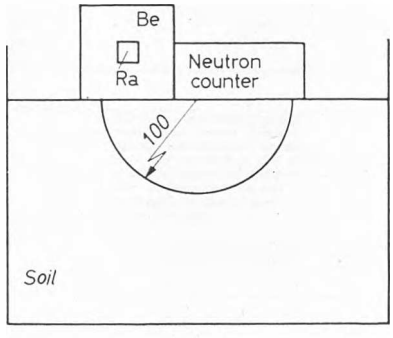

Fig. 1

The dependence of the number of counts per time unit on the moisture content of gravel and sand which was obtained during the test is shown in Fig. 2. On the same diagram are shown also the points obtained in experiments for the brick walls (the white circles represent the results of the test carried out at present and the black ones represent the results taken from JANIK and SZKATULA, 1955). The linear relation between the number of counts of the counter and moisture content of the walls, which was obtained during those experiments, is limited to the lower moisture contents of tested materials only. In

* The moisture content expressed by weight in relation to the weight of the whole soil mass.

the case of brick walls the maximum moisture content attained the value of about 13 per cent and up to this value it is admissible to apply this linear relation. A distinct discrepancy with the linear relation appears for the larger moisture contents.

The point on the diagram corresponding to the moisture content 100 per cent leads to this last conclusion. This point was obtained by filling the cylinder used for the test with water and placing the spark counter and the source of neutrons close to the surface of the water.

The whole obtained curve can be considered as a calibration curve for the spark counter. It is possible by using it to estimate the moisture content of the tested material from the measurements of the spark counter. Thus if the tested material is known to be fully saturated its porosity can be found in this way.

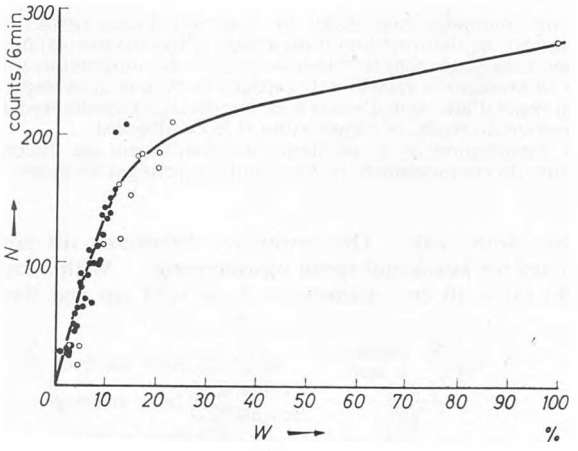

Fig. 2

It must be mentioned here that a relatively large dispersion of the points obtained during the tests is caused not by instability of the counter but by differences of humidity of various parts of the tested soil.

It seems that this matter needs some more explanation.

It was confirmed during the tests that a large dispersion of the points is caused not by accidental impurities in the gravel or admixtures, because the influence of the dry gravel in all tested cases was the same and remained in the limits of an admissible error. It must also be stated that the obtained dispersion is only a little larger than obtained usually during such measurements. The only factor therefore which can cause this dispersion is the possibility of different porosities appearing in various parts of tested gravel (i.e. between the upper and the lower layers). It must be pointed out that the range of information about the moisture content estimated by the use of neutrons obtained from the source $^{9}Be(\gamma, n)^{8}Be$ reaches a distance of 10 cm (Fig. 1, $-r = 10$ cm), as was confirmed by JANIK and SZKATULA (1955). The same phenomenon was carefully checked again by using layers of gravel of various thicknesses in these tests. The number of counts per time unit obtained by using this source depends therefore on the porosity of the upper layer of the gravel only whilst the moisture contents plotted in the curve correspond to the average porosity of the whole mass of gravel.

It must be emphasized that the electronic apparatus in cooperation with the spark counter is a very simple one and portable too (Fig. 3). Greater accuracy can be reached by using as a detector of slow neutrons a proportional counter filled with boron trifluoride gas (BF_3). This device has much greater efficiency in counting neutrons than a spark counter.

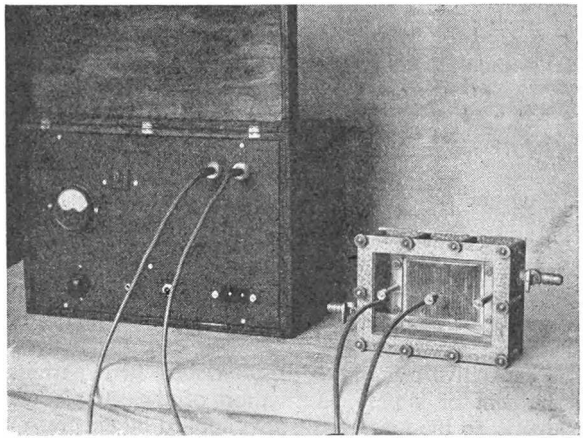

Fig. 3

A proportional counter however needs a much more complicated electronic set.

So far experiments have only been carried out on granular soils. By checking this method on cohesive soils one must expect that the obtained curve of relations will hold its validity. This method presents now a very easy and quick way of carrying out the measurements in the laboratory, but in its further application for field measurements of the moisture content of cohesive soils it can be expected to show its validity. Under normal conditions however the ground water table in granular soils would be a natural obstacle for carrying out the work.

References

JANIK, J. A. and SZKATULA, A. (1955). *Inżynieria i Budownictwo*, p. 349

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