Apparatus for Determining the Rate of Diffusion of Water in Soil

Appareil pour Déterminer la Vitesse de la Diffusion de l'Eau dans les Sols

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Summary

The paper describes a new apparatus which has been constructed in order to study the diffusion of water in soils. The apparatus consists of a metal cylinder with water in the lower part and a special container in the upper part holding an absorbent material which collects the water, transported by diffusion through the sample, which is placed between the water table and the absorbent. By means of the apparatus the test can be performed at a constant vapour pressure gradient in a room with ordinary but constant temperature and the diffusion can be followed continuously during the test.

Sommaire

La communication décrit un nouvel appareil qui fut construit pour etudier la diffusion de l'eau dans le sol. L'appareil se compose d'un cylindre en métal contenant de l'eau dans la partie inférieure et, dans la partie supérieure, un réservoir spécial pour recueillir l'eau transportée par diffusion à travers l'échantillon, qui est placé entre la surface de l'eau et la substance absorbante. L'appareil permet de réaliser des essais avec gradient de pression de vapeur constant dans une pièce à une température ordinaire mais constante, et la diffusion peut être observée sans interruption pendant l'essai.

Diffusion of water in soil seems to be an important factor in many problems met with in soil mechanics. In the *Proceedings of the Third International Conference on Soil Mechanics and Foundation Engineering, 1953*, Rengmark and Eriksson have described an investigation dealing with the passage of vapour through various coarse-grained materials. The method used in that investigation was relatively time-wasting, and the tests had to be made in a refrigerator. In order to simplify the test procedure, and to determine the rate of diffusion more rapidly and with sufficient accuracy, a new apparatus has been designed (by S. Fredén).

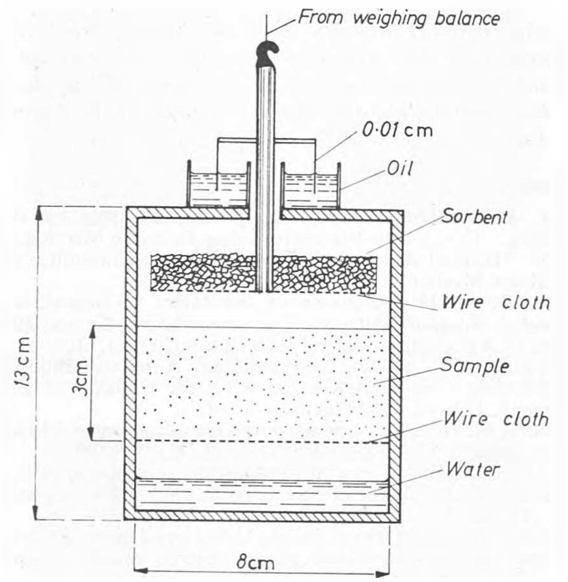

Fig. 1 Principle of the apparatus
Principe de l'appareil

Diffusion of water in the soil, or e.g. in a road bed, is due to the fact that various layers differ in temperature, and hence in the partial pressure of the water vapour. This gives rise to a vapour pressure gradient which causes the water vapour to diffuse towards some point where the vapour pressure is lower. To produce the vapour pressure gradient required for diffusion in the apparatus described in this paper, the material through which water is to diffuse is placed between a free water surface and an absorbent (silica gel). The vapour pressure gradient obtained in this manner is equal to the difference between the partial pressure of the water vapour at the free water surface and the partial pressure at the sorbent. The latter pressure is negligible in the present case. The quantity of diffusing water is recorded continuously. For this purpose, the sorbent container is suspended in such a way that it can be weighed at any arbitrarily chosen instant during the test without interrupting the course of the test. The successive increase in the weight of the absorbent during the test is a direct consequence of the quantity of water absorbed.

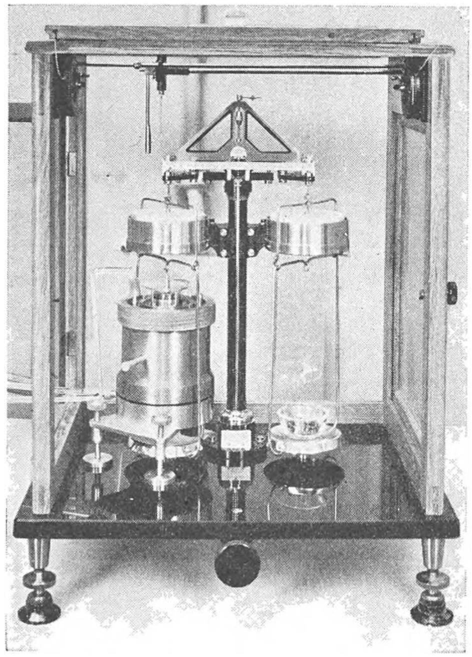

Fig. 2 Diffusion apparatus and balance
L'appareil et la balance

The general layout of the apparatus is schematically represented in Fig. 1. The apparatus consists of a metal cylinder, the lower part of which is filled with water, while in the upper part there is a special basin with a wire mesh bottom containing an absorbent substance which absorbs the water transferred through the sample by diffusion. The basin is suspended from one arm of a sensitive balance, see Fig. 2, so that the quantity of water sorbed can easily be determined at various moments in the course of the test, which need not be interrupted. The top part of the apparatus is provided with an oil seal to prevent the

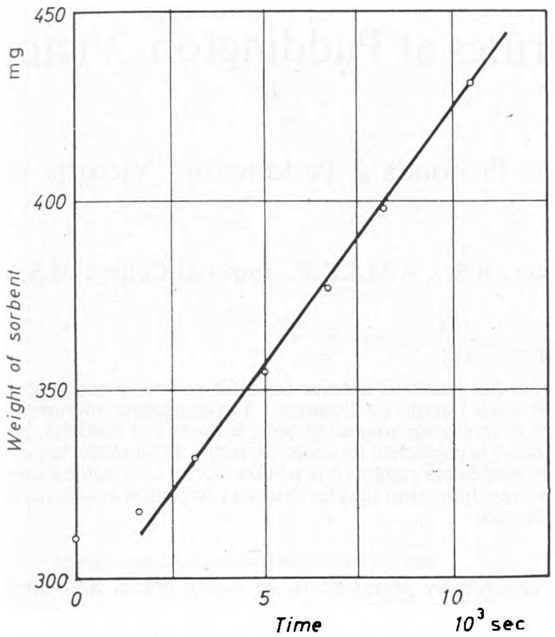

Fig. 3 Result of a typical test with the apparatus
Résultat d'un essai typique avec l'appareil

leakage of air from the apparatus. The sample of material in which the rate of diffusion of water vapour is to be determined is placed between the free water surface in the bottom part of the apparatus and the basin containing the absorbent. In order that it may be possible to determine the rate of diffusion

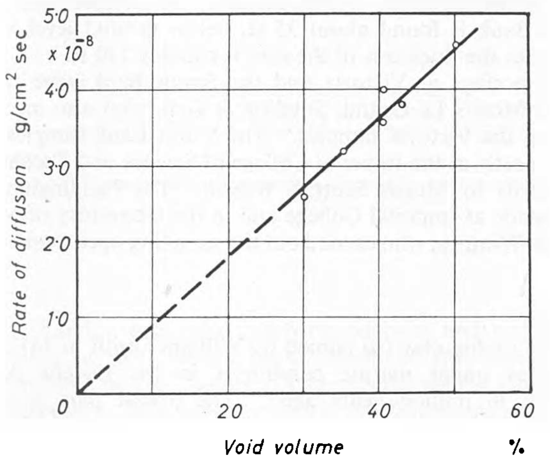

Fig. 4 Relationship between rate of diffusion and void volume
La relation entre la vitesse de diffusion et le pourcentage des vides

at a constant vapour pressure gradient, the partial pressure of the water vapour above the free water surface in the lower part of the apparatus must be kept constant. For this purpose, the apparatus is placed in a constant-temperature room.

The water is transferred through the material under test by diffusion, for which we have the expression

$$Q = - k_v . A . \text{grad}\, p_v$$

where Q is the quantity of moisture transferred per unit time, A is the cross-sectional area of the column of material under test, grad p_v is the water vapour pressure gradient, and k_v is the diffusion constant of the material under test.

The values observed in the tests are plotted in a diagram in which the ordinate shows the increase in weight of the absorbent, i.e. the quantity of water transferred by diffusion, while the abscissa represents the time. As may be seen from Fig. 3, the relationship between these two variables is linear. The quantity of moisture transferred per unit time, Q, can be obtained from the slope of the straight line in the graph. The value of Q is first determined without inserting any material sample in the apparatus. From this value we can compute the diffusion constant k_v of the air. Then the value of Q is determined after having inserted the material sample in the apparatus, and hence we can calculate the value of k_v for the sample in question.

Tests have been made on glass beads varying in size as well as on fractions of soil particles differing in grain size and on mixtures of these fractions. Moreover, the void volume of each sample has also been determined. The results of these tests are reproduced in Tables 1 and 2.

Table 1

Material: glass beads

Sample	*Grain size* mm	*Rate of diffusion, k_v**
1	2	$4{\cdot}4 \times 10^{-8}$
2	0·25–0·177	$4{\cdot}2 \times 10^{-8}$
3	0·147–0·125	$4{\cdot}7 \times 10^{-8}$

Table 2

Material: fractions of soil particles

Sample	*Grain size* mm	*Prop.* %	*Rate of diffusion, k_v**	*Void volume* %
1	4–2	100	$3{\cdot}6 \times 10^{-8}$	40·2
2	0·5–0·25	100	$4{\cdot}0 \times 10^{-8}$	40·4
3	0·125–0·074	100	$4{\cdot}6 \times 10^{-8}$	49·8
4	4–2 2–1	67 33	$3{\cdot}8 \times 10^{-8}$	42·8
5	4–2 0·5–0·25	67 33	$3{\cdot}2 \times 10^{-8}$	35·2
6	4–2 0·125–0·074	67 33	$2{\cdot}6 \times 10^{-8}$	30·1

* k_v is expressed in g/cm² sec at a sample height of 1 cm and a vapour pressure difference of 1 mm of mercury.

The test results indicate that the diffusion constants of materials of different grain sizes (see Table 1) are on the whole equal. Consequently, the rate of diffusion is independent of the void *width*. It is to be noted, however, that this statement may be presumed to be applicable only to those cases in which the temperature is constant. Furthermore, it is seen that the void *volume* has an important effect on the rate of diffusion, and it may be seen from Fig. 4 that there is a clear relationship between the two factors.