CALIBRATION OF GYPSUM BLOCKS FOR SOIL MOISTURE MEASUREMENTS

Key words: Building materials, moisture, calibration, gypsum block, electrical resistance, suction

1 SCOPE

This test method covers the determination of calibration curves of gypsum blocks used to determine the suction pressure in soil.

2 FIELD OF APPLICATION

Gypsum blocks can be used to indirectly determine the suction pressure in soil.

Gypsum blocks have been used in soil science for the past 50 years, and several types of commercial gypsum blocks are available on the market. The gypsum blocks are delivered with a standard curve showing the relation between measured resistance and suction pressure. There is no calibration curve for the actual gypsum block and there is no information on temperature dependency. This calibration procedure serves the purpose of calibrating gypsum blocks prior to application.

3 REFERENCES

No text.

4 DEFINITIONS

Moisture content

The gravimetric moisture content \( u \) (kg/kg) is the ratio of the mass of evaporable water to the oven dry mass of material.

Relative humidity

Relative humidity, \( RH \), of air is the ratio of actual partial water vapour pressure to saturation water vapour pressure at the temperature of the air.

Suction pressure

The suction pressure \( s \) (bar) is the pressure difference between the pore water pressure and the ambient total pressure.

Retention curve or soil moisture retention curve

Relationship between soil moisture content and suction pressure.
5 METHOD OF TEST

5.1 Principle

Gypsum blocks are brought to suction pressure equilibrium with kaolin at given moisture contents. AC-resistance of a gypsum block is determined at time of equilibrium. The water content of the surrounding kaolin is determined at time of equilibrium. The retention curve for kaolin is used to determine the kaolin suction pressure at equilibrium from the water content.

The measured AC-resistance at equilibrium versus the kaolin suction pressure constitutes the calibration curve for the gypsum block.

5.2 Apparatus

Electrical mixer (e.g., mixer for cement paste and mortar) for mixing kaolin and water.

Ventilated oven capable of maintaining a desired temperature of 105°C with an accuracy of ±2°C.

Containers with cap.

Gypsum block for measurement of suction pressure.

High-resolution AC-resistance measurement apparatus.

Kaolin powder (i.e., Fluka Chemie, No. 60609 distributed by Sigma-Aldrich Chemie).

Balance with a resolution of at least 0.01 g (preferably 0.001 g).

Thermometer with a resolution of 0.5°C.

Thin-walled pipe of outer diameter equal to the diameter of a gypsum block. The length should be 10–15 cm.

5.3 Preparation of test specimens

The gypsum blocks are soaked in water for at least 1 hour and the dried at room condition. This procedure is carried out twice in order to improve the performance of the gypsum blocks.

5.4 Procedure

5.4.1 The test shall be carried out at constant temperature of 23±1°C.

5.4.2 Kaolin and water are mixed thoroughly. The content of water should be between 20% and 60% by mass of the kaolin.

5.4.3 Sets of two containers ("A" and "B") with the same kaolin mixes are prepared for gypsum blocks. A hole is made at the centre of the kaolin in container "A" by using a piece of pipe. The pipe has an outer diameter equal to the diameter of the gypsum block.

5.4.4 A dry gypsum block is placed in the hole in container "A" and the wire is led through an opening in the cap of the container. The container is sealed and stored at high relative humidity (RH > 95%).

Measurements of the AC-resistance are carried out until equilibrium is observed. Equilibrium should be reached within 2–3 days.

5.4.5 When equilibrium is obtained the gypsum block is removed from container "A" and placed in the corresponding container "B". The kaolin mix in container "B" is the same as the kaolin mix in container "A". The procedure in Steps 5.4.3 and 5.4.4 is repeated for container "B" except that the gypsum block is not dry but in moisture equilibrium with the kaolin in container "A".

NOTE: The reason for placing the gypsum block in two containers with the same kaolin mix is to reduce the error which may occur if there is a (significant) suction gradient from the surrounding kaolin mix to the centre of the gypsum block. By equilibrating the moisture content in the gypsum block before placing it in container "B" the suction gradient will be reduced.

5.4.6 When equilibrium is obtained in container "B" the AC-resistance is recorded. The gypsum block is removed and a sample of kaolin is taken from the area next to the hole for the gypsum block. The sample should weigh more than 3 grams when the balance used for weighing has a resolution of at least 0.01 grams. The mass \( m_{\text{wet}} \) of the sample is determined shortly after removal from the container (less than a minute).

5.4.7 The sample is oven dried at 105°C until the weight loss is less than 0.01 gram over a period of 6 hours. The mass \( m_{\text{dry}} \) of the sample is determined after it has cooled to room temperature in a (dry) container with silica gel.

5.4.8 The gypsum block is dried in room condition until the AC-resistance is above 100 kΩ.

5.4.9 Steps 5.4.2 to 5.4.6 are repeated for at least 3 kaolin mixes having water contents ranging from 20% to 60%.

5.5 Expression of results

5.5.1 The moisture content by mass is determined by

\[
u = \frac{m_{\text{wet}} - m_{\text{dry}}}{m_{\text{dry}}}\]

where \( m_{\text{wet}} \) is the mass of the sample just after removal from the container and \( m_{\text{dry}} \) is the mass of the sample after it has been oven dried.
5.5.2 The suction pressure $s$ is determined by

$$s = \frac{0.202 \text{bar}}{\ln\left(\frac{0.500 \text{ kg/kg}}{0.706 \text{ kg/kg} - u}\right)^{1.323}}$$

where $u$ is the moisture content by mass.

This expression is valid for the proposed retention curve for kaolin of type Fluka Chemie, No. 60609 distributed by Sigma-Aldrich Chemie. If other types of kaolin (or soil material) are used the retention curve has to be determined for that specific material. The retention curve can be determined by using e.g. a thermocouple psychrometer.

5.5.3 Plotting the suction pressure $s$ of the kaolin against the resistance $R$ of the gypsum block to double log scale a curve fit having the following expression can be found:

$$\ln[R(T_0)] = A \cdot \ln[s] + B$$

where $A$ and $B$ are fit constants. The calibration temperature $T_0$ is in this case equal to 23°C.

5.5.4 For resistance measurements carried out at temperatures deviating from the calibration temperature, the following expression may be applied:

$$R(T_0) = \frac{R(T)}{1 + 0.064 \cdot \frac{1}{C} (T_0 - T)}$$

where $T_0$ is the calibration temperature (23°C) and $T$ the temperature at time of measurement.

This expression is only valid for $T_0 = 23°C$. If the calibration is carried out at another temperature, the corresponding relation must be found.

5.5.5 Having determined the calibration factors $A$ and $B$ the gypsum block can be used to obtain the suction pressure in soil. The suction pressure is then determined from the following expression:

$$s = \exp\left[\frac{\ln[R(T_0)] - B}{A}\right]$$

where $R(T_0)$ is the resistance of the gypsum block according to Section 5.5.4.

5.6 Accuracy

The accuracy of the calibration method depends on the handling of the samples. Samples for determining the water content of kaolin mixes should be handled in such a way that drying of the wet samples is reduced until $m_{\text{wet}}$ is determined. Required minimum size of samples is related to the resolution of the balance.

5.7 Test report

The test report shall include the following information:

a) Name and address of the testing laboratory
b) Identification number of the test report
c) Name and address of the organisation or the person who ordered the test
d) Purpose of the test
e) Choice of points of measurement and other circumstances (date and person responsible for sampling)
f) Method of sampling and specimen preparation
g) Address and detailed description of the place where the samples have been taken.
h) Date when the measurement was ordered
i) Date of measurement
j) Test method
k) Conditioning of the sample type and probe, ambient conditions during measurement (temperature, RH etc.)
l) Identification of the equipment used for measurement (product, model and laboratory equipment identification number)
m) Any deviations from method of measurement
n) Test results according to Clause 5.5
o) Inaccuracy or uncertainty of the measurement
p) Date and signature.
Figure A.1. Retention curve for kaolin of type Fluka Chemie, No. 60609 distributed by Sigma-Aldrich Chemie.

Figure A.2. Example of calibration curve for a gypsum block.
Figure B.1. Results from calibration of gypsum block No. 1 shown together with curve fit.

Figure B.2. Results from calibration of gypsum block No. 2 shown together with curve fit.

Figure B.3. Results from calibration of gypsum block No. 3 shown together with curve fit.

Figure B.4. Results from calibration of gypsum block No. 4 shown together with curve fit.

Figure B.5. Results from calibration of gypsum block No. 5 shown together with curve fit.

Figure B.6. Results from calibration of gypsum block No. 6 shown together with curve fit.
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