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(54) **METHOD OF TESTING LOOSE GROUND.**

(57) The method provides for introducing, by means of screwing-in, into the ground (2) a barrel (3) with a screw-shaped blade (4) on its end. At a depth (L_3) of the ground (2, 9) which is smaller than the depth (L_1) of location of the layer (1) of the ground (2) to be tested and which exceeds the pitch (t_1) of the blade by a value (L_4) the pressure (P_3) of the ground (2) on the lower surface (7) of the blade (4) is measured and in the event that it is not equal to the pressure (P_1) of the column of the ground (2) above the blade (4) in a non-deformated condition an axial force (P_4) is applied to the blade (4) through the barrel (3) so as to ensure the equality of these pressures (P_1, P_3). When the blade (4) reaches the depth (L_1) of location of the layer (1) of the ground (2) to be tested the process of screwing-in is discontinued and the barrel (3) is subjected to the influence of static forces directed downwards, the value of each subsequent force exceeding the value of the previous one by an equal value and the displacement of the barrel (3) is measured.

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SOIL-TESTING METHOD

Industrial Field

The invention relates to engineering geology surveys carried out in coping with construction projects and has specific reference to a soil-testing method.

Prior Art

In civil and industrial engineering there is always a need to test the soil founded whereupon will be important structures such as high-rise buildings, nuclear units of atomic power stations, hydroelectric plants, large industrial buildings, etc. Not excluded is the possibility that the bearing soil is one containing over 50% of uncemented fragmental rock with a particle size over 2 mm (e.g., detritial, ligneus). Gravel, coarse and fine sand, sandy loam, cleayey soil, clay are also a frequent ocurence.

The tests are needed for ascertaining the consolidation pressure, the bulk modulus of the soil and the rate of settlement of the structure. Thy should meet high accuracy requirements, for any error may lead to structural failure or unjustified expenditures on the project.

There is known a soil-testing method (Soils. Methods of Determining Stress-Strain Bahaviour at the Field, USSR Standard GOST 202786-85,p 20) consisting in preparing a test site by excavating a pit in the soil layer to be explored, placing a slab with a surface area of some 5000 cm^2 on the site, applying a step-wise increasing static load to the slab and measuring the settlement of the slab in response to the loads. The consolidation pressure, the bulk modulus of the soil and the rate of settlement are calculated from the test data.

However, the known method is inapplicable in testing deep layers of a soil with a high moisture content, for the test site may become flooded by the water and accessible therefore with difficulty. The fact that the flooding can increase the moisture content of the soil and influence its physical and mechanical properties before the application of static loads is intolerable. A high moisture content of the soil may also prevent the slab from contacting the tested soil layer uniformly over its entire surface area and lead to inaccurate results. Difficulties are experienced in installing, statically loading the slab and taking its settlement measurements under these conditions.

The prior-art method is practically of no avail in testing a deep layer of soft soil, for its strength is impaired by its deformation due to a sideways pressure of the soil en mass above the site after the excavation of the pit.

All in all, another method of soil testing has been developed (Soils, Methods of Determining Stress-Strain Behaviour at the Field, USSR Standard GOST 2027-85, pp 5-6, 20-21) pursuant whereto a layer of soil overlaying one under the test is deformed by a helical blade which is screwed into the soil down to a given depth being attached to the lower and of a shaft, a series of static axial loadings of downward direction is applied to the shaft when the screwing comes to an end, whereby each succeding loading exceeds the preceding one by the same amount, and the displacements of the shaft in response to the loadings are measured.

Needing no site specially prepared in the soil layer under the test, this method does not involve flooding or weakening of the tested layer and is therefore applicable to testing deep layers with a high moisture content and deep layers of soft soil.

However, the descending blade, wedging out the soil layers lying ahead of it, deforms the tested layer before the application of static loads. This impairs the accuracy and reliability of the test data.

Moreover, a fraction of the lower surface of the blade may become disengaged from the tested soil layer so that no iniform blade-to-soil contact-- indispensable as far as accuracy and reliability of the test data are concerned -- will exist in those cases when the blade descendes with each revolution of the shaft through a distance less than the pitch of the blade. Such a condition can be brought about when the sum of the forces which oppose the entry of the shaft and blade into the soil is slightlx greater than the sum of the forcess applied in order to effect this entry. Coming under the former heading are the resistance which the soil offers to the descending shaft tip, the frictional forces coming into play between the soil and the descending shaft and a vertical upward component of the resistance which the soil offers to the cutting edge of the blade. Coming under the latter heading are the downward axial force, the weight of the shaft and blade and the pull of the helical blade.

Summary of the Invention

The principal object of the invention is to provide a soil-testing method conducive to high accuracy and reliability of test data which are achievable by preventing deformation of the tested soil layer under the condition of a uniform contact between the lower surface of the blade and the tested soil layer.

This object is realized by disclosing a soil-testing method consisting in screwing a shaft with a helical blade at the lower end thereof into the soil so as to deform a layer of soil overlaying one under the test, discontinuing the screwing on reaching the tested soil layer, aapplying a series of static axial loadings of downward direction to the shaft -- whereby each successive loading exceeds the preceding one by the same amount --and measuring the displacements of the shaft in response to the loadings wherein according to the invention an equalizing axial load is applied to the blade through the shaft if the pressure exerted by the soil on the lower surface of the blade, as measured at a depth which is less than that of the tested soil layer by an amount exceeding the pitch of the blade, differs from the pressure of an undisturbed soil column overlaying the blade.

By equalizing the soil pressure coming on the lower surface of the blade with the pressure of the undisturbed soil column overlaying the blade we "transfer" the deformation of the soil due to the descending blade from the layers lying ahead thereof to the layers overlaying it. Preventing deformation of the tested soil layer before the application of static loadings, this "transfer" promotes accuracy and reliability of the test data.

The pressure sustained by the lower surface of the blade signifies contact between this surface and the soil, and the helical shape of the lower surface of the blade provides for uniformity of the contact which is a further guarantee of accuracy and reliability of the test.

Brief Description of the Drawings

A preferred embodiment of the invention will now be described by way of example with reference to the accompanying drawings, wherein

Figure 1 illustrates the shaft with the helical blade preparatory to testing a soil which is clay;

Figure 2 illustrates the shaft with the helical blade;

Figure 3 illustrates the shaft with the blade at an instant when the blade is at a depth which is less then that of the tested soil layer by an amount exceeding the pitch of the blade;

Figure 4 illustrates the shaft with the blade in a position when the blade is at the depth of the tested soil layer;

Figure 5 illustrates the shaft with the helical blade in a position preparatory to testing a soil which is fine compacted sand;

Figure 6 illustrates the shaft with the helical blade;

Figure 7 illustrates the shaft with the helical blade at an instant when the blade is at a depth which is less than that of the tested layer by an amount exceeding the pitch of the blade;

Figure 8 illustrates the shaft with the helical blade in a position when the blade is at the depth of the tested soil layer.

Embodiment

The disclosed soil-testing method consists in screwing a shaft with a helical blade at its lower end into the soil so as to deform a layer of soil overlaying one under the test. On reach a depth which is less than that of the tested soil layer by an amount exceeding the pitch of the blade, the pressure of the soil coming on the lower surface of the blade is measured. Should this pressure differ from the pressure of an undisturbed soil column overlaying the blade, an axial load equalizing the two pressures is applied to the blade through the shaft. The screwing operation is discontinued as soon as the blade is at the depth of the tested soil layer, and a series of static axial loadings of downward direction is applied to the shaft, whereby each successive loading exceeds the preceding one by the same amount, before measuring the displacements of the shaft in response to the loadings.

A development of the disclosed invention is adapted to test soil which is, e.g., clay. Referring to Fig. 1, when a building is being erected with a foundation 20 m wide, subjected to testing is as a rule a layer 1 of a soil 2 occuring at a depth L_1 which equals the width of the foundation, i. e., $L_1 = 20$ m. This layer 1 is schematically confined between dashed lines in Fig. 1.

Employed for testing is a shaft 3 with a length $L_2 =$ 23 m and a diameter $d_1 = 11.4$ cm (Fig.2) which is fitted with a helical blade 4 with a diameter $D_1 = 27.7$ cm and a pitch $t_1 = 8$ cm.

The pressure P_1(Fig. 1)/ of an undisturbed column of the soil 2 overlaying the blade 4 is 0.4 MPa at the depth L_1.

The shaft 3 is placed vertically at the surface 5 of the soil 2, the blade 2 downwards, and is screwed into a layer 6 overlaying the tested layer 1 by applying a torque $M_1 = 0.5$ tm and an axial downwardly directed force $P_2 = 1$ t, deforming thus the layer 6.

At a depth L_3 (Fig. 3) of the soil 2 which is less of the depth L_1 occuring whereat is the tested layer 1 by L_4 which is greater than the pitch t_1 of the blade 4, the pressure P3 exerted by the soil 2 on the lower surface 7 of the blade is measured. If this pressure differs from the pressure P_1 of the undisturbed column of the soil 2 overlaying the blade 4, an axial force P_4 is applied to the blade 4 through the shaft 3 to equalize the pressures P_1

and P_3. Taking into account that $L_1 = 20$ m and $t_1 = 8$ cm, measurements of the pressure P_3 are taken beginning with, e.g., $L_3 = 18.5$ m. Let $P_3 = 0.48$ MPa. In this case the pressure coming on the lower surface 7 of the blade exceeds the pressure P_1 of the undisturbed column of the soil 2 overlaying the blade 4. To reduce the pressure P_3 to 0.4 MPa, an axial force P_4 directed upwards is applied to the blade 4 through the shaft 3. maintaining the pressures P_1 and P_3 at the common level, the shaft 3 is lowered integrally with the blade 4 to the depth L_1. The screwing operation is discontinued and axial static loadings P_5, P_6, P_7 and P_8 (Fig.4)/ of downward direction are applied to the shaft 3, whereby each successive loading exceeds the preceding one by the same amount, before displacements L_5, L_6, L_7, L_8 (not shown) of the shaft 3 in response to the loadings are measured. These displacements are: $L_5 =$ 1.8 mm due to $P_5 = 0.1$ MPa, L_6 = 2.1 mm due to P_6 = 0.2 MPa, $L_7 = 2.0$ mm due to $P_7 = 0.3$ MPa, L_8 = 2.4 mm due to $P_8 =$ 0.4 MPa. The bulk modulus and other characteristics of stress-strain behaviour of the soil are calculated from these data.

Another development of the disclosed invention is adapted to test fine compact sand with a density of 2.1 g/cm^3. A foundation with a width of 10 m is required for erecting a building in this case. Consequently, the depth L_9 (Fig. 5) of the soil layer to be tested is approximately 10 m. This layer 8 of the soil 9 is schematically confined between dashed lines.

The test is carried out with aid of a shaft 10 with a helical blade 11 of the dimensions as follows: shaft length, L_{10} = 13 m; shaft diameter, d_2 = 11.4 cm (Fig. 6); blade diameter, $D_2 =$ 27.7 cm; blade pitch, $t_2 =$ 5 cm.

The pressure P_9 (Fig. 5) of the undisturbed column of the soil 9 overlaying the blade 11 is 0.21 MPa at the depth L_9.

The shaft 10 is placed vertically at the surface 12 of the soil 9, the blade 11 downwards, and is screwed into a layer 13 of the soil 9 overlaying the tested layer 8 by applying a turque $M_2 = 0.3$ tm and an axial downwardly directed force $P_{10} = 0.75$ t, deforming thus the layer 13. At a depth of 1 m (not shown) the force P_{10} is removed.

At a depth L_{11} = 8 m (Fig. 7) the pressure P_{11} of the soil 9 on the lower surface 14 of the blade 11 is measured, being 0.05 MPa. It will be noted that the depth L_{11} is less than the depth L_{10} by $L_{12} =$ 2 m. Since the pressure P_{11} coming on the lower surface 14 of the blade 11 is less than the pressure P_9 of the undisturbed column of the soil 9 overalying the blade 11, an axial force P_{12} of downward orientation is applied to the blade 11 through the shaft 10 owing whereto the pressure P_{11} increases from 0.05 MPa to 0.21 MPa. Keeping the pressures P_9 and P_{11} at the same level, the shaft 10 is screwed integrally with the blade 11 down to the depth L_9 where the tested layer 9 occurs. At this depth (Fig. 8) the torque M_2 is removed, so that the screwing action is discontinued, and four axial static loadings P_{13}, P_{14}, P_{15}, P_{16} of downward direction are applied to the shaft 10, each successive loading exceeding the preceding one by the same amount. The displacements L_{13}, L_{14}, L_{15}, L_{16} (not shown) of the shaft 10 in response to the loadings are measured, being as follows: $L_{13} = 0.9$ mm due to $P_{13} =$ 0.1 MPa, P_{14} = 0.7 mm due to $P_{14} =$ 0.2 MPa, $L_{15} = 0.9$ mm due to $P_{14} = 0.3$ MPa, $L_{16} = 1.0$ mm due to $P_{16} = 0.4$ MPa. The bulk modulus of the soil and other characteristics of its stress-strain behaviour can be calculated from these data.

Industrial Applicability

The disclosed invention may be of utility in testing the soil founded whereupon will be important structures such as nuclear units of atomic power stations, hydroelectric plants and large industrial buildings.

Claims

1. A soil-testing method consisting in screwing a shaft (3, 10) with a helical blade (4, 11) attached to the lower end thereof into the soil (2, 9) so as to deform a layer (6, 13) of the soil (2, 9) overlaying a layer (1, 8) subjected to the test, discontinuing the screwing operation when the blade (4, 11) reaches a depth (L_1, L_9) occuring whereat is the layer (1, 8) subjected to the test, applying static axial loadings (P_5, P_6, P_7, P_8, P_{13}, P_{14}, P_{15}, P_{16}) of downward direction to the shaft (3, 10) -- whereby each succeeding loading exceeds the preceding one by the same amount -- and measuring displacements (L_5, L_6, L_7, L_8, L_{13}, L_{14}, L_{15}, L_{16}) of the shaft (3, 10) in response to the loadings (P_5, P_6, P_7 P_8, P_{13}, P_{14}, P_{15}, P_{16}), characterized in that an axial load (P_4, P_{12}) bringing to a common level pressures (P_1, P_3, P_9, P_{11}) is applied to the blade (4, 11) through the shaft (3, 10) if the pressure (P_3, P_{11}) exerted by the soil (2, 9) on the lower surface (7, 14) of the blade (4, 11), as measured at a depth (L_3, L_{11}) of the soil (2, 9) which is less than the depth (L_1, L_9) of the layer (1, 8) subjected to the test by an amount (L_4, L_{12}) exceeding the pitch (t_1, t_2) of the blade (4, 11), differs from the pressure (P_1, P_9) of an undisturbed column of the soil (2, 9) overlaying the blade (4, 11).

INTERNATIONAL SEARCH REPORT

International Application No PCT/SU89/00079

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) [6]

According to International Patent Classification (IPC) or to both National Classification and IPC

Int.Cl.5 E02D 1/00

II. FIELDS SEARCHED

Minimum Documentation Searched [7]

Classification System	Classification Symbols
Int.Cl.4	E02D 1/00, 1/02, G01N 3/00, 3/08

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched [8]

III. DOCUMENTS CONSIDERED TO BE RELEVANT [9]

Category *	Citation of Document, [11] with indication, where appropriate, of the relevant passages [12]	Relevant to Claim No. [13]
A	SU, AI, 1008352 (B. I. BEZRUKOV) 3 March 1983 (03.03.83) see column 2, lines 31-38	1
A	SU, AI, 1214839 (B. I. BEZRUKOV ET AL) 28 February 1986 (28.02.86) see column 2, lines 4-16	1
A	SU, AI, 1382911 (MGU im. M.V. Lomonosova) 23 March 1988 (23.03.88) see column 2	1

* Special categories of cited documents: [10]

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"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

IV. CERTIFICATION

Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report
2 November 1989 (02.11.89)	6 December 1989 (06.12.89)
International Searching Authority	**Signature of Authorized Officer**
European Patent Office	