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[54] MEANS FOR DETERMINING THE SHEAR STRENGTH OF EARTH IN SITU

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[51] **Int. Cl.** **G01n 3/24**

[58] **Field of Search** .....73/101, 88 E, 151, 84; 166/212

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[57] **ABSTRACT**

Apparatus and a technique for the in situ measurement of the torsional shear strength of remotely located soil is provided. A probe and a reaction in close proximity to each other are embedded in soil in place at a remote point, e.g., the end of a bore hole; torque is applied to the probe, and resistance to rotation of the probe in the soil relative the reaction anchored to the soil is sensed and transmitted electrically to the surface as useful data. The apparatus is installed very remote from an operator's station by cooperatively employing drilling casing or drilling equipment by which the bore hole is maintained or formed.

3 Claims, 6 Drawing Figures

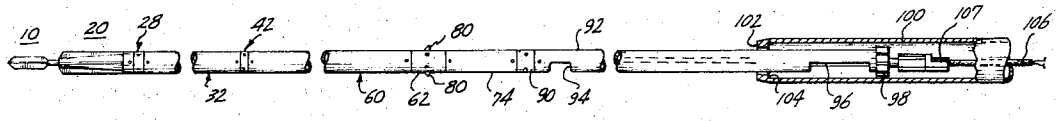


Fig. 1.

Fig. 2.

Fig. 3.

Fig. 4.

Fig. 5.

Fig. 6.

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MEANS FOR DETERMINING THE SHEAR STRENGTH OF EARTH IN SITU

SUMMARY OF THE INVENTION

It is known to determine the torsional shear strength of soil in situ by the use of a vaned probe, adapted to be embedded in a soil specimen at or closely adjacent the earth surface, to which torque is applied. The application of torque on the vaned probe tends to cause a cylindrical body of soil to be sheared from the surrounding body. Resistance between the two bodies to the shearing force constitutes data useful to soil engineers and geologists in their investigations respecting the condition of the earth. Such operations are disclosed in various technical publications, such as No. 193 (1957) of the American Society for Testing Materials entitled "Vane Shear Testing of Soils," and in prior patents. Vaned probes are shown in Carlson, U.S. Pat. No. 2,603,967, Gibbs, U.S. Pat. No. 2,907,204, Fletcher et al, U.S. Pat. No. 2,993,367, Bergfeldt, U.S. Pat. No. 3,216,243, and applicant's prior patent, U.S. Pat. No. 3,364,734, together with discourses on their use in soil testing. In situ testing where the situs of the soil is extremely remote, for example, hundreds or more of feet in the earth or underwater as often occurs in oil exploration activity presents practical problems.

The problem of placement of the testing equipment in the earth and of establishing a base of reference proximate the test site is considerable. The apparatus of this invention comprises a vaned shear probe mounted in the leading end of an extending hollow casing, and associated with closely located torque producing means fixedly mounted in the same casing. The leading end of the casing has anchor means engageable in the earth proximate to said probe. A sensor between said casing and its anchor means and the shaft of the vaned probe senses resistance to shear of the probe when torque is applied. An electrical signal is developed in the sensor which is easily transmitted to without the bore hole. At the surface, such signals are measured and provide the useful data. The casing is adapted to be raised and lowered on a cable within a drill casing in the hole. Placement of the probe is facilitated by providing extensible retractible pawls in the instrument casing which when extended may be engaged by the drill casing to apply downwardly directed mechanical force to drive the probe and reaction means into the soil. A technique of employing the equipment is disclosed. It will be seen that the main object of the invention is the provision of a method and means for accurately and simply measuring the shear strength of undisturbed soil axially ahead of a bore hole and remotely located from an operator's site.

DESCRIPTION OF THE DRAWINGS:

FIG. 1 is an elevational view mostly in section showing a preferred example of apparatus embodying this invention;

FIG. 2 is an enlarged view in elevation of the shear testing probe and cooperable reaction employed at the head end of the apparatus;

FIG. 3 is an enlarged elevation view showing the torque-generating and resistance sensing section of the apparatus;

FIG. 4 is an enlarged elevation view of the apparatus section containing extendible means by which the apparatus may engage and drive into soil in place;

FIG. 5 shows in enlarged scale the details of said extendible means; and

FIG. 6 is a cross-section view on line 6—6 of FIG. 2.

DESCRIPTION OF THE INVENTION:

The probe 10 comprises shank or shaft 12 having vanes 14 radially disposed on its front end. The leading edges 16 of the vanes are chamferred as shown to ease their entry into the earth. Other forms of probes will readily come to mind.

Reaction head 20 comprises annular body 22 having forward extending conical body 24, provided with a plurality of radial vanes 26. Body 22 at the rear is internally threaded to couple with threaded boss 27 of connector collar 28 as shown in FIG. 3. Conical body 24 has a longitudinal passage 25 which receives shaft 12 and provides bearing support of probe 10.

The sensor base 30 is supported at the rear of coupler 28 within shell or casing 32, and comprises a commutator plate 34 bearing annular commutator rings forming part of the sensor.

Torque is supplied to shaft 12 by electric motor 40 mounted on base coupler 42 at the rear end of shell 32. Throughout the apparatus, securement is obtained by suitable means such as set screws 44 and conventional threaded couplings as shown. Shaft 12 and the shaft of motor 40 are joined by drive coupling 46. Sleeve 48 is secured at 49 to shaft 12 within shell 32. Sleeve 48 carries on its forward end, spring arms 36 which bear on the rings of commutator plate 34, and transmit signals to the sensor evidencing resistance to torque supplied by the probe 10 as motor 40 is activated. Collar 13 on shaft 12 has leads 15 in circuit with spring arms 36. The sensor head is carried by the reaction head 20. The latter is fixedly engaged in earth at the remote end of bore hole 108. Thus, with rotative force being applied to the probe 10 in situ, shear strength data is derived in close proximity to an integral base in the earth.

Casing or shell 60 extends rearward of coupling 42, encases motor 40, and is coupled to pawl body 62 as shown in FIG. 5. Body 62 is transversely ported to provide slot 64. The longitudinally extending screw shaft 66 is journalled in slot 64 at its rear, by drive coupler 68, is secured to the shaft of reversible motor 70, which is mounted on block 72 secured within the next section of shell or casing 74. Operation of motor 70 rotates screw 66 in one or the other direction.

Internally threaded traveller 76 is mounted on screw 66 and has outstanding arms 78. Opposed pawls or lugs 80,80 are mounted in slot 64 on pivot pins 82. A link 84 joins each lug 80 to an arm 78 on traveller 78. Movement of traveller 78, upon rotation of screw 66, produces extension and retraction of pawls or lugs 80 depending upon the direction of motor rotation. When traveller 76 has fully extended the pawls, its rear bears on body 62 at the end of slot 64, and prevents further rotation of motor 70. This causes a rise in amperage which may be sensed by the operator as an indication that the pawls are fully extended. Conversely, when traveller 76 is moved to the other end of slot 64, a similar amperage rise will indicate full retraction of pawls 80.

Coupling **90** engages the rear of shell **74** and joins with shell section **92** which has access ports **94,96** near its ends. Shell **92** is provided with a knob **98** useful in pulling the probe and reaction equipment free from the earth following use, and preventing the equipment from dropping out of tube **100**.

The drilling tube **100** has annular cutters **102** at its end, and includes an internal shoulder **104** which engages knob **98** during extraction of the probe. Once the probe is pulled free of the earth, it is hoisted to the surface by a cable **106** attached to terminal block **107**.

When it is required to force the vaned probe **10** and reaction head **20** into the earth, the drill rod **100** is partially withdrawn from the remote end of bore hole **108**. The probe is lowered through the casing **100** and, conditions permitting, it is dropped so that probe **10** and reaction **20** enter the earth. When greater force is required, which is usual, the pawls **80** are extended to the sides in advance of the operating end of the withdrawn drill casing **100**. The casing is then lowered as in FIG. **5**. When the pawls **80** are contacted, the entire weight of the drilling casing bears on the instrument and can be employed to force the leading end of the probe into the earth.

A very practical application of this invention occurs in connection with underwater drilling operations. In such an operation, working from a surface platform or a vessel, a drill casing is lowered to the bottom and the drilling commenced. It is desireable to periodically test the shear strength of the earth through which the drill casing is being driven, but without removal of the drill from the hole as to do so creates a tremendous problem of ever re-inserting the drill in the hole due to the effects of currents, tides, and the like.

The test equipment is designed to be inserted into the drill casing and by it guided to the end of the bore hole. When testing is desired, the drill is stopped and partially withdrawn to retract the cutting end from the face of the bore hole **108**. The casing of the test equipment passes down in the drill casing and partially extends through the cutting end **102** so that the probe **10** and reaction **20** contact the bore hole face. Ordinarily mere dropping of the test equipment package is incapable of driving the vaned probe **10** into the earth or of engaging the firmed reaction **20** therein. The operator then, having established contact with the bore hole face, activates motor **70** to rotate screw **66** thus causing pawls **80,80** outward beyond body **62** as shown in FIGS. **4** and **5**.

Drill rod **100** is then lowered in the hole until the cutting end **102** bears upon pawls **80,80** (see FIG. **5**). Thus the entire massive weight of the lengthy drill casing **100** is transferred to the instrument package and hence to the probe **10** and reaction **20**.

The vanes **14** of the probe first slice into the earth at the face of bore hole **108** with minimal disturbance of the soil. Then the following vaned reaction enters the soil outward of the probe and forms an anchor or base for the instrument package proximate the probe, but without materially effecting the soil conditions at the probe.

When the operator is satisfied that the probe and reaction are properly placed, he energizes motor **40** applying torque to shaft **12**. Sleeve **48** also tends to rotate with shaft **12** and to carry fingers **36** in rotation relative the annular rings of commutator disc **34** which are immovable. Variations in current flow occur and are detected in sensor **30** and transmitted via conventional conductors to the surface. It will be understood that all conductors for motors **40** and **70**, and from sensor **30** are snaked lengthwise of the instrument package in passages provided (but not shown) in the various coupling and casing members. They all terminate in block **102** and thence pass to the surface as part of cable **106**.

When readings have been taken and it is desired to resume drilling, the instrument package is to be withdrawn. Drill rod **100** is withdrawn from pawls **80**; they are then retracted into slot **64** in body **62**. Then the drill casing is raised so that the internal lip or ledge **104** engages knob **98**. Continued lifting of rod **100** by the usually powerful system provided for such purposes applies longitudinal force on reaction **20** and probe **10** to withdraw it from the earth. Thereafter, the instrument package may be raised to the surface by its own cable **106** and drilling resumed.

The various joints between couplings and casing sections of the instrument package are normally sealed and water tight to exclude moisture from the sensor and the motors. The interior of the instrument package may also be pressurized before lowering by inserting air or an inert gas through fitting **110** on the side of coupling **90**. Such internal pressurizing will serve to prevent water intrusion when the instrument is used at considerable depths where high fluid pressures may be encountered.

Although a particular and preferred embodiment of the apparatus is shown and described, modifications and alterations following a study of this disclosure will naturally become apparent to those skilled in the pertinent art. All such as fall within the spirit and scope of the following claims, giving due regard to the doctrine of equivalency, are intended to be covered by this patent.

What is claimed is:

1. Apparatus for in situ measurement of the torsional shear strength of earth located in advance of the remote end of a bore hole comprising:

a torsion shaft having a vaned end axially insertable into earth in advance of the remote end of a bore hole, said shaft terminating a nominal distance outward from the end of the bore hole;

torque-generating means associated with said shaft to urge rotation thereof;

anchor means including radial vanes engageable with the earth at the remote end of said bore hole, said anchor means surrounding said shaft between its vaned end and said torque-generating means;

rigid structure fixedly coupling said anchor means and said torque-generating means;

means located between said torsion shaft vaned end and said torque-generating means for sensing resistance to rotation of said shaft to torque applied thereto by said torque-generating means, said means for sensing resistance being operative to produce an electrical signal proportionate to the degree of resistive forced sensed;

means for transmitting said signal to external of the bore hole;

means for measuring the strength of such signal;

gravity actuated means operable to insert said vaned shaft and said anchor means into and to engage earth at the remote end of a bore hole; and

said gravity-actuated means comprising expandible-retractible members associated with said rigid structure, and said bore is provided with a liner to engage said members when extended to apply the weight thereof to said rigid structure.

2. Apparatus according to claim 1 in which the rigid structure comprises a casing connecting between said torque-generating means and said anchor means.

3. Apparatus according to claim 1 in which the torque-generating means comprises a motor.

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