

United States Patent [19]**Handy**[11] **3,785,200**[45] **Jan. 15, 1974**[54] **APPARATUS FOR IN SITU BOREHOLE TESTING**[75] Inventor: **Richard L. Handy, Des Moines, Iowa**[73] Assignee: **Iowa State University Research Foundation, Inc., Ames, Iowa**[22] Filed: **June 1, 1972**[21] Appl. No.: **258,548**[52] U.S. Cl. **73/151**[51] Int. Cl. **E21b 49/00**[58] Field of Search **73/151, 88 E, 84; 254/29 R**[56] **References Cited****UNITED STATES PATENTS**

3,233,315	2/1966	Levake.....	254/29 R X
3,562,916	2/1971	Duckworth.....	73/88 E X

Primary Examiner—Jerry W. Myracle

Attorney—James J. Hill

[57]

ABSTRACT

Borehole test apparatus includes upper and lower laterally expandable side pressure units joined by a vertically expandable piston and cylinder unit. The laterally expandable side units are provided with diametrically opposing gripper surfaces to exert normal pressure to the sides of the borehole at vertically spaced locations when they are expanded. After the side pressure units are expanded to exert a predetermined normal force, the vertical cylinder unit is expanded to urge the side pressure units apart. One side pressure unit acts as a reaction base and the other shears the soil surrounding the borehole. The maximum vertical separation force tolerated by the soil is a measure of its shearing strength, and is recorded as a function of the normal pressure exerted by the expandable side pressure units to obtain the cohesion *C* and internal friction angle of the soil, rock, or other material tested.

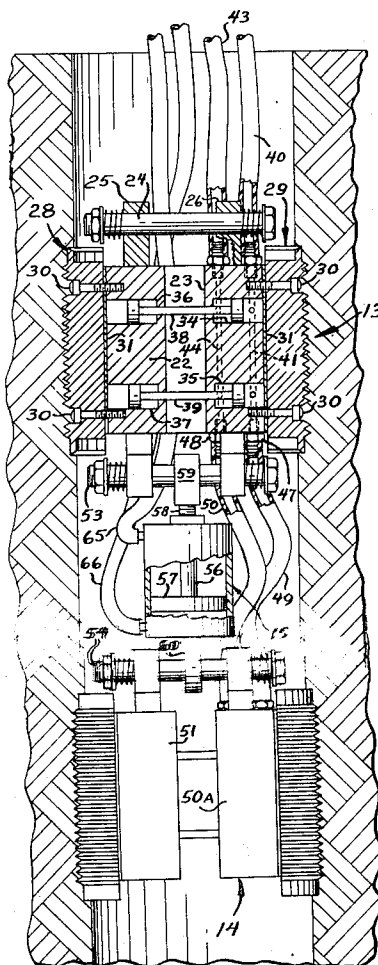
7 Claims, 3 Drawing Figures

Fig. 2

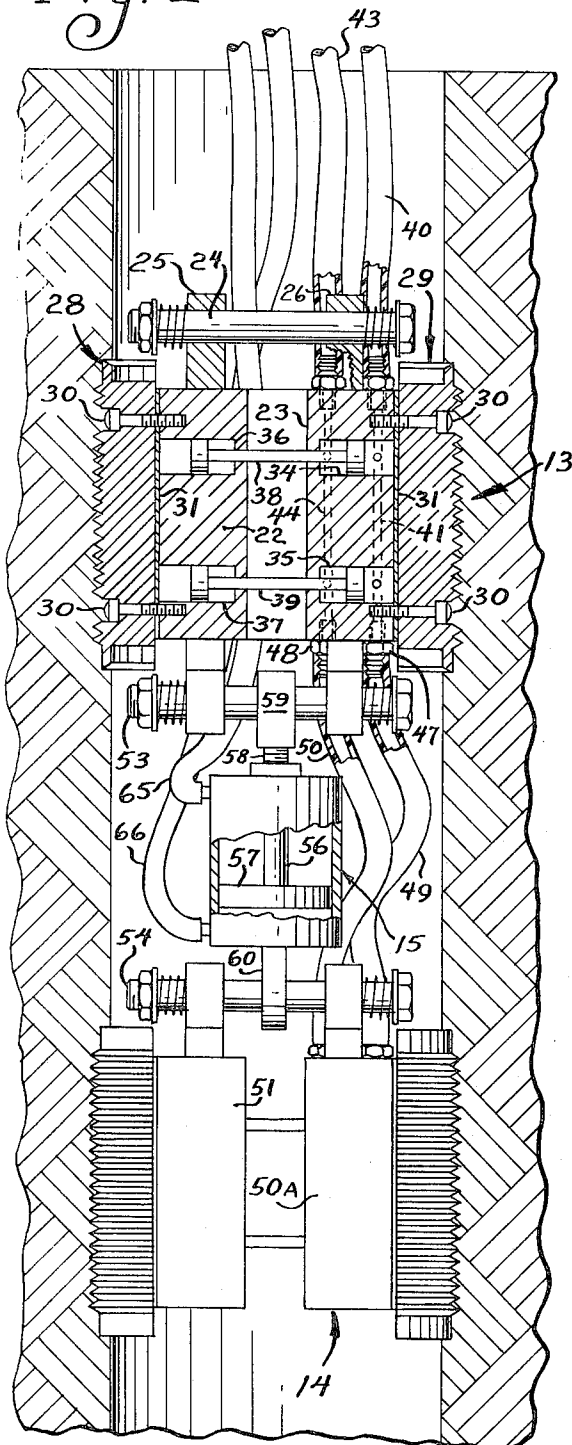
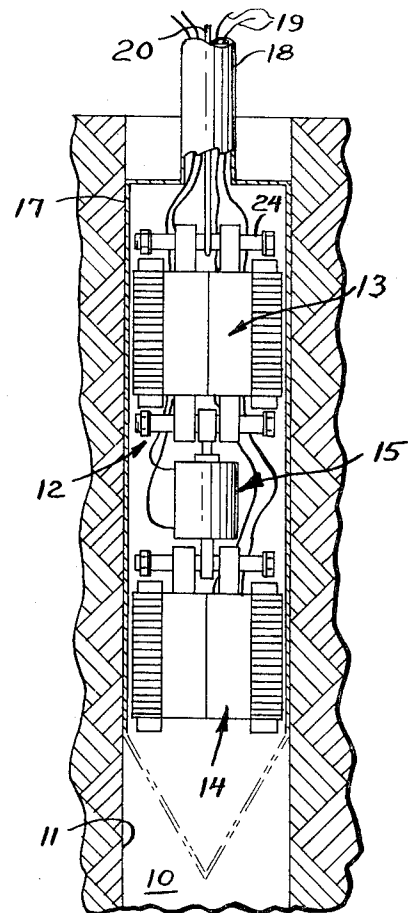


Fig. 1

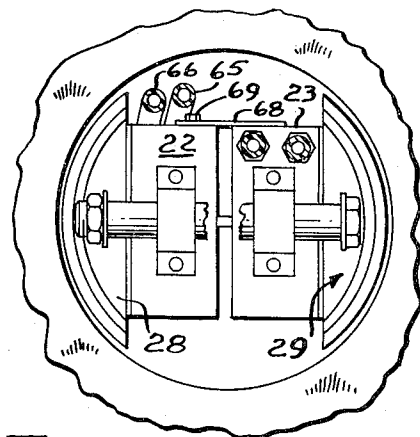


Fig. 3

APPARATUS FOR IN SITU BOREHOLE TESTING BACKGROUND AND SUMMARY

This invention relates generally to apparatus for measuring the shear strength of soils, soft rocks, and similar materials, and more particularly to apparatus for measuring basic strength parameters in situ in order to eliminate the necessity of obtaining and transporting undisturbed samples for laboratory testing.

The present invention is an improvement over the apparatus disclosed in U.S. Pat. No. 3,427,871 of Richard L. Handy and Nathaniel S. Fox, issued Feb. 18, 1969. The apparatus of this invention is intended for the practice of the method disclosed in that patent, and it offers substantial operational advantages over the apparatus disclosed therein while incorporating all of the features of that apparatus. The disclosure of U.S. Pat. No. 3,427,871 is incorporated herein by reference.

In the prior unit described in the above-identified patent, there is a base-plate which is set on the ground surrounding the borehole to form a reaction base for pulling the testing apparatus. There was only a single side pressure expansion unit and after insertion and inducement of the normal pressure the side pressure unit was pulled upwardly by reaction against the base-plate. The base-plate is eliminated with the present invention which provides a more portable apparatus and reduces set-up time.

The apparatus of the present invention includes upper and lower laterally expandable side pressure units which are joined by a vertically expandable cylinder and piston rod unit. The laterally expandable side units are provided with opposing gripper surfaces to exert normal pressure on the sides of a pre-formed borehole at vertically spaced locations when these side pressure units are expanded. After expansion of the side pressure units to induce a predetermined normal force on the soil surrounding the borehole, the vertical cylinder unit is expanded to urge the side pressure units apart. One side pressure unit acts as a reaction base and the other one shears the soil surrounding the borehole. In practice, both side pressure units may move relative to their original positions, but normally the one engaging the weaker stratum will move. The displacement of the side pressure units may be determined for a known applied vertical separation force exerted by the vertically expandable hydraulic cylinder unit to give a shearing stress versus shearing deformation relationship. Of most particular interest, however, is the maximum shearing stress attainable, which represents the shearing strength at a given normal pressure and may be plotted against normal pressure to give basic shear strength parameters cohesion (c) and internal friction (ϕ) as discussed in the above-identified patent.

The side pressure units include double-acting piston rod and cylinder units so that they may be contracted prior to insertion and enclosed within a cylindrical sleeve. The sleeve facilitates insertion of the apparatus and prevents nicking or gouging of the borehole wall during insertion. After the apparatus is inserted, the cylindrical guard sleeve may be withdrawn.

During operation of the present device, the shear plate pair encountering the weakest soil will move, and this is ordinarily an advantage when the weakest layer is not precisely known. Identification of the side pressure unit which moves during test can be established by watching the axial displacement of rigid conduits fed to

the apparatus. Further, tests which are now discontinued due to encountering a stone could be continued, since the other pair plate pair would move. This would account for about a 30 per cent improvement in gravelly soils, such as glacial till.

As an alternative where it is desired to limit shearing to one particular stratum, one lateral expandable cylinder might be made larger, or pressurized to a higher pressure in order to serve as an anchor for the reaction.

Other features and advantages of the present invention will be apparent to persons skilled in the art from the following detailed description of a preferred embodiment accompanied by the attached drawing wherein identical reference numerals will refer to like parts in the various views.

THE DRAWING

FIG. 1 is a vertical side view of apparatus constructed according to the present invention inserted in a borehole in a contracted state;

FIG. 2 is an enlarged vertical side view of the inventive apparatus with portions shown in cross section and the side pressure units expanded; and

FIG. 3 is a top view of the apparatus as shown in FIG. 1, but with the protecting sleeve removed.

DETAILED DESCRIPTION

Referring first to FIG. 1, reference numeral 10 indicates a borehole formed in ground having a cylindrical, vertical side wall 11 and adapted to receive soil test apparatus generally designated by reference numeral 12. The test apparatus 12 includes upper and lower side pressure units or "shear" units generally designated respectively 13 and 14. Each of the units 13 and 14 is laterally expandable under fluid pressure to exert a normal pressure against the side wall 11 of the borehole 10, as will be described in more detail below. The two side pressure units 13, 14 are connected together by a vertically expandable hydraulic cylinder unit generally designated 15. The apparatus 12 as shown in FIG. 1 is in a contracted state, prior to testing and immediately after insertion into the borehole, although under normal conditions, the apparatus would be inserted to a greater depth than is illustrated in the drawing.

It has been found useful to house the apparatus in its contracted state in a cylindrical sleeve or shield 17 sized to slide along the wall 11 of the borehole 10 without obstruction and provided with a central upper reduced conduit 18 through which the various fluid pressure lines 19 and a support cable 20 are routed. The protective sleeve 17 is used to prevent nicking or gouging of the side wall of the borehole during insertion because of the gripping shape of the soil-engaging surfaces of the side pressure units 13, 14. Further, because of the shape of these soil-engaging surfaces, and the tolerances involved, the apparatus may have a tendency to get stuck during insertion prior to being lowered to the desired depth. In practice, the shield 17 may be a Shelby tube sampler used to form the borehole 10. For lowering into a deep or dirty hole, the side pressure units 13, 14 are expanded inside the hole-cutter a short distance, and the cutter and testing apparatus are then lowered to the desired depth in the hole. The side pressure units are then collapsed and the cutter may be withdrawn.

The upper and lower side pressure units 13, 14 are similar in structure and operation so that only one need

be discussed in further detail in order to understand the principle of the invention. Further, each of these units is similar to the expansion shear head described in the above-identified U.S. Patent, and additional details may be obtained by referring to that patent.

Referring then in particular to the upper side pressure unit or shear head 13, which is shown in vertical cross section taken through a plane extending in a direction of expansion, first and second side blocks are identified respectively by reference numerals 22 and 23. The blocks 22, 23 are slidably mounted on an upper horizontal shaft 24 by means of apertured bosses 25, 26 respectively. The supporting cable 20 may be connected to the shaft 24, as seen in FIG. 1.

The blocks 22, 23 are further provided with side shoes designated respectively 28 and 29 which are secured to the blocks 22, 23 by means of screws 30 and which provide an upper pair of soil gripper surfaces. A layer of sealing material 31 is interposed between each block and its associated shoe to form a fluid-tight seal for the cylinder bores, two of which are formed in the block 23 and designated 34 and 35, and two of which are formed in the block 22 and designated 36 and 37. A double-piston rod 38 has its piston heads received respectively in the bores 34 and 36, and a similar rod unit 39 has its pistons received respectively in the bores 35, 37. Each of these individual cylinder units provided by a single bore is a double-acting cylinder and piston rod unit, however, the fluid inlet and outlet conduits are illustrated only for the block 23 for clarity. Thus, a pressure line 40 is in fluid communication by means of a vertical conduit 41 bored in the block 23 with the working face of the right-hand pistons of the rod units 38, 39. A second fluid pressure line 43 is in fluid communication with the rod end of these two pistons by means of a similar bored conduit 44. Corresponding pressure conduits are provided for the left-hand pistons received in the bores 36, 37.

When pressurized fluid (either gas or liquid) is forced into the line 40, the two side units expand relative to each other; and when pressurized fluid is forced into the line 43, the two side units contract relative to each other.

The bores 41, 44 may extend completely through the block 23 and provided with couplings 47 and 48 on which are received flexible lines 49 and 50 which are routed to the right-hand block 50 of the lower shear head 14, the left-hand block thereof being designated by reference numeral 51. Each of the blocks 50, 51, then, are similarly provided with upper and lower double-acting cylinder and piston rod units wherein opposing bores are provided with a common rod, and they provide a lower pair of soil gripper surfaces.

The lower ends of the upper blocks 22, 23 are slidably received on a transverse shaft 53 in a manner similar to that already described in connection with the shaft 24. Similarly, the upper ends of the lower blocks 50, 51 are slidably received on a transverse shaft 54. The vertically expandable piston rod and cylinder unit 50 includes a rod 56 which extends upwardly from a piston head 57 and is threaded as at 58 for attachment to the lower portion of a ring mount 59 received on the shaft 53 and rotatable about the axis thereof. The cylinder of the unit 15 is provided with a similar mount 60 which is rotatably received on the shaft 54 supporting the lower side pressure unit 14. The unit 15 may also be a double-acting cylinder and piston rod unit in

which case pressure feed lines 65 and 66 are arranged to communicate pressurized fluid to the opposite faces of the piston 57 so that it may be selectively extended or retracted.

In order that these two lines do not get pinched when the side pressure units are contracted, a plate 68 may be welded to the upper right side block 23 and slidably connected to the left side block 22 by means of horizontal slots and bolts 69 (see FIG. 3).

Still referring to FIG. 3, the shoes 28, 29 are seen to have curved peripheries when viewed from above so as to conform to the side wall of the borehole in which a test is being conducted. When viewed from the side, however, these surfaces are serrated, as best seen in FIG. 2, to provide a series of ridges or teeth for better engagement with the soil.

When it is desired to know the separation of the side blocks 22, 23 or 50, 51, a linear variable differential transformer, as described in the above-identified patent may be mounted between each pair of blocks for establishing such measurement. Similarly, a linear variable differential transformer may be connected between the upper side pressure unit 13 and the cylinder of the vertically expandable cylinder and piston rod unit 15 to measure the separation between the upper and lower units 13, 14. Alternatively, the volume of fluid fed to the cylinder and piston rod unit 15 may be measured and, from this figure, displacement can be calculated, knowing the pertinent dimensions for the unit 15.

The operation of the above-described apparatus in performing shear tests similar to the test described in the above-identified patent, will now be briefly described. After a borehole is formed, for example, with a Shelby tube, the apparatus is fitted into the cylindrical sleeve 17 and lowered into the borehole 10 to a desired depth. The sleeve 17 is then retracted, after fully contracting the upper and lower side pressure units 13, 14, if this is necessary.

Next, pressurized fluid is admitted to the line 40 (one of the fluid coupling lines 19 of FIG. 1) to expand the upper and lower side pressure units 13, 14. These units are expanded to exert a predetermined normal pressure on the soil surrounding the borehole. The pressure on the soil may be calculated by measuring the pressure in the fluid urging the plates apart. The separation of the side blocks of each unit may be measured by means of linear variable differential transformers, mentioned above, if desired. After waiting a few minutes for the soil to consolidate, pressurized fluid is admitted to the line 66 to expand the hydraulic cylinder unit 15, thereby urging the upper and lower shear heads 13, 14 apart to shear the soil at either location or at both locations engaged by these shear-heads. The maximum shear force is determined by monitoring the pressure in the vertical expansion cylindrical 15. The normal pressure is increased and the quick shear force again measured to develop a relationship between quick shear and normal pressure from which internal friction angle ϕ and cohesion, c , are determined.

Having thus described in detail an embodiment of the present invention, persons skilled in the art will be able to modify certain of the structure that has been illustrated and to substitute equivalent elements for those which have been disclosed while continuing to practice the principle of the invention; and it is, therefore, intended that all such modifications and substitutions be

5

covered as they are embraced within the spirit and scope of the appended claims.

I claim:

1. Apparatus for use in measuring properties of soil in a borehole comprising: upper and lower laterally expandable side fluid-actuated pressure units, each unit including first and second soil-engaging surfaces of fixed area conforming to opposite portions of said borehole and fluid pressure means for selectively moving said surfaces apart to engage said soil at opposite locations in said borehole to apply a predetermined normal pressure thereto; and a vertically expandable fluid pressure unit interconnecting said upper and lower units and being selectively actuatable to urge said upper and lower units relative to each other; whereby a relationship between normal pressure developed by the side pressure units and quick shear force developed by the vertically expandable unit may be developed.

2. The system of claim 1 further comprising cylindrical shield means for covering said apparatus when said apparatus is lowered into a borehole and adapted to be selectively withdrawn to expose said upper and lower units to engage the soil after removal of said shield.

3. The system of claim 1 wherein said vertically expandable means includes a piston rod and cylinder unit, said system further comprising means for connecting one movable portion of said piston rod and cylinder unit to both side sections of said upper side pressure unit while permitting lateral expansion thereof, and means for connecting the other movable portion of said piston rod and cylinder unit to both side sections of said lower side pressure unit while permitting the side sections thereof to move freely sideways.

4. The system of claim 1 wherein each of said upper

6

and lower side pressure units includes fluid pressure means for selectively urging the two side sections thereof in a contracted or expanded condition, said system further comprising flexible fluid coupling means for coupling the expansion fluid of said upper side pressure unit to said lower side pressure unit.

5. Borehole testing apparatus comprising: upper and lower laterally expandable side pressure units, each unit including first and second side sections; means for mounting said side sections together while permitting lateral expansion and contraction thereof, each side section being provided with a soil-engaging surface; a piston rod and cylinder unit having first and second relatively movable portions, one portion being connected to said upper side pressure unit and the other portion being connected to said lower side pressure unit; and fluid pressure means for selectively expanding or contracting the side sections of said upper and lower side pressure units in unison to apply a measurable normal pressure in said borehole, whereby said side pressure units may first be expanded to exert a predetermined normal pressure at a location in said borehole, and said piston rod and cylinder unit may then be actuated to urge said side pressure units relative to one another to exert a shearing force on the consolidated soil at said location of said borehole.

6. The apparatus of claim 5 further comprising means for measuring the fluid pressure in said cylinder and piston rod unit which pressure is representative of shear force.

7. The system of claim 5 wherein said piston rod and cylinder unit is arranged to force said upper and lower side pressure units apart during test.

* * * * *

35

40

45

50

55

60

65