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[54] **SOIL TESTING APPARATUS AND METHOD**

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[52] **U.S. Cl.** **73/84,** 73/101
[51] **Int. Cl.** **G01n 33/24**
[58] **Field of Search** 73/84, 101

[56] **References Cited**

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[57] **ABSTRACT**

The method and apparatus of this invention relates to the measuring of the in-place static friction of soils. It consists of driving a flat or planar test plate into the soil; extracting the test plate and recording the maximum force required to effect extraction. The test plate is removably connected to a driving rod, which embeds it down in the soil. The driving rod is removed, and the test plate is then extracted by a cable secured thereto. The maximum extraction force is a measure of the in-place static friction of the soil. The test plate is temporarily connected to the driving rod by a line which breaks readily upon separation of the driving rod from the test plate.

7 Claims, 9 Drawing Figures

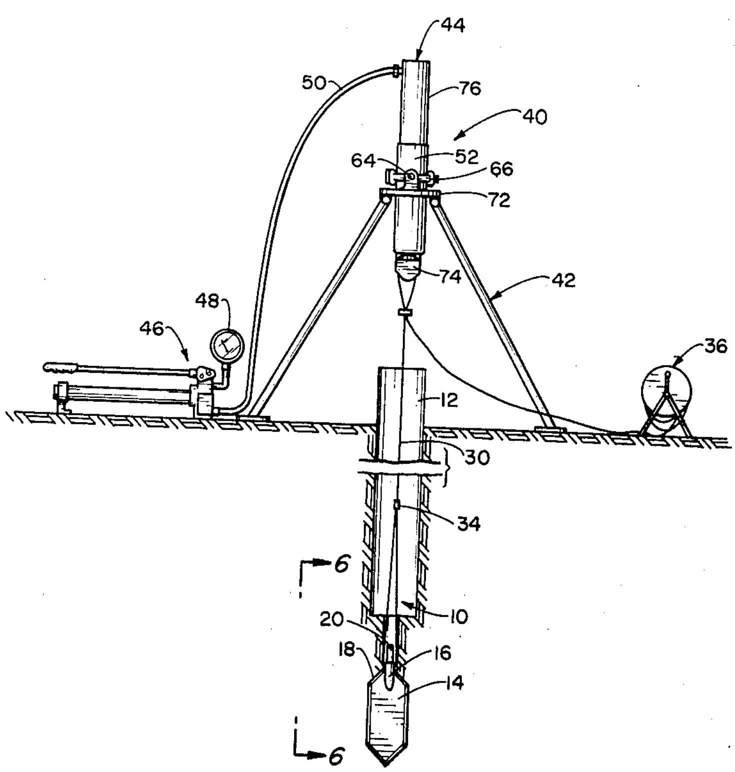


Fig. 1.

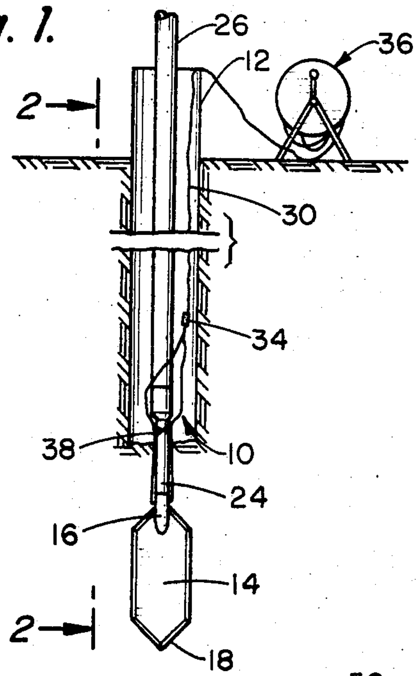


Fig. 2.

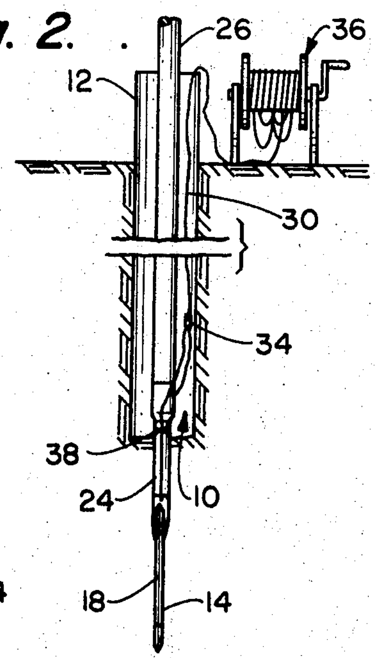


Fig. 3.

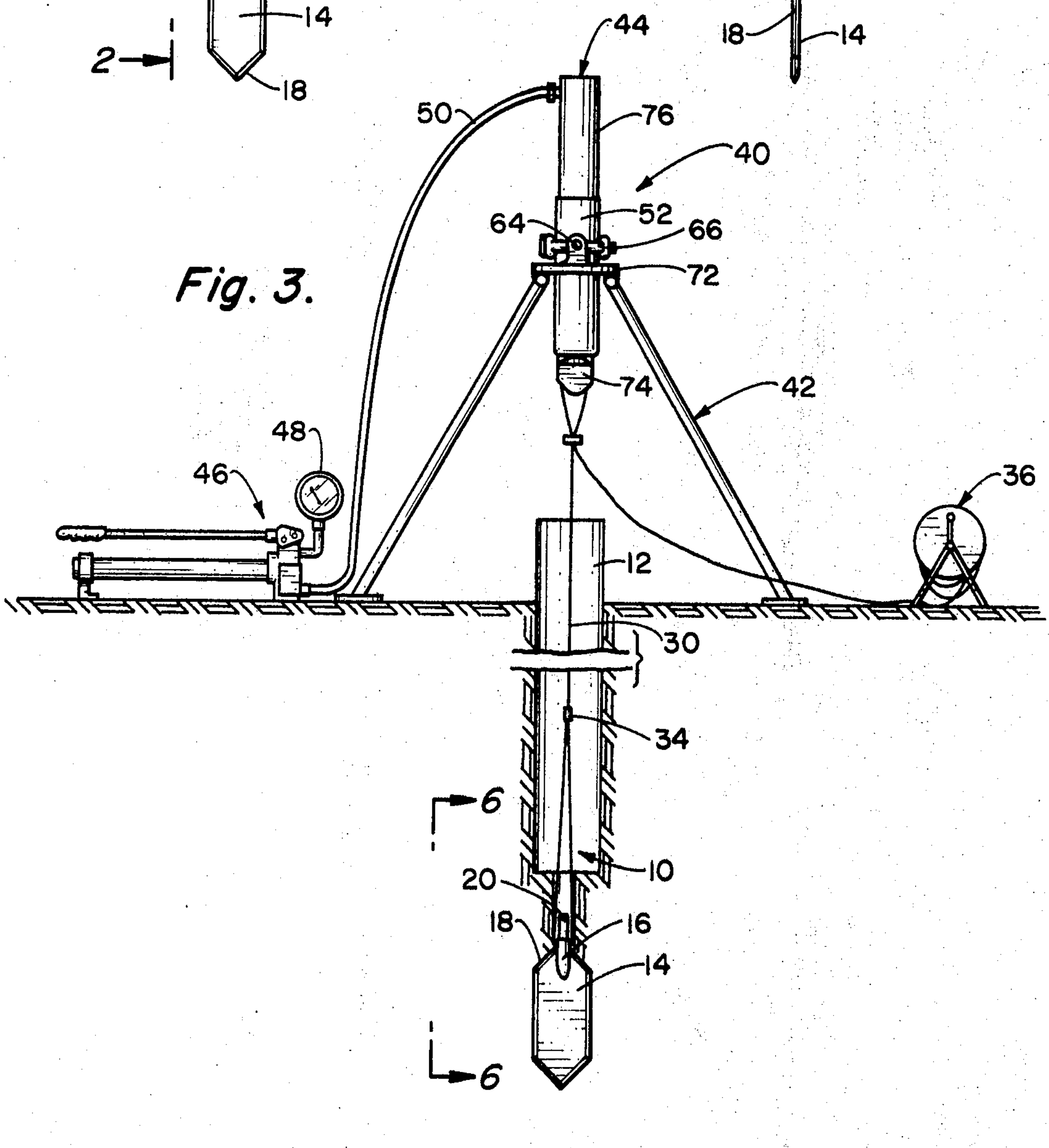


Fig. 4.

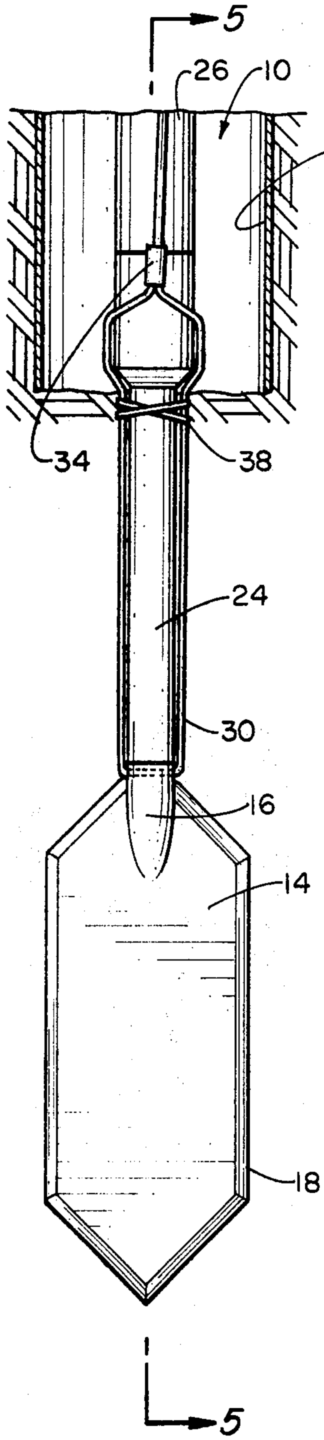


Fig. 5.

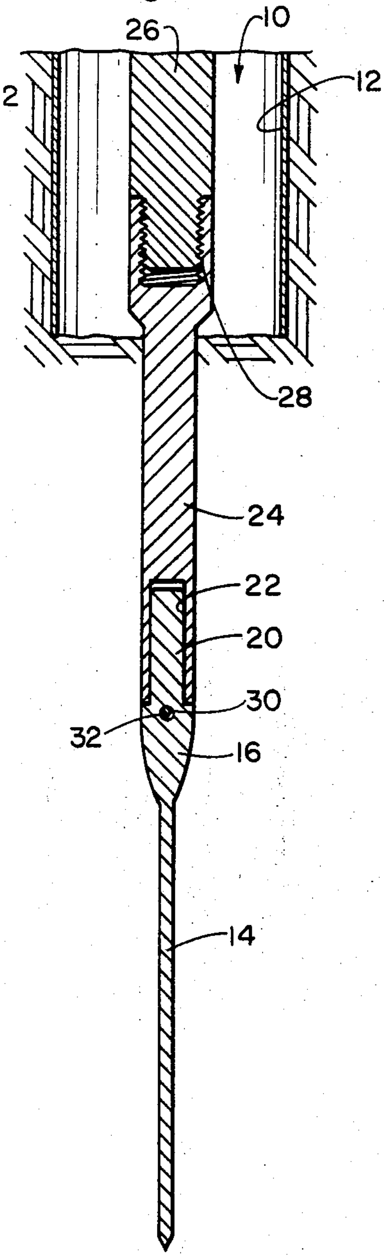


Fig. 6.

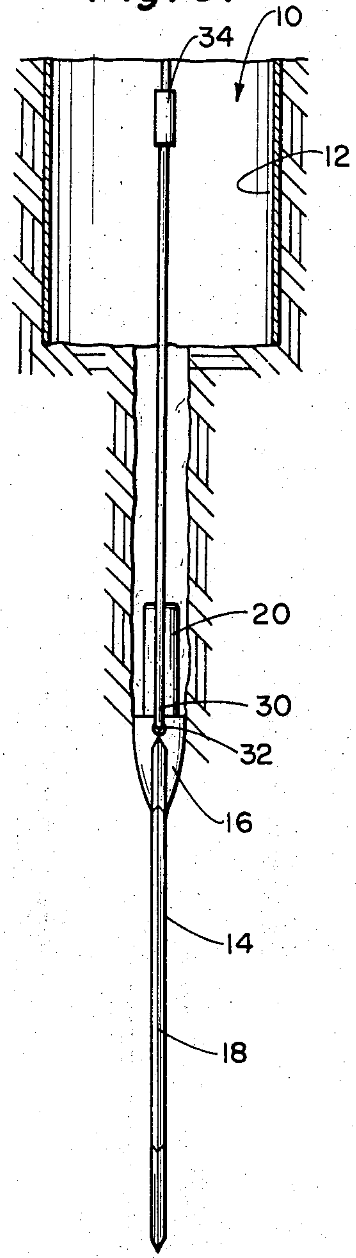


Fig. 7.

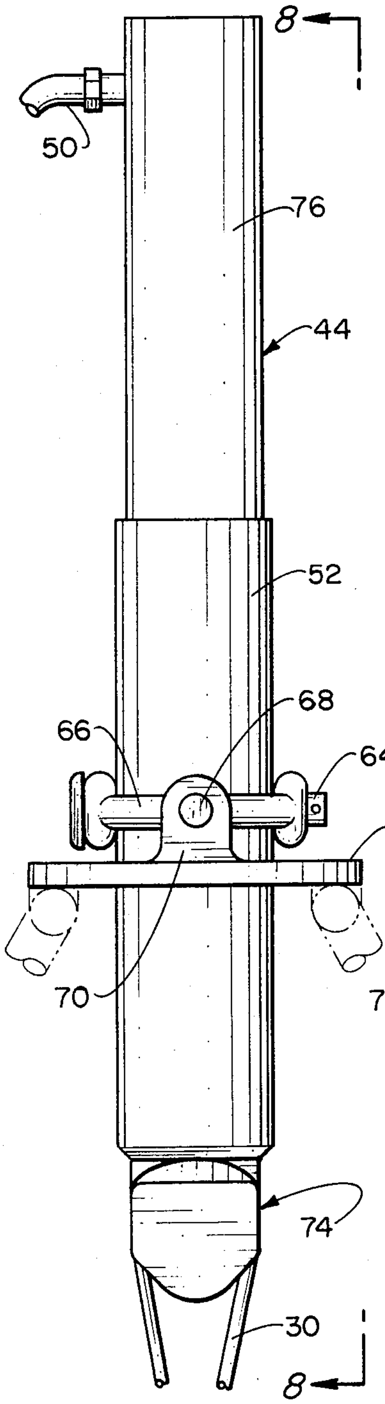


Fig. 8.

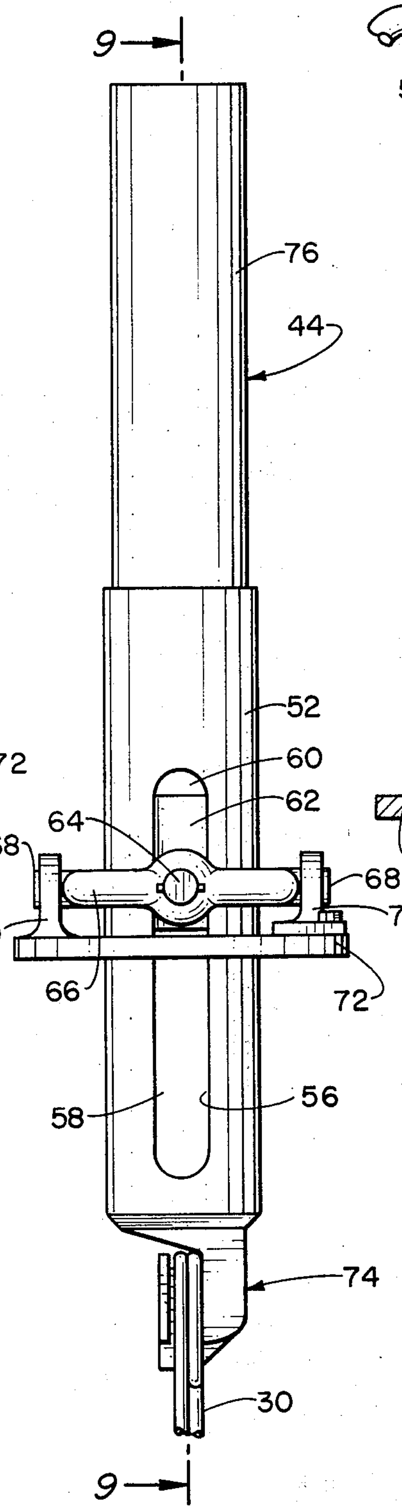
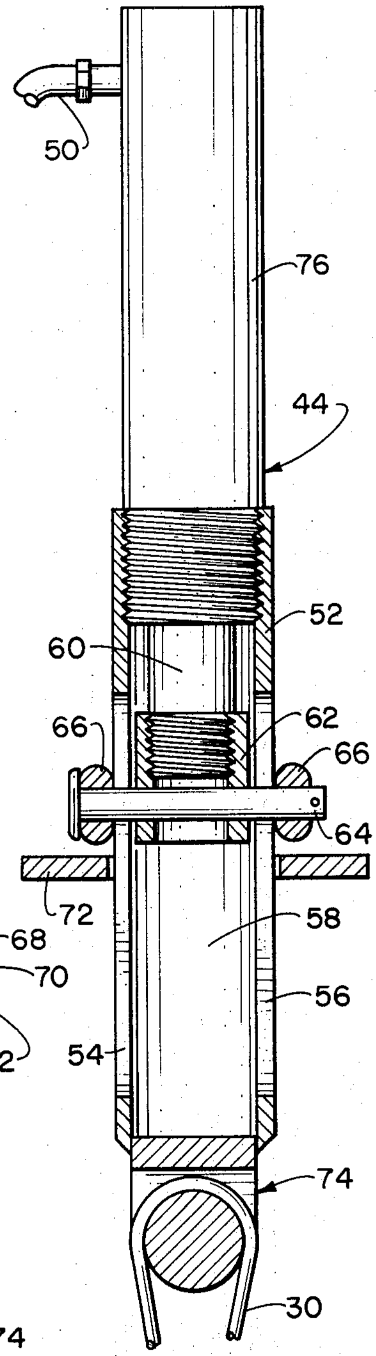


Fig. 9.



SOIL TESTING APPARATUS AND METHOD

BACKGROUND OF THE INVENTION

This invention relates generally to the field of determining friction pile capacities and more particularly to the determination of friction pile capacities by static analysis of the soil into which the pile is to be driven.

In the building of any structures upon the soil it is normal for foundation studies to be performed upon the soil. The reason for these foundation studies is to predict the load carrying capacity of a friction pile that is to be installed within the soil strata. The normal procedure is to advance a hole, either cased or uncased, in the soil strata. It is common to make certain tests of the soil as the hole is advanced through the soil. It is the objective of these tests to obtain knowledge of the soil conditions at various depths of the hole. In order to extract soil samples from the hole a standard drill rod is normally employed of a diameter of 1⅝ inches or larger. This drill rod is made up of a series of segments which are to be formed into a "string" and progressively lowered to greater and greater depths. Various types of soil sampling devices are attached to the lower end of the standard drill rod to take the soil sample at the bottom of the hole.

One way to avoid the driving of test piles is to employ some means to determine the capacity of the soil by measuring the frictional resistance of the soil. There have been known for a substantial period of time apparatuses which measure the frictional resistance of soil. One form of such previously known apparatuses relates to the driving of a rod into the soil, then extracting the rod and then measuring the force required to effect such extraction. However, rods exhibit a rather small area in contact with the soil and also the displacement volume and effect is great in proportion to the surface area. Therefore, a series of tests are performed in a given area with a rod type of measuring indicator with the test results averaged. It has been found that the results of such tests will vary widely, and there is no guarantee that even an average figure represents a true value of the frictional resistance of the soil.

Previously known forms of apparatus to measure the frictional resistance of the soil have not been designed to measure directly the static frictional resistance between the soil layer and a non-displacement smooth steel surface. The apparatuses of the prior art have been more concerned with measuring the internal friction or the shear strength of the soil instead of correctly measuring the in-place static friction. Surface friction is a main factor in predicting pile load capacity.

SUMMARY OF THE INVENTION

The method of this invention involves the embedding of a substantially flat or planar test plate about 16 inches below the bottom of a drill hole, by a driving rod which forces it down. Force from the driving rod is transmitted to the test plate by an adaptor shaft threaded onto the rod which presses the test plate down. Extraction of the test plate is accomplished by means of a hydraulic jack which is connected to a cable secured to the plate. During the inserting of the test plate down the drill hole, it is temporarily held to the adapter shaft by a rubber band, string, thin wire, or the like. After the test plate has been embedded into the soil, the driving rod is removed, fracturing the securing band. The test plate is then removed by pulling up the extraction cable. The maximum removal force is measured and recorded by an appropriate measuring apparatus; it represents the in-place static friction between the soil and a non-displacement smooth steel surface.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is a diagrammatic view of the apparatus of this invention showing the driving rod which embeds the test plate within the soil;

FIG. 2 is a side view of the apparatus of this invention taken along line 2—2 of FIG. 1;

FIG. 3 is a diagrammatic view showing a means to effect extraction of the test plate and the structure to measure the force required to effect such extraction;

FIG. 4 is an enlarged view of the test plate showing in more detail the connection between the test plate and the driving rod;

FIG. 5 is a cross-sectional view taken along line 5—5 of FIG. 4;

FIG. 6 is an edge view of the test plate during removal, taken along the same line as FIG. 2;

FIG. 7 is an enlarged view of one form of hydraulic jack which may be used to effect extraction of the test plate;

FIG. 8 is a side view of the hydraulic jack taken along line 8—8 of FIG. 7; and

FIG. 9 is a cross-sectional view of the hydraulic jack taken along line 9—9 of FIG. 8.

DETAILED DESCRIPTION OF THE SHOWN EMBODIMENT

The method and apparatus of this invention is found to be particularly adapted to the testing of the soil located at the bottom of a deep drill hole **10**. A casing **12** may be included within the hole but is not requisite to this invention.

The apparatus of this invention employs a substantially flat or planar test plate **14** having an integral upstanding connecting end **16**. Around the periphery of the plate **14** is a sharpened edge **18**. The edge **18** facilitates the embedding of the test plate **14** within the soil and enhances the non-displacement character of the test. The plate **14** is of steel about one-fourth of an inch in thickness. Approximately 50 square inches has been found to be a good effective surface area.

The connecting end **16** is ensmalled to an upstanding stud **20**, which mates in a sliding fit with a socket **22** formed in a short adaptor shaft or member **24**. In use, shaft **24** is a part of the driving rod assembly which also includes the conventional driving rod **26**, which forms no specific part of this invention. The driving rod **26** is threaded at **28** onto the connecting member **24**.

In order to extract the plate **24** after it is embedded, a cable **30** is attached to the plate **14** by being passed through aperture **32** located through the connecting end **16**. The end of the cable **30**, after being passed through the aperture **32**, is looped back onto itself and secured by a clamp **34**. The cable **30** is fed from a source such as a reel **36** which is located at the top of the hole **10**.

In lowering the test plate **14** to the bottom of the hole **10**, some means is desirable to secure the plate **14** to the driving rod assembly, because the stud **20** is free to slide from the socket **22**. Thus a band **38** is wrapped around the shaft **24** and the cable **30,** sufficiently tight to prevent the test plate **14** from dropping off the shaft **24** during the lowering operation. The band **38** can take any of numerous forms such as a rubber band, a string, a thin wire, a band of material, fabric, thin cable, or any other similar devices. After the test plate **14** is embedded within the soil, the band **38** readily fails or slips off to permit free release of the driving rod assembly from the test plate **14.**

The embedding procedure is accomplished in a conventional manner, by simply pushing or driving by any means the test plate **14** into the soil by means of the rod **26** and shaft **24.** The test plate **14** is preferably embedded into the soil about 16 inches. Up to this particular moment, the cable **30** remains loose, being merely paid out from the reel **36.**

After the plate **14** is embedded, the driving rod **26** and its connected shaft member **24** are lifted and removed from the hole. It slips off the connecting end **16** with very little resistance, as the band **38** fails or slips off. As a result the plate **14** is left embedded within the soil in an undisturbed manner with the attached cable **30** hanging loosely from the reel **36.**

The test is then performed by measuring the maximum force developed in the cable **30** during the extraction of the plate **14** from the soil. This extracting force is preferably supplied by a simple pull type hydraulic system assembly, the maximum hydraulic pressure developed within the assembly during the extracting operation being in turn a measure of a maximum force required. The maximum pressure is determined in conventional fashion by a maximum reading needle on a hydraulic gauge which measures the pressure in the hydraulic apparatus.

In case a pull type or tension jack is not available the more widely used push or compression type jack may be readily adapted to this function by the technique illustrated in FIGS. **3, 7, 8** and **9.**

This hydraulic ram assembly **40** includes a tripod **42** mounted over the hole **10,** a hydraulic jack **44,** a source of hydraulic fluid (not shown) and a pumping apparatus **46.** A pressure gauge **48** is connected to the pumping apparatus and is adapted to register the pressure required to effect withdrawl of the test plate **14.** The pressure gauge reading may be empirically converted to a force reading and divided by the surface area of the plate to obtain the unit value of frictional resistance. However, time will be saved and errors avoided if the face of the dial on the pressure gauge **48** reads directly in tons per square foot.

The pumping apparatus **46** is shown as a conventional hand operated pump. However, any other conventional type of pumping apparatus may be employed. The hydraulic fluid from the pumping apparatus **46** is conducted through conduit **50** to the jack **44.** As noted, the jack **44** may comprise either a pull type or the more common push type (which exerts a compression force) as shown specifically in the drawings, FIGS. **3, 7, 8** and **9.** This push type has here been converted to apply a pulling force on the cable **30.**

Although, as noted, a hydraulic jack of the pull type is preferred, the push type is more readily available, and is here depicted. It is to be understood that the structure depicted in the FIGS. **3, 7, 8** and **9** is to be considered an alternate to the preferred pull type.

It is believed to not be necessary to go into explicit detail of the construction of the compression jack **44** (push type) as such jacks are extremely common. The cylinder **76** of the jack **44** is screwed in to a sleeve **52,** which includes a pair of diametrically located longitudinal slots **54** and **56.**

Plunger **60,** which is connected to the piston (not shown) of the jack **44,** is screwed into a short connecting sleeve **62** which operates within the chamber **58** forming the interior of sleeve **52.** The connecting sleeve **62** has a pair of aligned openings therein which receive a diametric pin **64.** The length of the slots **54** and **56** matches the full length of travel of plunger **60.**

The pin **64** spans a ring **66,** which encircles the sleeve **52.** Ring **66** has a pair of trunnions **68** located diametrically opposite each other and transverse of the pin **64.** The trunnions **66** are pivotally mounted, through posts **70,** to a base ring **72.** The base ring **74** is pivotally connected to the upper ends of the legs of the tripod **42.**

Thus, a universal connection is established between plunger **60** and the tripod **42,** which permits the jack **44** to self align itself with cable **30** as force is applied to extract the test plate **14.**

A hook **74** is fixedly secured to the free lower end of the sleeve **52,** and receives a loop formed at the upper end of the cable **30.**

When a pull type of hydraulic jack is employed, it is simply suspended by universal joint from the head of the tripod **52,** and the operating pull member is connected to the cable **30.**

As the hydraulic fluid is pumped by the pumping apparatus **46** through conduit **50** into the jack **44,** the plunger **60** moves downward with respect to the cylinder **76.**

However, since the plunger **60** is supported by the fixed tripod **42,** the net result is that the cylinder **76** and sleeve **52** move upward, tensioning the cable **30** and extracting the plate **14.** The force developed is indicated on the pressure gauge **58.** A maximum reading needle on gauge **58** records the maximum pressure and hence the maximum extraction force. The invention thus obtains the in-place static friction between a smooth steel plate and each soil layer. The plate **14** is designed to be installed in each soil layer and tested in a similar manner to that commonly done through soil sampling in other known penetration tests. One distinction of the method of this invention is that the drill rod **26** is removed prior to extraction of the test plate **14.**

The apparatus and method of this invention provides for the obtaining of most accurate results to predict the load carrying capacity of a friction pile to be installed within the soil strata. The apparatus and method of this invention eliminates virtually all variables and sources of error by measuring directly only the static frictional resistance of each soil layer acting on the surface of a steel plate when the plate is subject to the static load. The method and apparatus of this invention may be easily and accurately accomplished even at the great depth to which soil borings may be carried out. The plate **14** of this invention, being relatively thin with sharp edges, measures practically pure friction on its flat surfaces with the displacement effect and disturbance to the natural soil density being so small as to be negligible. The results are therefore directly applicable to any non-displacement pile of any size or shape having a smooth surface in contact with the soil. Therefore, all variables inherent in the pile type (size, shape, method of installation and material composition) are eliminated, and only the actual soil conditions at a given depth and location are measured.

There are pile type coefficients or correction factors available to convert the values obtained by this invention to other types of piles, materials, effects when displacement driven, and other variables. Given the soil static friction values which are obtained by the method and apparatus of this invention and the available pile type correction factor or factors, the static load carrying capacity of any pile installed in the investigated soil strata may be calculated with a high probability of certainty. This invention decreases the full scale load testing of piles, by reducing the number of tests necessary or completely eliminating the need for them in certain instances. Therefore, more accurate and reliable prediction of pile load capacity or required pile length to develop a given pile load is accomplished.

A further advantage of the present invention is that because of its simplicity, accurate readings can be rapidly obtained. After the plate **14** is embedded into the soil and the drill rod **26** has been removed, the placement for the hydraulic jack on the tripod **42** over the hole, the looping of the cable **30** and the manual pumping of the pumping apparatus **46** are all done easily and quickly with no disturbance to other equipment located around the hole. The maximum load resistance will be automatically determined by a maximum reading indicator pointer on the face of pressure gauge **48.** The measured load will be a pure static force with no eccentricity or other secondary sources of error regardless of depth.

The load capacity of the apparatus of this invention need not be more than about one-quarter ton, since the highest value of unit friction encountered in various soils is not likely to exceed 7½ tons per square meter.

What is claimed is:

1. The method of measuring the frictional resistance of soil at the bottom of a hole comprising:
- providing a substantially flat test plate;
- attaching an extraction cable to the test plate;
- providing a driving rod;
- temporarily securing together the test plate and the driving rod to thereby prevent disassociation by gravity of the test plate from the driving rod while being lowered into the hole;
- applying a compressive force to the driving rod to embed the test plate in the soil at the bottom of the hole;
- extracting the driving rod and causing release of the test plate from the driving rod;
- extracting the test plate from the soil, and
- measuring the maximum extraction force required to extract the test plate from the soil.

2. The process of determining the in-place static friction of a soil stratum comprising:
- drilling a hole into the soil stratum;
- passing a substantially flat test plate down the hole into the soil stratum;
- providing a driving rod;
- embedding the plate into the stratum by means of the driving rod;
- removing the driving rod;
- extracting the test plate from the soil stratum; and
- measuring the maximum extraction force required during the extraction of the test plate from the soil stratum.

3. Apparatus for measuring in-place static friction of soil strata comprising:
- a substantially flat test plate adapted to be injected into the soil strata;
- a drive rod releasably connected to said test plate for driving said test plate into the soil strata;
- means for removing the drive rod from the test plate while leaving the test plate embedded in the strata;
- a cable secured to said test plate;
- tensioning means connected to the cable for exerting tension on said cable to extract said test plate from the strata; and
- means coupled to the tensioning means for measuring the maximum tension developed in said cable during the extraction of said test plate, thereby to measure the maximum extraction force required to extract said test plate from the strata.

4. Apparatus in accordance with claim **3** wherein said tensioning means comprises a hydraulic jack; and said tension measuring means comprising means for measuring the maximum hydraulic pressure developed in said jack during the extraction of said test plate.

5. Apparatus for predicting the load carrying capacity of a friction pile in a soil strata, said apparatus comprising:
- a flat test plate having an integral upstanding connecting end;
- a driving rod;
- an adapter shaft connected to one end of said driving rod in coaxial relationship therewith and slidably receiving said connecting end of said flat test plate to position said test plate in axial alignment with said driving rod and said adapter shaft;
- means for introducing an embedding force through said driving rod to said test plate to embed said plate a predetermined distance within the soil strata;
- releasable securing means attaching said connecting end of said test plate to said adapter shaft to permit said drive rod and said adapter shaft to be lifted and removed from the test plate without affecting the position of said test plate;
- a cable attached to said test plate for extracting said test plate from the soil strata;
- extraction means connected to said cable to extract the test plate from the soil strata; and
- means coupled to said extraction means to measure the maximum force deveoped by the cable during the extraction of the test plate.

6. The apparatus defined in claim **5,** in which said test plate is composed of steel.

7. The apparatus defined in claim **6,** in which said test plate has a sharpened peripheral edge to facilitate the embedding of the test plate in the soil strata.

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