Sept. 15, 1964 P. S. HEEREMA 3,148,538

SOIL PENETRATION AND FRICTION RESISTANCE MEASURING APPARATUS

Filed Dec. 7, 1960 2 Sheets-Sheet 1

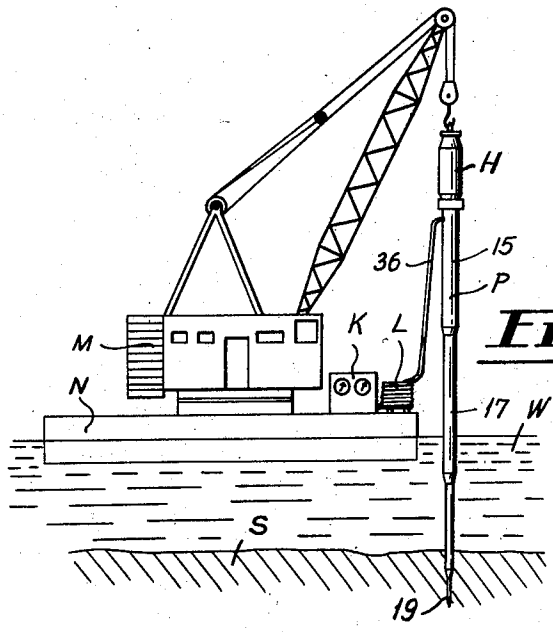


Fig. 1

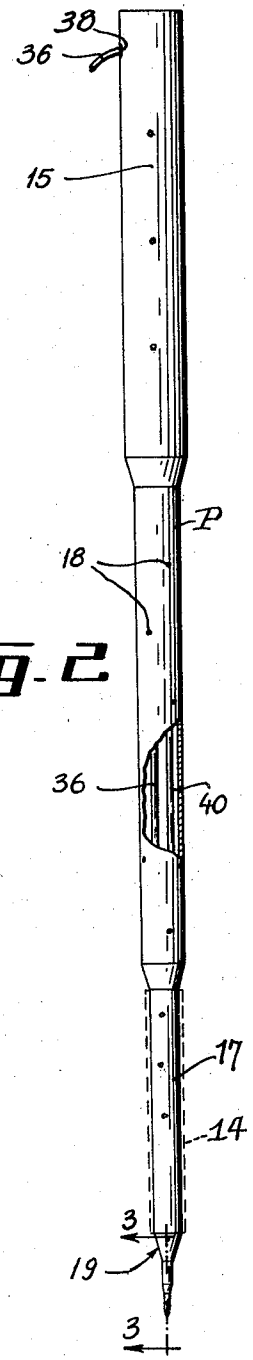


Fig. 2

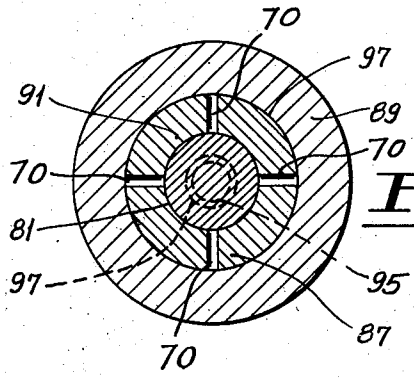


Fig. 5

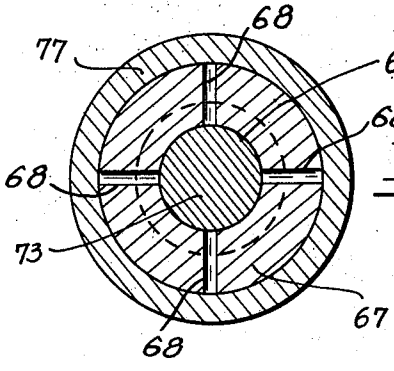


Fig. 4

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SOIL PENETRATION AND FRICTION RESISTANCE MEASURING APPARATUS

Filed Dec. 7, 1960 2 Sheets-Sheet 2

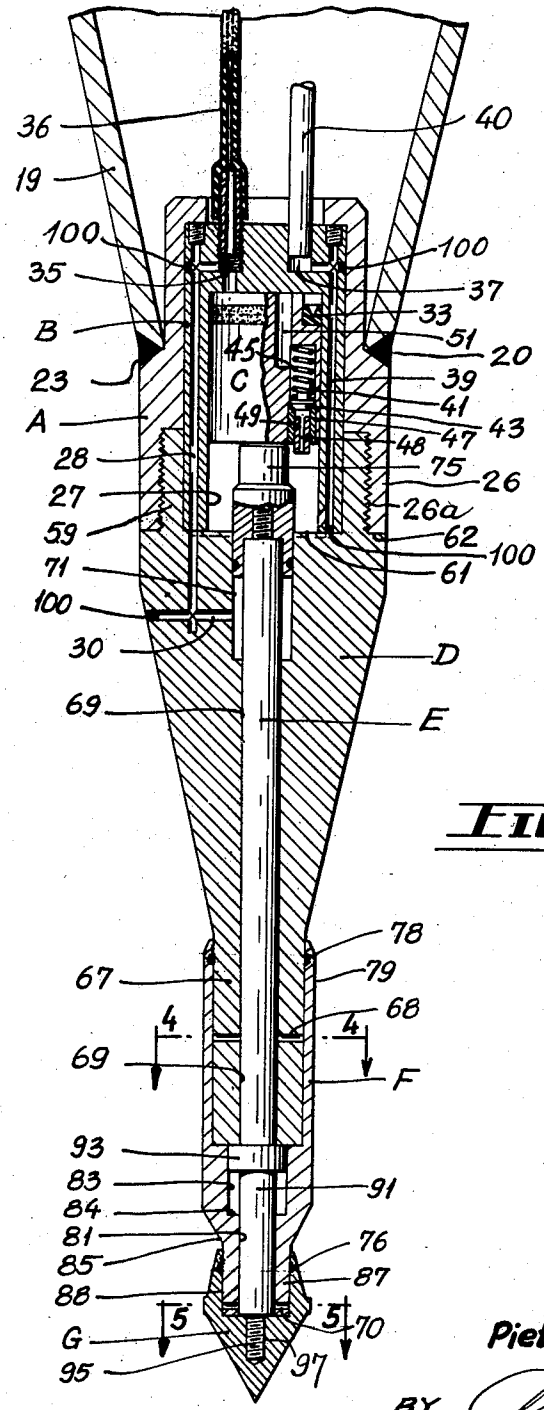


Fig. 3

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SOIL PENETRATION AND FRICTION RESISTANCE MEASURING APPARATUS

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5 Claims. (Cl. 73—84)

This invention relates to an apparatus for subsoil investigation, particularly for the predetermination of suitable pile lengths and the prediction of permissible pile loads.

One way of predetermining pile lengths on a pile driving job is to drive test piles in advance. In the case of a concrete pile job, an elaborate set-up is necessary before the commencement of the permanent pile driving. Therefore, steel index piles are sometimes driven and a correlation established, which enables the designer to estimate the proper length of the permanent concrete piles. Such an index gives rather crude results in that it supplies no data on subsoil conditions below its point. And, its driving record may lead to recording the presence of non-existent hard layers. Furthermore, a long steel index pile can absorb so much driving energy and build up so much friction over its length, that the large number of blows per foot to drive it may give the false impression that a hard layer has been reached.

A better expedient is the so-called "Dutch Cone Penetration Method," particularly when the cone used is provided with a soil friction measuring device, or sleeve. Pressures are measured hydraulically, through a device located at the top of the column. The column is gradually lengthened by coupling additional lengths as the cone is forced down hydraulically. However, a sure footing must be provided for the instruments. For example, in deep water, a strong platform must be constructed usually over already driven piles. The limit of penetration capacity, usually about ten tons, is soon reached. Then, further penetration is only possible with the aid of drilling, jetting, or percussion installations. This method is, therefore, extremely time-consuming and costly in deep water regions, where deep penetration into hard layers is necessary.

The Applicant's Development

The applicant has now evolved an apparatus which combines the speed and ease of the driving of a steel index pile with the information that the slow and costly penetration test provides. The applicant employs a drivable metallic index pile of normal pile size which is provided, at its tip, with a sleeve movable relative to the pile and a cone further movable relative to the sleeve. Hydraulic means is built into the tip of the pile to advance the cone and the sleeve. Pressure lines running up through the pile connect this hydraulic means with a hydraulic pump. Manometers are conveniently placed so that the observer can make two readings—the first indicating the pressure required to move the cone, and the second indicating the pressure needed to move the cone and the sleeve. The first reading provides data on the resistance of the soil. The second reading indicates the pressure needed to move the cone and sleeve, thus providing a basis for calculating friction of the soil. Means is provided for relieving the pressure when the cone and sleeve have moved a predetermined distance, when driving the pile may be resumed.

Having thus generally described the nature of the invention it will be referred to in more detail by reference to the accompanying drawings illustrating preferred embodiments, and in which

FIGURE 1 is a perspective view of a pile driving set-up showing a cone pile according to the invention in the process of being driven.

FIGURE 2 is a side elevation partly broken away, illustrating a test pile according to the invention.

FIGURE 3 is a cross-section along the line 3—3 of FIGURE 2 on a greatly enlarged scale showing the tip portion of the test pile.

FIGURE 4 is a cross-section as along the line 4—4 of FIGURE 3.

FIGURE 5 is a cross-section as along the line 5—5 of FIGURE 3.

Referring more particularly to FIGURE 1 of the drawings, a pile driving installation employing the applicant's test cone is illustrated. A pile driver M having a pile driving hammer H is mounted on a suitable base N, in this case, a floating base on water W overlying a soil bed S. The pile driver M is shown in the process of driving a test pile P, according to the invention. The preferred pile illustrated is a hollow steel pile P having a main body portion 15 and an end portion 17 of reduced diameter. The body of the pile is preferably provided with openings 18 extending from the wall to its bore to allow water to enter freely so as to equalize the pressure inside and outside the pile. The end of the reduced portion 17 is provided with a frustroconical hollow head 19. Mounted within the end of the hollow head 19 is a sleeve A provided with an annular outstanding shoulder portion 23 which abuts the annular end of the head 19 and is welded to it as at 20. Within the sleeve A is mounted a cylindrical housing B including a cylinder 27 housing a piston C. The piston is provided with an annular packing ring 33.

The housing B is provided with a boring 35 constituting an hydraulic fluid inlet and with a boring 37 constituting an hydraulic fluid outlet. A passage 39 in the wall of the housing B leads from the outlet 37 to the foot of the chamber 27. The piston 29 is provided with a valve chamber 41, housing a release valve assembly including a plug 43 urged into closed position by a spring 45. The plug 43 seats on a valve seat 47 screwed into the tapped lower end of the chamber 41 and having an orifice 48. The valve plug 43 is provided with an orificed tip 49 which normally projects through the orifice 48 beyond the sleeve 47. A passage 51 in the body of the piston C leads from its upper face to communication with the chamber 41.

The housing A has a downwardly extending skirt 26 offset from the lower end of the housing B and internally threaded as at 26*a* to receive the externally threaded collar portion 59 of a tapered tip member D. The inner surface of the collar portion 59 embraces the outer wall of the housing B. The tip member D has shoulders 61 and 62 to either side of the collar portion 59 respectively abutting the lower ends of the sleeve A and housing B respectively. The tip D is provided with a cylindrical bore 69 extending axially through it and having an enlarged upper portion 71 leading from the cylinder 27.

Operating within the bore 69 and its enlarged portion 71 is a piston E having a head 75. The tip member D has a cylindrical shank 67. A sleeve F has a cylindrical portion 79 engaging the outside of the shank 67. The sleeve F has a bore 81 with an enlarged upper portion 83 in communication with the bore 69 of the tip D. The sleeve F is adapted for axial movement relative to the shank 67. The lower end of the member F is tapered as at 85 to meet a cylindrical end portion 87. On the end portion 87 is mounted a cone G having a cylindrical bore 88 slidably receiving the end portion 87. The cone G is connected to a lower portion 91 of the piston E operating in the bore 81 of the sleeve 77. A flange 93 is provided on the piston E as shown slidable in the enlarged part 83 of the bore. The part 91 of the piston

E is connected to the cone G by a projecting screw portion **95** wich threadably engages a tapped bore **97** in the cone G.

Hydraulic pressure is supplied to the inlet **35** through a flexible tube **36**. This tube can be made of rubber or plastic material with a very thick wall and a small orifice to carry oil. The tube **36** leads through the bore of the hollow pile F and out through an opening **38** in the top of the pile and, from there down to where it is rolled in a coil L, and then from the coil to the hydraulic pump K. The outlet **37** may be connected to a similar exhaust line **40** which extends upward through the bore of the pile P, to above water level, or this line **40** may be omitted and escaping oil, escaping from the outlet **31** allowed to enter the water which fills the interior of the pile P.

The soil at test level is usually under great pressure and tends to force itself in between the moving surfaces. The testing apparatus of the invention is therefore provided with a pressure equalizing system which will now be described in conjunction with other means for preventing ingress of soil into the working parts of the device. For example, the foot **67** is provided with several channels **68** leading through it from the bore **69** to the outer surface of the foot **67**. Likewise, the lower end of the sleeve F is provided with channels **70** leading from the bore **81** to the outer surface. The housing B is provided with a channel **28** leading from the inlet **35** to the channel **30**, which, in turn, leads to the chamber **71**. These borings are straight line borings as indicated and provided where necessary with plugs **100** to close off access ports used in making the borings. The purpose of the channels **68** and **70** is to equalize the pressure on the inside of the cone bore **88** and all the way up through the bores **83**, **69**, etc. This helps to prevent the ingress of soil between the cone and the foot **87** and between the sleeve F and the foot **67**.

In addition, a gasket **76** is held in a groove on the inner wall of the cone G to act between the cone G and the foot **88** and between the sleeve F and the foot **67**. A gasket **78** is provided in a groove in the inner wall of the sleeve F to act between the sleeve F and the foot **67**. These gaskets help to block the soil attempting to enter between the relatively moving surfaces of the cone G and foot **88** and of the sleeve F and the foot **67**.

Operation

In operation, the pile F is driven by the hammer H of the pile driver in the same way as a permanent pile, until its lower end reaches a depth where readings of the soil resistance and the friction are needed. At this point, driving is interrupted and hydraulic pressure is applied against the piston C by feeding oil into the chamber **27** through the fluid entrance **35** from the hydraulic system. This forces the piston C in a downward direction. The piston C in turn pushes the piston E downwards and thus the cone G to the point where the flange **93** contacts the shoulder **84** of the sleeve F. At this point a reading is taken of the pressure that has been required to move the sleeve F and the cone G. Then, hydraulic pressure is again applied to the piston C which continues to depress the piston E which depresses the sleeve G to a point where the finger **49** of the valve **43** contacts the face **61**, thus releasing the pressure in the cylinder **27**. At this point, a further reading is taken of the pressure that has been required to move the cone G alone.

From the respective readings, namely (*a*) that taken at the moment where the cone G is fully depressed on the sleeve F, and (*b*) at the moment where the sleeve F is fully depressed, there can be calculated the resistance of the soil to the penetration of the cone and the resistance of the cone plus the sleeve respectively. Appropriate further calculation gives the resistance of the soil and the frictional resistance to the advance of the cone and sleeve.

When the sleeve or sleeve end cone are being thrust into the soil by hydraulic pressure, any upward movement of the pile P is prevented by the frictional resistance of the soil acting on the pile.

Cone and frictional readings can be alternated with pile driving and taken at any required depth and interval. The number of strokes per foot, cone resistance, and friction of the soil may thus be determined. After the required depth is reached and all readings have been taken, the index pile with test assembly can be withdrawn and used at other locations. The equipment of the pile with the slip cover **14** permits removal of the index pile from deep penetration.

The cone and sleeve are designed in such a way that they resist the hardest pile driving into very compact soil layers, without damage, bending, buckling or fine soil entering into and jamming the device.

For penetration into extremely hard soil, special alloy steels are employed for the parts of the pile. A preferred cone has a projected area of 25 square centimeters, and an angle of 60° from the axis. The sleeve embraces a cross-sectional area of 250 square centimeters. A suitable index pile is a thick walled steel pipe eight inches to fourteen inches outside diameter, gradually increasing into bigger diameters of twenty inches to twenty-four inches and even more, according to the length of the pile and the problem of handling such a long pile without bending. In a practical operation for underwater pile driving, a barge with a seventy-five ton derrick, with provision for one-hundred and fifty ton pull sets a twenty-four inch index pile of the type described, up to one-hundred and sixty feet long. Then, a flying McKiernan S10 steam hammer is used to drive the pile. When driving to the water level, subsequent lengths of dimensions suited to requirements may be welded on and driven down to reach the required depth of penetration. If a seventy-five ton or even a one-hundred and fifty ton pull will not remove the index pile, jetting may be employed. In this way, in one hundred feet of water a test of two hundred feet can usually be accomplished in from three to six hours. This is a big improvement over previous comparable soil investigation methods which might take between a week and two weeks at a time, because of the necessity of building and removing a temporary platform for the testing instruments.

I claim:

1. A test pile, comprising in combination a main driving body of substantially standard pile dimensions, said body having an upper end adapted to receive the blows of a pile driver and a lower extension of reduced diameter, the lower end of said extension carrying a test assembly comprising a housing portion, and a cylindrical foot extending axially from the housing portion, a sleeve slidably mounted on the foot for limited axial movement relative thereto, a cone mounted for slidable movement on the lower end of said sleeve, hydraulic means in said housing position for urging said cone axially of said sleeve through a given stroke and for urging said sleeve axially along said foot through a given stroke, hydraulic communications extending from a source of hydraulic pressure through said pile body to said hydraulic means, and means external to the pile and connected to said hydraulic communications for measuring the resistance exerted by said cone throughout the cone stroke and by the cone and sleeve throughout the sleeve stroke.

2. A test pile, comprising in combination a main driving body of substantially standard pile dimensions, said body having an impact driving head and a lower extension of reduced diameter, the lower end of said extension carrying a test assembly comprising a housing portion, a tapered portion below the housing portion, and a cylindrical foot extending axially from the tapered portion, a sleeve slidably mounted on the foot for limited axial movement relative thereto, said sleeve being provided with a lower foot with the lower end of reduced diameter, a cone mounted for slidable movement on the lower

end of said sleeve, hydraulic means in said housing portion for urging said core axially of said sleeve through a given stroke and for urging said sleeve axially along said foot through a given stroke, hydraulic communications leading through said body from a source of hydraulic pressure to said hydraulic means, and means external to the pile and connected to said hydraulic communications for measuring the resistance exerted by said cone throughout the cone stroke and by the cone and sleeve throughout the sleeve stroke.

3. A test pile, comprising in combination, a main body of substantially standard pile dimensions, a lower extension of reduced diameter extending from said body, and on said extension a test assembly comprising a housing portion, a tapered portion below the housing portion and a cylindrical foot extending from said tapered portion, a sleeve slidably mounted on said foot for limited movement relative thereto in an axial direction, said sleeve being provided with a lower end of reduced diameter and a cone mounted for sliding movement on said sleeve lower end, said test assembly housing being provided with an upper piston-receiving cylinder and an axial bore leading from said cylinder through said tapered portion and said foot, and the sleeve being provided with an axial bore in alignment with the axial bore of the tapered portion of the foot and having an enlarged upper portion providing a shoulder, a first piston operating in said cylinder, a second piston operating in the bore of said tapered portion and foot and the channel of said sleeve and connected to said cone, said second piston having a flange spaced from its lower end, means for supplying hydraulic fluid to the cylinder to operate said piston and means for relieving said fluid pressure at the lower end of the stroke of said first piston, said first piston being in contacting alignment with the second piston whereby when the first piston is depressed to a certain point it depresses the second piston to depress the cone, the second piston being provided with lost motion means for engaging said sleeve whereby when the second piston is depressed to a further point to depress said sleeve until at a predetermined point of depression the pressure is relieved, and means for indicating the pressure required to move the piston whereby the penetration resistance of the sleeve and cone and the cone alone may be determined.

4. A test pile as claimed in claim 2 in which said foot has at least one pressure relieving channel extending therefrom from its bore to its face thereby to relieve pressure between the bore and the face and said assembly above said foot having at least one channel leading from the bore to the face and communicating with the upper side of the piston receiving cylinder.

5. An assembly for test piles comprising a housing portion, a tapered portion below the housing portion and a cylindrical foot extending from said tapered portion, a sleeve slidably mounted on said foot for limited movement relative thereto in an axial direction, said sleeve being provided with a lower end of reduced diameter and a cone mounted for sliding movement on said sleeve lower end, said test assembly housing being provided with an upper piston-receiving cylinder and an axial bore leading from said cylinder through said tapered portion and said foot, and the sleeve being provided with an axial bore in alignment with the axial bore of the tapered portion of the foot and having an enlarged upper portion providing a shoulder, a first piston operating in said cylinder, a second piston operating in the bore of said tapered portion and foot and the channel of said sleeve and connected to said cone, said second piston having a flange spaced from its lower end, means for supplying hydraulic fluid to the cylinder to operate said piston and means for relieving said fluid pressure at the lower end of the stroke of said first piston, said first piston being in contacting alignment with the second piston whereby when the first piston is depressed to a certain point it depresses the second piston to depress the cone, and when the second piston being provided with means for engaging the sleeve whereby when the second piston is depressed to a further point to depress said sleeve until a predetermined point of depression the pressure is relieved, and means for indicating the pressure required to move the piston whereby the penetration resistance of the sleeve and cone and the cone alone may be determined.

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