PORTABLE POWERED

PROBE FOR PERMAFROST

by

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Portable Powered Probe for Permafrost

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A system of probe rods driven by a small commercially available rotary impact drill was developed through field testing, which will permit a single operator to drive and retrieve the probe at depths as great as thirty feet in thawed silt. An enlarged tip on the probe rod was found to be essential in reducing driving resistance and simplifying retrieval. Different tip shapes and sizes were tested and found to significantly affect the driving rate. For the 0.5 inch diameter probe rods used, a tip of 0.625 inch diameter having a conical tip angle of roughly twenty degrees was found most suitable. The smallest driver-drill tested, weighing less than nine pounds, proved satisfactory for most applications. A heavy-duty model drill, weighing 23 pounds, was needed to penetrate some drier silt soils and thin layers of seasonal frost. The system described provides a simple means of determining depths to hard layers such as frozen ground or bedrock, without resorting to heavy drilling equipment.

Permafrost, silt, probe, drilling

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INTRODUCTION

Hand probing with steel rods of around 1/2 inch diameter has been used for many years as a simple method of detecting shallow permafrost. This study was initiated to develop a small, lightweight electrically powered driving unit which would serve to probe to greater depths than could be attained by hand probing. Available 1/2 inch impact drivers and drills were first evaluated to determine their capabilities for this use. Development work was also done on different probe rod tip shapes. A system was developed incorporating 1/2 inch segmented drive rods with an enlarged rod tip, which could be driven and retrieved to depths up to thirty (30) feet by a single operator. This system uses a commercially available 1/2 inch electric hammer-drill with 1/2 inch drive rods threaded to connect in five foot segments, and an enlarged probe tip to relieve rod friction.

Description of Impact Drivers and Drills

Initial field tests were performed with three electric impact tools, having specifications as shown by Table I. The smallest tool found practical for probe driving use was the 8 1/2 pound Milwaukee (Brand) Model 5388 "Heavy Duty Hammer-Drill". Progressively heavier and more powerful units such as the 23 pound Milwaukee Model 5300 rotary hammer and the 29 1/2 pound Pow-R-Tron Electric Hammer were able to drive the rod against heavier resistance, as would be expected. Actual driving energy levels of these units were not available. In initial trials using a 1/2 inch straight probe rod with a conical tip of the rod diameter, the maximum depths attained with the three above drivers in thawed silt soils were five, eight, and twelve feet, respectively. By comparison, hand probing with the same rod was possible only to about four feet.
TABLE 1

Description of Drive Hammers Evaluated

<table>
<thead>
<tr>
<th>Manufacturer and Model</th>
<th>Amperage/ Voltage</th>
<th>Blows per Minute</th>
<th>RPM</th>
<th>Weight (pounds)</th>
<th>Approximate Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>Milwaukee Model 5388 Hammer Drill</td>
<td>6.2A/115 V</td>
<td>19,000</td>
<td>950</td>
<td>8.5</td>
<td>$185.00</td>
</tr>
<tr>
<td>Milwaukee Model 5300 Rotary Hammer</td>
<td>10 A/115 V</td>
<td>3,250</td>
<td>600</td>
<td>23.0</td>
<td>$498.00</td>
</tr>
<tr>
<td>Pow-R-Tron Model 25P Impact Hammer</td>
<td>15 A/115 V</td>
<td>NA</td>
<td>0</td>
<td>29.5</td>
<td>No longer made</td>
</tr>
</tbody>
</table>

Advantages of Rotary-Hammers

The initial field trials of the above drivers and drills demonstrated that while rod rotation during driving was relatively unimportant, rod rotation was critical in pulling the rod out after completion of driving. Straight impact drivers such as the Pow-R-Tron hammer, while excellent for rod driving, could easily drive the rod to a depth where manual pulling was impossible. Units of this type would have to be converted to provide some upward hammering action to provide for rod removal. By contrast, the rotary units permitted easy rod removal because their chucks grasped the rod positively and the rotation reduced rod friction from the static level to the sliding friction level. This permits a single operator to manually pull the rod from depths as great as thirty feet in silts, by spinning the rod during removal. For this reason, further testing was confined to the rotary hammer units.

Probe Rod Design Considerations and Tests

Because of the difficulties in reaching depths much greater than hand probing with straight probe rods with the small Milwaukee impact drill, a 3/4 inch diameter bullet shaped probe tip, 3 inches in length, was fabricated and found to greatly increase the ease of probe penetration
and probe removal. The enlarged tip creates a slightly enlarged hole, which minimizes probe rod friction with the sides of the hole. This enlargement also proved of benefit in hand probing.

A series of alternative lengths and shapes of 3/4 inch diameter tips were next fabricated and field tested in an attempt to quantify the effects of these factors on the ease of probing. Details of the probe tips tested are shown by Figures 1 and 2. All field tests were performed with the Milwaukee Model 5388 impact drill, with the operator exerting as much down pressure as reasonably practical (100 pounds \(\pm\)) to maximize the penetration rate.

Two sites, termed the "Ester" and "University Farm" sites, were used to evaluate the various tip shape effects. The Ester site, located 8 miles west of Fairbanks, was a hillside location adjacent to a house foundation recently drilled to explore the soils and permafrost condition. The water table depth was not measured at this site. The University Farm site was located in the experimental farm field below the University campus at Fairbanks, and has roughly 30 feet of thawed silt overlying permafrost silts. The water table at the Farm site is at a depth of approximately 15 feet. Soils at both sites are uniform fine silts with moisture contents in the range of 30 to 40 percent. The Ester Site is in the Minto Silt Loam Agricultural soil series, while the University Farm site is in the Tanana Silt Loam series.

Initial field testing evaluated the effects of 3/4 inch diameter tip shapes and lengths, when used on 1/2 inch diameter probe rods. The effects of tip shape on penetration time as shown by Figures 3 and 4 indicate that a long, relatively sharp tip doubled or tripled the penetration rate when compared to a relatively blunt tip. The sharper tip used had a tip cone length of two diameters, and the blunt tip had a cone length equal to half the tip diameter.

Tips of various lengths with similar nose shapes showed similar penetration rates for tip lengths of 2 and 3 inches and increased penetration resistance when lengths exceeded roughly four to six inches (Figures 5 and 6). Increasing the tip length apparently increases the side wall friction with the probe hole. A cylindrical body section 0.5 to 1.0 inches in length appears to be a satisfactory compromise which will minimize tip friction and provide a flat surface for gripping during the tip machining operation.
The effect of tip diameter was investigated in a third series of field tests, using 5/8 inch diameter tips as shown by Figure 2. In this test series, all of the 5/8 inch diameter tip shapes and lengths proved superior to the best performing 3/4 inch diameter tips at all depths. Apparently a tip diameter roughly 1/8 inch larger than the probe rod diameter is sufficient to eliminate the problems with rod wall friction which occur when a straight 1/2 inch diameter probe rod is used with no tip enlargement.

Probe rod connections to the impact hammer were initially made with a fabricated 5/8 inch by 6 inch driving mandrel, which was provided with three lengthwise flats 120 degrees apart for positive gripping with a standard 1/2 inch 3-finger key chuck. The lower end of the mandrel was machined with a 3/8 inch diameter tang threaded with 18 threads per inch (National Coarse Thread). Probe rods were threaded with 3/8 inch diameter by 1/2 inch long NC threads and machined with two flats at each end to aid in gripping when making rod connections. No problems were experienced with this method of rod connection. However, the threaded male end of the driving head broke off twice in use, and a revised design is needed at that end. Details of the recommended mandrel, probe rods, and rod tip are shown by Figure 8.
SUMMARY

A system was developed and tested for probing through thawed silt soils for purposes of determining the presence of and depth to frozen layers or bedrock. Because no soil samples can be taken, this system is useful primarily for extending information from soil borings, determining changes in permafrost depths with time at the same locations, and measuring thaw depths in areas of known permafrost, soil, and bedrock depth conditions. Probing has been accomplished through fine gravel embankments up to six feet in thickness as well as through silts, peat, and clayey silts. Depths of 30 feet have been easily attained in thawed silt using a 1/2 inch electric impact drill weighing only eight pounds, and rods were easily retrieved from that depth by spinning the rod during removal. The variables of rod tip shape and size were explored through field tests, and the most satisfactory tip size for 1/2 inch diameter probe rods was found to be 5/8 inch in diameter with a conical tip two diameters (1 1/4 inch) in length. With power supplied by a portable 1 kw generator, this system has proven very useful for studying the thermal effects of embankments and structures on permafrost.
Tip Set #1: 3/4" Diameter, Shape Varied

Tip Set #2: 3/4" Diameter, Lengths Varied

Tip Designations & Lengths (L)

F = 2"
G = 3"
H = 4.75"
I = 10"

Figure 1: Details of different 3/4" diameter probe tips used in field testing programs.
Tip Set #3: 5/8" Diameter

Figure 2: Details of different 5/8" diameter probe tips used in field testing programs.
Figure 3: Effects of Shape of 3/4" diameter tips on penetration time at Ester Site.

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Figure 4: Effects of shape of 3/4" diameter tips on penetration time at University Farm Site.
Figure 5: Effects of length of 3/4" diameter tips on penetration time at Ester Site.
Figure 6: Effects of length of 3/4" diameter tips on penetration time at University Farm Site.
Figure 7: Effects of different 5/8" diameter tip shapes on penetration time and comparisons to best 3/4" diameter tips. University Farm Site.
Figure B: Details of recommended probe rods.