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NOTES

Recording Soil Penetrometer

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1. Introduction

One method of measuring soil strength is to force a penetrometer through the soil and observe the resulting driving force. Although a complete mechanics is not available to describe the components of soil reaction to the penetrometer,[1] many researchers have used this simple device to develop correlations between soil mechanical strength and other variables of interest.

Strong correlations have been shown to exist between penetrometer measurements and root penetration and elongation,[2–4] off-the-road vehicle trafficability,[5] soil hydraulic conductivity,[6] and some soil parameters.[7] Soil penetrometers are also used to measure soil strength profiles[8] and changes in soil strength resulting from tillage operations.

Commercially available penetrometers use proving rings or hydraulics to indicate force applied, and marks on the shaft to indicate depth. To make soil strength versus depth readings with any degree of speed, three men are required; one to operate the penetrometer and call out the tip depth, one to read and call out the force applied, and one to record data. The advantages of a one-man recording penetrometer are obvious, considering only the man-hours required to gather the data. Other advantages of the recording penetrometer include: (a) a permanent record of force versus depth: (b) a number of replications can be made on one chart; (c) by using different coloured inks, penetrometer indications from two locations can be placed on one chart and compared directly; and (d) when a number of replications are placed on one chart, a line averaging those tests can be drawn by eye with reasonable accuracy, thus reducing the time spent in data reduction.

Experience over a four-year period with the device described here shows that the man-hours required for gathering data were reduced by over 70%, and the office time required to convert the information to usable graphs was reduced by about 75%, compared with an indicating penetrometer.

2. Method of operation

The penetrometer consists of two components (*Fig. 1*), the force-measuring component and the depth-measuring component. The force measurement is obtained by the relative displacement between an outside barrel (A) and the handle-plunger (B). As the spring (C) is compressed the recorder arm (D) moves the recording pen down the chart attached to the chart plate (E); that is, the force measurement is recorded in the vertical direction.

The depth measurement is provided by the relative movement of the foot-plate shaft (F) and the penetrometer tip (G) as the tip is forced into the soil. A beaded-chain loop (H) is attached to the shaft and around the drive sprocket (I). The drive sprocket is directly connected to the chart-drive sprocket (J), which has a diameter one-half that of the drive sprocket. Thus the depth measurement is made horizontal and to a one-half scale. This ratio may be changed by replacing the chart-drive sprocket. The depth-measuring component is attached to the force-measuring component by ring clamps (K) which can be loosened and the two components can then be separated for transportation.

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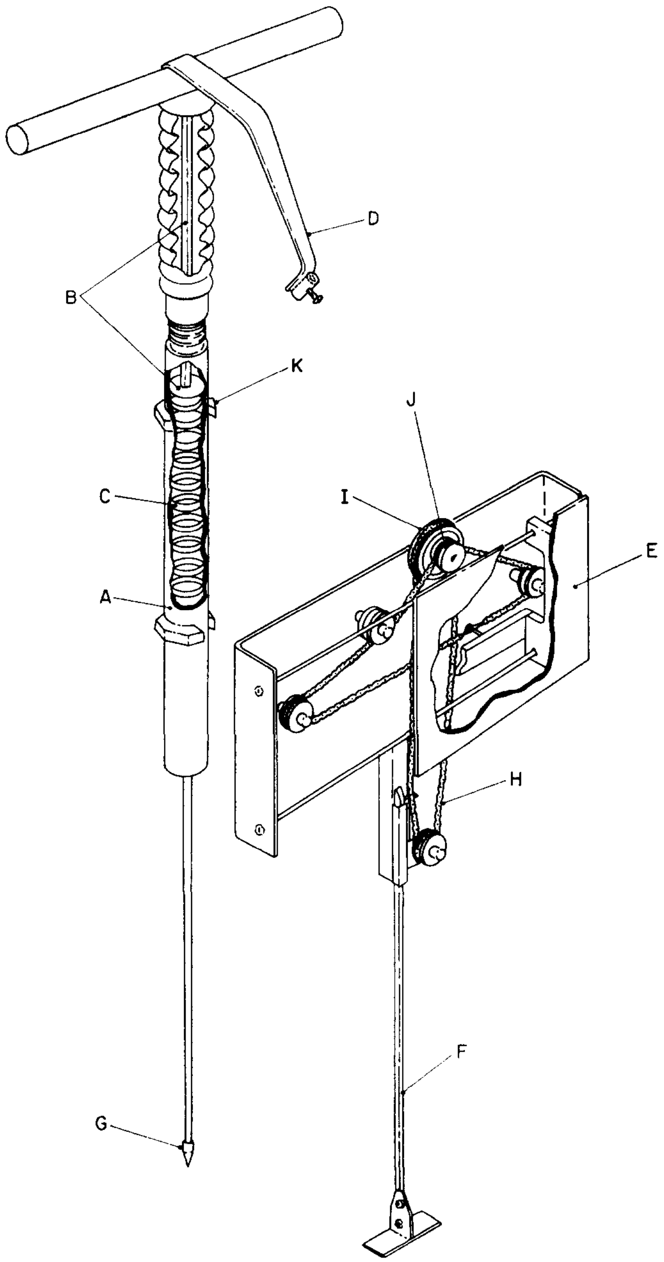

Fig. 1. Sketch of recording penetrometer. Force component (left) and depth component (right)

3. Some features

The plunger shaft connecting the handle to the calibrated spring is square, to prevent its turning, and is covered with a protective bellows to keep out dust and dirt. The footplate shaft is also square, and slides in a hollow square sleeve.

Stainless steel beaded drive loops and brass sprockets are used in the depth-component drive system. This system provides a positive chart drive and, with a spring link in the slack side of each loop, allows the chain to slip if excessive loads are applied for any reason.

The penetrometer tip is a 30° right circular cone having a base area of 0·20 in². It is made of stainless steel.

Since the device is made in components, it can be taken down to a disassembled length of 15 in by removing the plunger shaft, the cone shaft, and pushing the footplate shaft upward. Total weight of the unit is 9·5 lb.

A full-scale pressure of 600 lb/in² may be applied to the penetrometer tip with a 120 lb applied force. The full-scale range is easily decreased for softer soils by increasing the cone tip size or by replacing the calibrated spring.

The depth range for this unit is 14 in with a 7 in full-scale chart indication. The chart-drive sprocket can be changed to provide either a greater or lesser full-scale deflection.

A calibrated overlay has been used to make chart readings.

4. Use

The recording penetrometer described here has been rugged and reliable in four years of field research. It is simple to use and, with a few minutes explanation, unskilled labour can make over 100 recordings per hour. The recording system is relatively insensitive to the rate of penetration so long as the downward force is applied smoothly. The biggest problem is the tendency of the calibrated spring to "cock" while being forced through a compacted layer, and when the tip passes through that layer the tip is forced into the soft soil rather rapidly. With some experience, this effect can be minimized.

Force readings can be reliably made to the nearest 10 lb in², and depth readings to the nearest $\frac{1}{4}$ in. Comparison tests between this recording penetrometer and a proving-ring penetrometer have been in close agreement.

Fig. 2 shows isodynamic charts of two treatments of a tillage test, illustrating one use for this instrument. The left chart shows soil penetration resistance where disc harrowing was the only

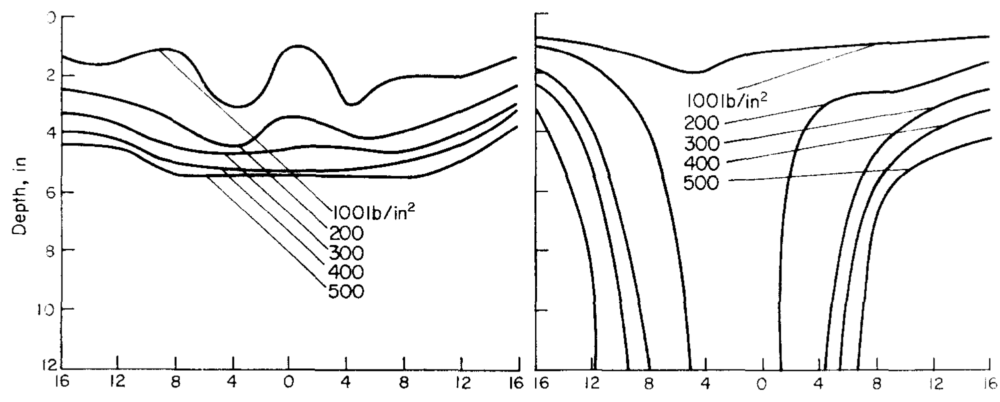

Fig. 2. Isodynamic charts illustrating soil strength where harrowing was the primary tillage (left), and where a subsoiler was used preceding planting.

tillage treatment. The right chart illustrates penetration resistance where a subsoiler was run just ahead of the planter. Each chart represents the average of five penetrometer measurements made at 4 in intervals to either side of the row, with four replicated plots.

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