Dynamic Cone Penetrometer User's Guide

ODOT Project No. 2141

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Submitted by

ERES CONSULTANTS, INC.

ACKNOWLEDGMENT

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GUIDELINE PREPARATION

This project is being conducted under the supervision of Dr. Michael Ayers. Other project team members contributing to these guidelines include Douglas Steele, Shreenath Rao, Kelly Smith, and Robin Jones.

INTRODUCTION

The Dynamic Cone Penetrometer (DCP) is a rapid and inexpensive device for characterizing unbound paving materials and subgrade soils. The DCP may be used to estimate the strength of these materials through the use of correlations with the California Bearing Ratio (CBR) and resilient modulus (M_r).

The DCP, shown schematically in figure 1, consists of the following components: a 15.8-mm (5/8-in) diameter steel drive rod with a replaceable cone tip, an 8-kg (17.6-lb) weight or hammer which is dropped a fixed height of 575 mm (22.6 in), a coupler assembly, and a handle. The cone tip has an included angle of 60 degrees and a diameter at the base of the cone of 20 mm (0.79 in). The drive rod may be unmarked or graduated so that increments of 5.0 mm (0.2 in) may be determined. The apparatus is typically constructed of stainless steel, with the exception of the cone tip, which may be constructed from hardened tool steel or a similar material.

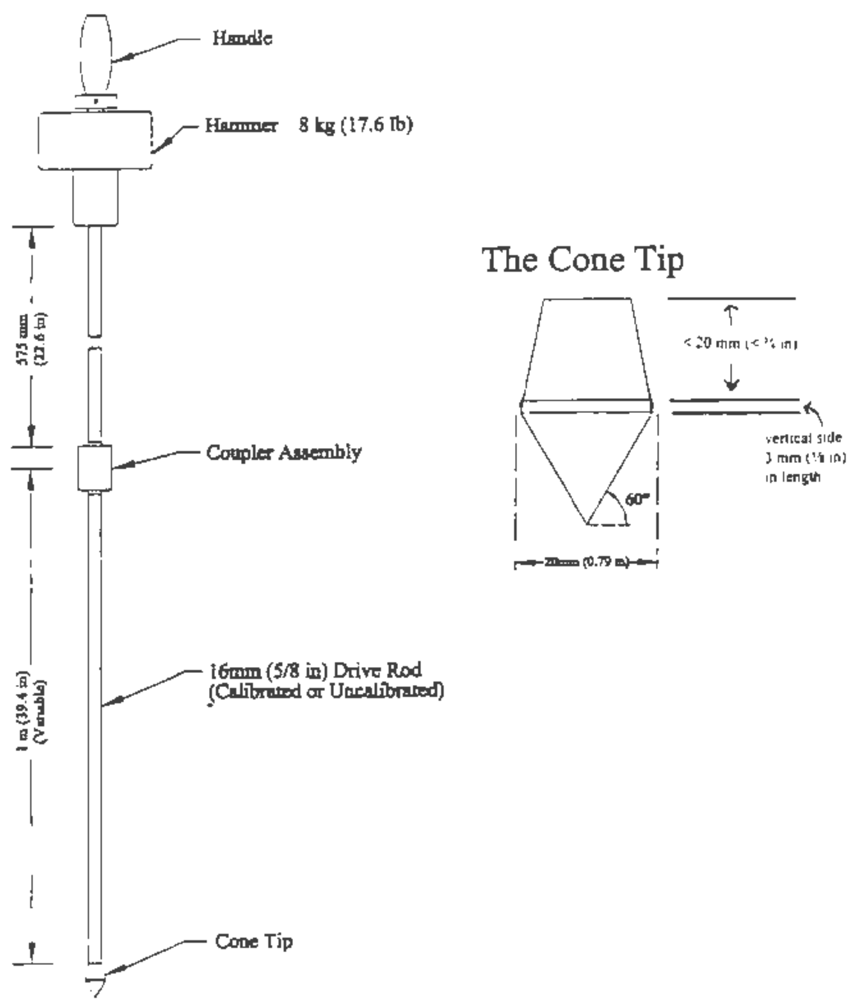

Figure 1. Schematic of the DCP Device

SCOPE

The method covers the measurement of the penetration index of the DCP through non-stabilized or unbound paving materials and subgrade soils. Determination of the CBR or M_r value through the use of correlation equations is provided. An example is included to illustrate the analysis and use of the correlations.

SIGNIFICANCE AND USE

The DCP is only effective in horizontal construction applications, such as pavements and floor slabs. The DCP is typically used to measure material properties to a depth of 1 m (3.3 ft) below the surface. However, the depth of penetration can be increased by the use of drive rod extensions. If drive rod extensions are used, care should be taken to ensure proper calibration of the device, since the mass and inertia will change.

The DCP can be used to determine the strength characteristics of fine- and coarse-grained soils, granular construction materials, and weak stabilized or modified materials. The DCP cannot be used in highly stabilized or cemented materials or for granular materials containing aggregates larger than 50 mm (2 in).

The DCP can be used to estimate the strength of in situ materials underlying a surface course or stabilized layer by first drilling or coring an access hole.

REQUIRED EQUIPMENT

In addition to the DCP apparatus, the following equipment is needed:

- Lubricating oil or anti-seize compound for the threaded connections.
- Tool set for assembling/disassembling the DCP.
- Data recording form (table 1).

Depending on the test conditions, the material being evaluated, and the type of DCP, the following equipment may also be needed:

- A vertical scale longer than the longest drive rod or rod extension graduated in millimeters or tenths of an inch if the drive rods are not graduated.
- Reference jig for use with a graduated drive rod.
- Rotary hammer drill capable of drilling a minimum diameter hole of 40 mm (1.6 in) or a coring apparatus with a minimum core barrel diameter of 25 mm (1 in). Either should be capable of making a hole through a surface course or stabilized layer.
- Wet/dry shop vac or suitable alternative to remove loose material and fluid if an access hole is made prior to testing.
- Field power supply, as needed, to power the equipment listed above.
- An extraction jack.

DETAILED TESTING PROCEDURE

Equipment Check

Prior to beginning a test, the DCP should be inspected for fatigue-damaged parts (coupler and handle) and excessive wear of the drive rod and cone tip. All joints must be securely tightened, including the coupler assembly and the cone tip to drive rod.

Basic Operation

The Operator holds the device by the handle in a vertical or plumb position and lifts and releases the hammer when it lightly contacts the handle. The Recorder measures and records the penetration per drop.

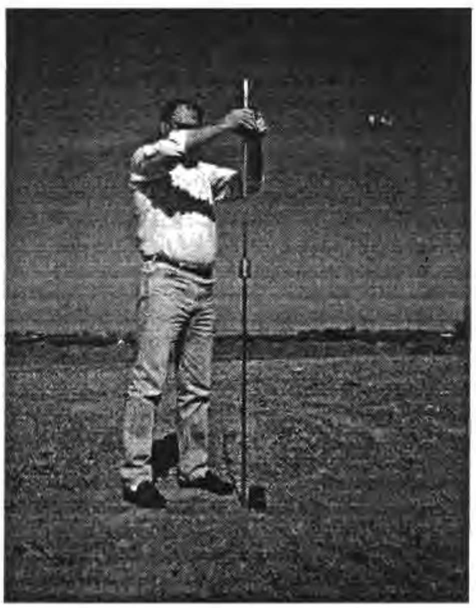

Figure 2. DCP Operation

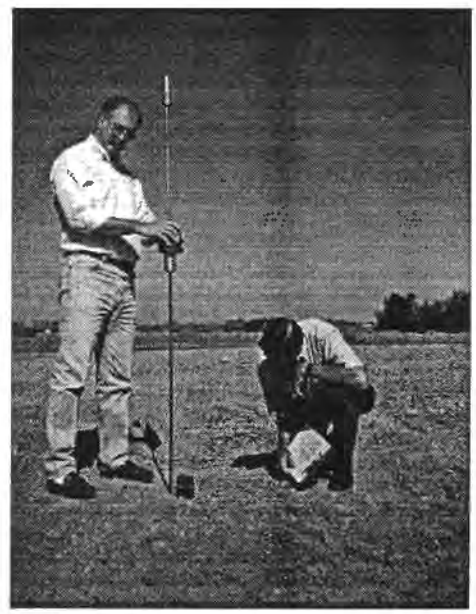

Figure 3. Initial DCP Reading

<u>Initial Reading When Testing a Surface Layer</u>

The DCP device is held vertically and the cone tip is placed on the surface of the material to be tested such that the widest part of the cone tip is approximately level with the surface. An initial reference reading is taken so that depth determinations can be made as the DCP is advanced into the material. The distance from the bottom of the hammer to the surface of the material is measured to the nearest 5 mm (0.2 in), or an initial reading is obtained from the calibrated drive rod.

Initial Reading When Testing a Subsurface Layer

When testing soils or granular materials underlying a surface course or a stabilized layer, a reference reading is taken as described above. If the material will not allow penetration to the widest part of the cone tip, obtain a reading by noting the approximate cone tip penetration. A rotary hammer drill or coring apparatus meeting the requirements stated above is then used to provide an access hole to the layer to be tested. If a rotary hammer drill is used, the diameter of the hole should be a minimum of 40 mm (1.6 in). If coring is used, the minimum core barrel diameter should be 25 mm (1 in). Wet coring requires that the DCP test be performed as soon as possible, not longer than 10 minutes following completion of the coring operation. The coring fluid must not be allowed to soak into or penetrate the material to be tested. A wet/dry shop vac or suitable alternative should be used after drilling or coring to remove loose material and fluid from the access hole. Following the drilling or coring, place the DCP cone tip in contact with the material to be tested and obtain a reading or measurement. The difference in these values corresponds approximately to the depth of the stabilized or granular layer.

Seating the DCP

Following the initial reading, as described above, the cone tip will be seated with a single drop of the hammer.

Testing Sequence

The DCP should be held in a vertical or plumb position. The hammer is raised by the Operator until light contact is made with the handle. The hammer shall not impact the handle when being raised. The hammer is then allowed to free fall and impact the coupler assembly. The drop number and corresponding penetration are recorded on the data recording sheet (table 1).

Depth of Penetration

The maximum required depth of penetration will vary from application to application. For typical highway applications, penetration of 800 mm (30 in) will generally be adequate.

The penetration to the nearest 1 mm (0.05 in) is measured and recorded for each drop. Note that the operator may elect to drop the hammer more than once per depth reading if the material is stiff and the penetration per drop is low. If multiple drops are used, the penetration index is the total penetration depth divided by the corresponding number of hammer drops.

Refusal

The presence of large aggregates or rock strata will either stop the penetration or deflect the drive rod. If, after 20 drops, the device has not advanced more than 5 mm (0.2 in) or has noticeably deflected from the vertical position, the testing shall be stopped and the device moved to another test location. The new test location should be located a minimum of 1 m (3.3 ft) from the prior location to minimize testing error caused by disturbance of the material.

Extraction

Following completion of the test, the device may be extracted by driving the hammer upward against the handle or by use of the extraction jack, as shown in figure 4.

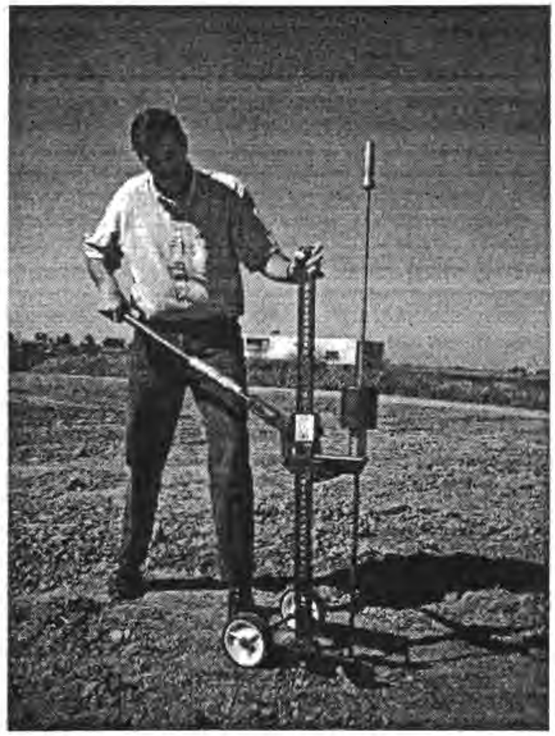

Figure 4. DCP Extraction Device

Data Recording

A form similar to the one shown in table 1 is suggested for data recording. The Recorder enters the header information prior to the test. The actual test data are recorded in columns 1, 2, and 3. The entry in column 2 will be 1 unless the operator elects to do multiple drops before obtaining the DCP reading. Multiple drops may be desirable if the material being tested is stiff and the penetration per drop is low. Reading Number 0 (column 1) corresponds to the initial DCP reading at the surface of the layer to be tested. Reading Number 1 corresponds to the initial seating drop. When testing a subsurface layer through a drilled or cored access hole, Reading Number 0 corresponds to the pavement surface, Reading Number 1 corresponds to the reading at the top of the layer to be tested, and Reading Number 3 corresponds to the initial seating drop.

CALCULATION AND REPORT

The penetration per drop and average penetration index shown in table 1 are computed after testing. The penetration per drop is calculated for each reading after the seating drop. If desired, the penetration per drop may be plotted against the reading number to determine approximate layer interfaces. The layer interfaces may also be estimated by examining the data to determine where the penetration per drop values change substantially. The average penetration index is then calculated by averaging the penetration per drop values within each layer. The average penetration index value is then used to determine the CBR or resilient modulus values by the use of the correlation graphs shown in figures 5 and 6.

Granular materials frequently exhibit very low penetration rates, which may or may not cause the test to be abandoned. Small incremental penetration depths should be excluded from the calculation of average penetration rate where it is considered abnormal.

The estimates of CBR and resilient modulus are based on a hammer weight of 8kg (17.6 lb), a drop height of 575 mm (22.6 in), and a 60 degree cone tip. The DCP configuration should be noted on the data sheet in order to verify that the correlations used in the analysis are valid. The correlations presented in this report correspond to the dimensions and weights shown in figure 1.

Table 1. DCP DATA SHEET

Project ____________________ Date ____________________

Location ____________________ Personnel ____________________

Material Type ____________________ DCP Configuration ____________________

Notes ____

(1) Reading Number	(2) Number of Drops Between DCP Readings	(3) DCP Reading (mm or in)	(4) Penetration per Drop (mm or in per drop)	(5) Average Penetration Index (mm or in per drop)
0	Surface Reference		-	-
1	Seating		-	-
2				
3				
4				
5				
6				
7				
8				
n				

(1) Reading number (beginning with 0, each time the scale or graduated drive rod is read the reading number is incremented by 1).
(2) Number of blows between DCP readings (the usual range is from 1 to 10).
(3) The DCP reading is the distance from the reference surface to the bottom of hammer or the reading from the graduated drive rod.
(4) The penetration per drop is calculated as the difference in the penetration per drop values for two successive readings divided by the number of drops between the DCP readings.
(5) The average penetration index is calculated as the sum of all of the penetration per drop values within a layer divided by the total number of values summed.

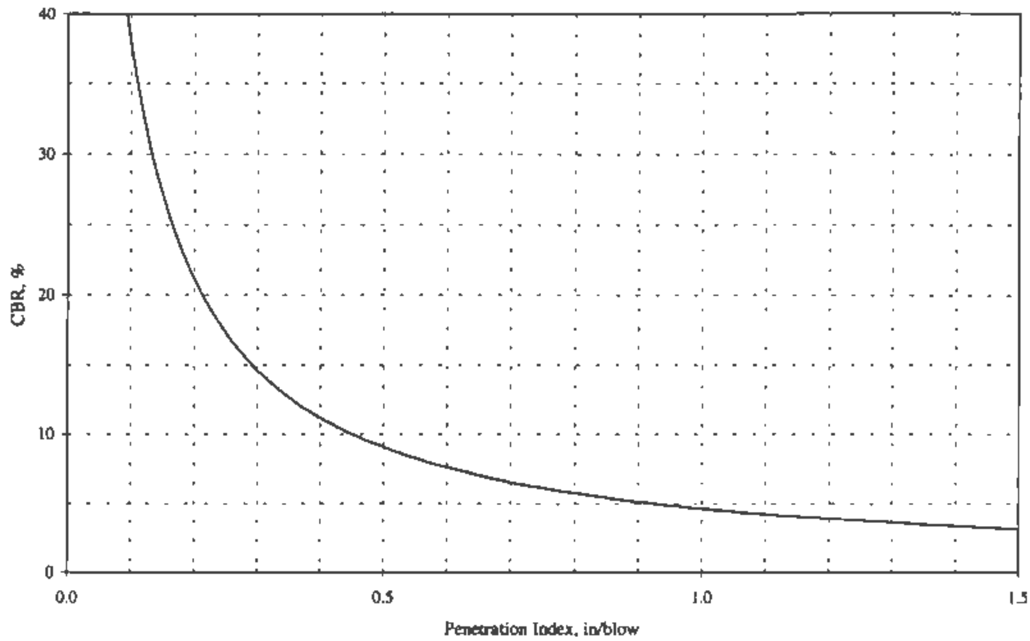

Figure 5. DCP/CBR Correlation Graph

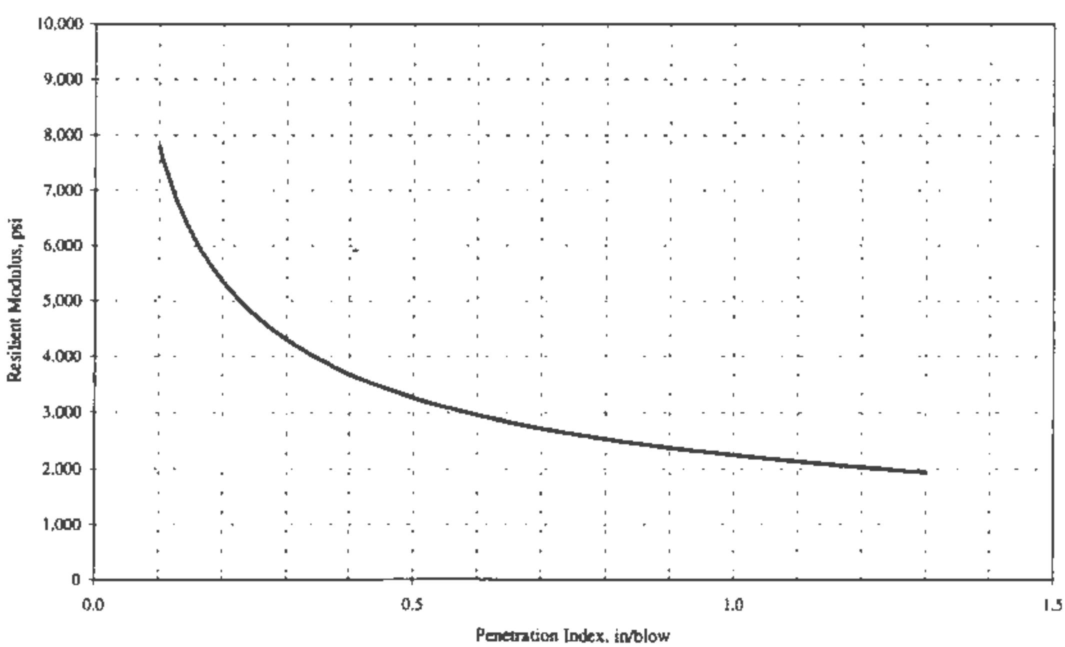

Figure 6. DCP/M_r Correlation Graph

EXAMPLE

Example - Data Sheet

Project Example

Date April 12, 1997

Location Major County

Personnel MEA, TJK

Material Type Sand

DCP Configuration Standard

Notes Testing performed directly on roadbed surface

(1) Reading Number	(2) Number of Drops Between DCP Readings	(3) Calibrated Rod Reading (mm or in)	(4) Penetration per Drop (mm or in per drop)	(5) Average Penetration Index (mm or in per drop)
0	Surface Reference	0.5 in	-	-
1	Seating	1.5 in	-	-
2	1	2.5 in	1.0 in	-
3	1	3.6 in	1.1 in	-
4	1	4.6 in	1.0 in	-
5	1	5.8 in	1.2 in	-
6	1	7.0 in	1.2 in	1.1 in/blow
7	1	9.1 in	2.1 in	-
8	1	11.3 in	2.2 in	-
9	1	13.4 in	2.1 in	-
10	1	15.7 in	2.4 in	-
11	1	17.9 in	2.2 in	-
12	1	20.0 in	2.1 in	2.2 in/blow
13	1	24.1 in	4.1 in	
14	1	28.2 in	4.1 in	
15	1	32.3 in	4.1 in	
16	1	36.5 in	4.2 in	4.1 in/blow
n				

Sample Calculations and Analysis

- The basic test information and columns 1, 2, and 3 were filled out by the Recorder during the testing.
- The penetration per drop (column 4) values were determined by subtracting successive DCP readings recorded in column 3. For example, the DCP reading corresponding to reading number 3 was 3.6 in and the DCP reading corresponding to reading number 2 was 2.5 in. The penetration per drop recorded for reading number 3 is therefore 1.1 in (3.6 – 2.5). Similar values are calculated for all reading numbers.
- There is an obvious change in the penetration per drop values between reading numbers 6 and 7. This difference corresponds to a change in layer characteristics that should be accounted for in determining the average penetration index (column 5). The average penetration index is calculated by summing all of the penetration per drop values in a layer divided by the number of values. For example, the average penetration index value for the assumed first layer would be 1.1 in/blow [(1.0+1.1+1.0+1.2+1.2)/5]. The values for the second and third layer are 2.2 in/blow and 4.1 in/blow, respectively. Refer to figure 7 for a plot illustrating the differences in the penetration per drop for each of the layers.
- The average penetration index values are then used with the appropriate correlation graph (figures 5 and 6) to determine the CBR and resilient modulus values. Refer to figures 8 and 9 for this example.

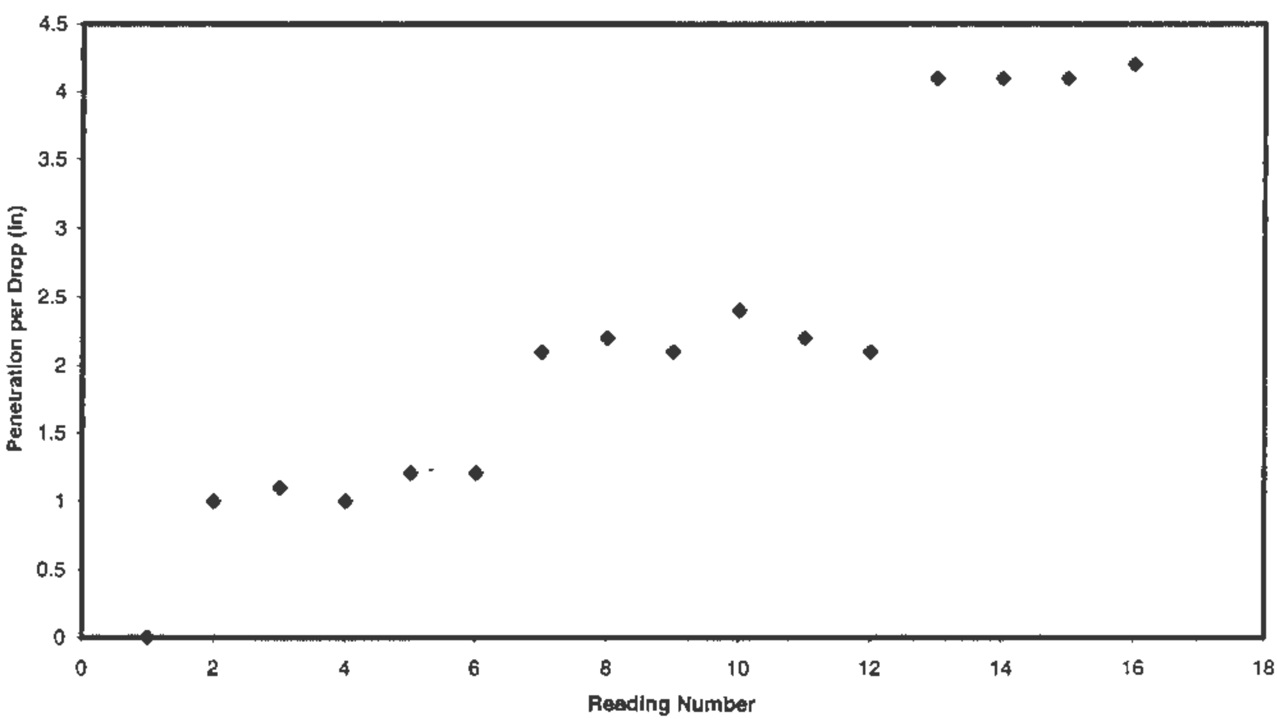

Figure 7. Example Plot to Determine Layer Interfaces

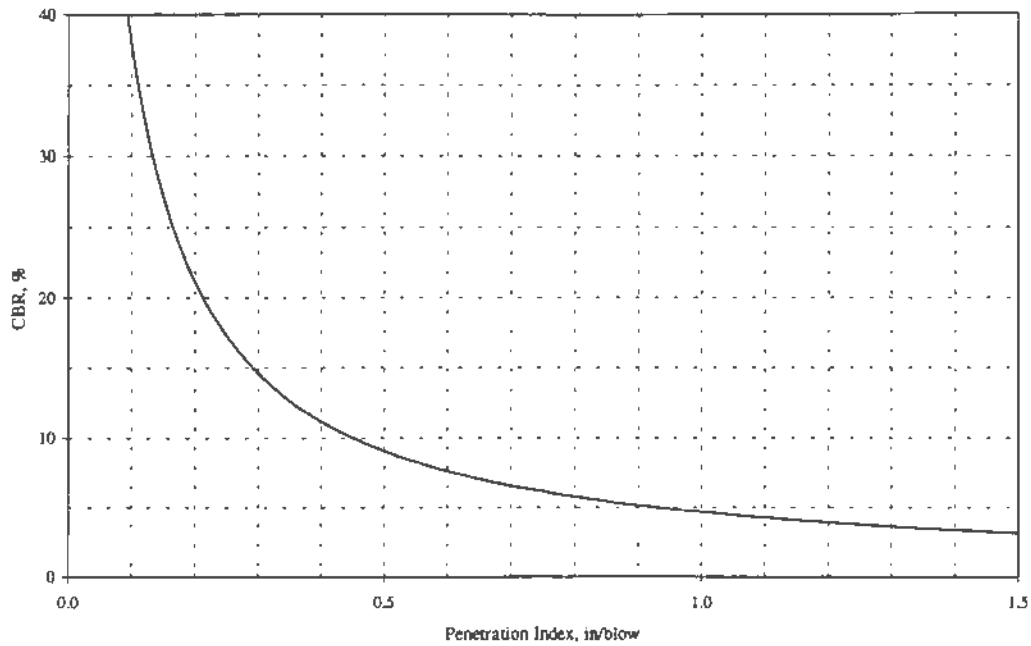

Figure 8. DCP/CBR Correlation Graph for Example Problem

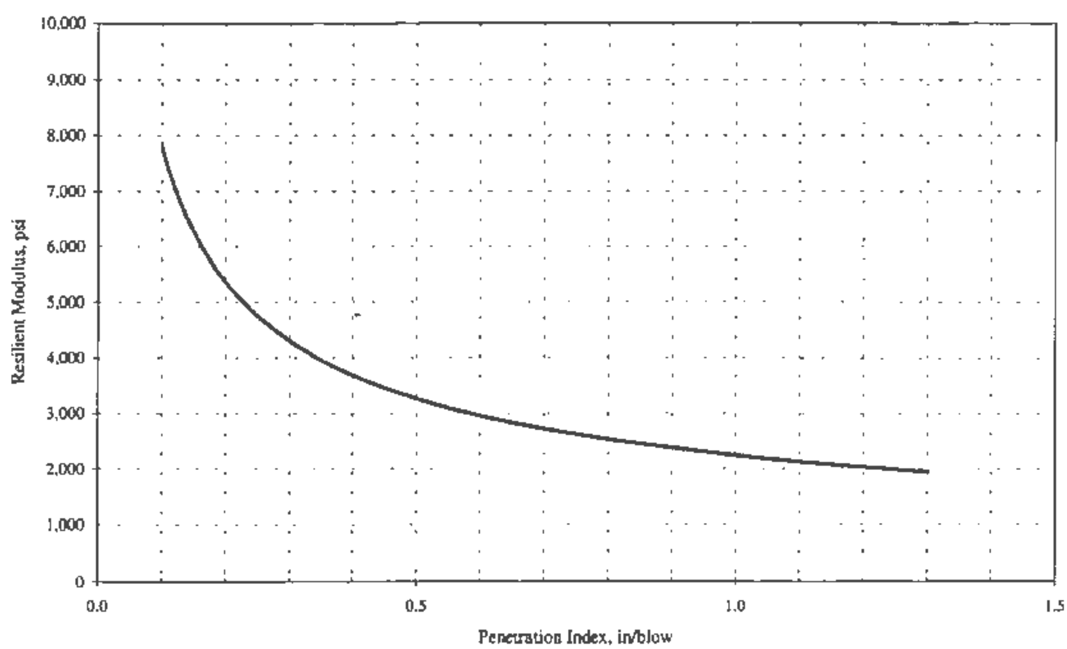

Figure 9. DCP/M_r Correlation Graph for Example Problem

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