



INDOT Research

TECHNICAL *Summary*

Technology Transfer and Project Implementation Information

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Dynamic Cone Penetration Test (DCPT) for Subgrade Assessment

Introduction

In-situ penetration tests have been widely used in geotechnical and foundation engineering for site investigation in support of analysis and design. The standard penetration test (SPT) and the cone penetration test (CPT) are two typical in-situ penetration tests. The dynamic cone penetration test shows features of both the CPT and the SPT. The DCPT is similar to the SPT in test. It is performed by dropping a hammer from a certain fall height and measuring a penetration depth per blow for each tested depth. The shape of the dynamic cone is similar to that of the penetrometer used in the CPT. In road construction, there is a need to assess the adequacy of the subgrade to behave satisfactorily beneath a pavement. A recently completed Joint Transportation Research Program project showed that the DCPT can be used to evaluate the mechanical properties of compacted subgrade soils. In the present implementation project, the application of the DCPT is further investigated. Present practice in determining the adequacy of a compacted subgrade is to determine the dry density and water content by the sand-cone method or with

a nuclear gauge. However, the use of the resilient modulus (M_r) has become mandatory for pavement design. To find the M_r , a time-consuming testing procedure is required which demands significant effort. Therefore a faster and easier alternative for compaction control in road construction practice is desired. To this end, the present project aimed to take a first step in the generation of data to create appropriate correlations among subgrade parameters and DCPT results.

The present research project consists of field testing, laboratory testing, and analysis of the results. The field testing includes the DCPT and nuclear gauge tests. In the planning stage, several road construction sites were selected for the field testing. For the selected road construction sites, both the DCPT and nuclear tests were performed at the same location, allowing a comparison between DCPT and nuclear test results. Soil samples for the selected project sites were also obtained for the laboratory testing program.

Findings

For clayey sand classified in accordance with the United Classification System (sandy loam classified in accordance with INDOT standard specifications Sec. 903), the equation for the dry density in terms of PI can be used for predicting γ_d using field DCP tests.

Since such predictions using the DCPT are subject to considerable uncertainty, DCPT should be performed for compaction control in combination with a few conventional test

methods, such as the nuclear gauge. These can be used to anchor or calibrate the DCPT correlation for specific sites, reducing the uncertainty in the predictions. Site-specific correlations do appear to be of better quality.

The DCPT should not be used in soil with gravel. Unrealistic PI values could be obtained and the penetrometer shaft could be bent.

Implementation

Results from the field testing, laboratory testing and analysis lead to the following conclusions and recommendations:

- 1) Field DCP Tests were performed at seven sites. Four sites contained clayey sands, one contained a well graded sand with clay and two

contained a poorly graded sand. For each test location, in-situ soil density and moisture contents were measured using a nuclear gauge at three different depths. The relationship between the soil properties and the penetration index were examined. Though the data shows considerable scatter, a trend appears to exist, particularly if each site is considered separately, the penetration index decreases as the dry density increases and slightly increases as moisture content increases. It may be possible to improve the correlation by normalizing the quantities in a different way and by obtaining more data.

2) For clayey sand classified in accordance with the United Classification System (sandy loam classified in accordance with INDOT standard specifications Sec. 903), the equation for the dry density was derived in terms of the PI as follows:

$$\gamma_d = \left(10^{1.5} \times PI^{-0.14} \times \sqrt{\frac{\sigma'_V}{p_A}} \right)^{0.5} \times \gamma_w$$

where PI = penetration index in mm/blow; and p_A = reference stress (100kPa).

This equation can be used to predict γ_d from the measured PI value. The actual γ_d will be in a range defined by the calculated $\gamma_d \pm 1.63$ kN/m³.

3) To investigate the relationship between the shear strength of poorly graded sand and the penetration index, direct shear tests were performed on samples obtained from the field. The results of the direct shear tests also show considerable scatter.

4) For clayey sands and well-graded sands with clay classified in accordance with the United Classification System (sandy loam classified in

accordance with INDOT standard specifications Sec. 903), unconfined compression tests were conducted. The test results show some correlation with the penetration index (PI). It was observed that PI decreases as unconfined compressive strength increases. Additionally, the resilient modulus was calculated from s_u at 1.0% strain using the Lee (1997) equation. The following correlation was developed between Mr and PI:

$$Mr = -3279PI + 114100$$

where Mr=resilient modulus in kPa; and PI=penetration index in mm/blow

This relationship should be used with caution since it is derived from a very weak correlation based on highly scattered data for different sites. There is a need for further study to gather sufficient data to refine this relationship into a reliable equation.

5) For clayey sand classified in accordance with the United Classification System (sandy loam classified in accordance with INDOT standard specifications Sec. 903), the equation for the dry density in terms of PI can be used for predicting γ_d using field DCP tests.

6) Since such predictions using the DCPT are subject to considerable uncertainty, DCPT should be performed for compaction control in combination with a few conventional test methods, such as the nuclear gage. These can be used to anchor or calibrate the DCPT correlation for specific sites, reducing the uncertainty in the predictions. Site-specific correlations do appear to be of better quality.

7) The DCPT should not be used in soil with gravel. Unrealistic PI value could be obtained and the penetrometer shaft could be bent.

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