The Ohio Department of Transportation
Office of Research & Development
Executive Summary Report

Use of Dynamic Cone Penetrometer in Subgrade and Base Acceptance

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Problem

Base and subgrade weakness can shorten pavement life and increase maintenance costs. Ohio's current methods of evaluating base and subgrade, proof rolling and nuclear density gauge testing, do not yield a stiffness profile throughout the depth of the base and subgrade and have other limitations as well. The Dynamic Cone Penetrometer (DCP) quickly and easily penetrates underlying layers and accurately locates weak areas, measuring soil stiffness to a depth of 3 ft (0.91 m). DCP testing merits consideration as an acceptance criterion for base and subgrade materials. In 2004, the ASTM adopted standard D6951-03, "Standard Test Method for Use of Dynamic Cone Penetrometer in Shallow Pavement Applications".

Objectives

The primary objectives of this study were as follows:

1. Develop and implement a procedure for using DCP results as an acceptance criterion for subgrade and unbound base material.
2. Develop a threshold, based on DCP readings, for unsuitable material.
3. Establish stiffness parameters, based on DCP readings, for pavement design and rehabilitation.
4. Develop QA/QC procedures for subgrade acceptance based on stiffness.

Description

Automated DCP testing was performed on ten projects in 2003 and 2004. DCP tests were performed on natural soil, treated soil, granular base, and thin asphalt concrete pavements at 100 ft (30.5 m) station boundaries. Test points could be anywhere transversely within the future lanes. Testing could be stopped when penetration depth reached 1 m (3.3 ft) or upon refusal. In four cases, DCP testing was conducted through core holes in the completed asphalt concrete (AC) layer, and in one case the DCP penetrated through the thin AC layer.

On the ten projects, twelve soil sections were tested: five cement-treated, one lime-treated, one lime/cement-treated, and five untreated. A statistical analysis of test results showed no variations in DCP results stemming from the different soil stabilization treatments.

On some projects, DCP data were also collected from the base layer to measure base stiffness.

DCP data underwent noise reduction and then were analyzed to identify statistically uniform subgrade soil layers.

Sample data showed that construction quality varied among projects tested. For example, of the projects with treated soil, 80 percent did not achieve the designed effective depth of 300 mm (11.8 in). Also, DCP tests of two types of open-graded granular base (OGGB) yielded penetration rates (PR) indicating that the top layer was weaker than the lower layer.

In summary, the DCP test results show that the subgrade layer is far from homogeneous, and the inconsistent results point to potential problem spots. All the subgrade sections tested for this project had passed ODOT inspection and were accepted. The extra ODOT requirements for subgrade layer construction did not achieve the goal of ensuring a better quality (stiffer and more uniform) subgrade layer immediately beneath the pavement structure.

Conclusions

Using the data from the nine ODOT projects analyzed, this study found that the 95th percentile PR for stabilized soil is 8 mm/blow (0.31 in/blow). Therefore, the acceptable PR for the stabilized soil layer shall be set at 8 mm/blow (0.31 in/blow).

DCP tests were performed on two types of two-layered OGGB. The PR readings in the top layer of the OGGB were usually higher (weaker) than the PR readings in the lower layer. This finding raises two concerns: (1) the stability of OGGB is questionable, and (2) its ability to support the construction traffic without severe surface deformation is also questionable. This study also found that the NJ OGGB is stiffer and more uniform than the Iowa OGGB. As a result, it is recommended that the state use untreated OGGB with great care.

The 95th percentile PR of the Ohio 304 base is 8 mm/blow (0.31 in/blow). This value can be used initially to accept the Ohio 304 base.

At many test locations, the stabilized soil did not achieve its potential stiffness throughout its designed depth. The DCP may be the only device available that can identify this nonuniformity problem. Soils stabilized with lime had similar PR values as those treated with cement.

The current Ohio DOT specification stipulates additional requirements for constructing the top 300 mm (11.8 in) of the soil to form a stronger platform to support the pavement structure. DCP test results indicated that, in many cases, the constructed subgrade layer did not meet these specifications. Field studies have found that severe distress in a few localized weak areas can bring a project to total failure. Thus current ODOT subgrade construction requirements do not guarantee a uniformly sufficiently stiff subgrade layer.

The acceptable PR for a thin AC surface course on a low-volume road shall be set at 7 mm/blow (0.28 in/blow). The subgrade shall be tested prior to paving, making sure that the subgrade PR is less than 12 mm/blow (0.47 in/blow).

Study results strongly suggest that using a DCP to evaluate a thin AC layer is possible, and furthermore that a DCP-based low-volume road pavement design and acceptance procedure can be developed. Development of such a procedure will greatly improve the quality of often-neglected low-volume road construction.

Recommendations

More DCP test data is needed to formulate a good standard. ODOT should therefore develop a Project Special Provision and implement DCP testing on more construction projects. The data collected can be used to modify and enhance the standard values this study recommends and develop a standard specification.

It is recommended that more projects with thin AC on a gravel base, natural soil, or stabilized soil be identified and tested. Results may then enable the development of a DCP-based low-volume road design and acceptance procedure.

It is recommended that ODOT use untreated OGGB with great care.

Also recommended is a follow-up study aimed at the following objectives:

1. Learn the effect of off-vertical driving on manual DCP readings.
2. Determine the effect of soil density and moisture content on DCP readings.
3. Identify the effects of "surcharge" pressure over the soil surrounding the DCP measurement.

Implementation Potential

It is recommended that ODOT implement DCP testing for quality control in two phases:

Phase 1: Develop a Project Special Provision to incorporate DCP acceptance criteria into construction contracts. Start collecting DCP data from a wide range of construction projects to verify the following recommended acceptance levels:

- For Ohio dense grade base, PR < 8 mm/blow (0.31 in/blow)
- For cement, lime, and lime/cement stabilized soil, PR < 8 mm/blow (0.31 in/blow)
- For subgrade construction, a uniform stiffness (indicated by uniform PR readings) for the top 300 mm (11.8 in) of soil
- For a thin AC layer (e.g., on a low volume road), PR < 7 mm/blow (0.28 in/blow).

Phase 2: Establish acceptance levels for different soil types and/or regions and modify the acceptance standards based on data collected during Phase 1. Revise and migrate the Project Special Provision to the ODOT Construction Specification.