PUTTING RESEARCH TO WORK **BRIEF**

New Stiffness Gauge Shows Potential, But Not Yet Ready for Adoption

Designing and building lasting, economical pavements and structures requires accurate assessments of subgrade stability. Subgrade material needs both the strength to support heavy equipment during construction, and the stiffness to carry traffic and yield good pavement performance over many decades.

Wisconsin DOT currently uses several traditional, qualitative methods for subgrade evaluation, including visual inspection, proof rolling (passing over the subgrade with a heavy roller to locate soft spots), time-consuming moisture-density tests, and observation of construction equipment on site (noting how deeply the equipment sinks into the soil).

What's the Problem?

All of these methods provide a qualitative assessment of the subgrade quality, rather than a direct assessment of stiffness or strength. Recently, other agencies have begun to use two new devices to more directly monitor subgrade properties: the Dynamic Cone Penetrometer, which provides an index of strength, and the Soil Stiffness Gauge, which directly measures stiffness.

The two devices measure different spatial zones; while the DCP indexes shear strength (a measure of compressive strength) as a function of depth, the SSG measures near-surface stiffness averaged over a zone. Prior to this research, WisDOT had not thoroughly examined the effectiveness of the two methods, or how their findings correlate with one another.

In addition, because nearly 60% of Wisconsin subgrade is poorly suited to highway building, WisDOT encourages the use of additives to improve soft subgrades. Direct monitoring of these combined materials' stiffness and strength would allow WisDOT to assess the quality of compaction during construction.

Research Objectives

Investigators sought to assess the suitability of the SSG and DCP for subgrade evaluation, looking specifically at the quality of data collected under ordinary field conditions. Researchers sought to:

- Recommend methods of measurement and of interpreting and using the data.
- Establish a reasonable correlation between SSG stiffness and the DCP Penetrometer Index, or DPI (the amount of penetration per blow, which is inversely proportional to shear strength). Researchers aimed to identify an effective depth for each subgrade at which the two data sets could be correlated.
- Examine the correlation between the mechanical properties of soils (stiffness and strength) and the index properties of soils obtained from traditional tests (density and moisture content).

Methodology

Researchers selected 13 Wisconsin construction sites located on a variety of subgrades, including natural earthen materials, industrial by-products, chemically stabilized soil, and other materials. They examined the subgrades with the SSG and DCP at various depths. They also measured in-place dry unit weight and moisture content with a nuclear density gauge.

The team compared the findings from each method to assess the impact of dry unit weight and water content on SSG-measured stiffness and DCP-measured index of shear strength. They also collated SSG and DCP data to discern whether the tools' measurements correlate effectively, and if so, at what depths.

Finally, investigators examined samples from each site in the laboratory to determine index properties,

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"The Soil Stiffness Gauge is a simple-to-use device that offers a quick way of monitoring construction progress, construction quality, and earthwork quality."

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The new Soil Stiffness Gauge (left) and the Dynamic Cone Penetrometer (right quantifiable information on the stiffness and strength of subgrades.

soil classification, and compaction characteristics, comparing data and indices drawn from the SSG and DCP to data derived from traditional tests.

Results

Researchers observed a simple, linear, semi-logarithmic relationship between stiffness measured by the SSG and shear strength as indicated by the DPI. For most materials, the best correlation occurred when DPI was averaged over a DCP penetration depth of 152 mm. Compacted subgrades yielded stronger correlations than uncompacted.

Test results indicated that neither dry unit weight nor moisture content alone controls stiffness or strength. Researchers found these relationships:

- Stiffness and shear strength increased with dry unit weight.
- Stiffness declined when moisture content varied up or down from 5% in coarse soils and 10% in fine soils.
- Shear strength decreased as moisture content increased in most fine materials.

In addition, the SSG and DCP have potential for both structural property assessment and earthwork quality control in conjunction with moisture-density tests. Measurements from the two tools can be used to generate design modulus figures that correlate well together, and the DCP is widely accepted to produce modulus values that correlate well with an important design input, the California bearing ratio, or CBR.

Potential Benefits

Both the SSG and the DCP show good potential for use in on-site subgrade evaluation. They provide direct, quantifiable assessments of subgrade stiffness and strength, a capability lacking in traditional assessment methods. Both tools have applications for quality control: The SSG in particular takes measurements very quickly, allowing engineers to take readings in many locations to establish the uniformity of the earthwork.

Further Research

Wisconsin-specific modulus and/or CBR correlations must be developed before the SSG and DCP can provide design inputs for WisDOT.

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"The hope we had for these devices was that we would be able to get away from moisture-density testing. But they don't allow us to do that yet."

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