JOINT TRANSPORTATION RESEARCH PROGRAM

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# Control Guidelines for Aggregate Drainage Layers and Evaluation of In-Situ Permeability Testing Methods for Aggregates

## Introduction

This research project evaluated methods for measuring performance parameters of aggregate drainage layers in-situ to provide INDOT guidance for developing performance-based specifications for these layers. The work focused on two experimental methods—the light weight deflectometer (LWD) and the air permeameter test (APT).

## Findings

The work performed included the following.

- An extensive field-testing program on two experimental testing strips constructed at Purdue University's SBRITE facility. The strips were comprised of a layer of Indiana #53 (IN #53) aggregate constructed over compacted natural soil or the cement-treated subgrade. Testing on the aggregate was performed with high spatial density on a 3 ft × 3 ft grid and included LWDs, APTs, nuclear density tests, and imaging of the aggregate surface.
- Similar testing programs at three construction sites in Indiana. At one of the sites, additional APTs were performed on two bound drainage layers: a cement treated base, and an open graded asphalt.
- An extensive program of constant and falling head laboratory tests and APTs on laboratory prepared samples of IN #53 and on pervious concrete, the latter used as a model material.

Statistical analyses of the data collected at the SBRITE site, enabled by the large size of the statistical sample, showed that the measured parameters exhibited different dispersion, as measured by the coefficient of variation (CV). Of the data collected on the aggregate layers, the greatest dispersion was observed in the hydraulic conductivity ($k$) values, followed by the LWD deflections, and the dry density. At all sites, the range of the $k$ data exceeded a few thousand ft/day.

The observed spatial variability in the properties of the compacted aggregate could be, at least in part, ascribed to material heterogeneity produced by segregation, which in this work was quantified through a parameter termed median feature size (MFS) extracted from images of the aggregate surface. Linear correlation analyses demonstrate a strong correlation between the MFS and the in-situ hydraulic conductivity ($k$), supporting the hypothesis that local material heterogeneities drive variability in hydraulic conductivity at the local scale.

Cement-treatment of the subgrade reduced LWD deflections, facilitated compaction of the aggregate, and promoted more homogenous conditions, both in the subgrade and in the overlying aggregate.

Based on APT and nuclear density tests, coarse aggregates, such as IN #53, appear to be valid options as drainage layers. However, laboratory tests indicate that variation in the percentage of fines and material heterogeneity may lead to lower values of $k$. Laboratory hydraulic conductivity tests also suggest that the applicability of Darcy's law to this material may be limited to small gradients, and that the aggregate may be susceptible to internal erosion.

Although both LWD deflections and nuclear density measurements are being used in practice for quality assessment of compacted subbase granular layers, across both strips at the SBRITE site the two measurements were not found to be strongly correlated. Moreover, the LWD data showed significantly greater dispersion than the $\rho_d$ measurements. For the untreated strip, measurements performed on the aggregate layer were found to be controlled by deformations in the underlying subgrade, with weak information provided on the state of compaction of the aggregate layer.

The sturdy and compact design of the APT apparatus and the simplicity of operation are well suited for rapid and frequent measurements in the field. Moreover, extensive testing demonstrates that measurements using the APT can be consistently performed on compacted IN #53 aggregate. However, in its current configuration, it cannot be reliably used to test materials with higher *k*. Additionally, values of saturated hydraulic conductivity derived from the APT are highly sensitive to the degree of saturation of the aggregate. Concurrent measurements of the degree of saturation are therefore needed to map spatial variability of the in-situ degree of saturation.

Stochastic analysis of the LWD data collected at the experimental SBRITE site on both the subgrade and the aggregate layer demonstrates that small statistical samples are generally not reliable for quality control, and that the estimate of the population mean based on such samples carries great uncertainty. The degree of uncertainty is dependent on the distribution of the population and increases for datasets characterized by greater variability.

Moreover, information pertaining to local problematic areas, which are often the source of damage in pavement systems, is not captured when utilizing QA/QC criteria based on the mean of a sample, thus compromising efforts in quality assessment. These observations highlight the importance of assessing uncertainty evidenced by the dispersion in the data during a quality assessment campaign.

Samples of the nonwoven geotextile fabric used as a separator layer over a portion of the two SBRITE strips exhumed following the completion of the testing program showed significant damage, evidence that the geotextile did not survive and could, therefore, not fulfill its intended functions as separator/filter.

## Recommendations

Based on the work performed, the following recommendations for implementation are provided.

- Under conditions like those encountered at the SBRITE site, cement-treatment of the subgrade is recommended.
- Construction methods to limit segregation of aggregates in the field should be enforced and aggregate compaction should be performed using vibratory rollers, with early and final passes in static mode.
- The use of LWD deflection-based criteria is recommended for the QA/QC of untreated and cement-treated subgrades and of aggregate layers constructed on cement-treated subgrade.
- The LWD is not recommended for the QA/QC of aggregate layers constructed on untreated subgrades.
- In the current state of development, implementation of the APT for QA/QC is not recommended, due to issues with the method used to account for the degree of saturation and the extensive testing required for mapping this property in the field.
- The use of rapid non-destructive tests (e.g., LWD) that can be performed in large numbers and at high spatial density is recommended for QA/QC.
- Uncertainty as measured by the dispersion of the data should be assessed and guidelines formulated in probabilistic terms as part of a QA/QC campaign.
- Consideration should be given to assessing material segregation as part of QA/QC protocols for aggregate layers.
- A higher-class geotextile product compared to the one used in this project is recommended to provide separation and filtration functions.

The study also highlighted the following areas where additional research is warranted to further support INDOT's transition towards performance-based specifications:

- investigation of susceptibility of IN #53 and of other candidate aggregates to segregation and internal erosion,
- advancement of image analysis method for segregation quality control,
- improvement in data interpretation and further validation of air permeameter test (APT),
- advancement of LWD test interpretation, and
- development of risk-informed QA/QC.

## Recommended Citation for Report

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