JOINT TRANSPORTATION RESEARCH PROGRAM

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Improved Light Weight Deflectometer Test (LWD) and Analysis

Introduction

The stability and strength of subgrade, subbase, or base courses are influenced by three main factors: material type, construction methods, and environmental conditions. Of these, construction practices—particularly compaction—are often the most critical. Typically, these layers are built using local materials such as natural, stabilized, or granular soil. Ensuring proper compaction is essential and is usually verified through in-place density tests.

The sand cone and nuclear gauge tests are widely used for in-place density measurement, but they have notable drawbacks. The sand cone test is time-consuming and difficult for granular soils, while the nuclear gauge raises safety and regulatory concerns due to its radioactive probe. To overcome these issues, many DOTs are adopting the light weight deflectometer (LWD) test, which eliminates safety risks and logistical challenges while also providing the in-situ modulus of geomaterials—a key parameter for pavement characterization.

The LWD test measures stiffness by dropping a 22-lb weight onto an 11.81-in. plate, applying about 14.5 psi, while a sensor records deflection, which is inversely related to stiffness. This fast, performance-based test is widely used for quality control (QC) and quality assurance (QA) in earthwork, with acceptance based on maximum allowable deflection. INDOT sets deflection criteria for subgrade types like IBC and IBL through onsite tests (ITM 514), though these reflect index density rather than true stiffness.

INDOT began LWD testing for compaction acceptance for aggregates in 2016, expanding in 2018 to chemically modified soils. However, the criteria for these soils was based on limited data and lacked direct performance links. A major challenge was the need for large test sections (100 ft × 24 ft), impractical in tight areas, like bridge approaches or lane widening or patching—common uses of aggregate No. 53. With over 200 LWD devices in use, maintaining reliable QA required regular calibration and verification.

This study was initiated to overcome these challenges and establish maximum allowable deflections for compaction QA without relying on test sections. INDOT needed a method to define LWD deflection criteria for both chemically and non-chemically modified subgrades that retained the performance focus of the LWD test.

The solution was to develop a specialized laboratory testing program. Since no full-scale laboratory LWD setup existed, the study created a robust, large-scale testing facility at the INDOT research center. This facility enabled controlled material testing and the development of deflection criteria for various pavement materials. It also supported deeper understanding of material behavior and deflection mapping using advanced sensors, which aided correlation with falling weight deflectometer (FWD) and resilient modulus tests.

Because Indiana contractors often use Zorn and Dynatest LWD devices, the study also developed equipment-specific factors for standardized calculations. The research expanded to include finite element (FE) modeling to simulate various materials and test conditions, which were validated against large-scale lab and full-scale accelerated pavement testing (APT) models.

Findings

Initial experimental and numerical analysis revealed the following.

- Integrating the viscoelastic plastic model into LWD measurements significantly improved the prediction of pavement and soil behavior under impulsive loading, offering a clearer understanding of dynamic responses through detailed hysteresis effects.
- FEM simulations closely matched laboratory and full-scale APT tests, confirming the model's accuracy in

capturing time-sensitive material behavior.

- The laboratory setup, equipped with sensors and calibrated for static and dynamic loads, effectively tested various materials and conditions, supporting the development of reliable deflection criteria.
- Early results indicated Dynatest LWD equipment was more reliable than Zorn, though this finding was based on FE simulations; therefore, laboratory testing was required to make well-informed decisions.

Implementation

The successful implementation of improved LWD testing methods for soil compaction quality control involved a multifaceted approach: developing a state-of-the-art laboratory facility, establishing standardized testing protocols, integrating advanced finite element (FE) modeling, and ensuring rigorous calibration and verification of LWD equipment. The following highlights current benefits and future applications.

Laboratory Testing Facility Development

A large-scale laboratory testing facility was developed to perform LWD tests, enabling the study of different materials under controlled conditions. The facility included a sandbox to accommodate varying degrees of compaction, saturation, and material types, allowing precise, consistent testing. INDOT can enhance its quality control process using this facility.

Standardized Testing Protocols

Standardized protocols were created to ensure consistency and reliability in LWD measurements. These include detailed procedures for conducting tests, calibrating equipment, and interpreting results. Protocols also specified conditions such as loading plate type and drop height, ensuring accurate and comparable results across projects.

Finite Element (FE) Modeling and Numerical Simulations

FE models simulating material behavior under LWD testing were developed using the viscoelastic plastic material model. These simulations predicted deflection basins for various materials and were validated through comparisons with laboratory and full-scale tests. The models provided realistic deflection basins that support Mechanistic-Empirical Design (MEPDG) applications.

Calibration and Verification

The laboratory served as a hub for calibrating and verifying LWD equipment, a critical need due to the widespread use of these devices in INDOT projects. Regular performance checks against known standards ensures accuracy. Rigorous calibration helps maintain reliable LWD measurements statewide.

Equipment-Specific Protocols

With Zorn and Dynatest LWD equipment commonly used by Indiana contractors, equipment-specific protocols were developed. These protocols account for each device's unique characteristics, ensuring deflection criteria apply regardless of the equipment used. Initial findings suggested Dynatest provided more reliable results, but further testing is needed to confirm and refine these protocols.

Training and Education

Training programs are essential for INDOT personnel and contractors to ensure proper implementation. These programs cover standardized protocols, calibration and verification, and result interpretation. Comprehensive training will equip stakeholders with the necessary skills to conduct LWD tests accurately and effectively.

Continuous Improvement

LWD testing implementation should remain ongoing, with continuous monitoring and improvements based on field data and user feedback. Regular reviews of deflection criteria and protocols will keep them relevant and effective. Incorporating advancements in LWD technology and methods will ensure INDOT maintains a state-of-the-art approach to soil compaction QA.

This research study's successful implementation strengthens INDOT's quality control processes. By developing robust acceptance criteria, a specialized laboratory facility, and standardized protocols, INDOT is better positioned to ensure durable, reliable pavement structures across diverse construction scenarios.

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