

JOINT TRANSPORTATION RESEARCH PROGRAM

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SPR-4100

2018

Maximum Allowable Deflection by Light Weight Deflectometer and Its Calibration and Verification

Introduction

There are three primary factors that may substantially affect the stability and strength of subgrade, subbase course, or base course: type of material, construction, and environment. Construction, particularly compaction, may be the dominant factor because subgrade or subbase course is commonly constructed using local materials such as soil or granular soil, either natural or stabilized. One of the common practices to ensure compaction quality is the in-place density test, which determines whether compacted soil density meets requirements.

Currently, sand cone and nuclear gauge tests are widely used to find the in-place density of compacted soil; however, these tests have drawbacks. The sand cone test requires digging a hole and using calibrated sand—a time-consuming test for granular soil. The nuclear gauge test uses a probe that contains radioactive source material. In light of these disadvantages, there is a tendency for state departments of transportation (DOTs) to find alternative tests for field soil compaction quality control. The light weight deflectometer (LWD) test is one of the most promising alternative in-place tests and is increasingly used for field soil compaction control. The LWD test overcomes the disadvantages associated with the sand cone and nuclear gauge tests and is capable of providing the in-situ modulus of geomaterials—one of the key parameters used to characterize the properties of pavement structural layers.

To date, the LWD test has already been used by the Indiana Department of Transportation (INDOT) for compaction quality assurance (QA) of lime and cement modified soils, subgrade treatments with aggregates, and aggregate subbase or base. However, the implementation of LWD for compaction QA requires construction of a 100 ft. long, 24 ft. wide test section prior to other uses. There are numerous cases where aggregate No. 53 is used in construction of subgrade, subbase course, and base course in small areas, such as bridge approaches, lane widening, patching, and shoulders, and construction of a test section is not possible. Additionally, there are over 70 LWDs currently used in construction projects by INDOT. Maintaining a quality control process requires timely and appropriate calibration and verification of the LWD devices. This research study was therefore performed to address these issues, particularly to develop maximum allowable deflections for compaction QA in small areas.

Findings

The Proctor test for aggregates is performed in accordance with the AASHTO Designation: T 99 by INDOT (2017). Corrections may be necessary if the oversize material is above a certain percentage. However, the laboratory test results indicate that the differences between the original and corrected maximum densities and between the original and corrected optimum moisture contents for both materials were not significant for practical applications.

When performing LWD testing on aggregates in a Proctor mold, the interface condition between the aggregate material and the inner wall of the mold will affect the deflection measurements, depending on the aggregate size and moisture content. The deflections increased by about 11.8% to 18.8% for No. 43 aggregates and by 1.9% to 6.7% for No. 53 aggregates when the inner wall of the mold was lubricated.

Different from the well-known bell shaped moisture-density relationship, the moisture-deflection relationships for aggregates did not show an optimum moisture content at which the deflection would be at a turning point. The results of the laboratory experiments imply that a minimum deflection may not exist in terms of different moisture contents.

When compacted at the optimum moisture content, the modulus of aggregates increased considerably as the moisture content decreased. When compacted at a random moisture content, the modulus of No. 53 aggregates remained relatively unchanged, but the modulus of No. 43 aggregates increased noticeably as the moisture content decreased. Coarser aggregates are more sensitive to the moisture content than finer aggregates with respect to deflection or modulus.

The results of LWD tests in the test pits indicate that No. 53 aggregates can contribute to the structural capacity, but No. 43 aggregates can only contribute to the structural capacity when its thickness is 8 in. or more. The deflection decreased as the thickness of aggregate layer increased. As the layer thickness increased to a certain level, the deflection became stable.

It is necessary to adjust the target deflection or modulus by taking into consideration the field and construction conditions. However, caution should be exercised when selecting either deflection or modulus as the target parameter for field compaction QA using LWD.

It may become very challenging to compact geomaterials in small and confined areas to the same degree as those in large areas. Therefore, the target deflection values should be adjusted according to the characteristics of compaction in small areas. Field LWD tests revealed that the deflections for light-weight compactor were greater than those for large roller. The overall ratios between the deflections in small and large areas are 1.192, 1.239, and 1.227 for 2017, 2016, and historical projects, respectively. No rigorous scientific methods are currently available to determine a factor for adjusting the target deflection. To avoid unnecessary complexity, 1.219 (the average of the above three deflection ratios) is used as the adjustment factor for considering the characteristics of small area compactions.

Placing an unbound aggregate layer on chemically modified subgrades may produce an inverted two-layer system; thus, the deflections may increase as the aggregate layer thickness increases. Nevertheless, the field LWD test results did not fully agree with the variation trend of deflection for the inverted layer system. The potential effect of inverted layer system was not considered when determining the maximum allowable deflections.

The structural response of an elastic layer system to external loading may vary dramatically with the boundary condition. The deflection at the outside edge may be up to 40% and 35% greater than the deflections in the middle and inside edge, respectively. Therefore, caution should be exercised when determining the position from which to perform LWD testing for compaction QA, particularly in small areas.

Extensive in-situ LWD testing indicates that for small area compaction, a minimum of 5 LWD tests are required to provide reliable compaction QA. A minimum of 8 to 10 LWD tests are necessary for large area compaction. The minimum sample size should increase as the compaction area increases, taking into account the requirement of at least 10 LWD tests for a test section of 100 ft. by 20 ft. for compaction of aggregates.

The majority of the projects have a COV of 20% to 35%. For small area compaction, a COV of 20% or less may indicate “Low” variation, a COV of 20% to 35% may indicate “Normal” variation, and a COV greater than 35% may indicate “Poor” variation.

Annual verification is necessary to ensure repeatability of LWD deflection measurements.

Implementation

The following recommendations are made for future implementation:

- When performing the laboratory Proctor test to determine the target deflection (or modulus), the inner wall of the mold should be properly lubricated.
- It is important to compact aggregate materials near the optimum moisture content level.
- For aggregate compaction, the LWD deflection varies significantly with the moisture content. It is recommended that the LWD test for compaction QA should be conducted within two hours after compaction.
- The maximum allowable deflections recommended by this study should be further fine-tuned, taking into account statewide field practice and experience in roadway construction.
- Back calculation of the aggregate modulus from the mold or in-situ deflection is subject to the effects of many factors. It is advisable for INDOT to continue to use deflection as the target parameter for QA of compaction.
- Different LWD devices may have different features, leading to different deflection or modulus measurements. Further effort is needed for INDOT to support more than one type of LWD devices.
- Caution should be exercised when determining the position for performing LWD testing for QA of compaction. In small compaction areas, it is advisable to perform LWD testing three feet away from the outside edge or in the middle of the lane or shoulder under uniform compaction.
- Urgent effort is needed to assess the possible positive and negative effects of the calibration interval and determine the optimum calibration interval.
- Discrepancies observed in field compaction and LWD testing by different contractors and inspectors suggest that necessary training is needed to further improve construction quality and ensure QA consistency.

Recommended Citation for Report

Zhao, G., Yao, Y., Li, S., & Jiang, Y. (2018). *Maximum allowable deflection by light weight deflectometer and its calibration and verification* (Joint Transportation Research Program Publication No. FHWA/IN/JTRP-2018/21). West Lafayette, IN: Purdue University. <https://doi.org/10.5703/1288284316866>

View the full text of this technical report here: <https://doi.org/10.5703/1288284316866>

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