

New Jersey Department of Transportation Bureau of Research Technical Brief



Alternatives to Nuclear Density Testing

The New Jersey Department of Transportation would like to replace the nuclear density gauge with non-nuclear based devices/methods when assessing the quality of compacted unbound pavement layers. However, currently available testing methods/procedures have not been verified for New Jersey materials; thus, warranting the need for evaluating available non-nuclear devices/methods. Three devices were considered in this including: the Dynamic Cone Penetrometer, the Light Weight Falling Deflectometer, and the Briard Compaction Device.

Background

Naturally existing soils and quarry-produced aggregates play a crucial role in highway infrastructure. These materials are typically used to construct base or subbase layers in rigid and flexible pavements. During the construction of these pavements, it is essential to properly compact base/subbase and subgrade materials to suitable density levels. This is primarily because the performance of rigid or flexible pavements is highly dependent on the quality of the compacted subgrade and unbound base/subbase layers. In other words, compaction defects in these layers typically result in distresses in the upper hot mix asphalt (HMA) or Portland cement concrete (PCC) layers.

In practice, highway agencies employ specifications that rely on selecting a specific aggregate type and a minimum density level (e.g., 95% of the Proctor maximum dry density). The density requirement is determined using the nuclear density gauge (NDG), which is currently considered the primary tool for assessing the quality of compacted base/subbase and subgrade layers. As an example, the New Jersey Department of Transportation (NJDOT) currently uses the NDG for assessing the compaction quality of Embankments, Aggregate and Base Courses, and Foundation/Backfill of Structures. The popularity of the NDG is mainly due to its portability, ease of use, accuracy, and timely results.

Despite the popularity and advantages of the NDG, there are several concerns and safety risks associated with using this device. Strict regulations for using the NDG require specific transportation and storage methods/procedures only appropriate for nuclear devices. These regulations also require having trained licensed personnel to operate the NDG, making the NDG onerous and expensive. In addition, when using the NDG, the operator may be exposed to harmful radiation; thus, the NDG can pose a safety risk. Furthermore, the NDG only measures a density value as opposed to a modulus or design-specific value. From a design perspective, the engineer uses an assumed modulus value for designing pavement structures, while in the field compaction quality is controlled using a density value. This results in a gap between the mechanistic-empirical pavement design stage and the quality control stage during the construction of pavement structures. Therefore, it is highly desirable to evaluate other methods/devices that can replace the NDG and provide design engineers with design-specific measurements that can help in avoiding over/under designed pavements.

Research Objectives and Approach

The overall goal of this study is to evaluate alternative non-nuclear methods for use during the acceptance of soil and quarry produced aggregate compaction. The specific objectives to achieve this goal include:

- Determining the current state-of-practice as related to using alternative non-nuclear methods for assessing the quality of compacted soil and subbase/base pavement layers.
- Selecting and evaluating the accuracy of the non-nuclear density/strength/moisture-based testing device or procedures.
- Developing a laboratory procedure for compacting large soil/aggregate samples.
- Conducting field evaluations of the proposed technology(s).
- Conducting a cost analysis comparison between the selected non-nuclear device/method and the NDG.
- Developing a draft specification for the most promising alternative device/method.
- Providing recommendations to NJDOT.

Findings

The following conclusions were drawn based on the observations made through conducting extensive laboratory and field testing using the selected non-nuclear devices and the nuclear density gauge:

- The laboratory procedure developed for compacting large samples was found to be satisfactory. The actual moisture contents and densities were within $\pm 0.5\%$ and $\pm 5 \text{ lbs/ft}^3$ of their targeted values, respectively.
- Mold size did not have a significant impact on testing results (especially in the case of LWD). This is the case because testing results obtained from large samples were statistically similar to those obtained from small samples.
- The moisture content within the compacted samples (up to $\pm 2\%$ of OMC) was sensitive to parameters measured from all devices evaluated. The DCP was the most suitable device for capturing the change in moisture contents within the samples while all other devices showed mixed trends within their results, specifically when preparing samples at 2% below and 2% above OMC.
- Based on the comparison of the standard error of the mean results, variability was similar for all non-nuclear devices. In addition, DCP showed higher variability when the soils had higher moisture content than the OMC.
- All of the parameters measured from these four devices were able to distinguish between the four aggregate types.
- The DCP prediction model developed was found to be adequate at predicting laboratory and field DCP measurements. The model was also found to be significantly dependent on moisture content, percent passing sieve No. 4, and percent passing sieve No. 200.
- The DCP prediction model, which was developed and calibrated as a part of this study, was used successfully for identifying a set of recommended DCP penetration rates that would ensure satisfactory compaction of unbound pavement layers in the field.
- Specifications for using the DCP as a compaction acceptance tool for natural soils and engineered aggregates was successfully developed.

Recommendations

The following are the recommendations from the study:

- It is recommended that NJDOT implements the procedure developed as a part of this study for specifying minimum DCP values for quality acceptance of unbound subgrade and base/subbase layers during the construction of roadway pavements. It should be noted; however, that this procedure is limited to only non-plastic granular materials (i.e., NJ natural sands, DGA, and RCA).
- Due to the limited number of field sections tested and the types of aggregates considered in this study, it is recommended to conduct testing on additional field sections constructed using different types of aggregates than those considered as a part of this study. This will further widen the implementation of the developed specifications.
- It is recommended that future research evaluates the ramifications of waiving the requirement for measuring field moisture content as this directly impact the practicality aspect of the developed DCP specifications and might hinder implementation efforts.

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A final report is available online at: <http://www.state.nj.us/transportation/refdata/research/>. If you would like a copy of the full report, send an e-mail to: Research.Bureau@dot.state.nj.us.

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