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# Evaluation of Non-Destructive Density Determination for QA/QC Acceptance Testing

## INTRODUCTION

Density of soil and asphalt layers is often considered the most important variable in the construction of durable, longer-lasting roads. To meet density requirements, contractors and transportation agencies follow quality control (QC) and quality assurance (QA) procedures to ensure specifications are met, and performance is achieved.

For soils construction, contractors utilize the nuclear density gauge (NDG) as part of their QC process to monitor density and soil moisture. DOTD utilizes their similar nuclear devices for QA processes for soil layers by measuring density, every 1000 ft. or so, for final acceptance. For asphalt pavement construction, contractors utilize the NDG to establish rolling patterns for asphalt pavement construction, while final density acceptance requires the in-place density of HMA pavements to be measured from core samples cut from the pavement after compaction.

While the NDG and roadway cores are known to be the most precise methods to determine densities, these procedures have their limitations. NDG limitations include nuclear radiation, increased safety and training requirements, and special storage and handling. For the asphalt coring process, drilling cores create damage to the new pavement, long testing times, and small sample size.

DOTD and contractors alike are interested in the potential of the low to non-nuclear gauges to overcome disadvantages of the NDG and core sample method. Low to non-nuclear gauge methods offer advantages of economic savings, faster data measurement, no intense federal regulations, lesser safety concerns, no extra licensing and intense training, improved calibration techniques, non-destructive testing, faster testing times, and increased density measurements throughout the entire paving project.

## OBJECTIVE

The first objective of this research was to conduct a validation study to compare the new lower nuclear sourced density gauge (LNDG) and moisture probe for soil density and moisture determination compared to the density readings of conventional NDGs for the geotechnical group. The asphalt group compared density results from a NNDG and NDG against roadway cores. Additionally, the research will evaluate the nuclear and low/non-nuclear gauge as QA devices for non-destructive density determination. The research will utilize intensive field tests and core samples to determine their effectiveness benefits, and implementation potential for QA/QC applications within DOTD.

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## SCOPE AND METHODOLOGY

LTRC's Geotechnical group conducted field evaluations at two sites for moisture/density gauge comparisons. Two types of density gauges were evaluated. The first was the currently utilized NDG (nuclear density gauge) and the second was a newer LNDG (lower nuclear sourced density gauge). The moisture and density readings of the devices were compared to the moisture and density readings provided by a conventional NDG. Other elements were evaluated including performance, cost, reporting, and training requirements.

LTRC's Asphalt group evaluated gauge and core density data from nine asphalt projects around Louisiana. From these nine projects, 11 different asphalt lifts were evaluated utilizing four different non-destructive density gauges. The density gauges utilized included a NDG, same gauge utilized by geotechnical group, a thin-layer nuclear density gauge (TLNDG), and two non-nuclear density gauges (NNDG). The density readings from the gauges were compared with core densities utilizing linear regression and analysis of variance (ANOVA) statistical analysis. Similar to geotechnical group, other elements were evaluated including performance, cost, reporting, and training requirements.

## CONCLUSIONS

The geotechnical research group concluded:

- The LNDG was found to capture the dry density relatively well compare to the NDG with a returned R2 value of 0.84 and the LNDG moisture content results were slightly wetter with an R2 value of 0.67 when compared to the NDG.
- The LNDG maximum depth capability does not meet the current DOTD TR-401 depth requirements for base course and embankment depth quality assurance tests.
- The LNDG requires a longer test time than the NDG.
- The LNDG has a smaller radioactive source that is sensitive to other radioactive devices and is even affected by naturally occurring radiation.
- The LNDG has a separate moisture probe with a diameter larger than the LNDG probe.
- The LNDG's smaller source needs replacing on an 8 to 10-year cycle, which would create maintenance costs, labor, and paperwork for the Department.
- The NDG is safe when utilized properly with normal exposure rates well below the annual allowable limit of 5000 mrems.
- NDG safety training costs were from $9,500 to roughly $25,000 a year per 3-year training cycle.
- Both devices require time, effort, training, and consideration. The NDG is a known quantity and is well established within DOTD.

The asphalt research group concluded:

- The linear regression results of the TLNDG and NNDGs showed fair to good correlation to roadway cores, NDG showed fair to poor correlation to roadway cores.
- ANOVA hypothesis testing showed that the both NNDG results were not significantly different. Furthermore, as indicated by the greater P-value for NNDG results than for NDG results, calibrated NNDG results agreed better with core results than did nuclear gauge results.
- Sand patch results were mixed and a strong conclusion could not be made regarding surface texture effects on the density gauges.
- NDG and TLNDG testing time was typically 10 to 15 minutes from gauge setup and calibration to density results, while the NNDG typically only needed 5 minutes from gauge setup to density results.
- Cost comparisons of each density measuring tool (Core rig, NDG, and NNDG) exhibited that NNDGs would provide the most cost savings.

## RECOMMENDATIONS

Based on the results of the geotechnical research, the authors recommend retaining the NDG for soils density for both QC and QA testing due to limitations of the LNDG. The authors recommend further testing of the LNDG once the technology improves, essentially in the depth of the probe.

Based on the results of the asphalt research, the authorsalso recommend the use of the non-destructive testing for both QC and QA testing provided the manufacturer's and AASHTO T-343 recommendation to calibrate the device daily by applying a core-calibration offset is followed. The authors do not recommend the use of either gauge for QA testing without conducting the recommended calibration.


*Figure 1*
*Soil density gauges (NDG on left; LNDG on right)*