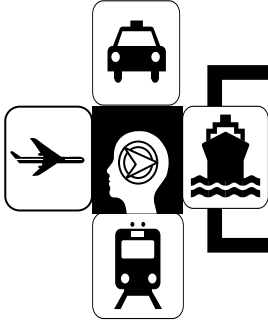


JERSEY DOT'S

"Turning Problems into Solutions"



Tech Brief

Evaluation of the Humboldt Stiffness Gauge (HSG)

Need a solution?
Think Jersey DOT

FHWA-NJ-2002-002-TB

January 2002

SO, HERE'S THE PROBLEM...

- Quality control of placed fill or pavement materials is a vital component during the construction process
- Current practice is to use the nuclear density device to measure soil density
- Special attention and permitting is needed for the use and storage of a nuclear density device
- Also, density measurements of Portland cement stabilized soil are incorrect when determined by a nuclear density device

AND, HERE'S OUR SOLUTION

- Find a fast, repeatable and accurate method to determine dry density of placed fill or pavement materials
- Evaluate if the device can be used in any other means for pavement design

We set out to evaluate the Humboldt Stiffness Gauge's (HSG) ability to determine the dry density of various New Jersey subgrade soils, as well as a Portland cement stabilized dredge sediment. The NJ subgrade soils were used in controlled laboratory testing to evaluate the HSG's repeatability and accuracy. The controlled laboratory testing also involved determining the typical measurement depth of the device, as well as the HSG's ability to provide accurate density measurements when large objects are buried beneath it.

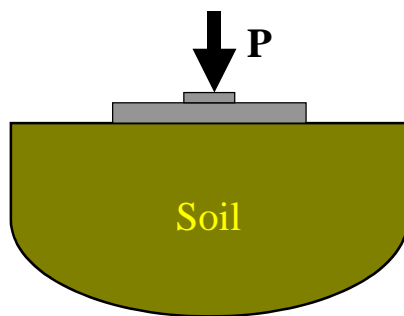
A large scale field evaluation was conducted using the HSG on Portland cement stabilized dredge sediment. The stabilized dredge sediment (SDS) was used to construct two large test embankments. Previous quality control testing with a nuclear density gauge showed a percent error as high as 75 percent when using a nuclear device on Portland cement stabilized soil. Over 400 measurements were conducted using the HSG during the construction of the embankments.

HERE'S WHAT IT LOOKS LIKE... AIN'T IT A BEAUTY!!!



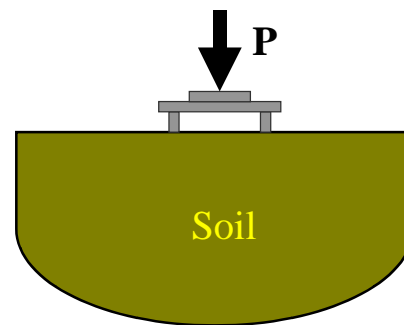
The Humboldt Stiffness Gauge (HSG) acts as a miniature plate load test, as shown in the figure below. The HSG imparts very small displacements to the soil ($< 1.3 \times 10^{-6}$ m or 0.00005 inches) at 25 steady state frequencies between 100 and 196 Hz. The stiffness is determined at each frequency (displacement) and is then averaged. The stiffness is determined by the ratio of the force to displacement ($K=P/\delta$). The displacement (δ) is proportional to the outside radius of the HSG, and the Young's Modulus (E) and Poisson's ratio (μ) of the soil.

The device is built and sold by the Humboldt Manufacturing Co. in Norridge, Illinois.



Miniature Plate Load Test

$$K = P/\delta = (2rE)/(1-\nu)^2$$



HSG

$$K = P/\delta \sim (1.77rE)/(1-\nu)^2$$

THIS IS WHAT IT CAN DO

- 1) Provide data for quality assurance/quality control
- 2) Estimate dry density of soils
- 3) Determine the stiffness of various soils

HERE'S WHAT WE CAME UP WITH...

The HSG was evaluated in the laboratory to estimate the dry density of various subgrade soils. The results from the HSG were compared with the Balloon Density Test results. Moisture contents were determined by oven drying. All of the subgrades were compacted in small soil bins at 3 inch intervals. At the end of each interval, a test with the HSG was conducted. At every 6 inches, the Balloon Density test was conducted. Results from the analysis show that the HSG typically measures to depths of 9 to 12 inches below the device. The depth is somewhat dependent of the stiffness (the larger the stiffness, the deeper the measurement). Results also show that the dry density estimation from the HSG compares well with the density measured by the Balloon Density test, as well as the assumed based on the weight of soil used and the volume of soil compacted. The only drawback of the HSG is that a calibration of the HSG stiffness and the soil's dry density and moisture content is needed. Attempts were made to see if a general calibration equation could be used for the soils tested, however, the results were poor. Therefore, for each soil the HSG is to be used on, it is recommended that a calibration be made.

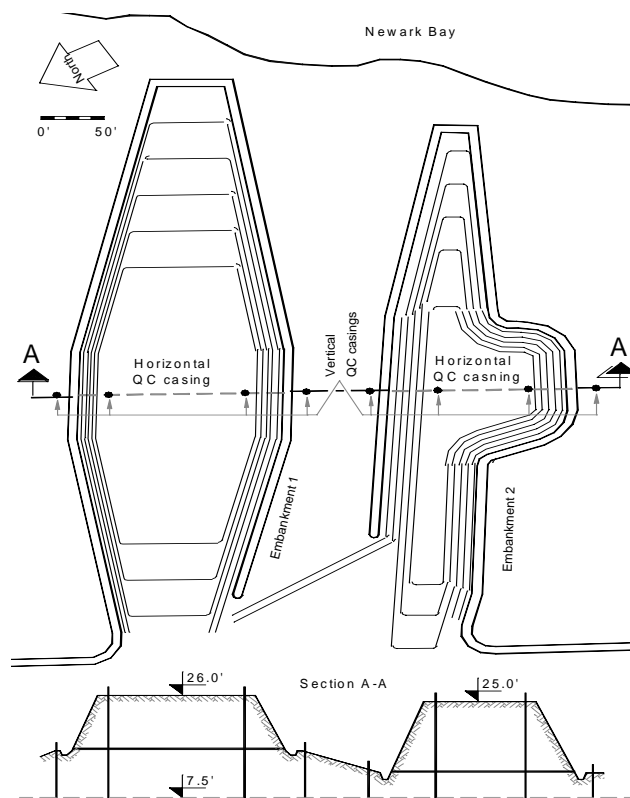
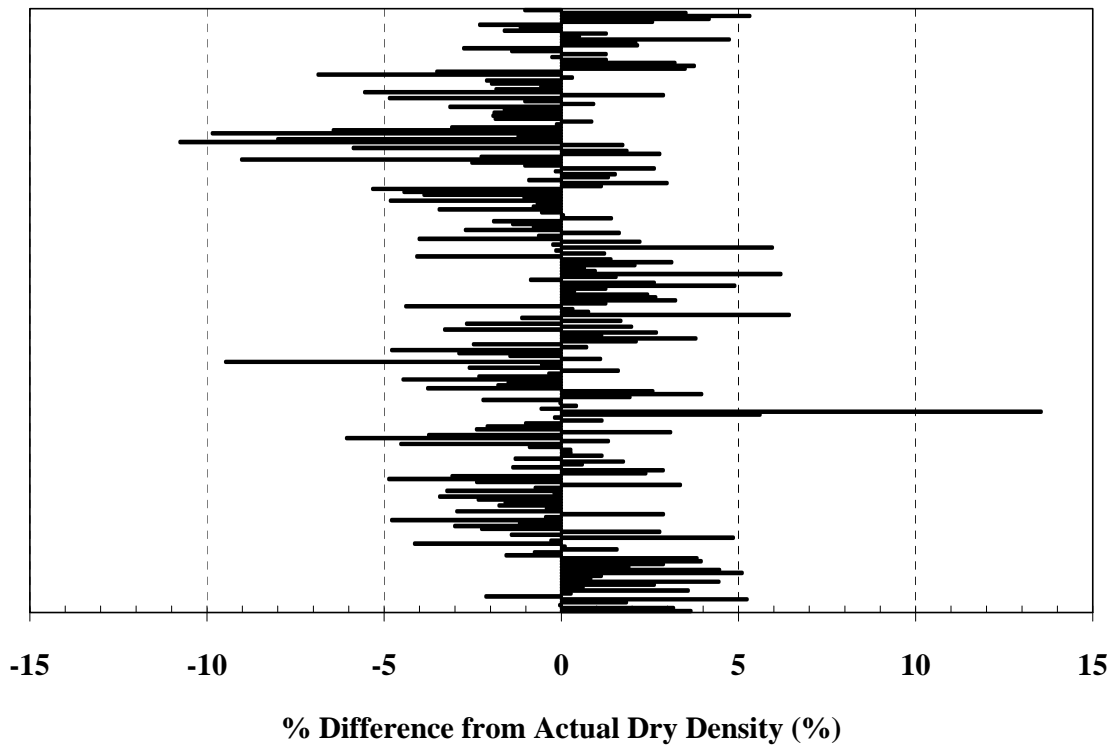
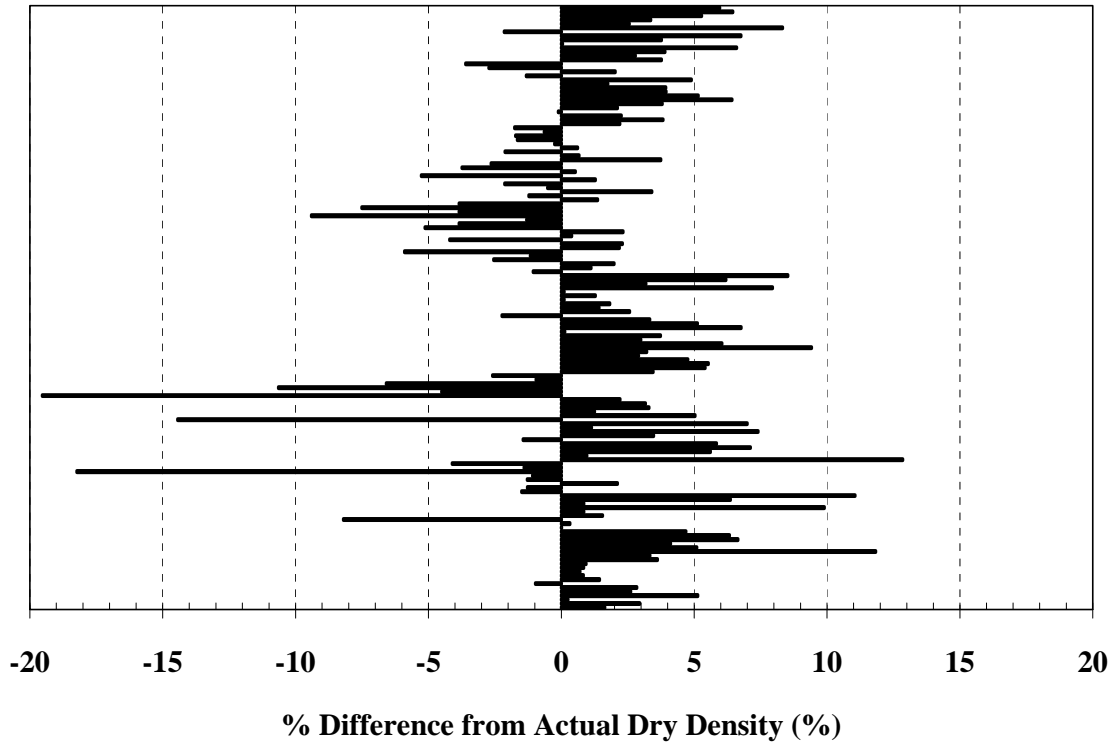


Fig. 1 The schematic of embankments and installed casings

A large scale field evaluation was conducted on two test embankments in Elizabeth, NJ. The embankments were constructed entirely of Portland cement stabilized dredge sediments (SDS). The SDS was primarily a silt with sand and clay. Over 400 tests were conducted on both embankments, with the HSG estimations compared to dry density measurements made with a nuclear density gauge and oven drying. Comparisons of the testing are shown in the following two figures. As shown in the figures, the estimated results from the HSG are typically within 5 percent of the actual, as determined from the nuclear density gauge and oven drying. However, the advantage of the HSG in this project was that due to erroneous moisture content measurements made by the nuclear gauge in Portland cement stabilized soils, oven drying was needed. Therefore, a period of at least 12 hours had to pass for quality control dry density measurements. Meanwhile, for the HSG, results were known immediately after the test was conducted.



THE BOTTOM LINE...

The Humboldt Stiffness Gauge (HSG) evaluated in the study proved to be an effective tool for determining the dry density of compacted soils. This was proven both in the laboratory and in the field. The study also showed the advantages of using the HSG over the standard nuclear density gauge in Portland cement stabilized soils.

While this study illustrated that the HSG can be a valuable tool in determining the dry density of soils, we noted there are improvements that can be made to improve the accuracy and speed of testing, as well of other possible applications. They are:

- development of global soil calibrations
- continual evaluation of the HSG for modulus determination via a stiffness-modulus correlation

FOR MORE INFORMATION CONTACT

NJDOT PROJECT MANAGER:	Anthony Chmiel
PHONE NO.	(609) 530-3711
e-mail	Anthony.Chmiel@dot.state.nj.us
UNIVERSITY PRINCIPAL INVESTIGATOR:	Dr. Ali Maher
UNIVERSITY:	Rutgers University -CAIT
PHONE NO.	(732) 445-2232
e-mail	mmaher@rci.rutgers.edu

A final report is available online at

<http://www.state.nj.us/transportation/research/research.html>

If you would like a copy of the full report, please FAX the NJDOT, Bureau of Research, Technology Transfer Group at (609) 530-3722 or send an e-mail to Research.Bureau@dot.state.nj.us and ask for:

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