CASE STUDY:
STIFFNESS BASED COMPACTION QC OF A GRANULAR SUBGRADE

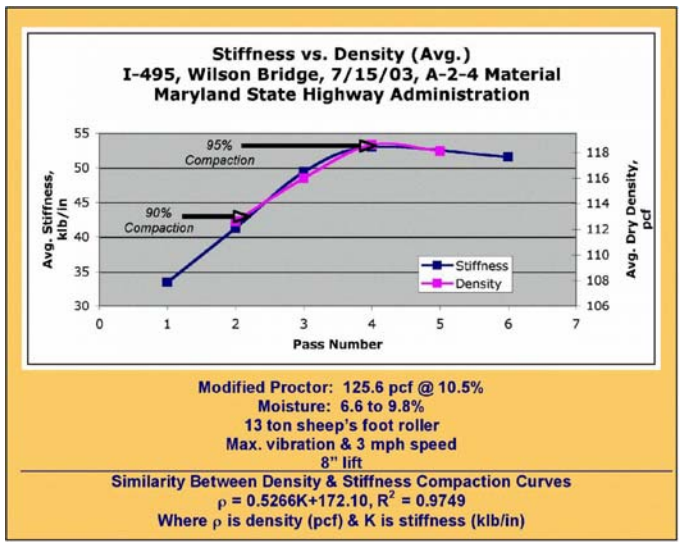
MINNESOTA DOT
DISTRICT 2
423 WEST ZEH ST.
THIEF RIVER FALLS, MN 56721

Traditional subgrade compaction QC test methods do not evaluate in-place material strength or the structural uniformity of each lift as placed. Evaluating these two factors is essential if cost is to be held to a minimum while assuring the performance needed for the roadways intended function and projected life. This type of evaluation is essential if the industry's trend towards modulus based mechanistic design and performance specifications for roadways are to be supported. Also, traditional methods do not provide contractors with sufficient real-time feedback so as to optimize the balance of quality and cost.

Accordingly, a simple and precise modulus or stiffness based QC test method for subgrades was needed by the Minnesota Department of Transportation (MnDOT), District2, Thief River Falls Construction Office that would evaluate the required factors as compaction occurs. At the same time this method needed to provide an index of percent compaction so as to fit within the framework of traditional specifications. Finally, the method needed to provide an index of resilient modulus to support the future use of mechanistic design and performance specifications.

District 2 selected an in-place QC test method developed under FHWA Study 2(212) that did not interfere with or delay the construction process. Without penetrating the ground, the method used the Humboldt GeoGauge to measure the stiffness of each lift and thereby evaluate percent compaction. Using a test section or strip of subgrade material, lift stiffness at controlled moisture content was measured and spatially averaged as a function of compactive effort. Initially this data was compared to density as a function of effort to confirm the findings of FHWA 2(212) that maximum stiffness occurs at optimum compaction as constrained by site conditions. The resulting empirical relationship was used to establish QC stiffness targets for the subgrade that corresponded to the traditionally specified levels of percent compaction.

FHWA 2(212): Compaction vs. Stiffness



The Humboldt GeoGauge is a 10" diameter, 11" tall, 22 lb. electro-mechanical instrument that when placed on the surface of the ground evaluates the stiffness of the top 9" to 12" of material. It vibrates the ground over a range of discrete frequencies, applies force, measures the resulting deflection and displays the results in about a minute. It was chosen by MnDOT District 2 because measurements could be made at a rate greater than the rate of compaction, it has no licensing or safety requirements and its performance (reliability, precision & bias) had been proven by FHWA Study 2(212) & TRB NCHRP Project 10-65.

Humboldt GeoGauge

In the summer of 2004, District 2 chose road TH200 in Ada, MN for its initial use of this QC test method. The method was contractually specified. This was the only way District 2 thought that sufficient data could be collected for a comprehensive evaluation of the method. The subgrade was an AASHTO A-1-b material, placed in two 12" lifts over two miles of 2-lane roadway. Stiffness was measure approximately every 100 ft. on each lane for each compacted lift, one 1,000 ft. section at a time. Based on test strip measurements

HUMBOLDT

Scott Fiedler
Humboldt Mfg. Co.
7300 West Agatite Avenue, Norridge, Illinois 60706
Tel: 800-544-7220 Ext. 231, Email: fiedler@humboldtmfg.com

at the start of the project, a stiffness value of 23 klb/in was assigned as a target corresponding to the specified 90% compaction. Moisture was measured approximately every 500 ft. by either time-domain-reflectometry or field oven. Density was measured randomly as a check on the method and took precedence in judging quality if there was a conflict with stiffness.

The over 1,000 stiffness QC tests made on the TH200 project indicated that the level of compaction was from 87% to 97% (18.2 klb/in to 32.2 klb/in for 95% of the data). This was better than the best quality traditionally possible for the material in District 2's experience. Moisture content was typically 3.5% below optimum, varying from about 6% to 12%. This was consistent with the best quality traditionally possible.

The level of material compliance with the specification and small variability in the quality of compaction was unprecedented in the experience of MnDOT District 2. The real-time nature of the stiffness QC tests forced the continuous attention of the contractor to compaction quality as was evident by the section-by-section adjustments in roller patterns and watering. This real-time attention to quality also resulted in a significant reduction in the contractor time and effort traditionally needed to accomplish this kind of job.

The material strength achieved and its uniformity, as evident from the stiffness tests, was consistent with supporting a 20-year roadway life. According to FHWA guidelines, A coefficient of variation (COV) of less than or equal to 20% in subgrade strength will support a 20-year life. The COV achieved for TH200 was less than 14%.

District 2 found that the material and construction uniformity enabled by this test method was sufficient to require stiffness testing intervals of no smaller than every 500 ft.

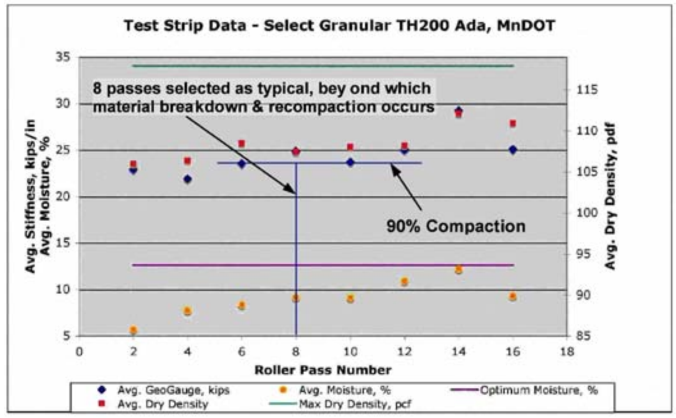
Since the completion of the TH200 job, the stiffness measurements made as part of the test method has been shown to have a strong relationship to resilient modulus and so are useable as an in-place index[1].

District2, Thief River Falls Construction Office, of the Minnesota Department of Transportation has deemed the success of this first use of stiffness based compaction QC testing sufficient to warrant continuing and broadening use of it on subgrades and bases in the 2005 and 2006 construction seasons.

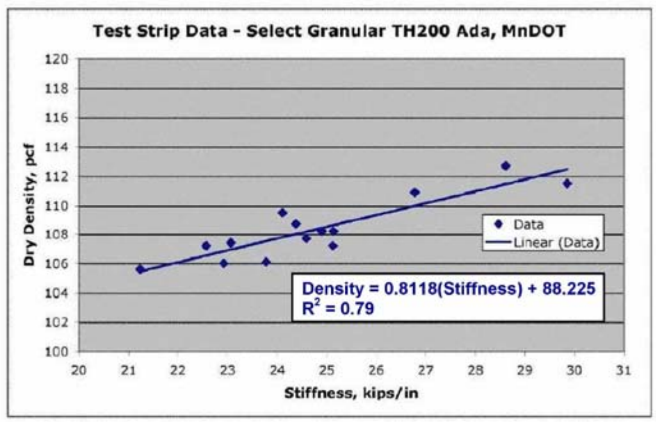
For more information contact:

Melvin Main, Main Associates
717-792-3181, mel@mainassoc.com
or
J. T. Anderson
Resident Engineer, MnDOT District 2
216-681-0927
J.T.Anderson@dot.state.mn.us

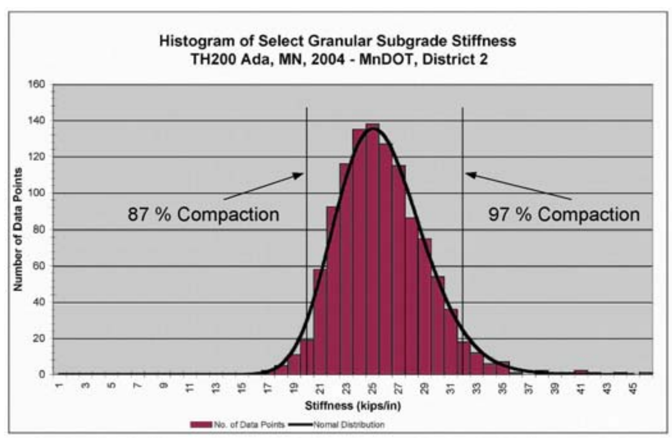
Test Strip: Assignment Of Target Stiffness



Test Strip: Stiffness vs. % Compaction (Density)



QC Test Data



---

1 Development Of Resilient Modulus Prediction Models For Base And Subgrade Pavement Layers From In Situ Devices Test Results, 2004, Ravindra Gudishala, Louisiana State University, Baton Rouge, LA 70808