Viable & Practical Stiffness Based In-Place QC Testing of Compacted Subgrade Material

Case Study

MnDOT District 2

GeoGauge™

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Problem

- **Traditional Subgrade QC Testing**
  - **Does not Evaluate In-Place Strength & Uniformity**
  - **Does not Provide Real-Time Feedback**
    - **Contractor Cannot Make Immediate Corrections**
    - **Slows Process**
    - **Variability Undetected**
  - **Does not Support:**
    - **Modulus Based Mechanistic Design**
    - **Performance Specifications**

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Objective

- **Implement Modulus or Stiffness Based QC Testing**
  - **Provide A Measure of Strength & Uniformity**
  - **Index Of Percent Compaction**
  - **Index Of Resilient Modulus For Future**
  - **Be Simple, Precise & Non-Invasive**
  - **Perform At A Rate Greater Than Compaction Process**

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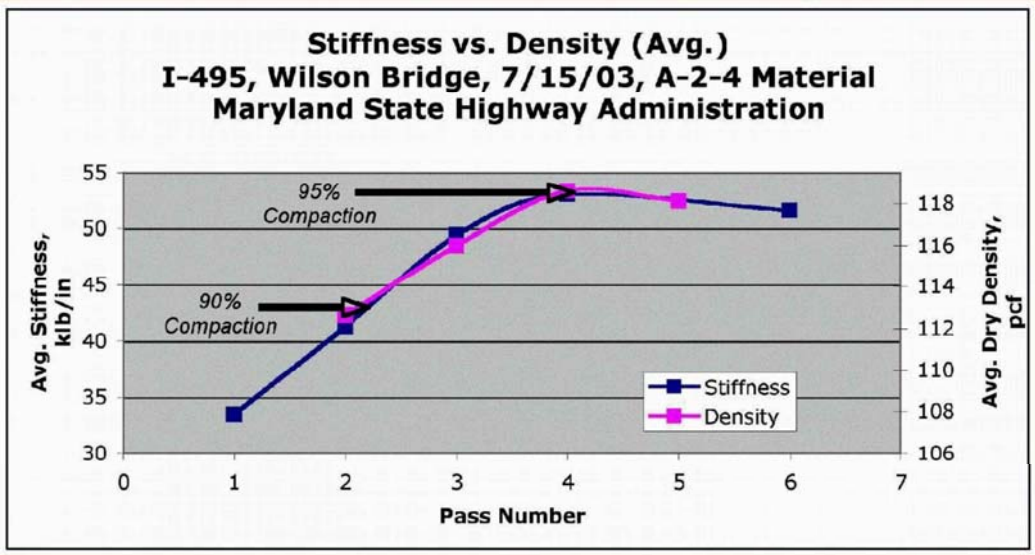
Approach

- **Method Developed By FHWA Study 2(212)**
  - **Optimum Compaction Occurs At Max. Lift Stiffness**
    - **At A Level Of Effort**
    - **At A Moisture Content**
  - **Percent Compaction Relates To Lift Stiffness At Controlled Moisture**
  - **Test Strip Used To Assign Target Stiffness For QC Testing**
  - **Humboldt GeoGauge To Measure Stiffness At Time Of Compaction**
- **Initially Over Sampling QC Measurements**
- **Specify Method On A Trial Basis**
- **If Successful, Broaden Use & Experience**

FHWA Study SPR-2(212)

- Compaction vs. Stiffness
- GeoGauge Performance Validated
  - Principle Of Operation
  - Calibration
  - Bias
  - Precision
  - Depth of Measure



Modified Proctor: 125.6 pcf @ 10.5%
Moisture: 6.6 to 9.8%
13 ton sheep's foot roller
Max. vibration & 3 mph speed
8" lift
Similarity Between Density & Stiffness Compaction Curves
$\sigma = 0.5266K+172.10$, $R^2 = 0.9749$
Where σ is density (pcf) & K is stiffness (klb/in)

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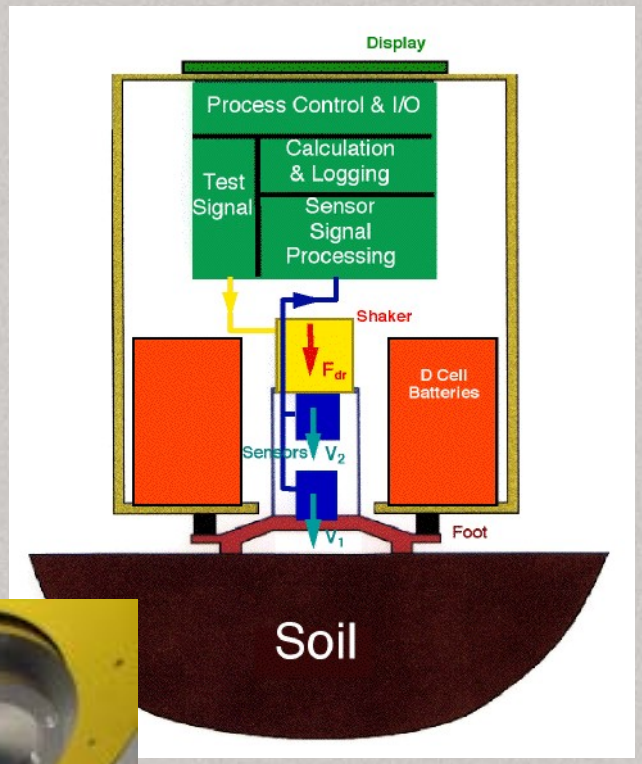
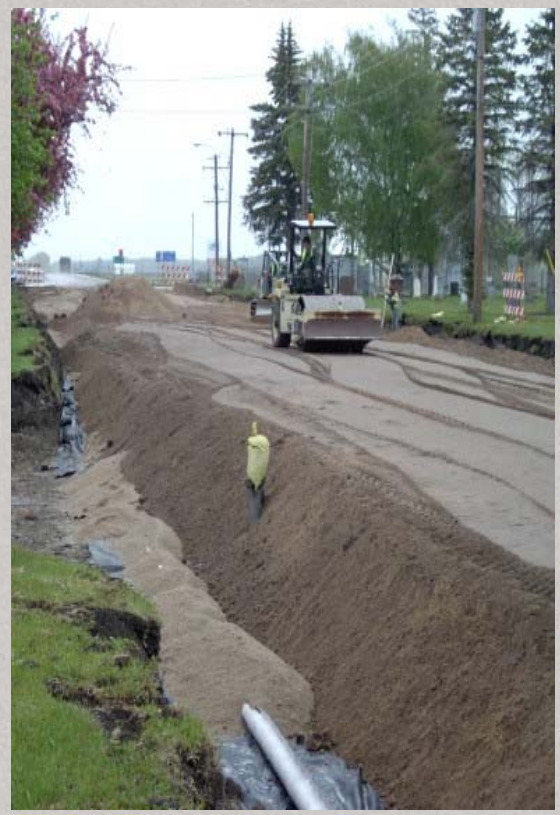
- **Measures Stiffness In 75 seconds**
  - **No Construction Delays**
- **Non Destructive**
- **11” OD X 10” Tall, 22 lbs.**
- **No License or Safety Issues**



Trial Specification is First Step

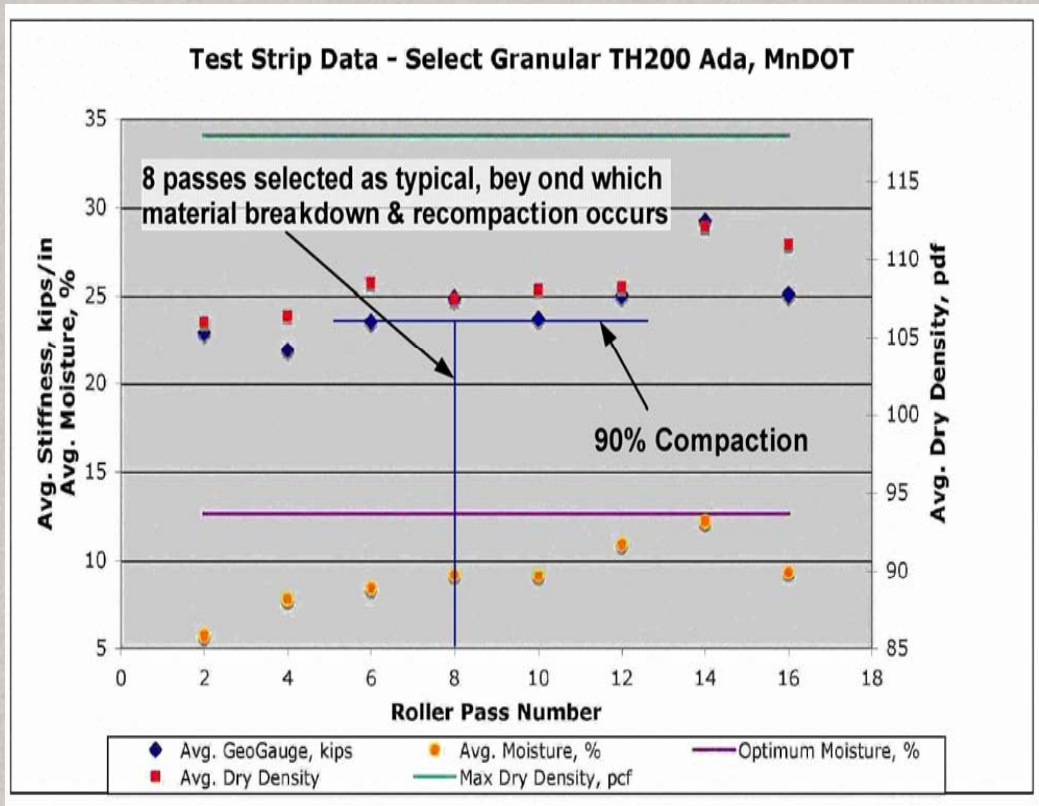
Best Way To Ensure Sufficient Data For Evaluating QC Testing Method & Implementing Future Use

- **TH200, Ada, MN, MnDOT District 2, Summer 2004**
- **Granular Subgrade, AASHTO A-1-b**
- **Two 12” Thick Lifts**
- **One Mile Of 2 Lane Roadway**
- **Test ~ Every 100’ Per Sampling Patterns**
  - **Stiffness (GeoGauge)**
  - **Moisture (TDR or Oven)**
- **If Stiffness Not Within +/- 5% Of Target**
  - **Re-Compact At The Discretion Of The Engineer**
  - **Tolerance Altered re Results & Experience**

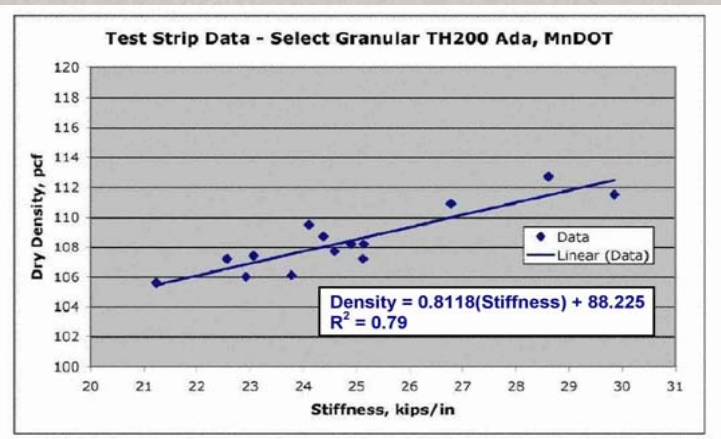


Test Strip Data

23 klbf/in At 8 Passes Selected As Target Minimum (~90% Compaction)



Select Granular Test Strip					
Roller Pass #	Avg. GeoGauge, kips/in	Avg. Dry Density. pcf	Max Dry Density, pcf	Avg. Moisture, %	Optimum Moisture, %
2	22.9	106.0	117.9	5.7	12.6
4	21.9	106.4		7.8	
6	23.5	108.5		8.4	
8	24.9	107.5		9.2	
10	23.7	108.1		9.1	
12	25.0	108.2		10.9	
14	29.2	112.1		12.2	
16	25.1	111.0		9.3	



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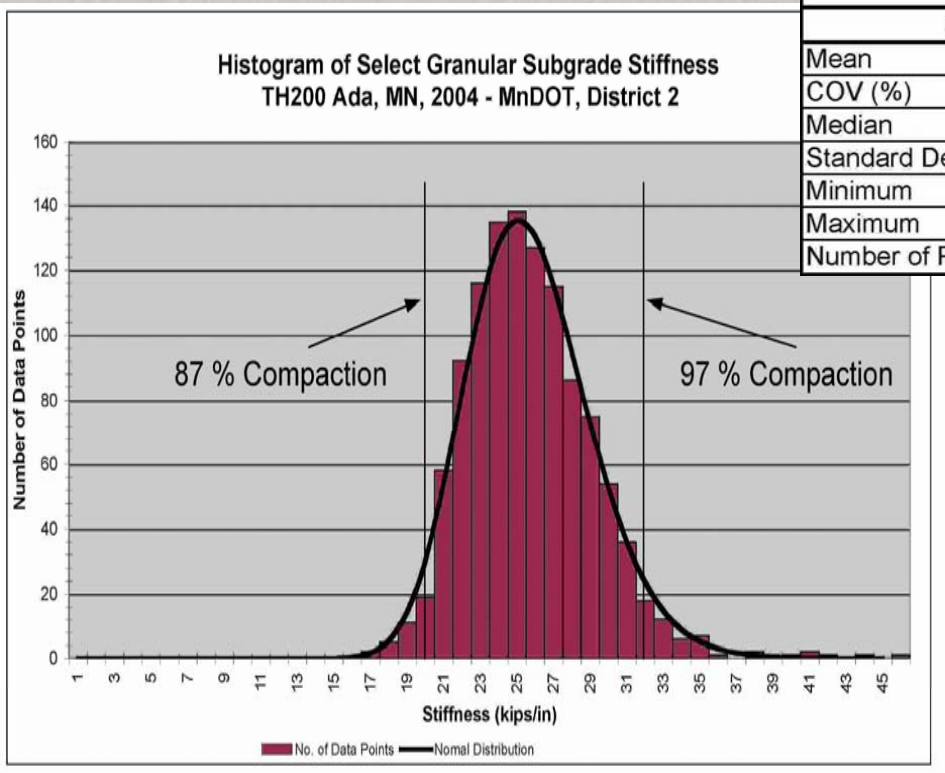
QC Test Data: Stiffness



Statistics: Select Granular Subgrade			
Stiffness, kips/in		*Oven Moisture. %*	
Mean	25.2	Mean	9.0
COV (%)	13.6		
Median	24.8	Median	9.1
Standard Deviation	3.4	Standard Deviation	1.9
Minimum	16.1	Minimum	3.6
Maximum	45.5	Maximum	15.1
Number of Points	1121	Number of Points	102

- **Consistent With Test Strip**
  - ***Target (23) vs. Avg. (25)***
- **95% Of Data Within +/- 28% Of Target Stiffness**
  - ***87% to 97% Compaction***
- **Distribution Indicates Uniform Compaction & Load Distribution**
- **Meets FHWA Guideline For 20 Year Life**

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Conclusions & Recommendations

Stiffness Based QC Testing Ensures & Facilitates Quality Compaction

- Provides Unprecedented Levels Of Quality
- Provides A Good Assessment Of:
  - Resistance To Loading
  - Structural Uniformity
- Density Will Be Weaned From Method
- Future Spec.: 19 Of 20 Stiffness Measurements Within +/- 28% Of Target
- Sampling Can Be At Traditional 500’ Intervals
- Will Be Used Elsewhere In District 2 & Recommended to MnDOT In General