Appendix C
On-Site TAC Meeting Presentation

"MN DOT Approach for QA Using LWD" (Siekmeyer)

Pavement Foundation Quality Assurance
"the path followed in Minnesota"

Transportation Pooled Fund Project Meeting
June 2, 2015
University of Maryland

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Please Consider an Easier Path

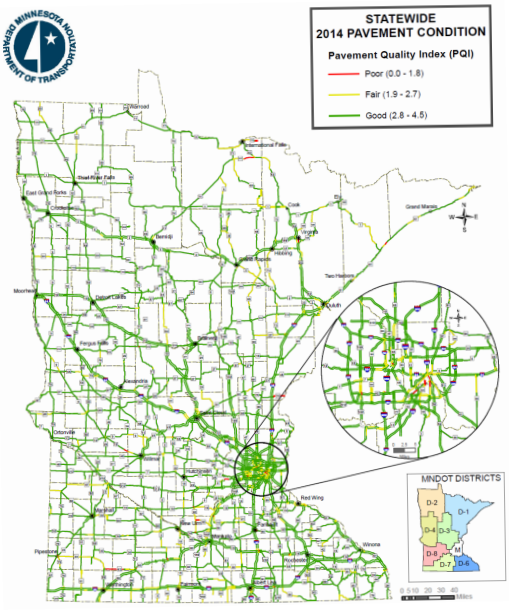
- Communicate Need for Better Foundations
- Understand Compaction Testing History
- Implement Mechanistic Pavement Design
- Implement Performance Requirements
- Deploy Light Weight Deflectometers

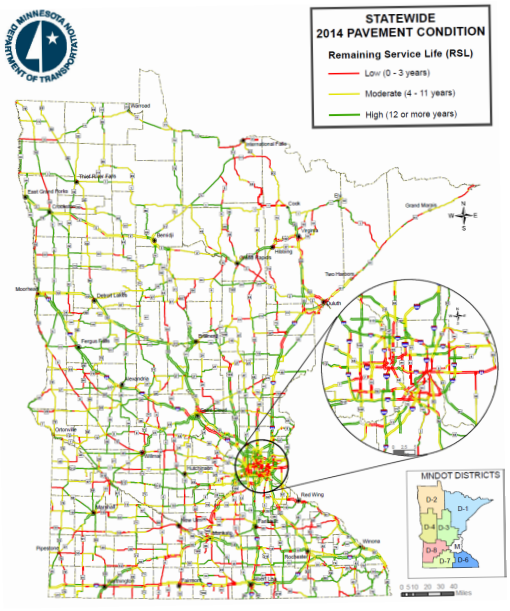
Acknowledgements

- MnDOT Districts and Local Agencies
- State DOTs and Federal Highway Administration
- Contractors and Equipment Manufacturers
- Universities and Consulting Engineers
- U.S. Congress “MAP-21 Performance”
- Minnesota Legislature and Legislative Auditor

Road Foundations are Important.

Poor Performance has Consequences.





Consequences of Poor Performance

- Unable to maintain our public assets.
- Waste labor, energy, and natural resources.
- Public confidence reduced.
- New investments (higher gas tax) difficult.

Compaction Testing History

Ralph Proctor reminds us:

- **Optimum Moisture is for Compaction**
- **Strength is Not Achieved by Density Alone**
- **Need to Avoid Rutting during Construction**

Ralph Proctor

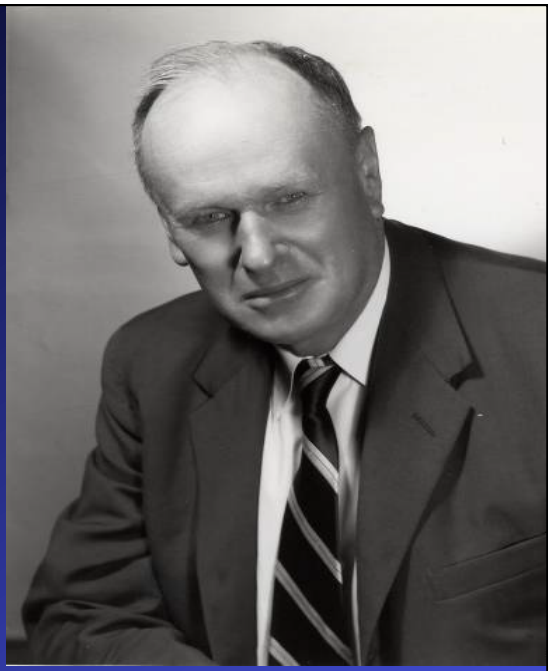


photo courtesy of Dr. J. David Rogers
University of Missouri-Rolla

Is this what Ralph Proctor intended?

Photo courtesy of Bomag

No. It is not.

- Ralph Proctor's original quality assurance method, which was implemented more than 80 years ago, was a performance based penetration test.
- What we are doing is not what Proctor and his staff were doing in the 1930s and 1940s.
- "Firm blows" were used, not 12 inch drops.

Why Are We Doing This?

"We've always done it this way."

"always" ??

Ralph Proctor, 1945, Trans 110, ASCE

- "Methods for hand compaction, such as dropping various weight tampers from different heights and mechanical tampers, were tried and discarded."
- "No use is made of the actual peak dry weight."
- "The measure of soil compaction used is the indicated saturation penetration resistance."

Proctor Penetrometer

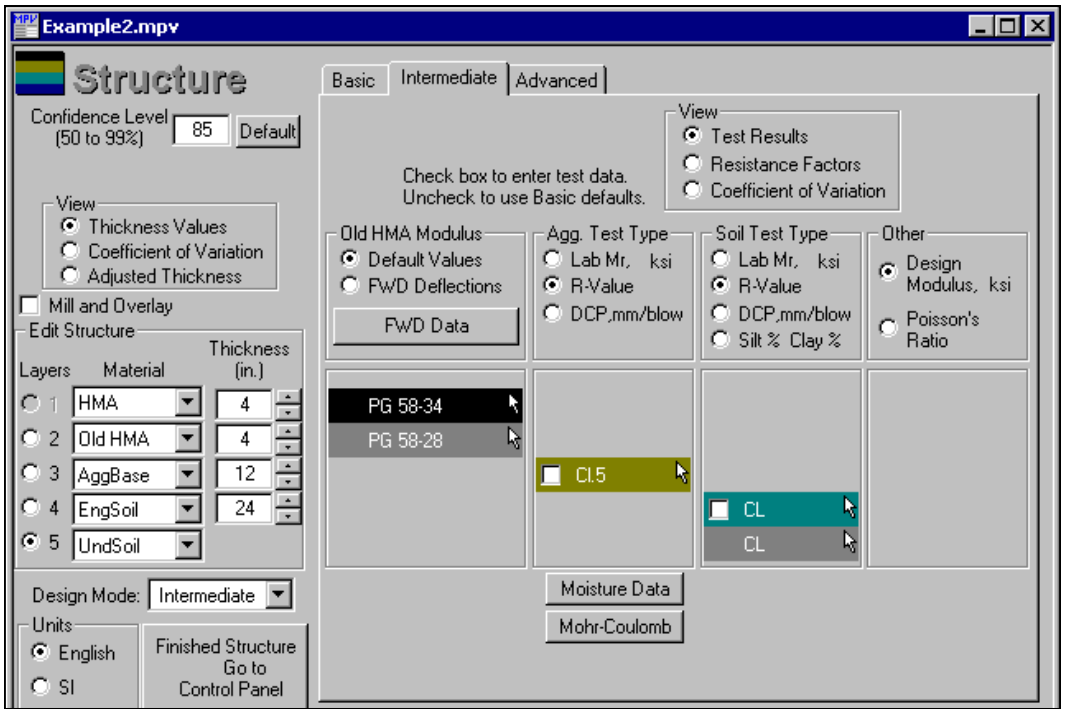
Photo courtesy of Humboldt

Hveem and Carmany, 1948, HRB

- "It can easily be shown that the density of a granular mass is one to the least reliable and least informative of all determinations which can be made."
- "The internal structure of the particle arrangement may vary considerably without any significant change in density."

Mechanistic Empirical Design in MN

- Provides the framework for performance based material property inputs
- Sponsor: MN Local Road Research Board
- Contact: Bruce.Tanquist@state.mn.us



Innovation Provides Solutions
Performance Tests are Available

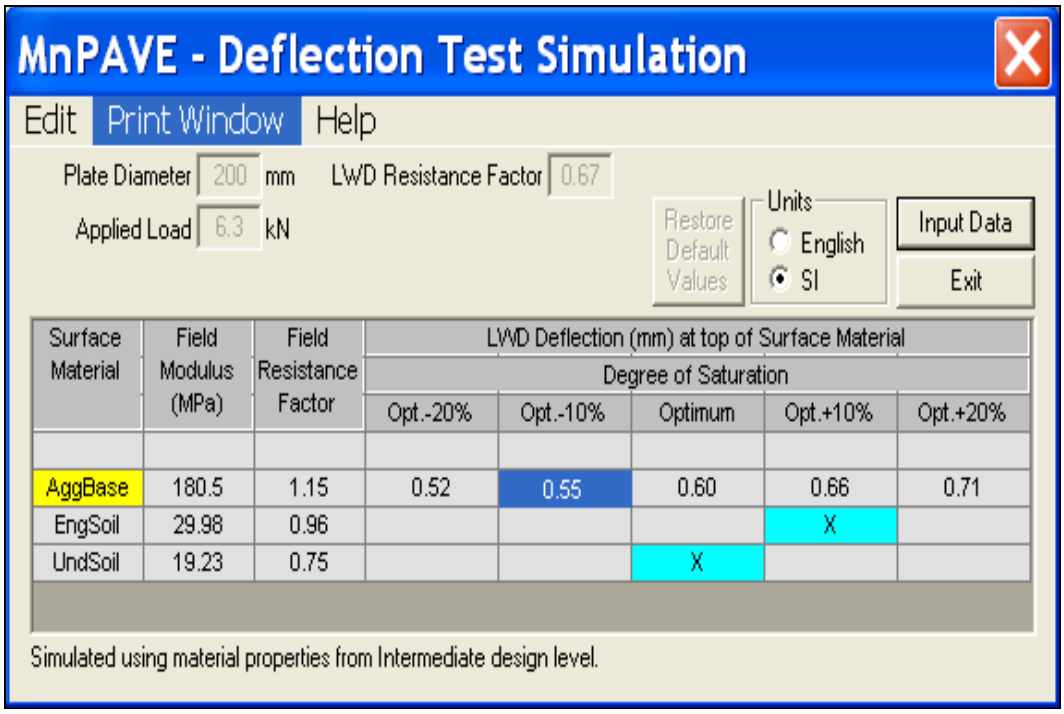
Light Weight Deflectometer

ASTM E 2583 07

Benefits of Performance Tests

- Empowers inspector with useful measures
- Optimizes compaction of subsequent layers
- Increases uniformity of pavement support
- Verifies current pavement design inputs
- Creates as-built record of construction
- Optimizes future pavement designs

MINNESOTA DEPARTMENT OF TRANSPORTATION



Estimated Target Values Granular

Grading Number	Moisture Content	Target DPI	Target LWD Deflection Zorn	Inverse DPI
GN	%	mm/drop	mm	drops/10cm
3.1-3.5	5 - 7	10	0.4	10
	7 - 9	12	0.5	8
	9 - 11	16	0.7	6
3.6-4.0	5 - 7	10	0.4	10
	7 - 9	15	0.7	7
	9 - 11	19	0.8	5
4.1-4.5	5 - 7	13	0.6	8
	7 - 9	17	0.7	6
	9 - 11	21	0.9	5
4.6-5.0	5 - 7	15	0.7	7
	7 - 9	19	0.8	5
	9 - 11	23	1.0	4
5.1-5.5	5 - 7	17	0.7	6
	7 - 9	21	0.9	5
	9 - 11	25	1.1	4
5.6-6.0	5 - 7	19	0.8	5
	7 - 9	24	1.1	4
	9 - 11	28	1.2	4

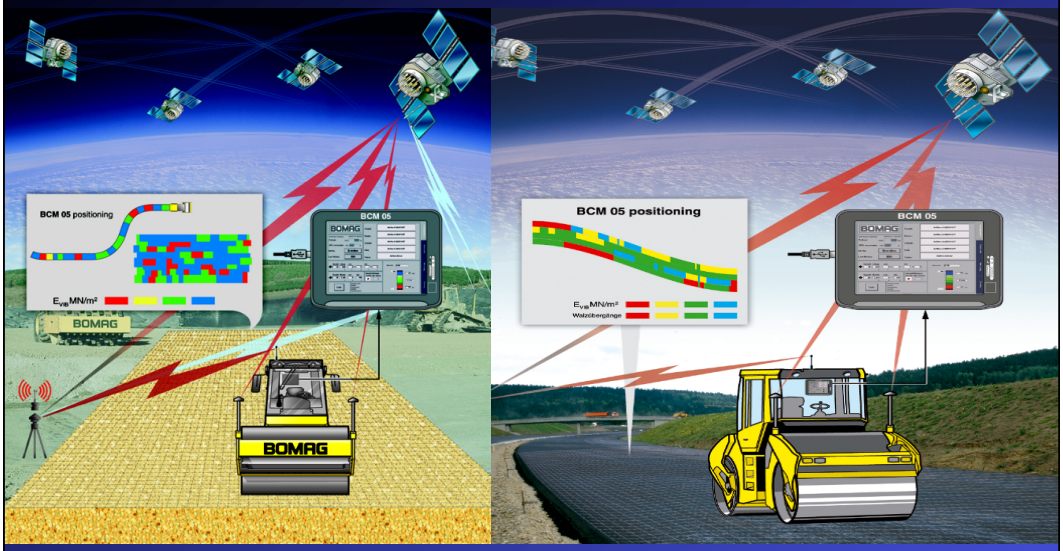
Why Deflection not Modulus?

- Engineer determines the allowable deflection target value for each layer during design.
- Deflection target value is specific to the moisture content range during construction.
- Inspection personnel measure deflection and moisture to verify that the design values are achieved.

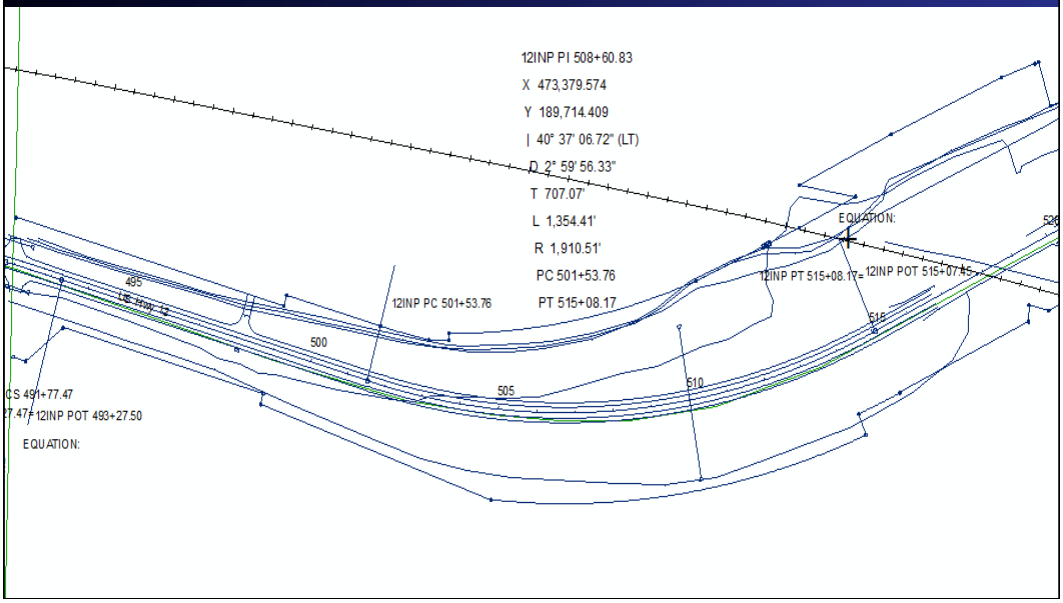
Implement Performance Management

- Quality Control by the Contractor
  - Prepares quality control plan
  - Includes moisture testing
  - Includes roller compaction value
  - Includes corrective actions to be taken by contractor
- Quality Assurance by Agency Owner
  - Review and approval of the contractor's QC plan
  - QA testing using the light weight deflectometer (LWD) and dynamic cone penetrometer (DCP)
  - Archive of electronic QC and QA data

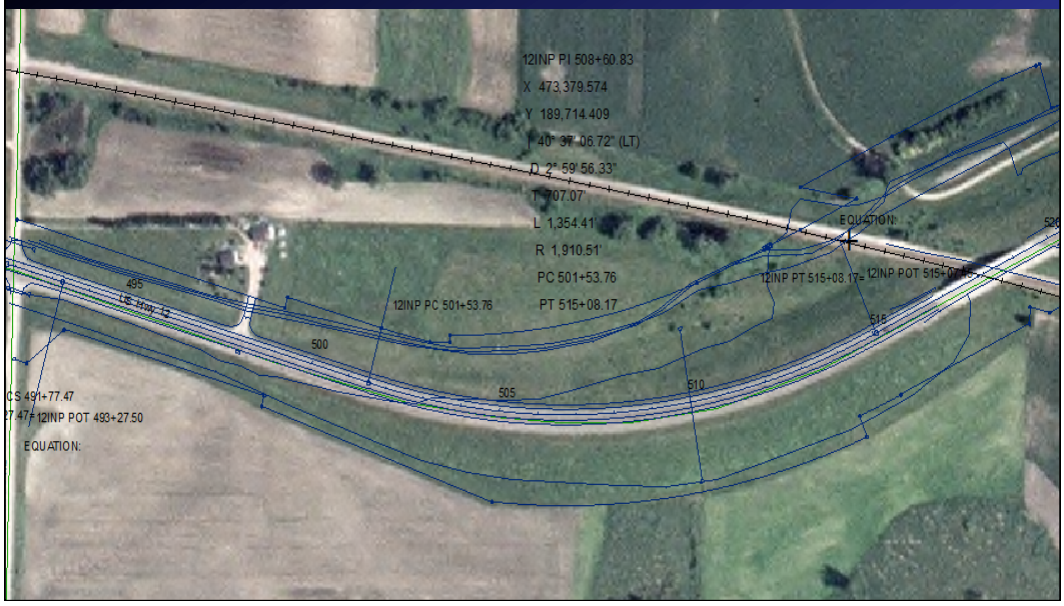
Bomag Soil and Asphalt IC Systems



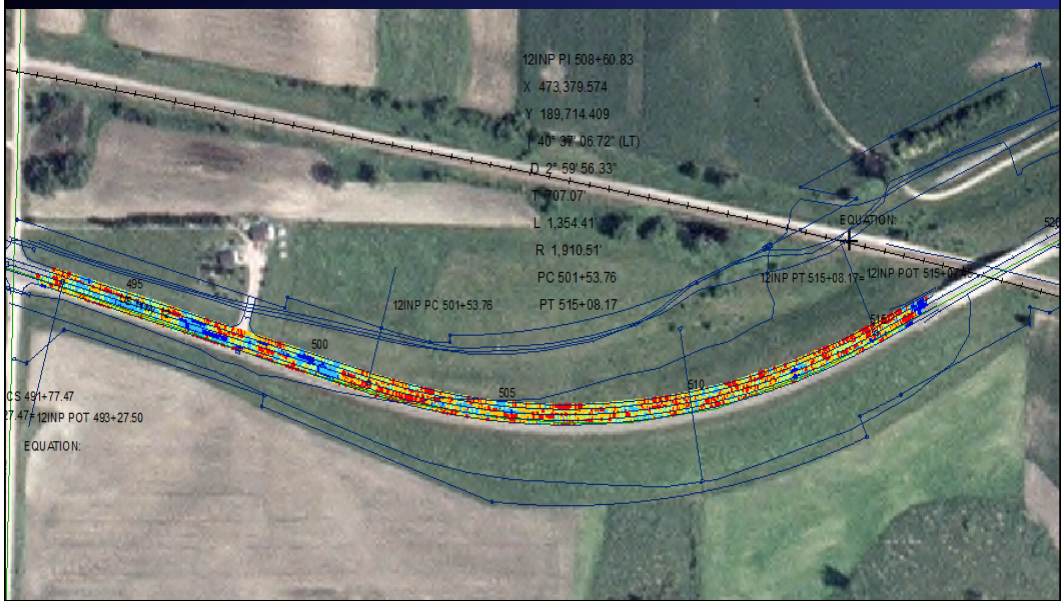
Import Alignment from CAD



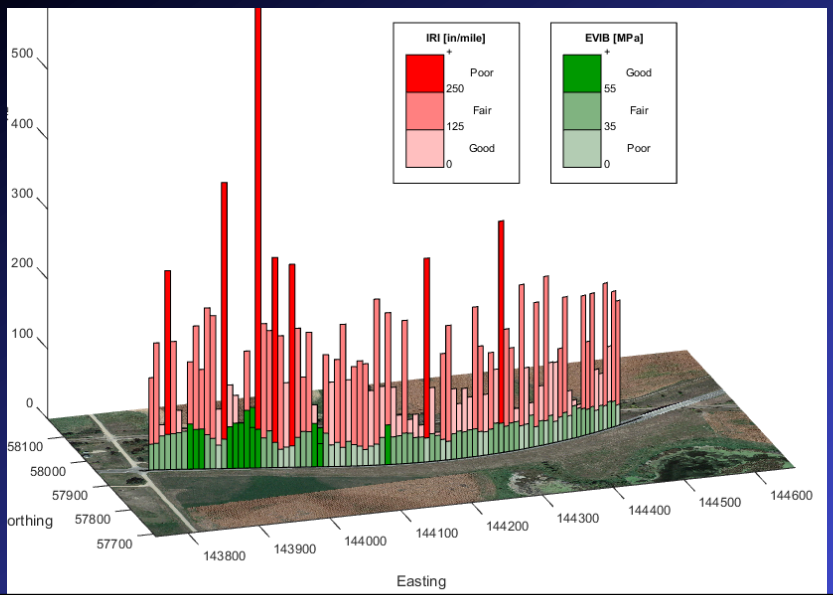
Import Aerial Photography



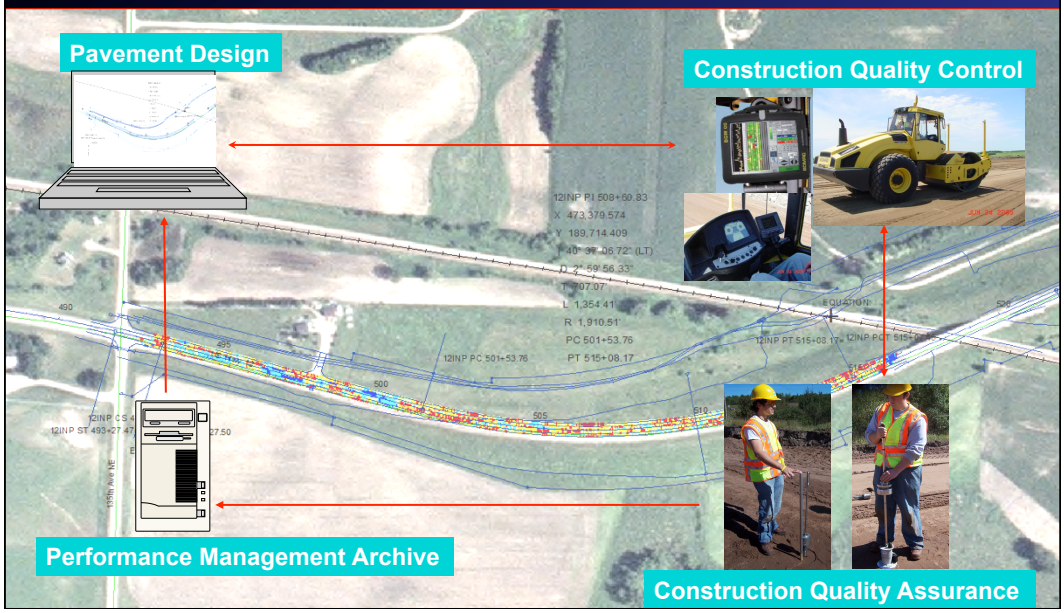
Import IC Roller Data

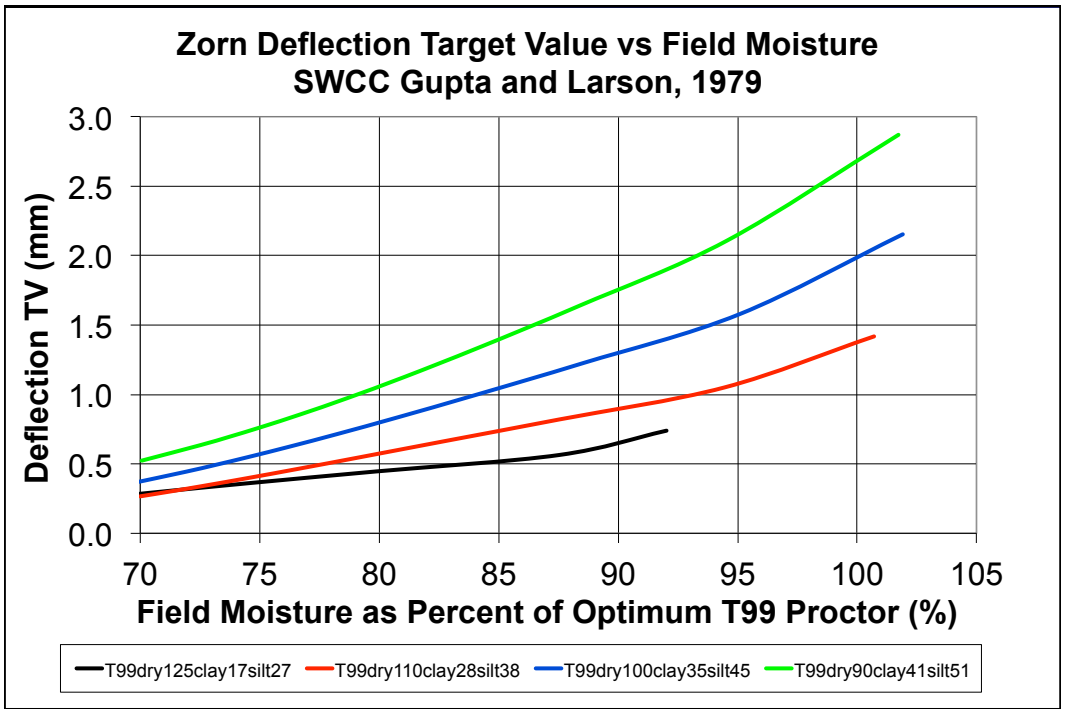


Import Pavement Performance Data

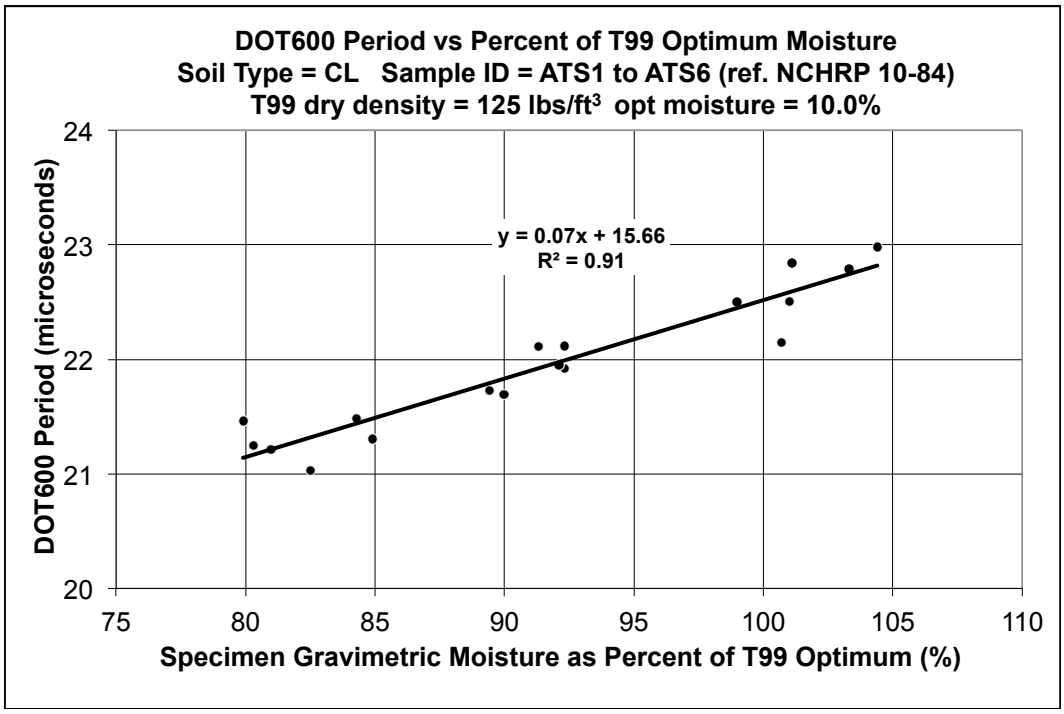


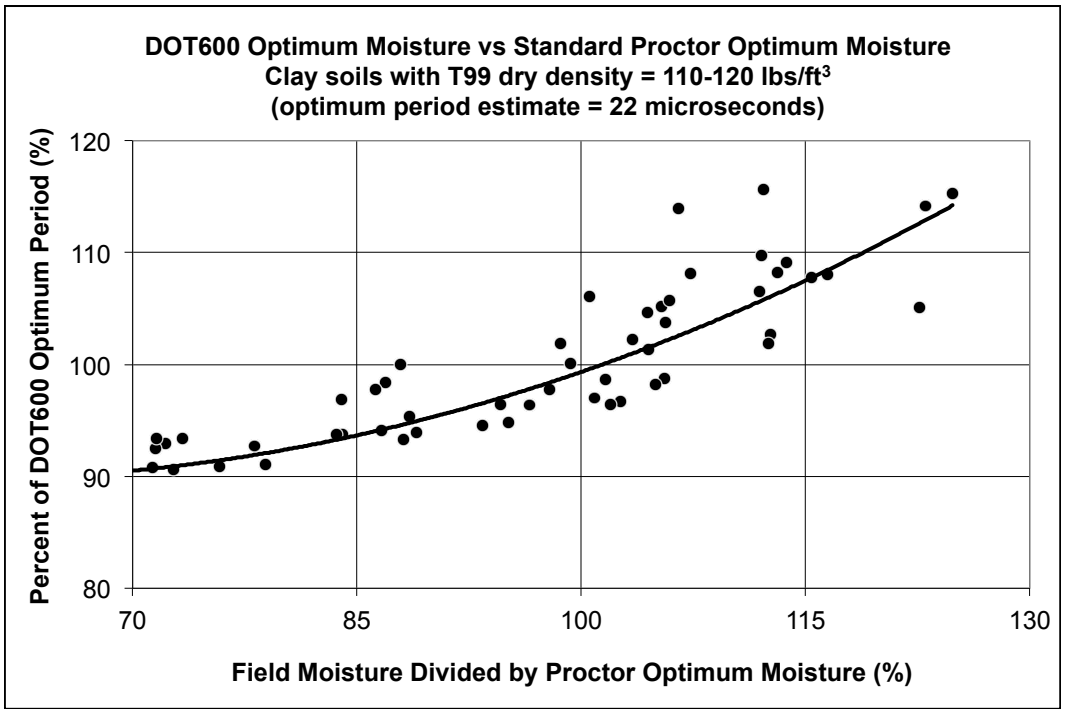
Design, Construction and Performance




Zorn Deflection Target Value vs Field Moisture
SWCC Gupta and Larson, 1979
Deflection TV (mm)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
70
75
80
85
90
95
100
105
Field Moisture as Percent of Optimum T99 Proctor (%)
T99dry125clay17silt27
T99dry110clay28silt38
T99dry100clay35silt45
T99dry90clay41silt51


CAMPBELL
SCIENTIFIC, IN
DMM600


DOT600 Period vs Percent of T99 Optimum Moisture
Soil Type = CL Sample ID = ATS1 to ATS6 (ref. NCHRP 10-84)
T99 dry density = 125 lbs/ft3 opt moisture = 10.0%
y = 0.07x + 15.66
R² = 0.91
DOT600 Period (microseconds)
24
23
22
21
20
75
80
85
90
95
100
105
110
Specimen Gravimetric Moisture as Percent of T99 Optimum (%)



Summary

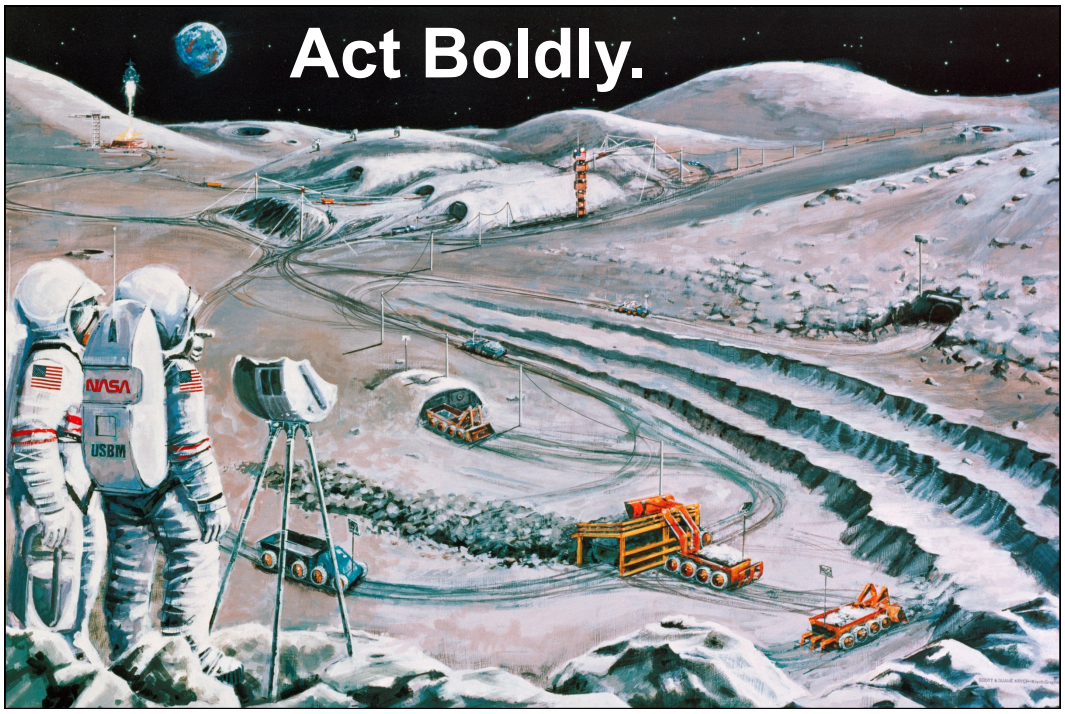
- Compaction equipment and field tests are now available that can measure the properties used to design pavements and predict performance.
- LWDs can be used during construction quality assurance to efficiently verify design target values.
- Several options exist to quantify moisture and more field measurement devices are coming.
- The time is now to accelerate implementation of performance based quality assurance so that our investments are well spent.

Action Items and Future Work

- Continue participation with national projects
- Industry/Agency inspector certification training
- Educate designers, opportunity to refine/validate design
- MnPAVE enhancements to better predict LWD targets
- Specification to include design-based LWD targets
- Further development of commercial DEM modeling
- Further development of moisture/suction field test
- Continue Volunteer Internship at Minnesota Legislature

Thank You.

Questions?


Act Boldly.
NASA
USBM