Pavement Foundation Quality Assurance Opportunities

Arizona Pavements and Materials Conference
Phoenix, Arizona

November 15-16, 2017

John Siekmeier P.E. M.ASCE

Your Destination...Our Priority

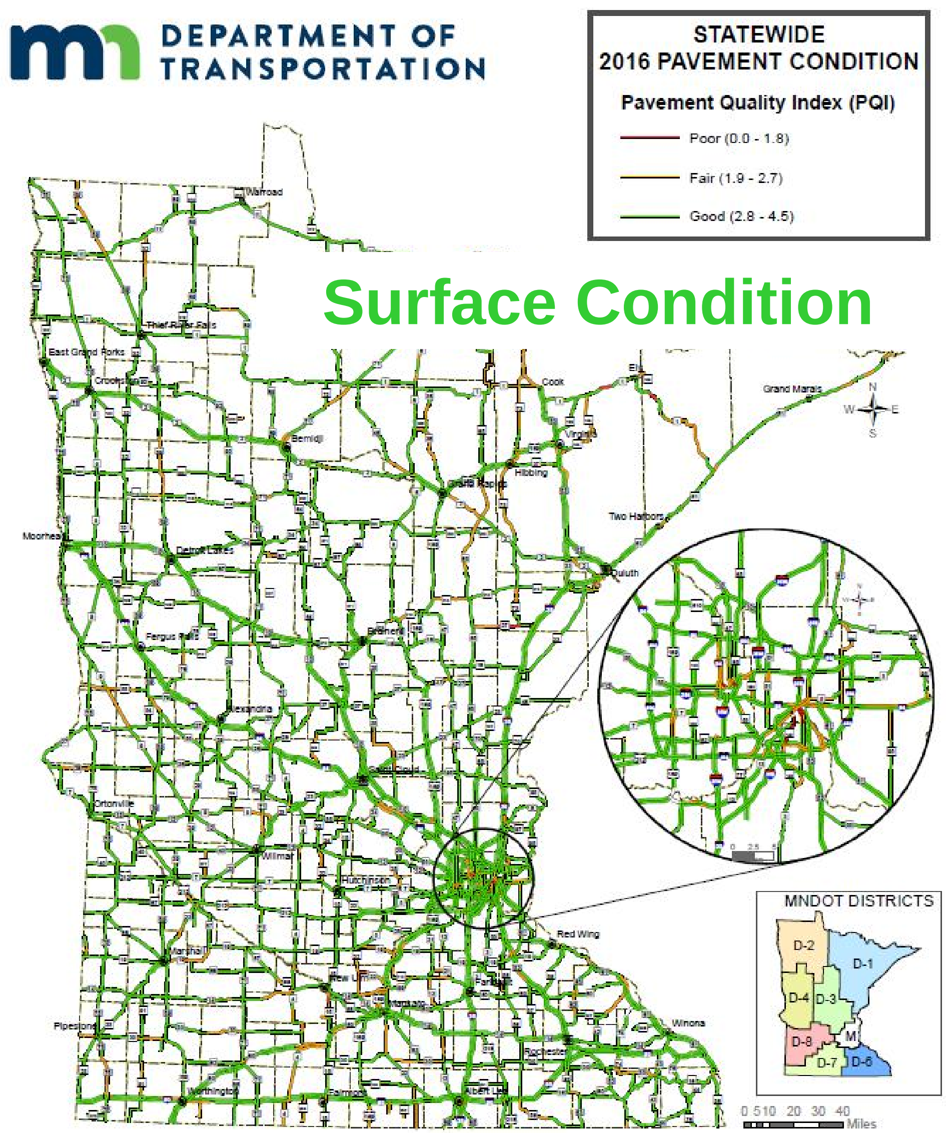
Acknowledgements

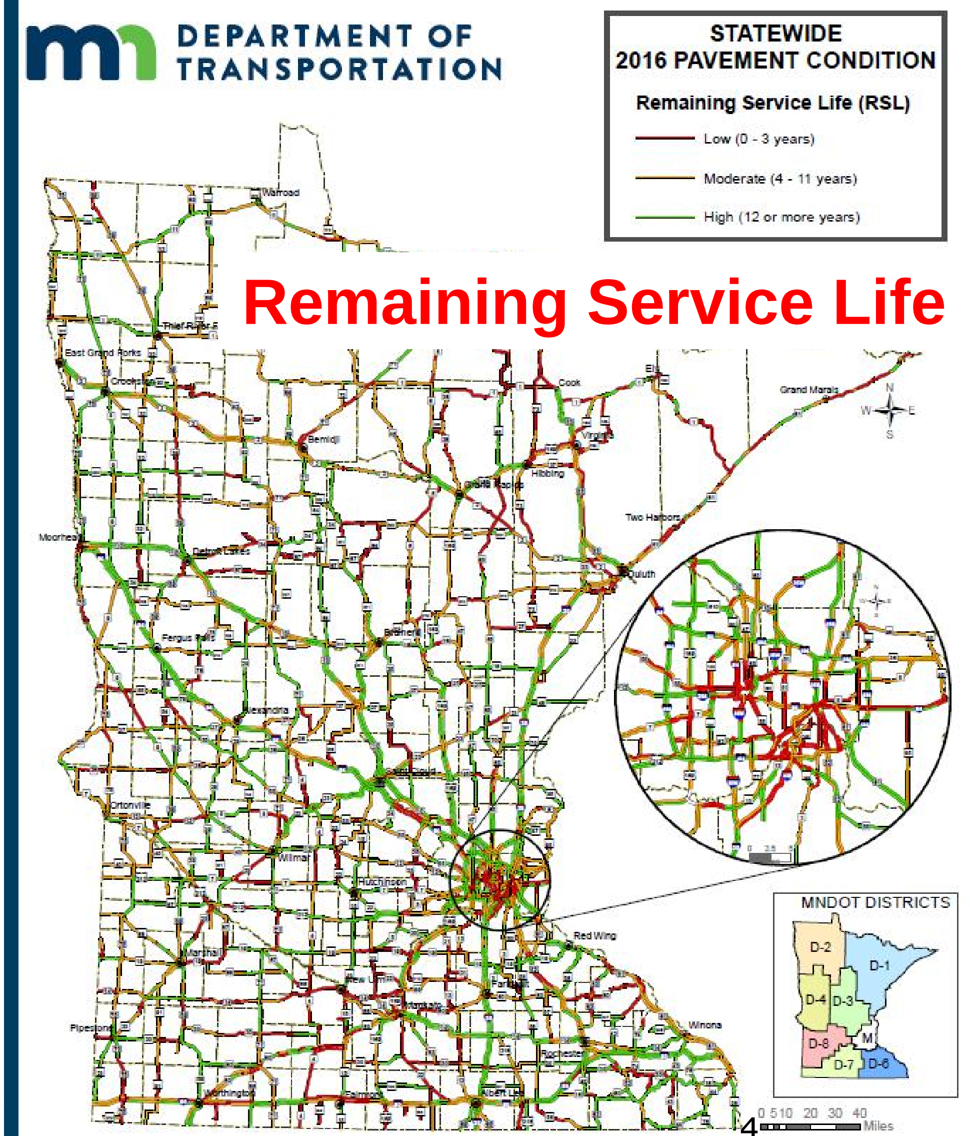
- Minnesota DOT Districts and Local Agencies
- Other State DOTs, FHWA and NCHRP
- Contractors and Manufacturers
- Universities and Consulting Engineers
- U.S. Congress “MAP-21” and “FAST”

Presentation Outline

- Pavement Foundations are Important
- Pavement Design Framework
- Performance Based Specifications
- Quantifying Moisture and Geogrid
- Lessons Learned and Next Steps

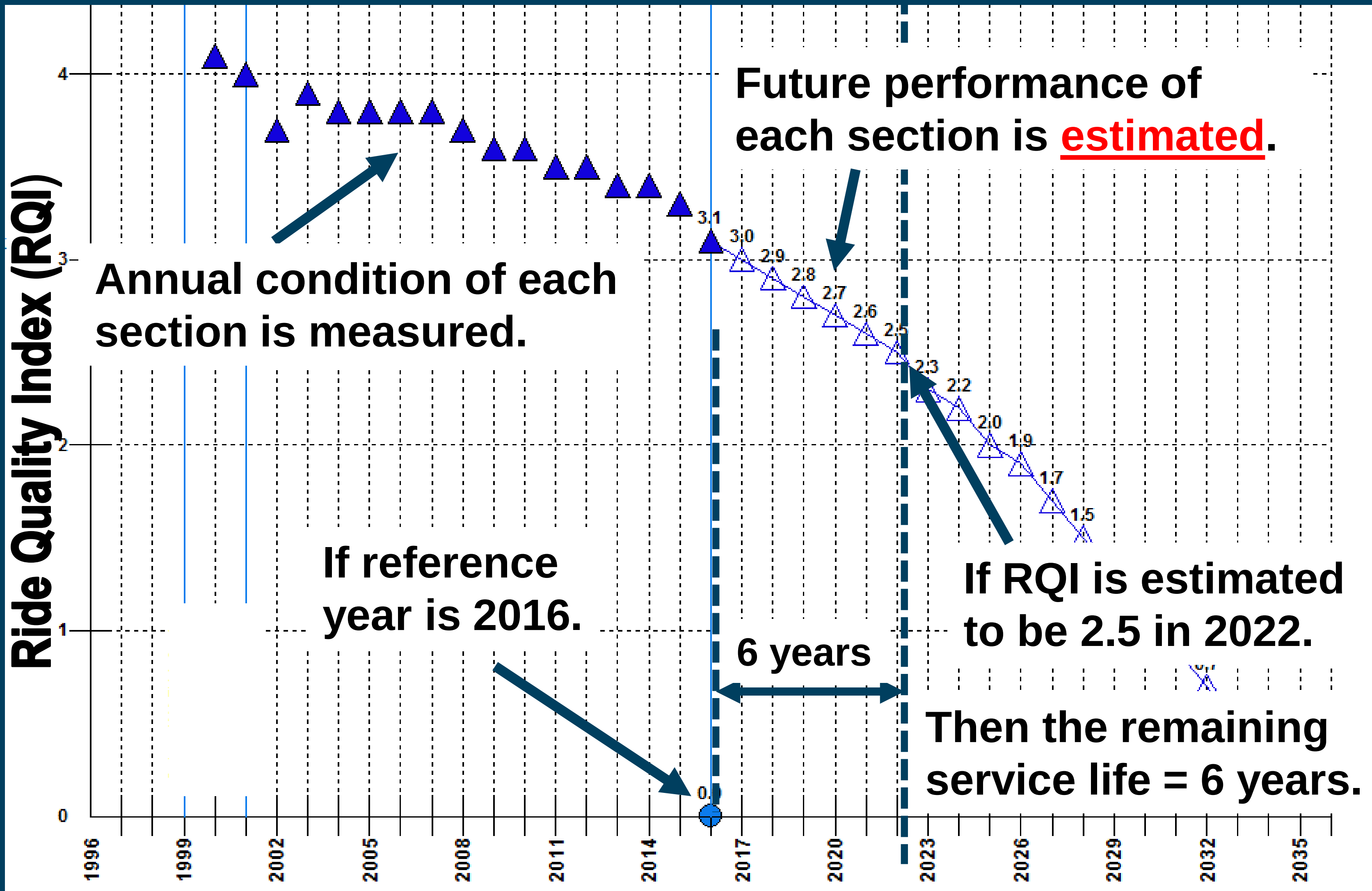
Pavement Foundations are Important





Pavement Management Van

What is Remaining Service Life?



Mechanistic Pavement Design is Part 1 of the Solution

- Provides the framework for using performance based material properties
- Free pavement design software available www.dot.state.mn.us/app/mnpave/index.html
- Just Google “MnPAVE”

Minnesota Department of Transportation
Office of Materials & Road Research
1400 Gervais Avenue, MS 645
Maplewood, MN 55109

Memo

TO: PCMG, CMG, MnDOT Districts, Materials Engineers, Soils Engineers, State Aid

FROM: Glenn M. Engstrom, Director
Office of Materials & Road Research

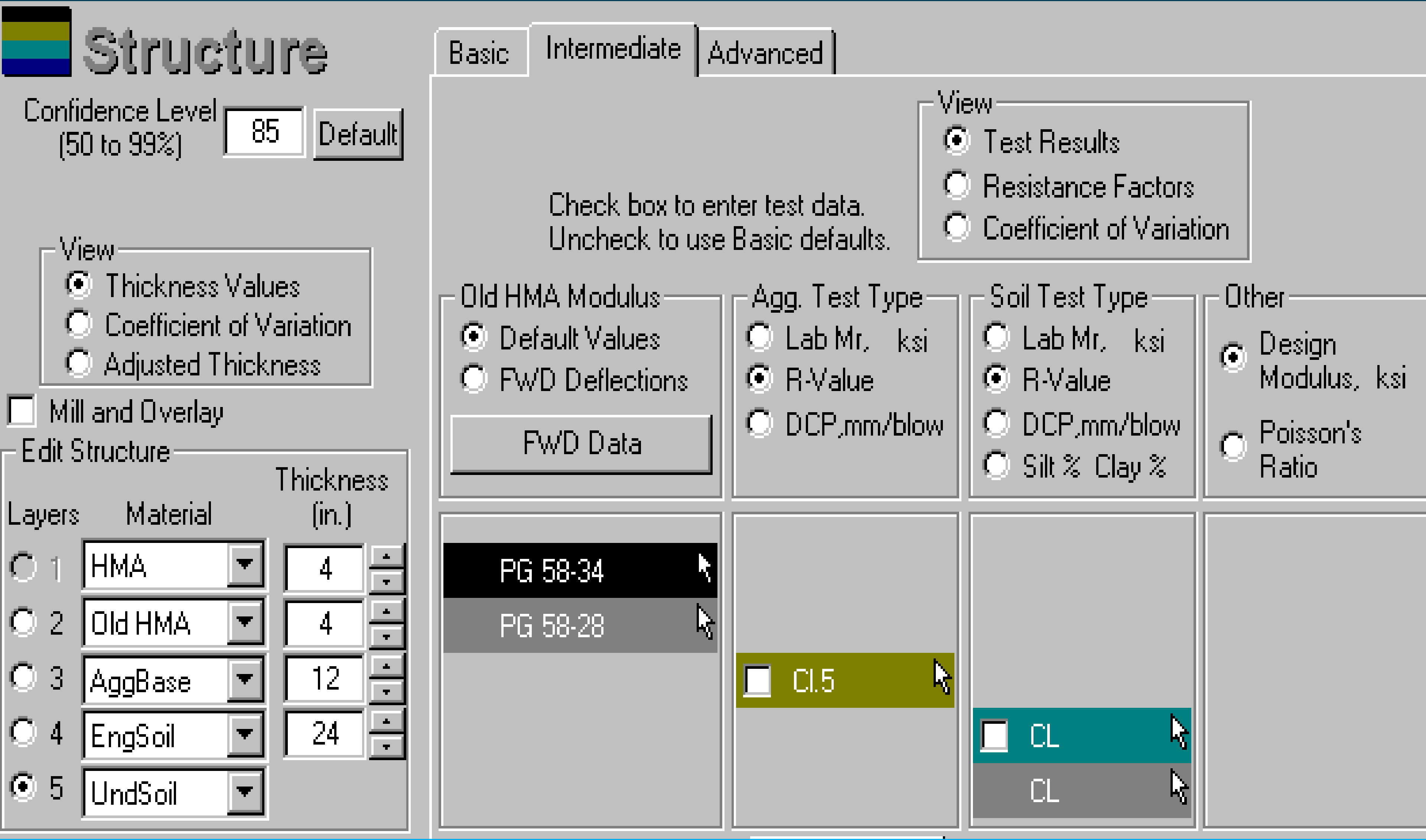
DATE: October 31, 2014

SUBJECT: Pavement Design Manual Publication

I am pleased to announce the publication of the MnDOT Pavement Design Manual.

This publication represents a significant effort to update pavement design procedures and codify existing documents into a single point of reference. As of November 1, 2014, all MnDOT pavement designs shall follow the pavement design, pavement-type selection, LCCA, and alternate bidding as laid out in the Pavement Design Manual. To view the manual, please follow http://www.dot.state.mn.us/materials/pvmtdesign/newmanual.html

Design Requires Performance Inputs



Performance Based Construction Testing is Part 2 of the Solution

- Draft specifications produced by NCHRP 10-84 and Transportation Pooled Fund TPF 5(285)

- Modified version is available at NRRA Pooled Fund website (Geotechnical Team)
  http://www.dot.state.mn.us/mnroad/nrra/index.html

- Just Google "NRRA"

Change is Underway

- From Traditional Construction Testing
  - Specify Relative Density
  - Specify Gravimetric Moisture
  - Observation and Test Rolling

- To Performance Based Construction Testing
  - Specify Modulus and/or Strength
  - Specify Volumetric and/or Gravimetric Moisture
  - Observation, Test Rolling, and/or Intelligent Compaction

DCPs and LWDs in Indiana

	DCPs	LWDs
Indiana DOT	130+	60+
Private Sector	30+	10+

DCP Indiana DOT Test Method No. 509-15P
LWD Indiana DOT Test Method No. 508-12T

Back to the Future: Ralph Proctor reminds us.

- Strength is not achieved by density alone.
- Optimum moisture is for compaction.
- Need to avoid rutting during construction.

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

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

Dynamic Cone Penetrometer

ASTM D 6951-03

Light Weight Deflectometer

ASTM E 2583 07
(includes load measurement)

ASTM E 2835 11
(no load measurement)

AASHTO TP 123-01 draft
(determining lab target values)

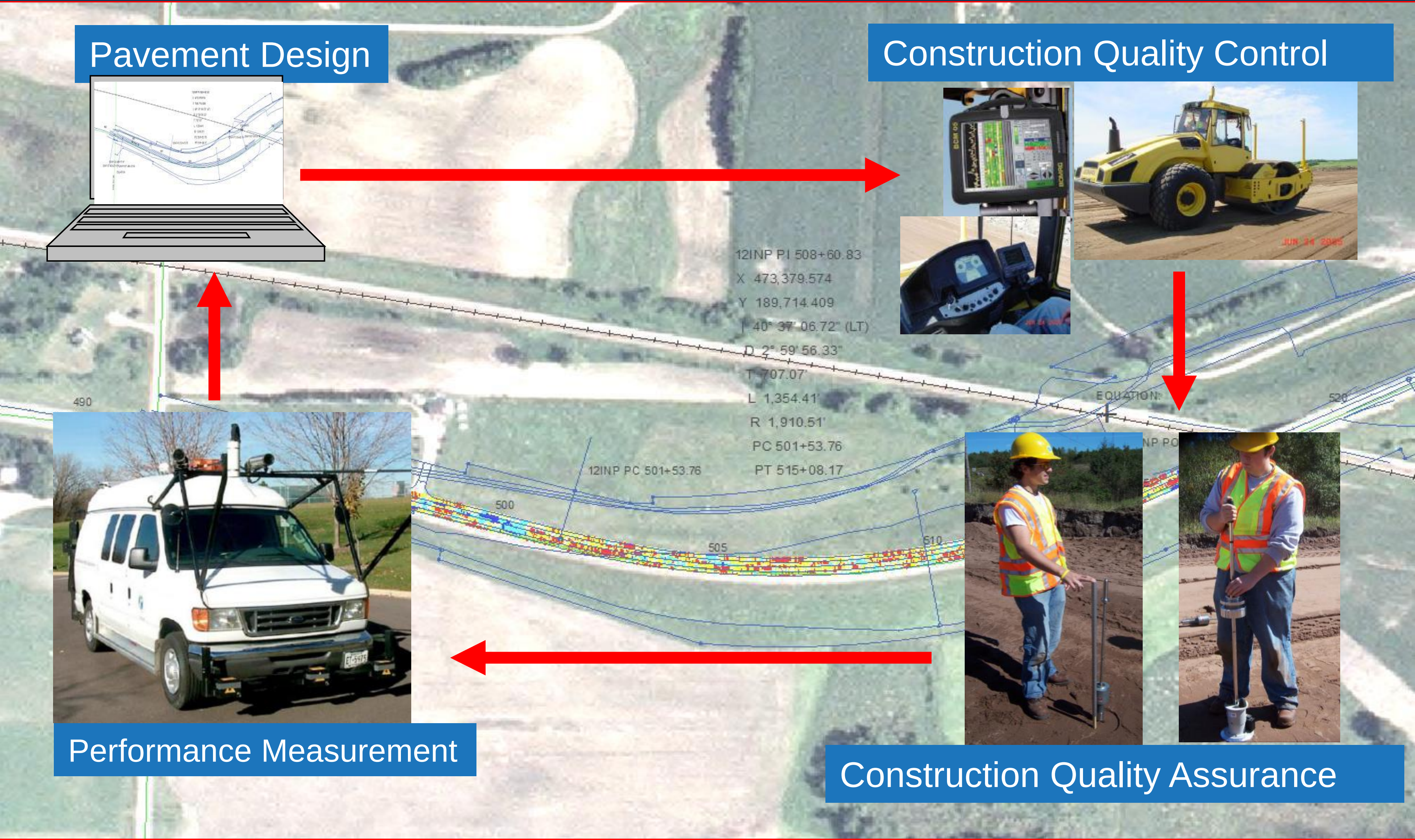
AASHTO TP 456-01 draft
(field quality assurance)

http://roads.maryland.gov/OPR_Research/MD-17-TPF-5-285-LWD_REPORT.pdf

Benefits of Performance Tests

- Empowers inspector with useful measures
- Verifies pavement design inputs
- Creates as-built record of construction
- Optimizes future pavement designs

Design, Construction and Performance



Construction Testing Summary

- LWDs and DCPs are being used to measure properties that significantly affect performance (this includes moisture measurement).

- Minnesota DOT policy encourages compaction equipment be used to fully map the as-built pavement layers.

- AASHTO draft specifications are available for performance based construction management.

Quantifying the Importance of Moisture

MnROAD Case Studies

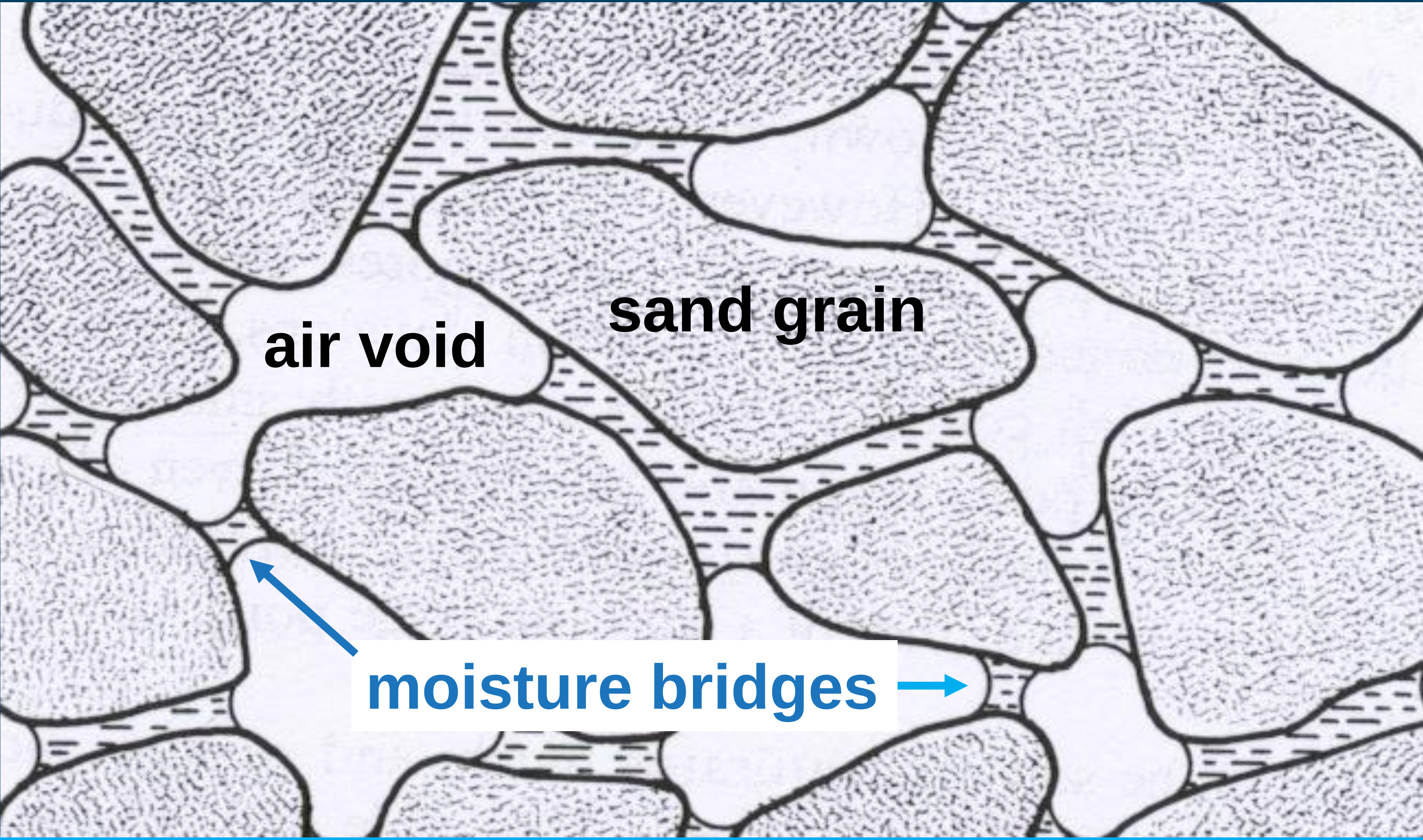
Ruth Roberson Thesis, 2007

Lessons Learned from Case Studies

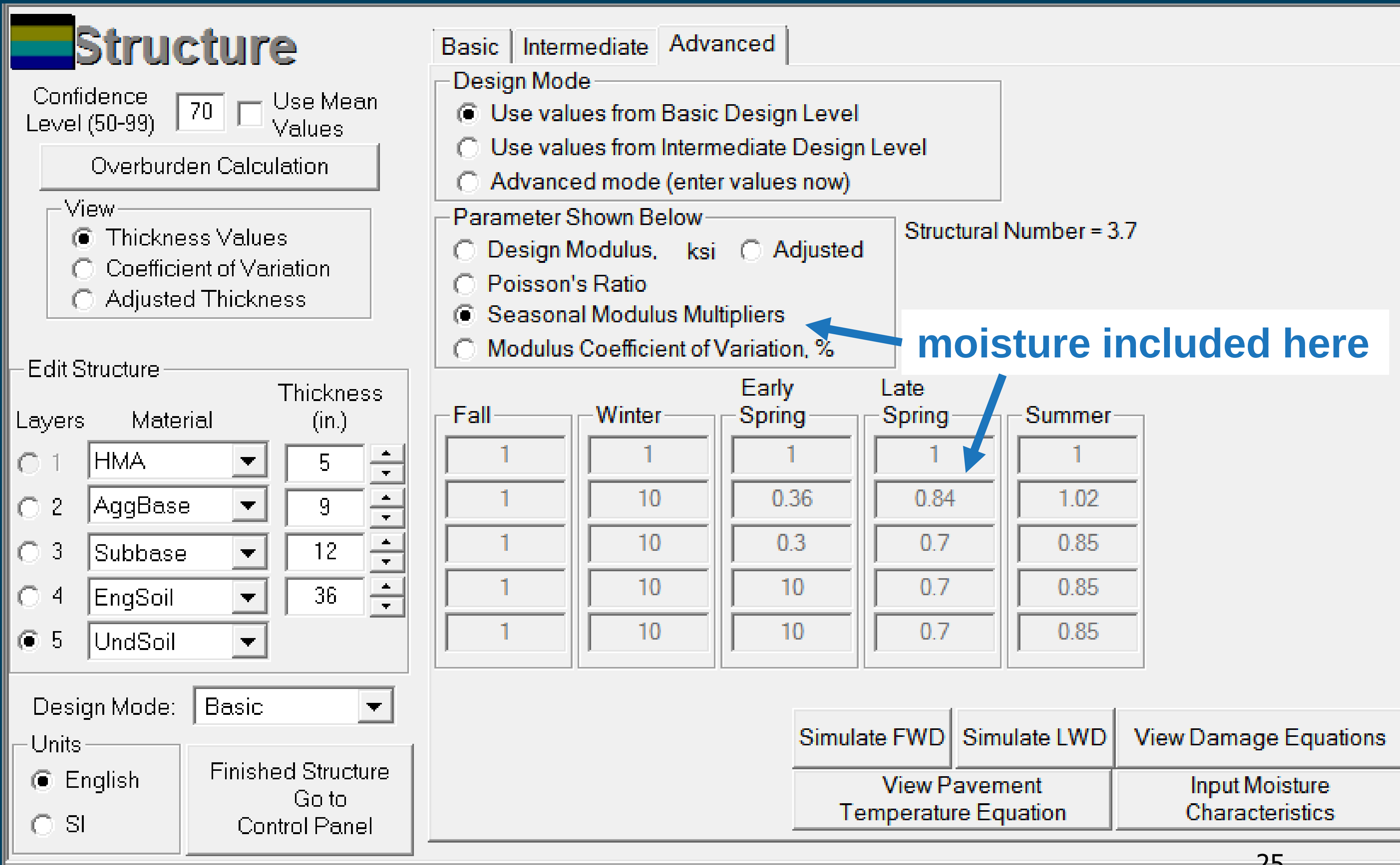
- Modulus and strength are greatly affected by the moisture between the particles, which causes a suction or tensile stress between the particles.

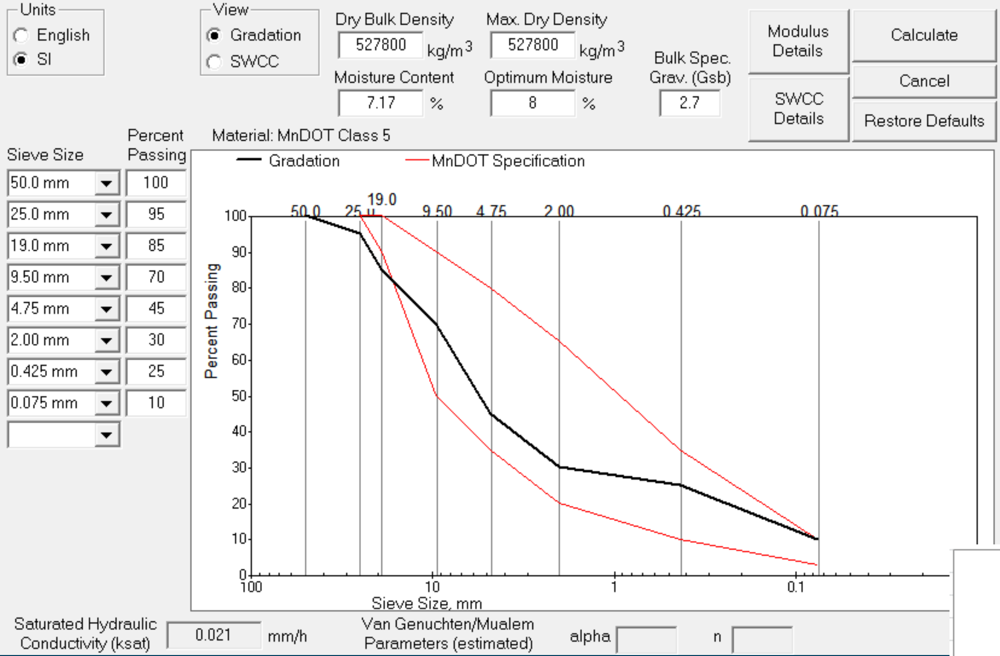
- Tensile stress between particles depends on:
  - Quantity of sand, silt, and clay particles (gradation)
  - Particle shape (roughness)
  - Porosity (total void space “openness”)
  - Moisture content (how much water is in the voids)

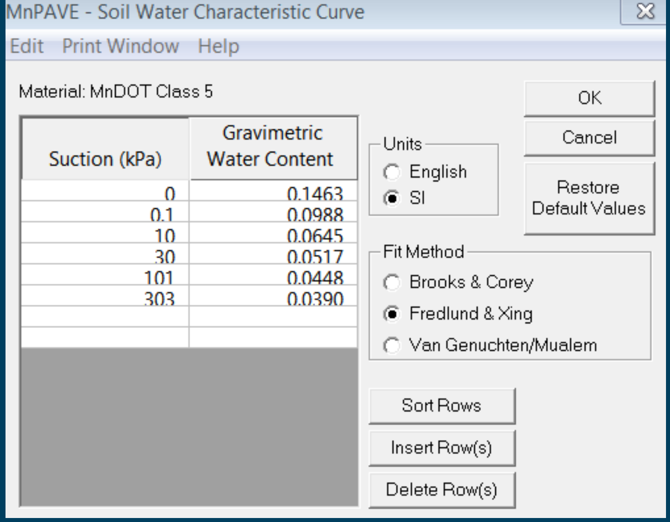
Fundamentals of Soil Physics, Hillel

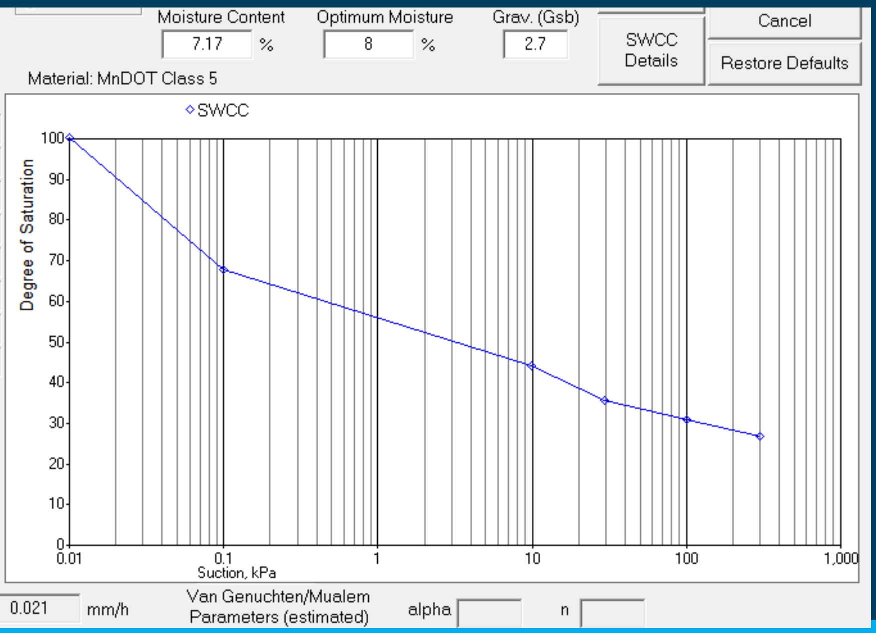


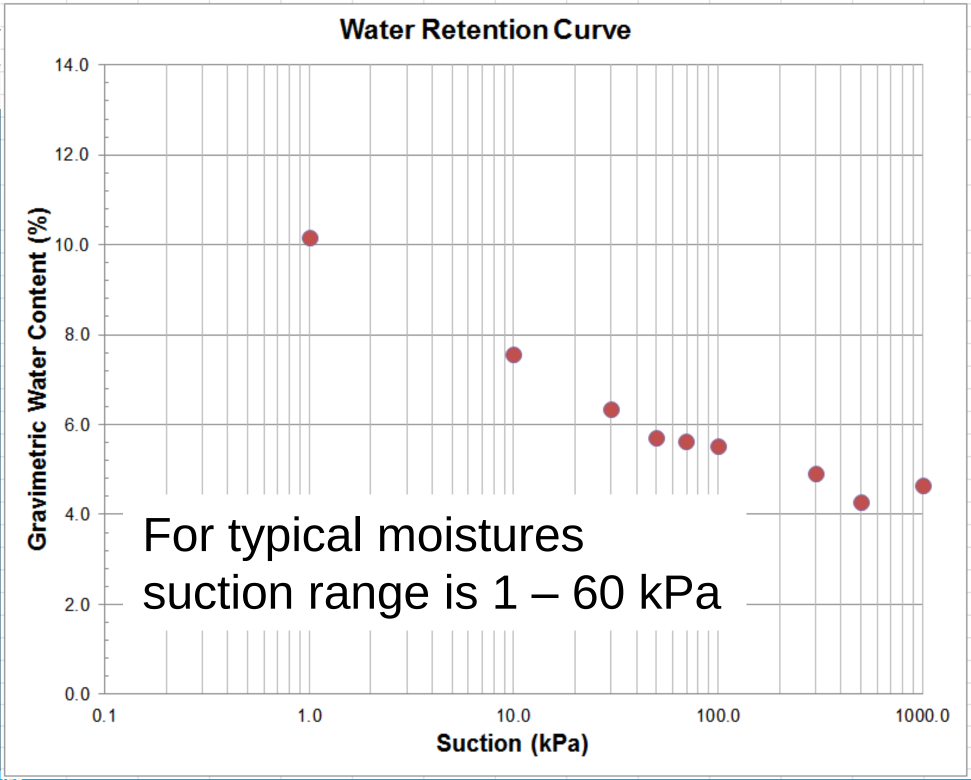
Need Moisture Content Inputs





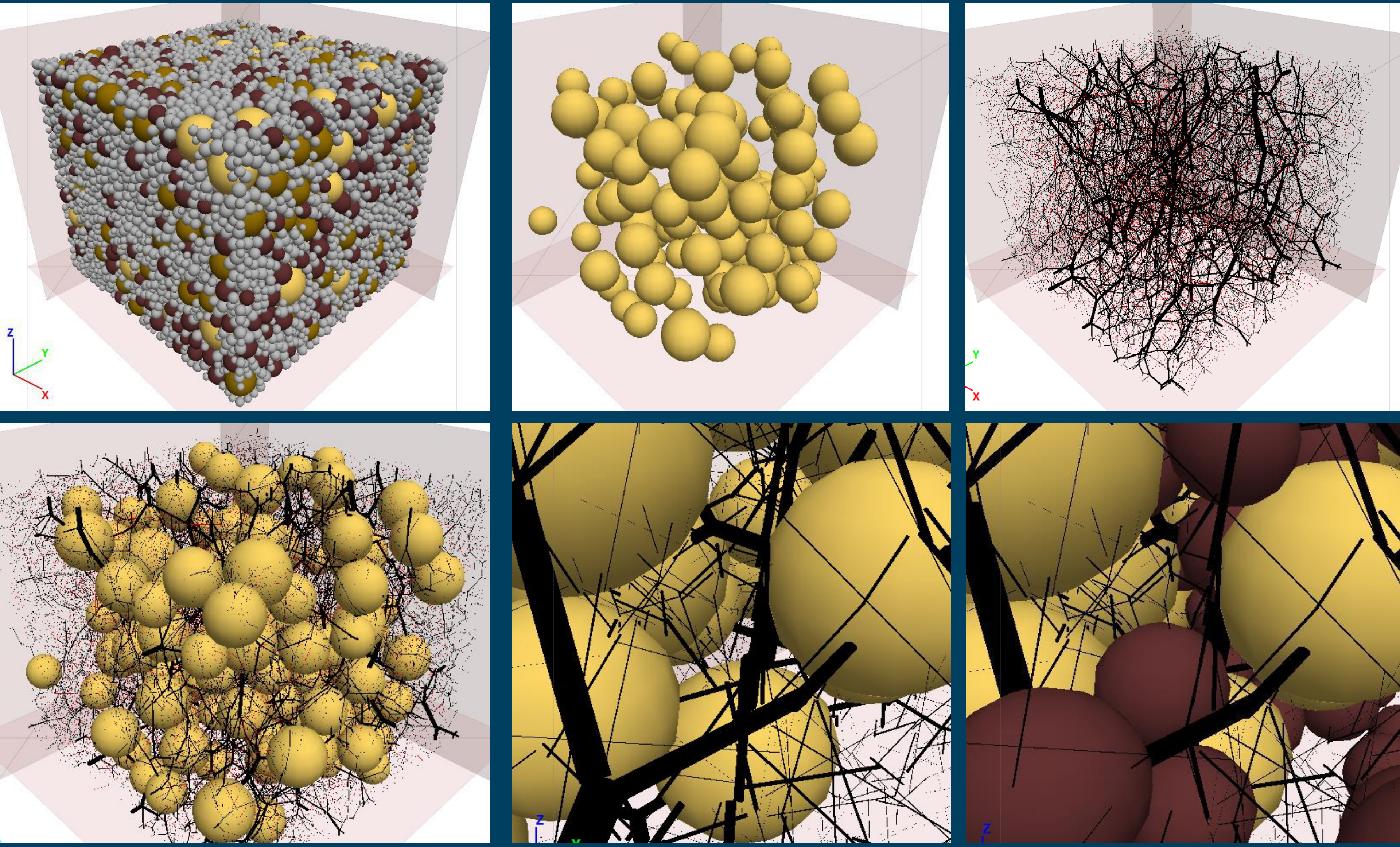




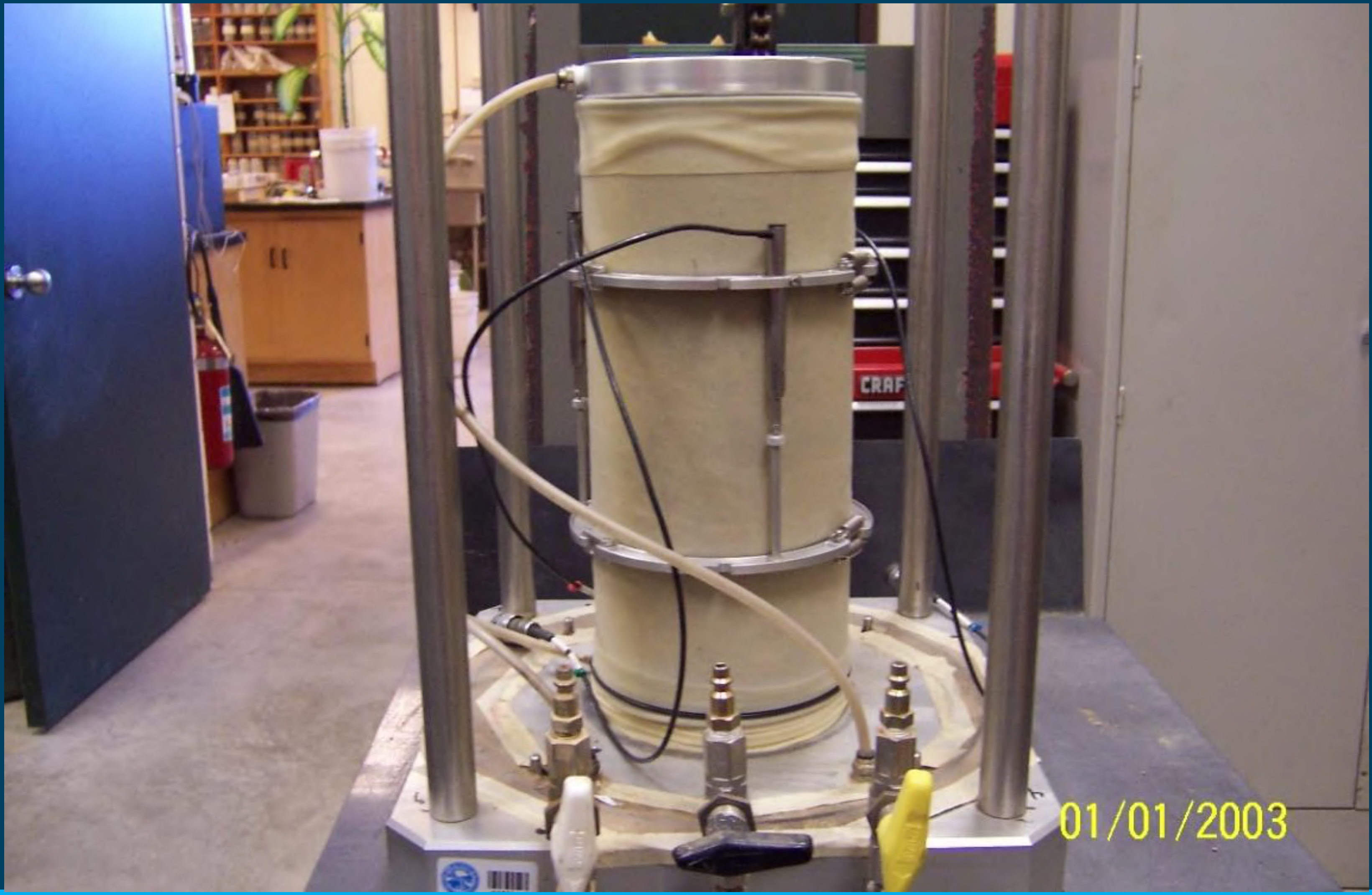


For typical moistures suction range is 1 – 60 kPa

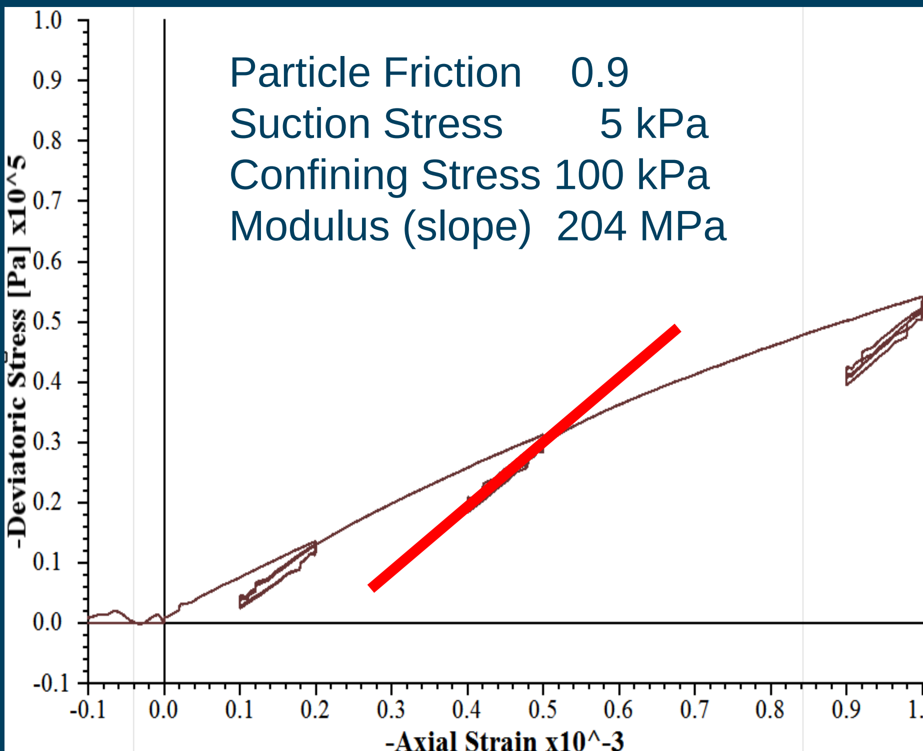
Distinct Element Model with Suction

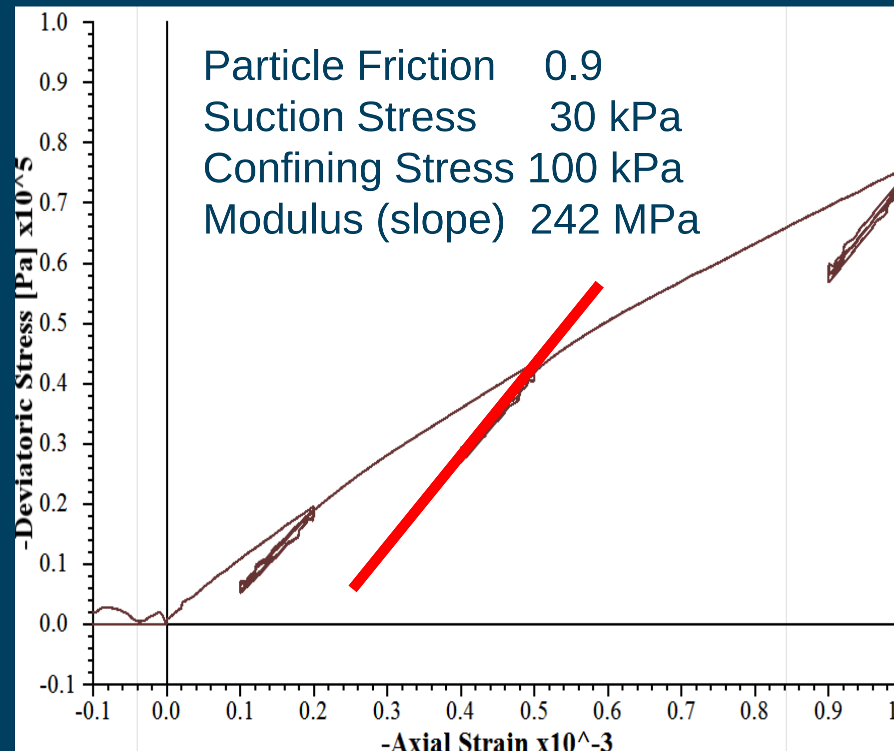


Laboratory Resilient Modulus



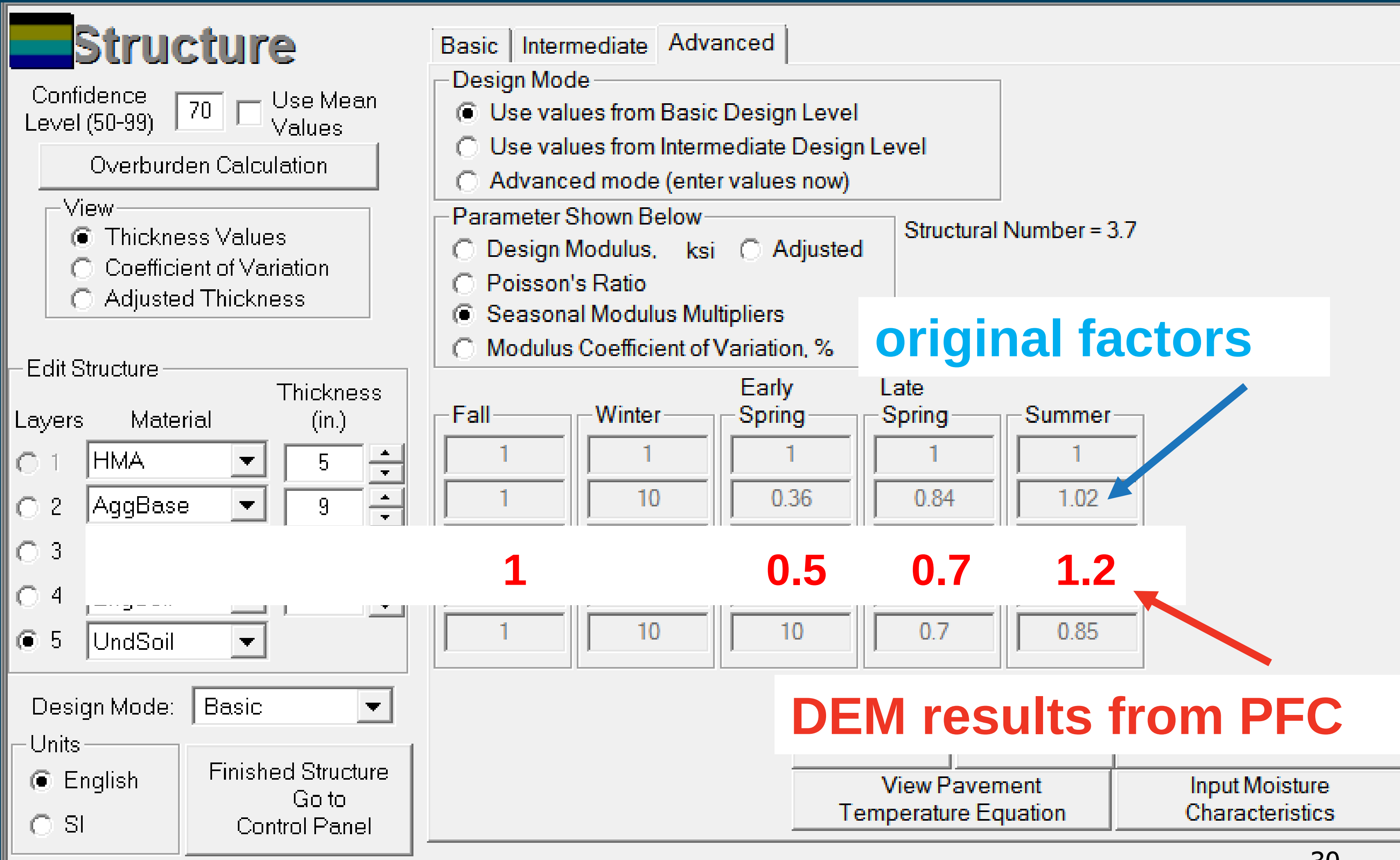
Numerical Modeling Results





Increasing suction increases resilient modulus.

Seasonal Factors Compared



Quantifying the Benefit of Geogrid

Geogrid History and Widening

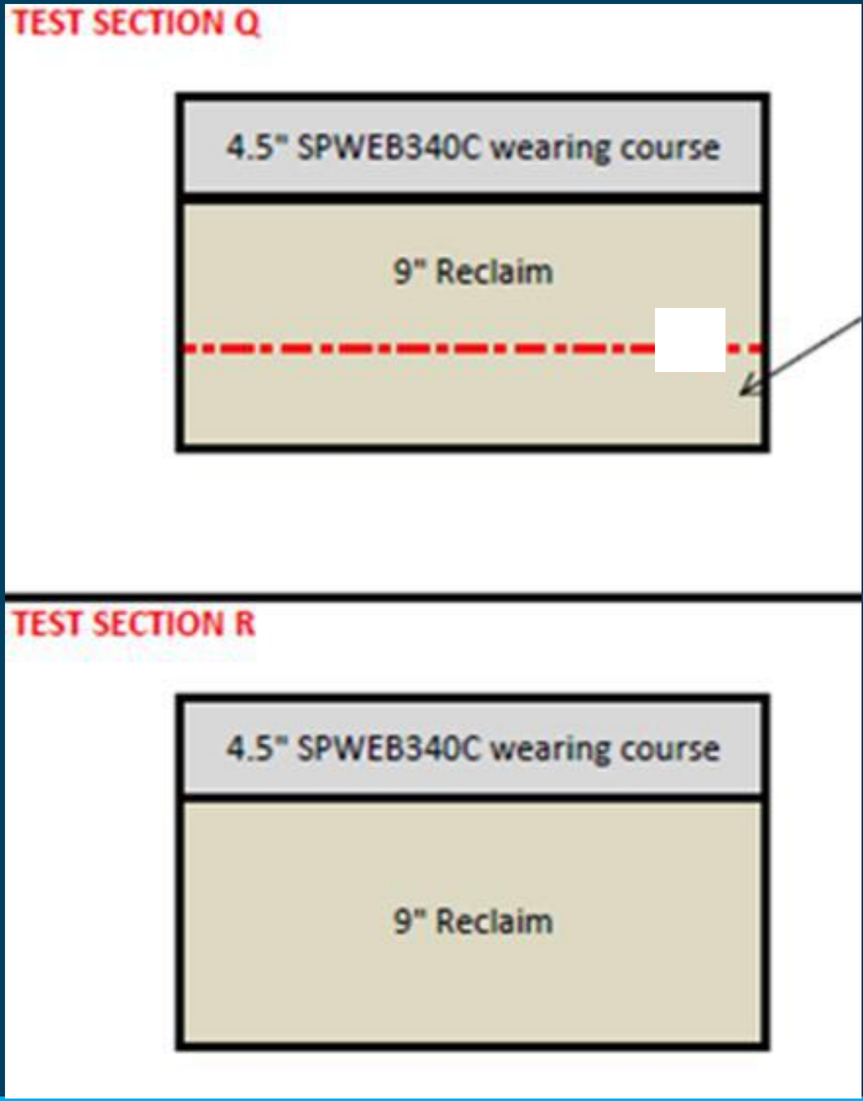
Photo courtesy of Jim Bittmann

TH 72 Geogrid Installation 2011

Photos courtesy of Jim Bittmann

Geogrid in Aggregate Base Layer

- Ideally geogrid would be the only difference between test sections.
- Reality is that other variables include soil, water, and temperature.



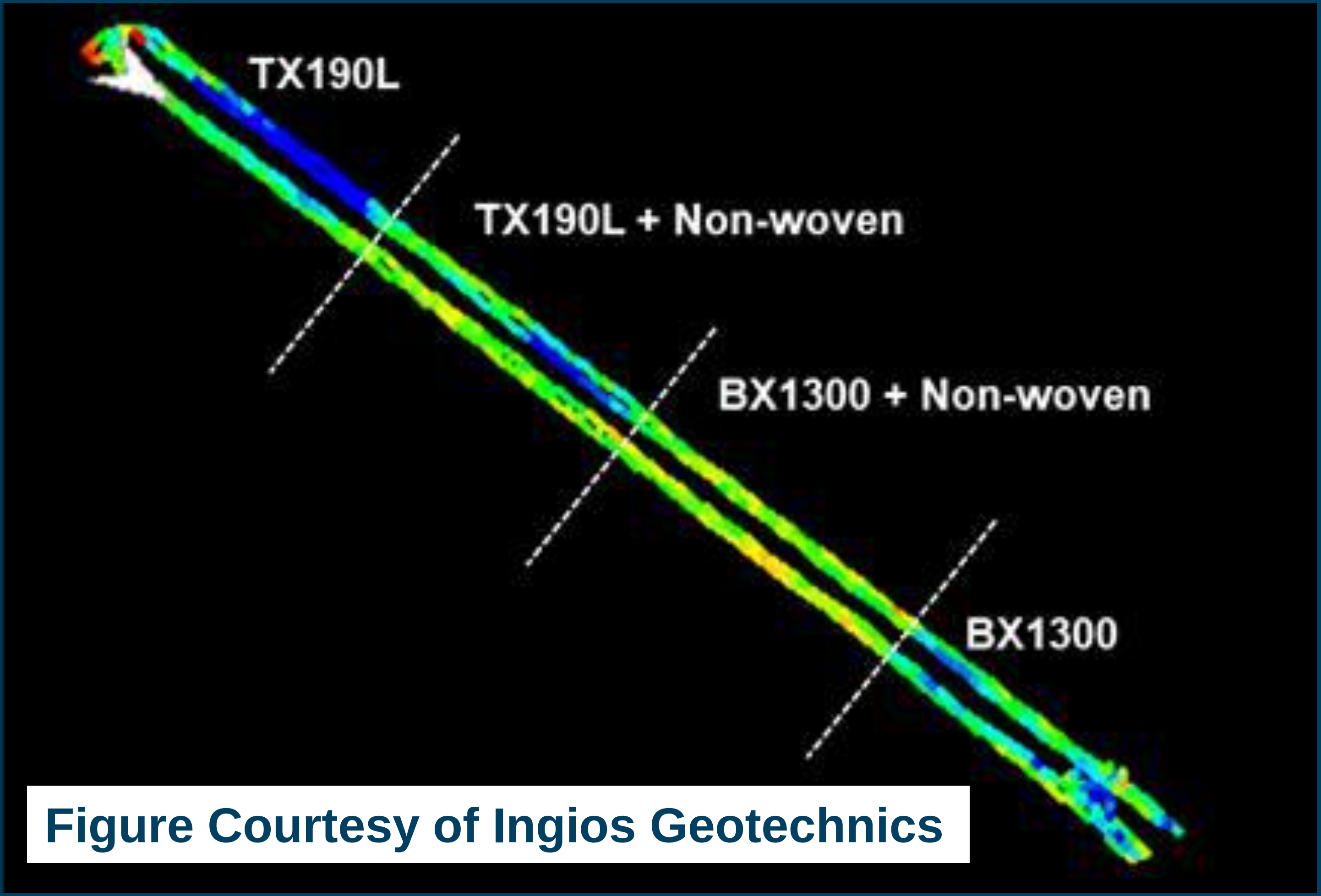
Field Testing and Numerical Modeling of In Situ Resilient Modulus

Automated Plate Load Test (Ingios)

Trunk Highway 72 September 2016

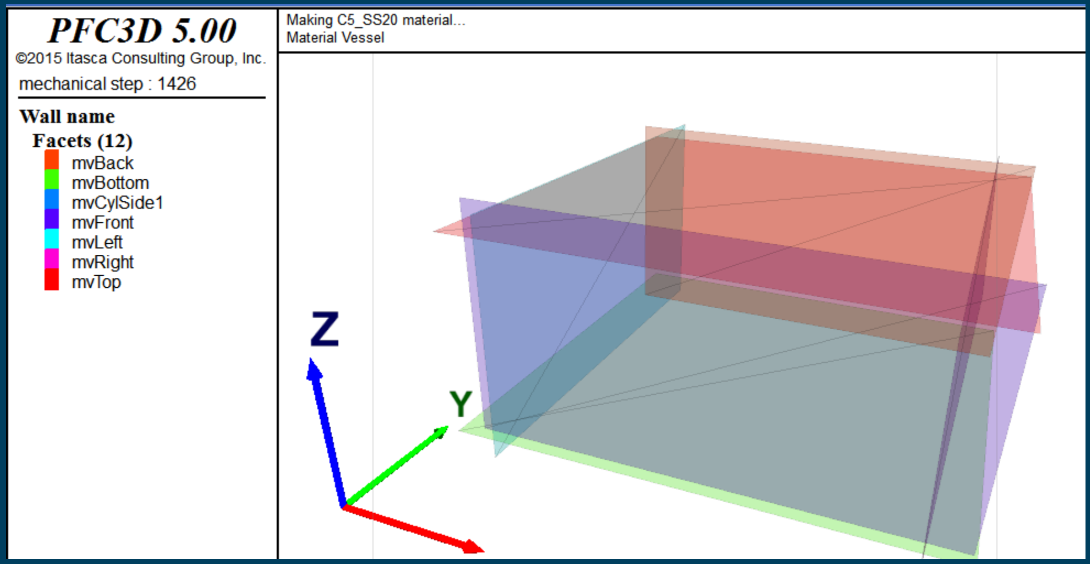
MnROAD July August 2017

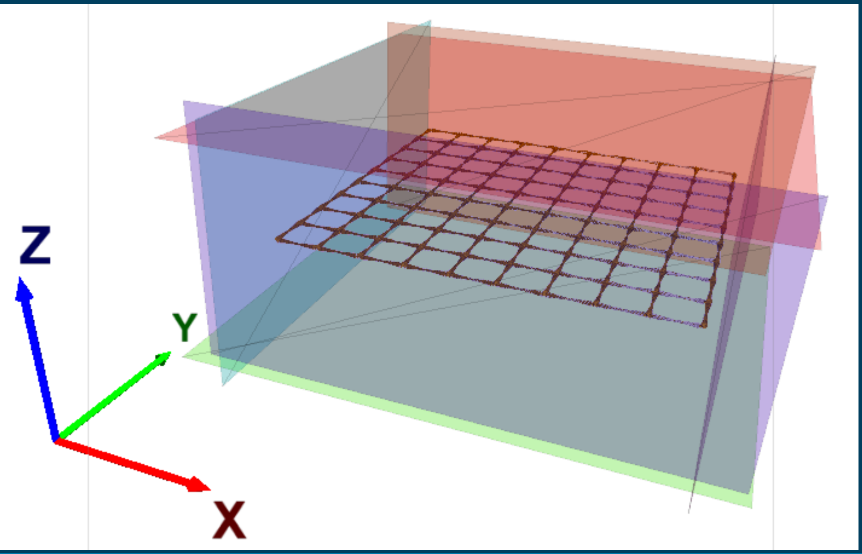
IC Map of Geogrid MnROAD 2017

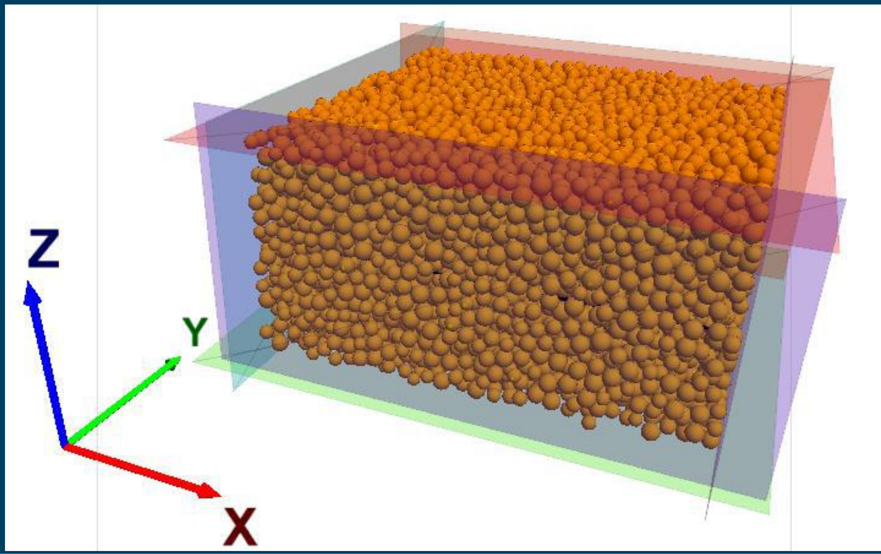


Link to Research Pays Off Seminar, David White, October 2017
http://www.dot.state.mn.us/mnroad/researchpaysoff/index.html

Numerical Modeling of Geogrid







Parameters Studied

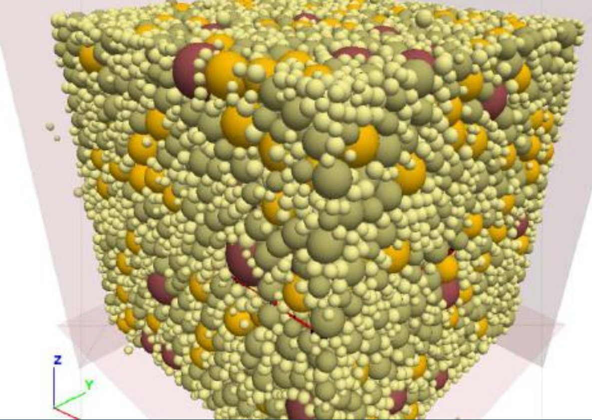
Aggregate gradation

Friction between particles (roughness)

Moisture content (suction/tensile stress)

Confining stress

Geogrid depth within aggregate base layer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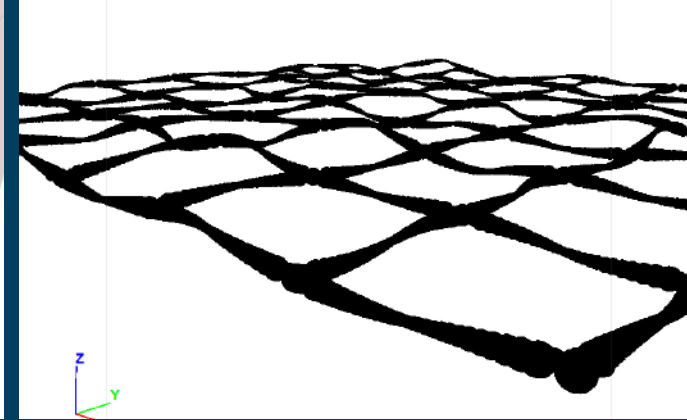
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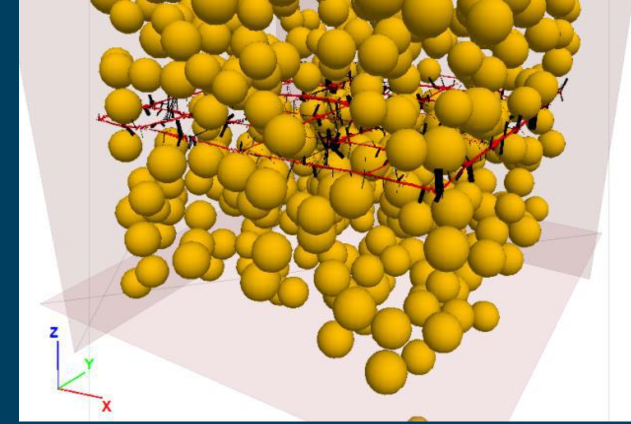
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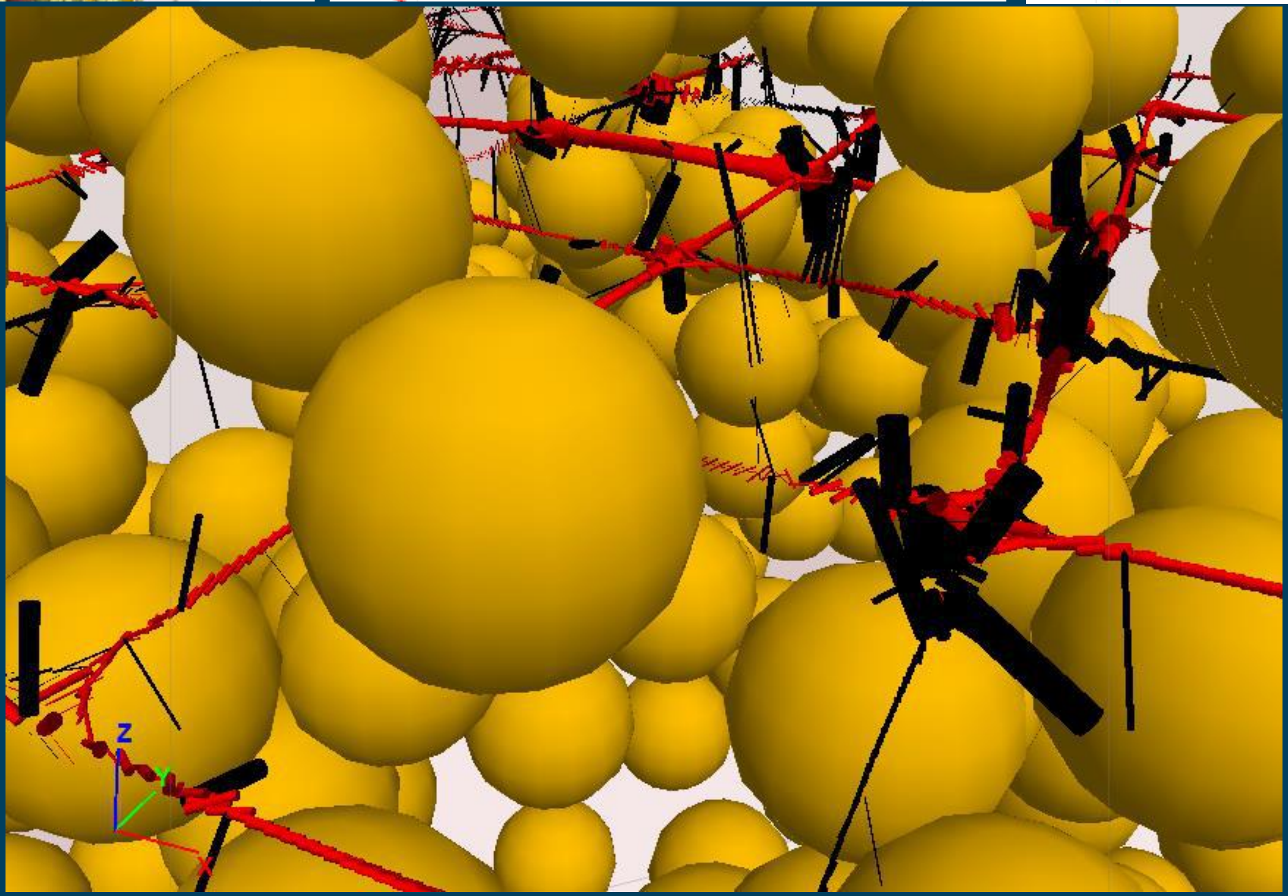
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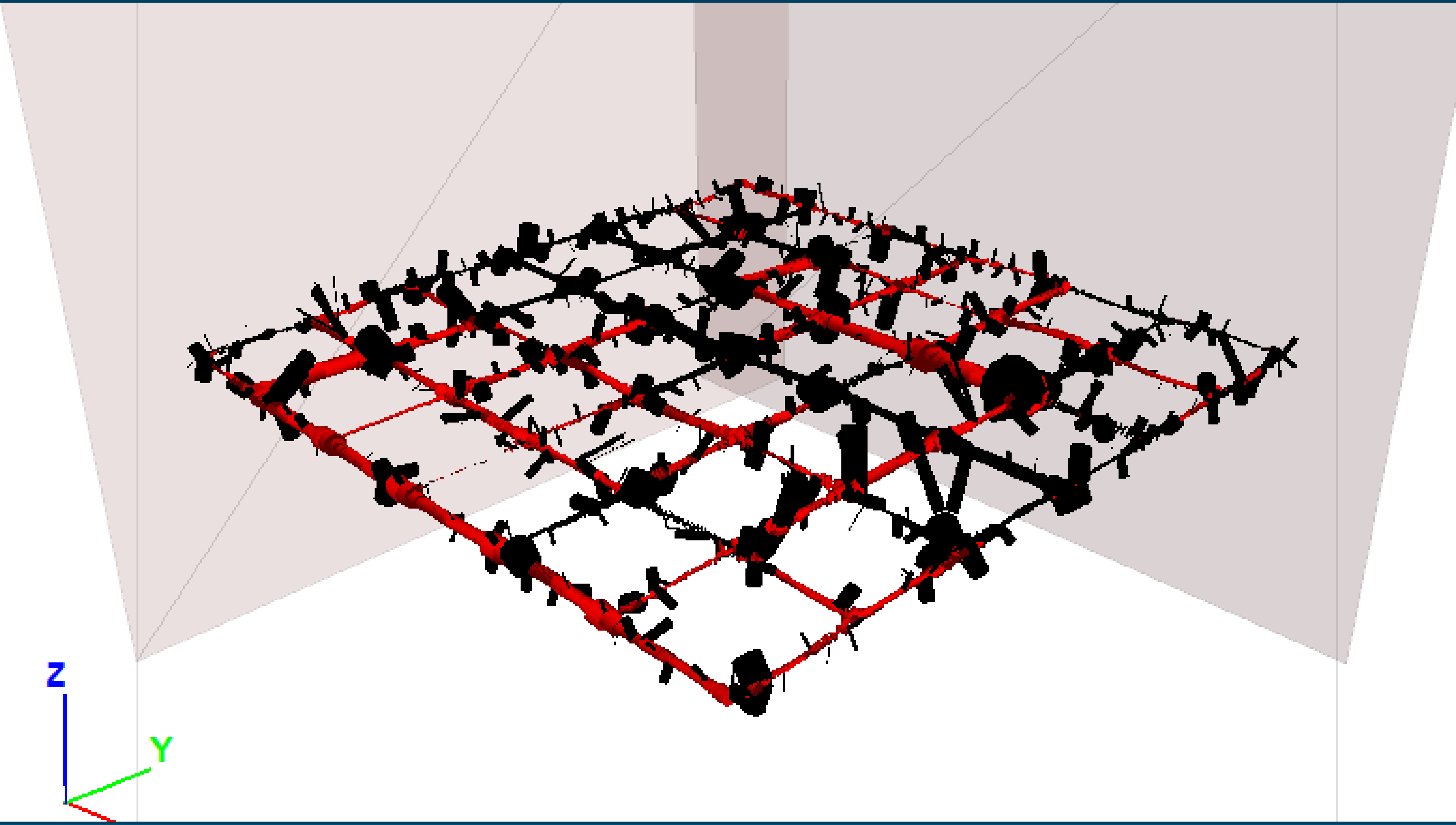
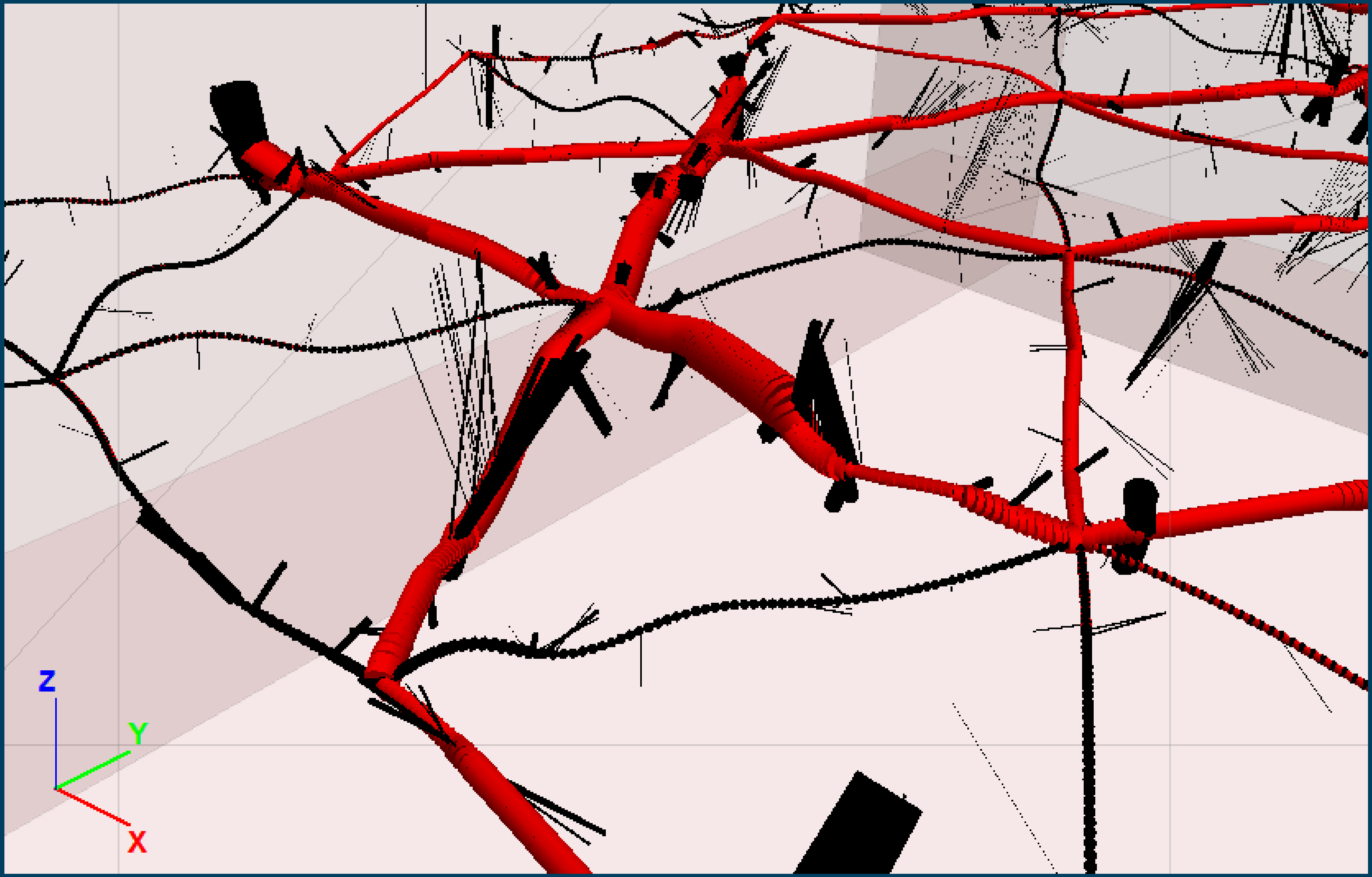
Geogrid with Red Showing Tension



Triaxial Grid Deformed by Aggregate



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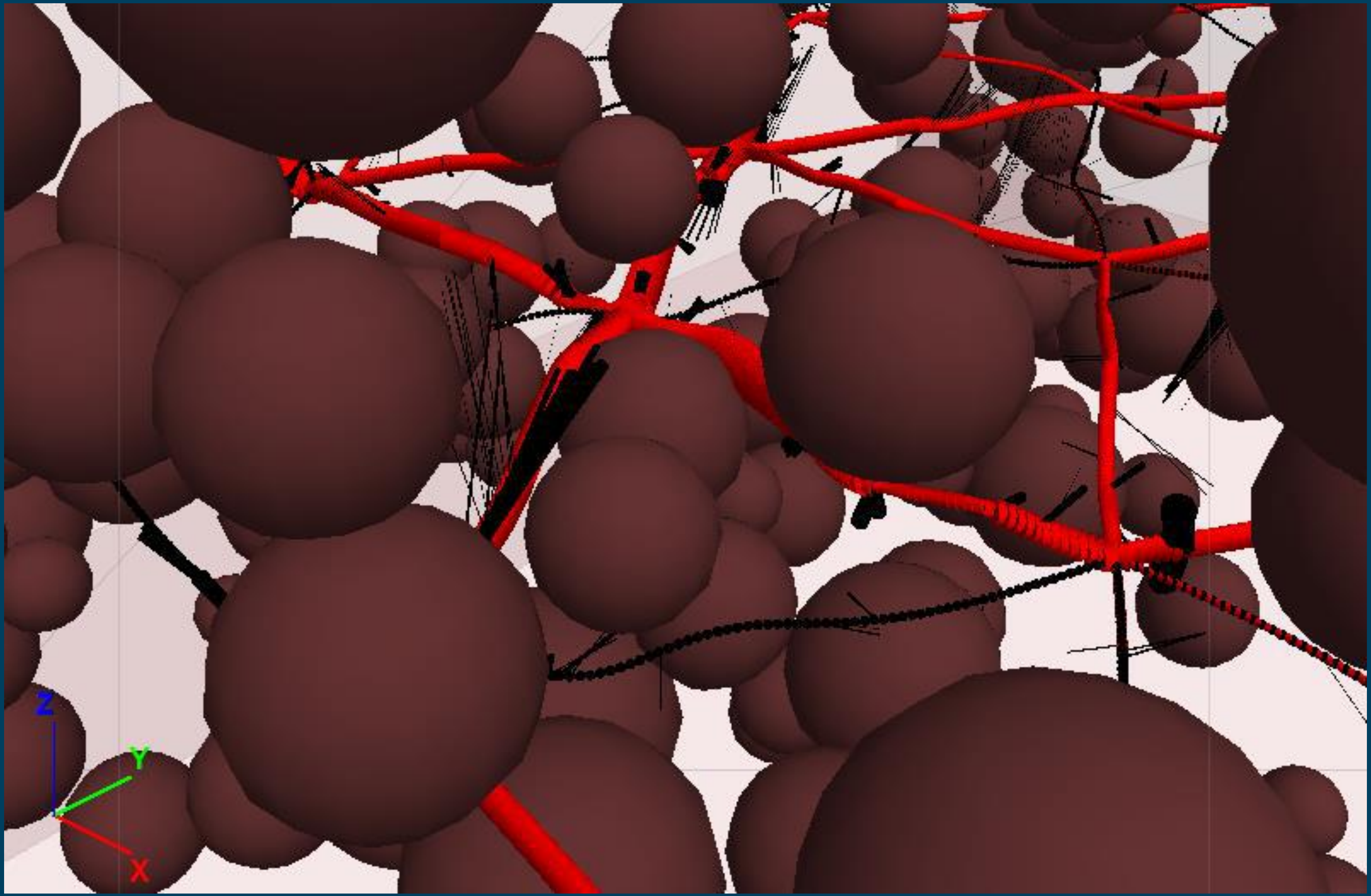
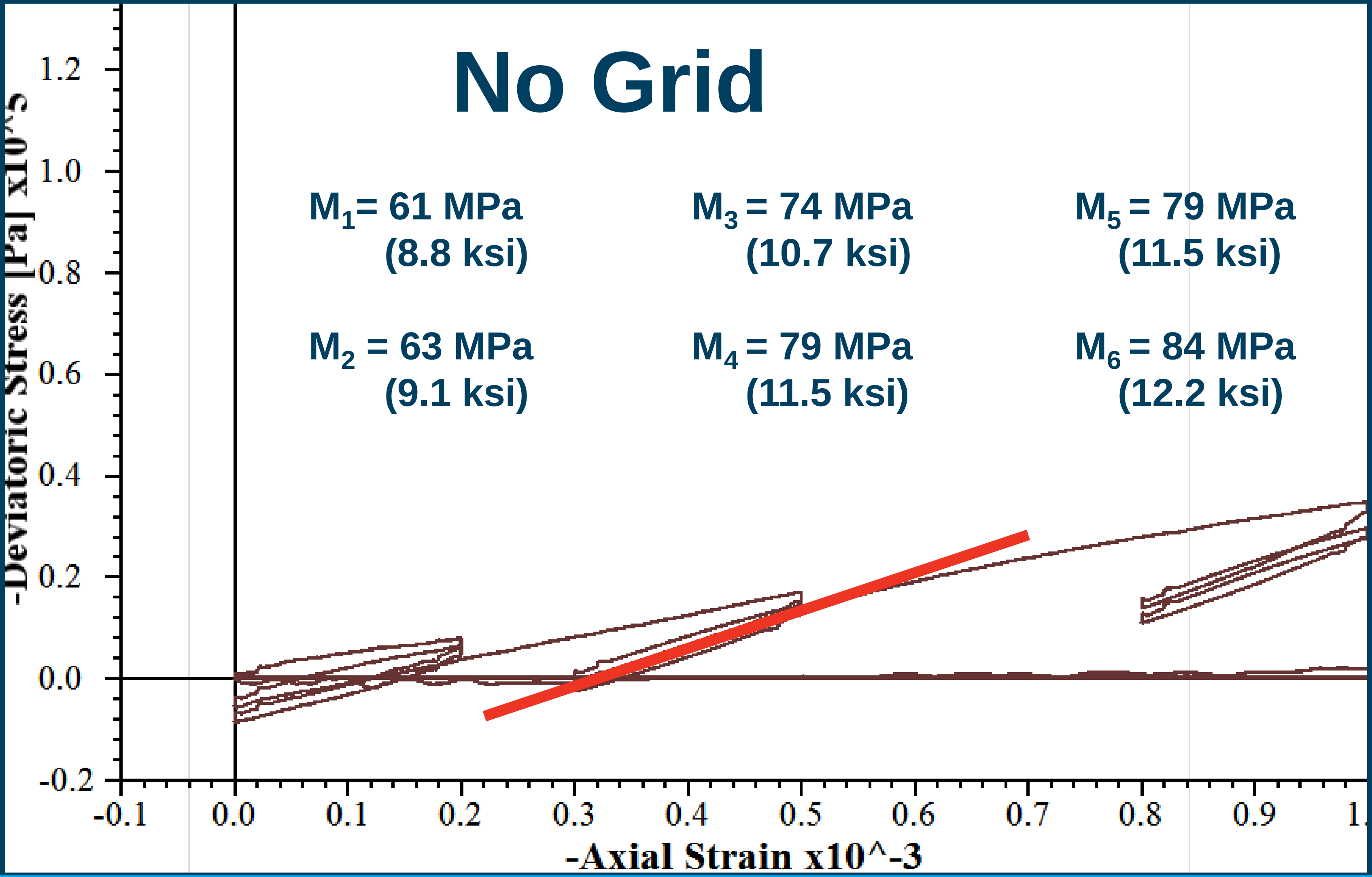


Modulus of 8 Inch Aggregate Base Layer

Confinement = 150 kPa Particle Friction = .8 Moisture Tension = 1 kPa (gap 3 mm)



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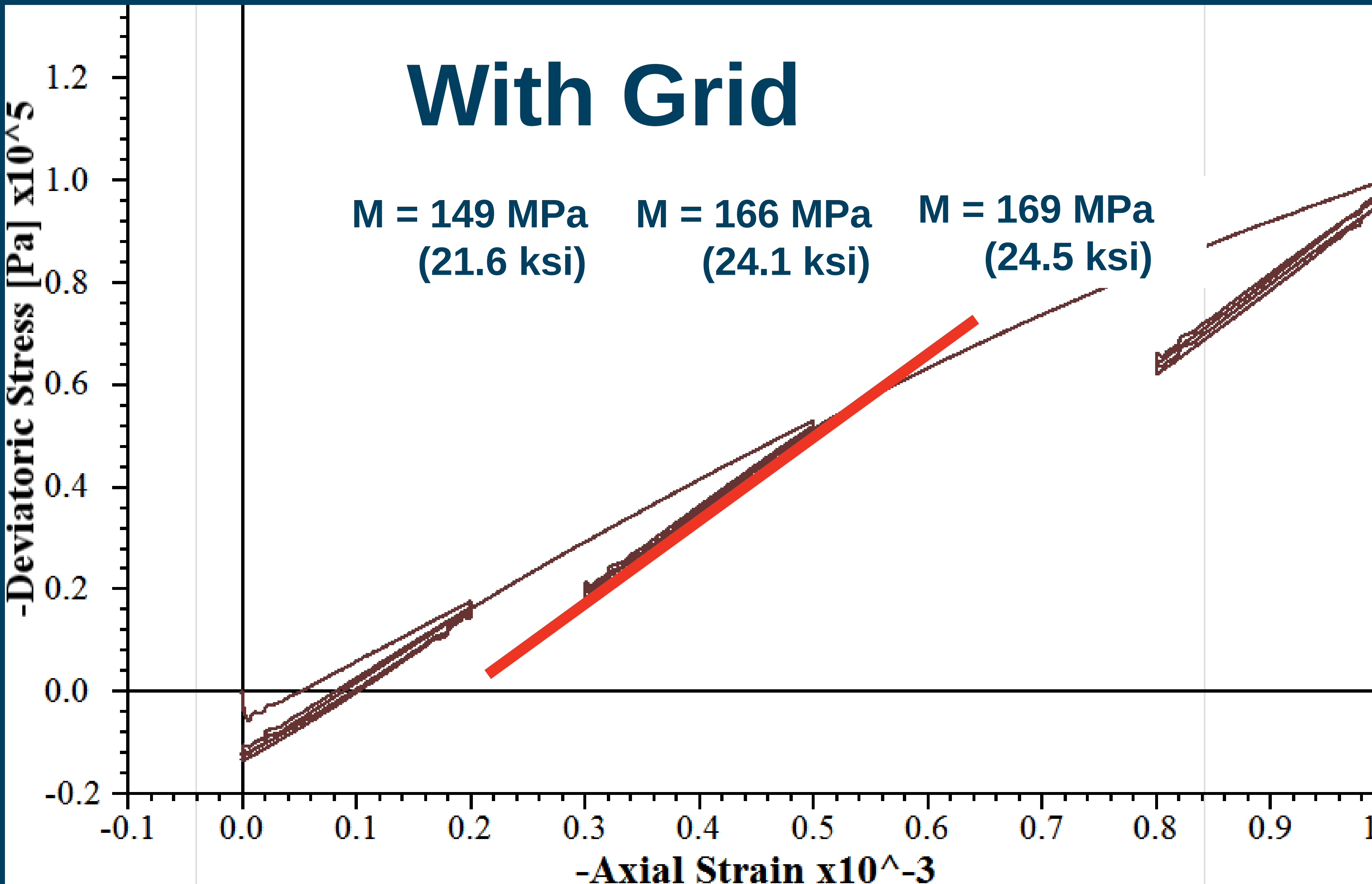

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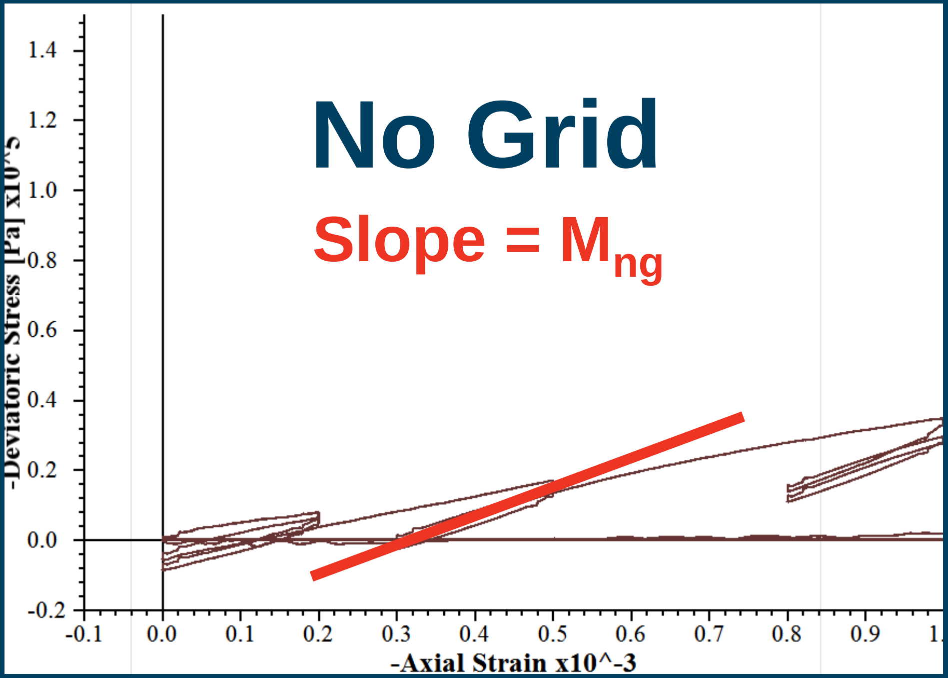
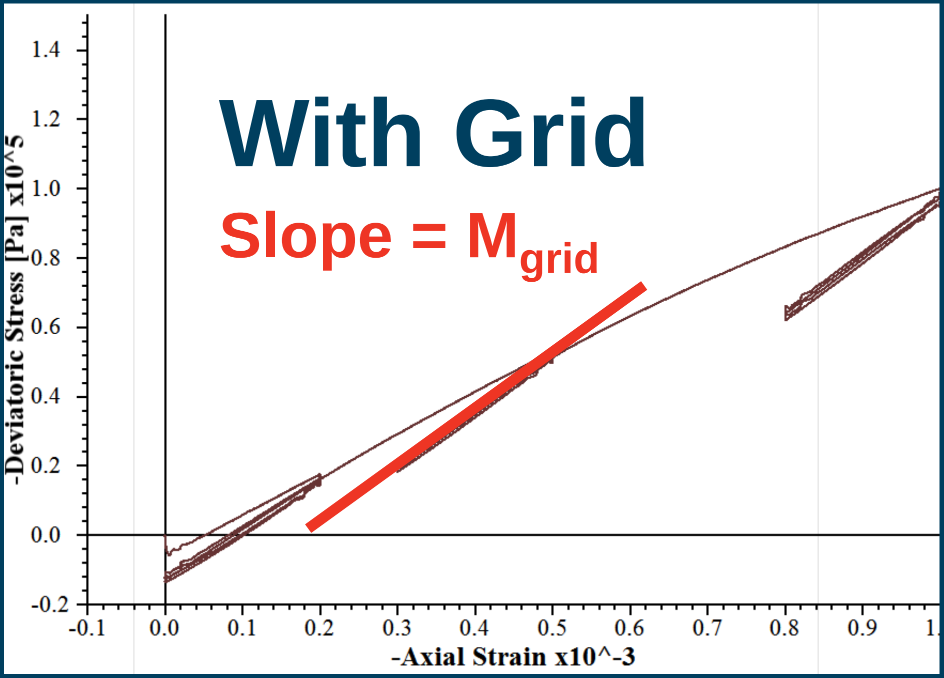




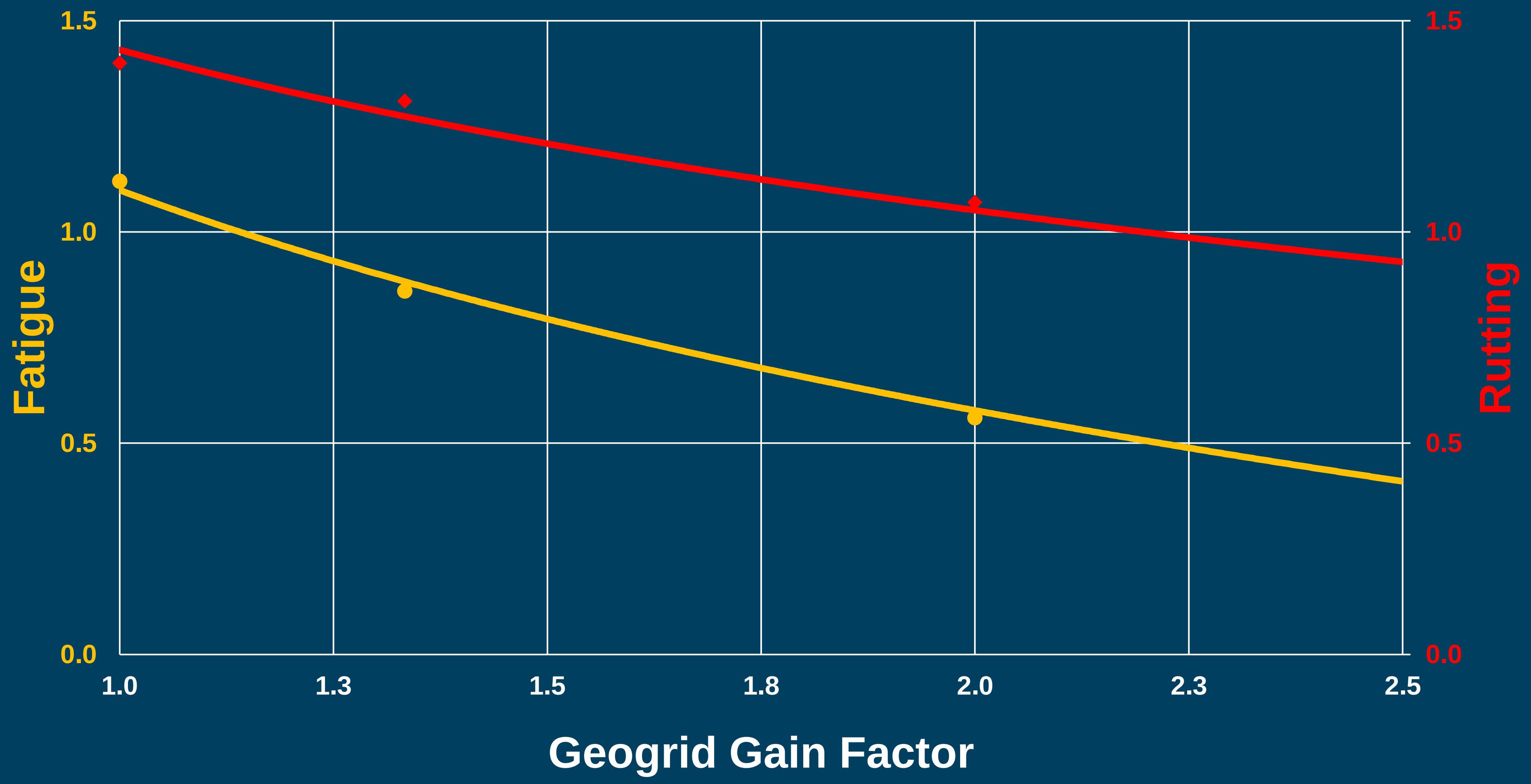
Geogrid Gain Factors

(M_2/M_1 at axial strain)

(0.02%)	(0.05%)	(0.1%)
2.4	**2.2**	**2.1**
2.4	**2.1**	**2.0**

Rutting vs Geogrid Gain Factor

Damage must be less than of 1.0 to achieve 20 year design life.



Lessons Learned and Next Steps

- Modulus increases as moisture suction increases.
- Geogrid provides a quantifiable benefit that enhances pavement performance.
- Implementation continues so that the people's investments are used more effectively.

Thanks for Listening.

Please ask questions and keep pulling together.