

# Rational Incorporation of Subsurface Drainage within an M-E Design Framework



*January 2003*

*TRB COMMITTEE A2K06  
SUBSURFACE DRAINAGE*

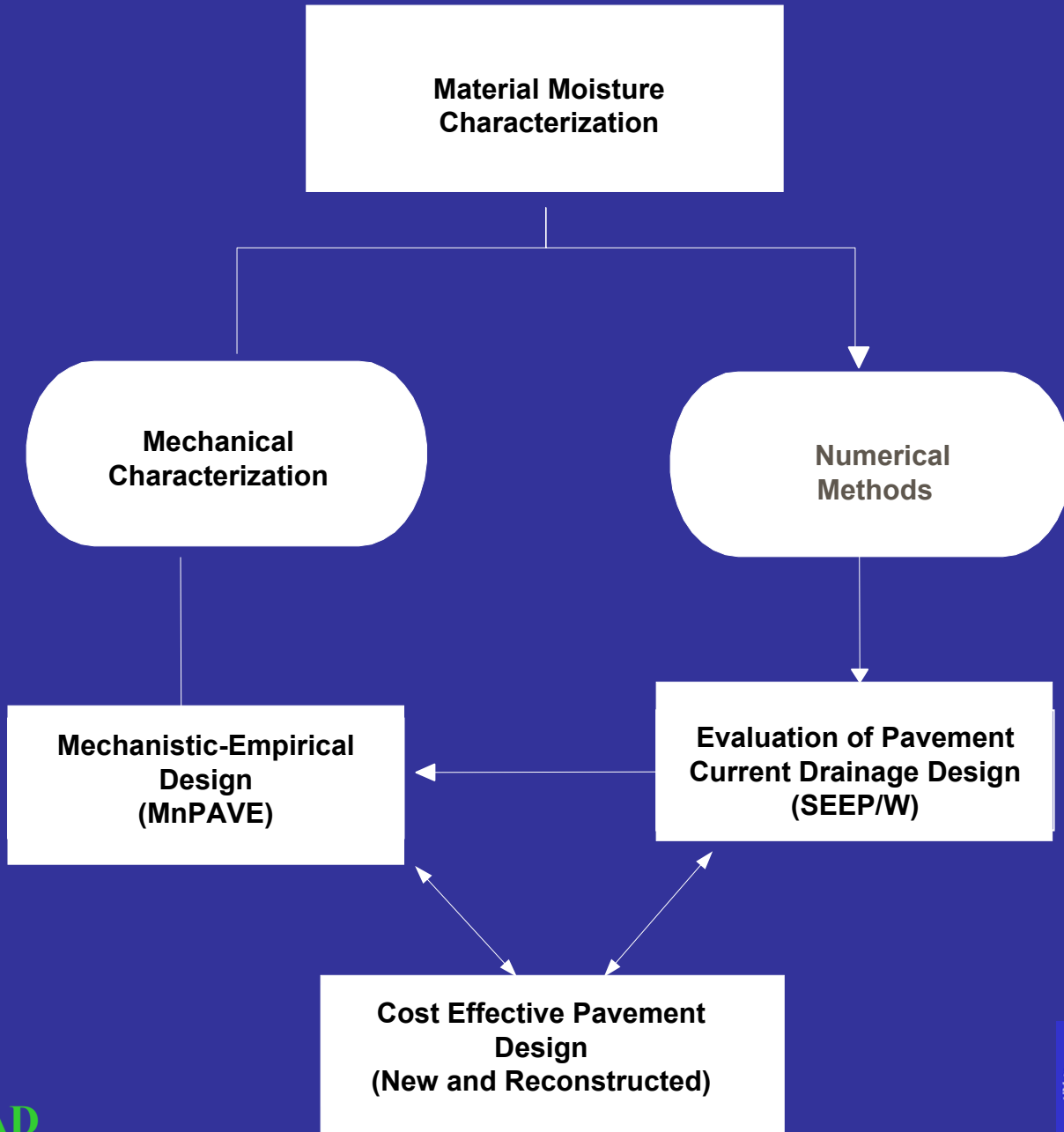
*Ruth Roberson*

# Acknowledgments

- Local Road Research Board (LRRB)

## Special Thanks

- Dr. Bjorn Birgisson (U of Florida, Gainesville)
- Defne Apul (UNH, RMRC)
- Bruce Tanquist (Mn/DOT)



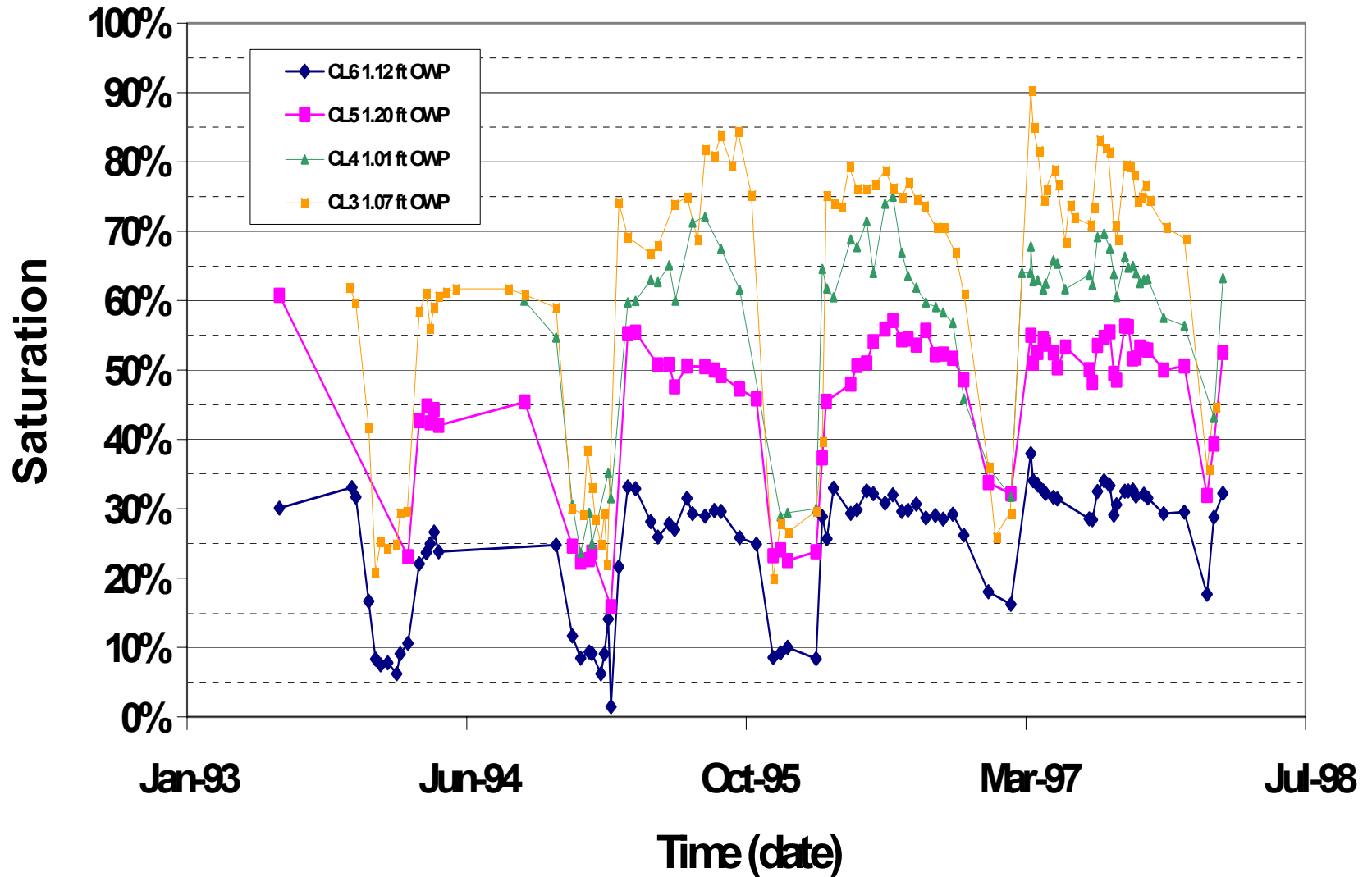
# Objective

Linking Material Moisture Characteristics to  
Design Parameters

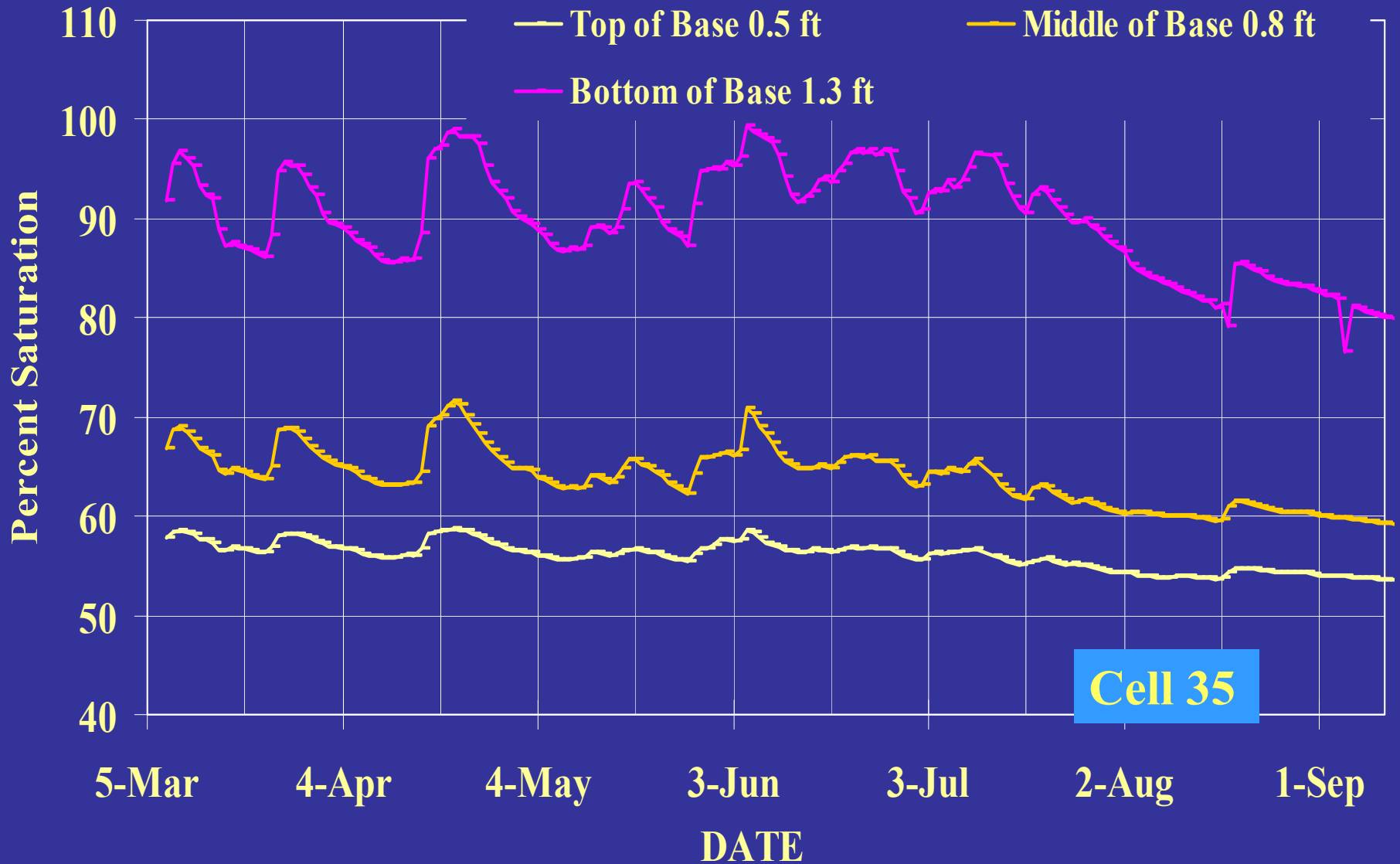
# Material Characterization for M-E and Drainage Design

- Develop Framework for Incorporation Into Design
  - Measurements and Instrumentation (MnROAD)
  - Moisture Conditions
    - Determine moisture regime
    - Develop soil property functions
    - Determine relationship to design variables
- Implementation
  - Design
    - M-E design (Material Properties)
    - Evaluating Current Drainage Designs

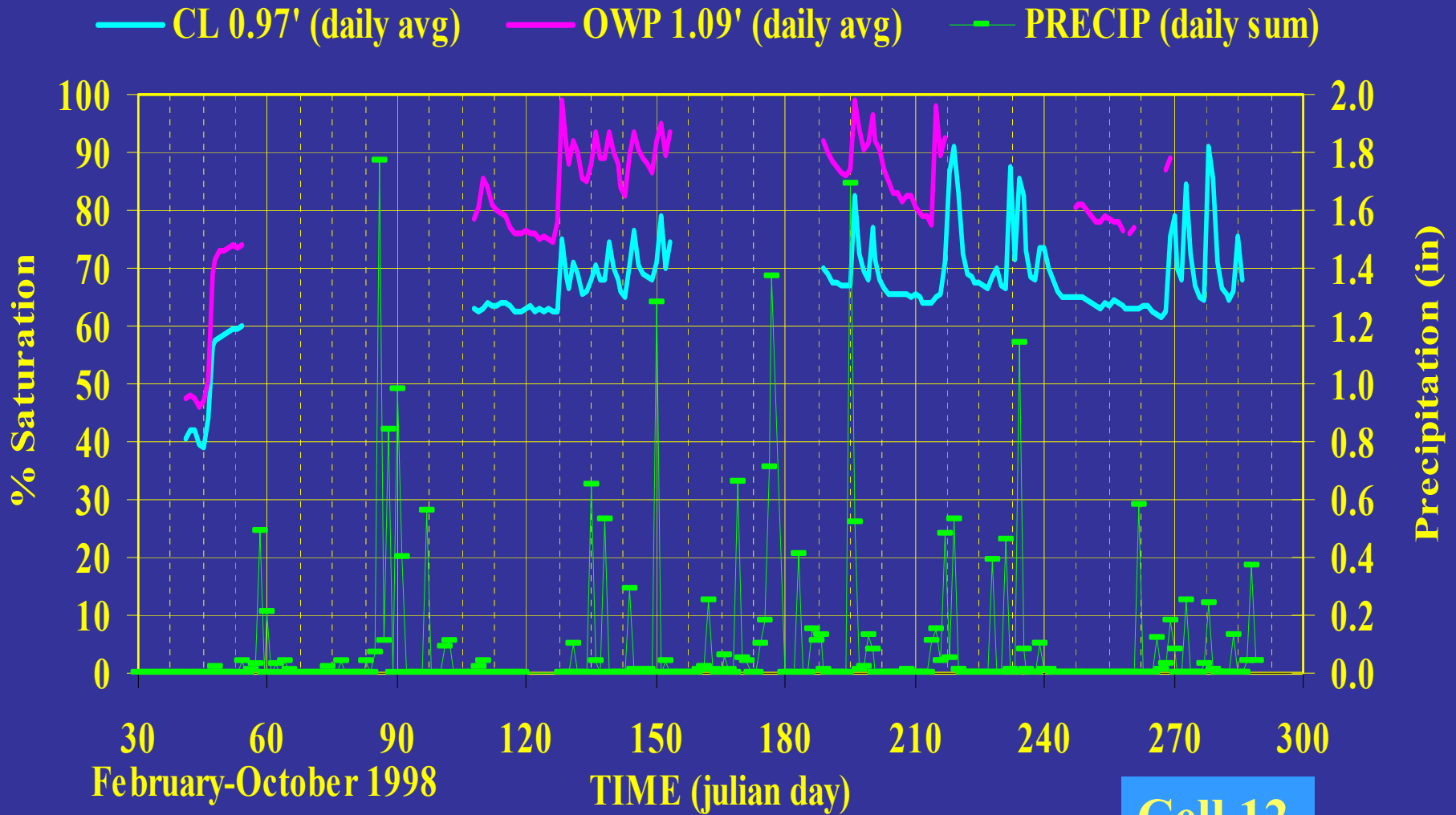
# Mn/ROAD Seasonal Moisture Content



# Base Water Contents



# Base Water Contents



Cell 12

# Moisture Conditions

- Moisture conditions within the pavement system vary over time and space.
- Material characterization must take into account both saturated and unsaturated properties.
- Saturated and unsaturated properties must be considered in M-E and pavement drainage design.

# Material Characterization for M-E and Drainage Design

- Estimating SWCC (SV Database)
  - Pedo-transfer function
  - Van Genuchten, Fredlund and Xing, Brooks and Corey, etc.. (Cu, PI, D10, D60, density)
- Evaluate Drainage Designs (SEEP/W)
- M-E Design
  - Resilient Modulus
  - Pore suction resistance factors
    - $\tau = c' + (\sigma_n - u_a) \tan \phi' + (u_a - u_w) [(\Theta^k) \tan \phi']$  (Vanapalli 1996)

# Applications

## ■ Design

- Evaluating Current Drainage Designs
- ME-design

# Soil Water Movement

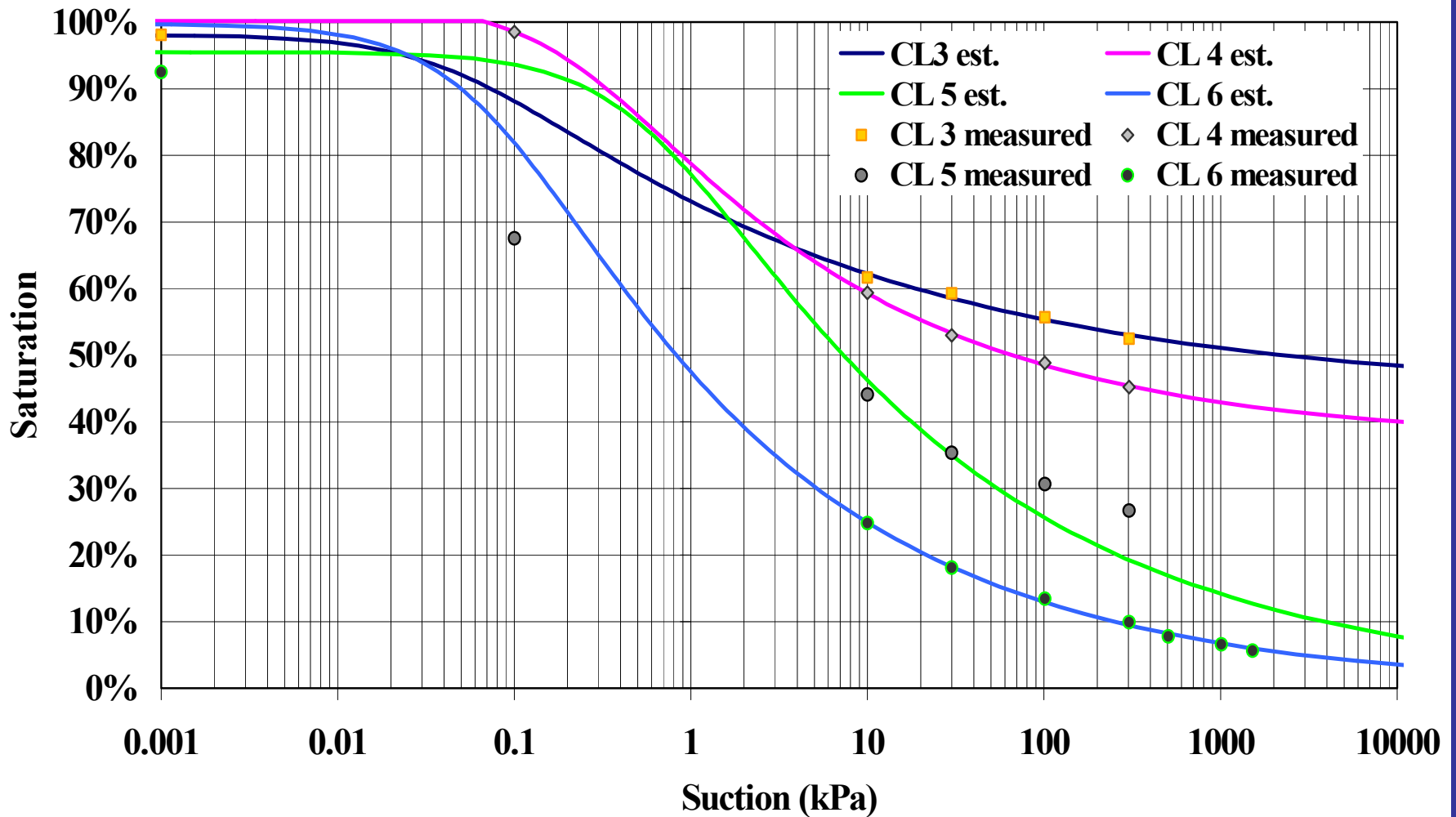
- **Flux is the volume flow rate per unit area ( $\text{cm}^3/\text{sec}/\text{cm}^2$ ).**
- **Saturated conditions: flux is proportional to the gradient and the hydraulic potential is independent of the conductivity.**
- **Unsaturated conditions: flux remains proportional to the hydraulic gradient but conductivity depends on hydraulic potential.**

$$q = -K \nabla H \text{ (Darcy's law)}$$

$$q = -K(\Psi) \nabla H \text{ (Richards 1931)}$$

$$\partial\theta/\partial t = \nabla \cdot [K(\Psi) \nabla H] \text{ (Richards equation)}$$

# Soil Water Characteristic Curve

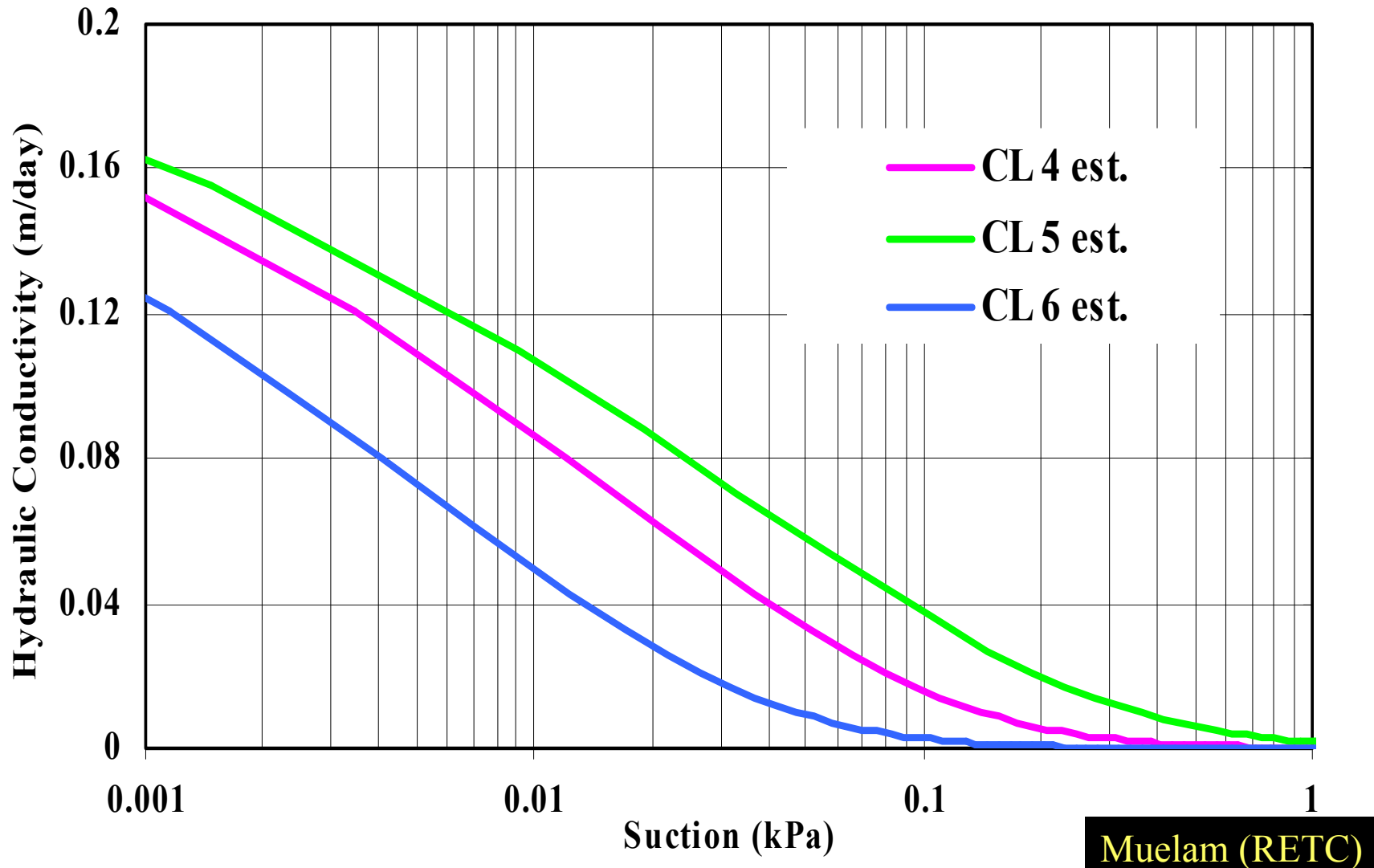


Van Genuchten fit (RETC)

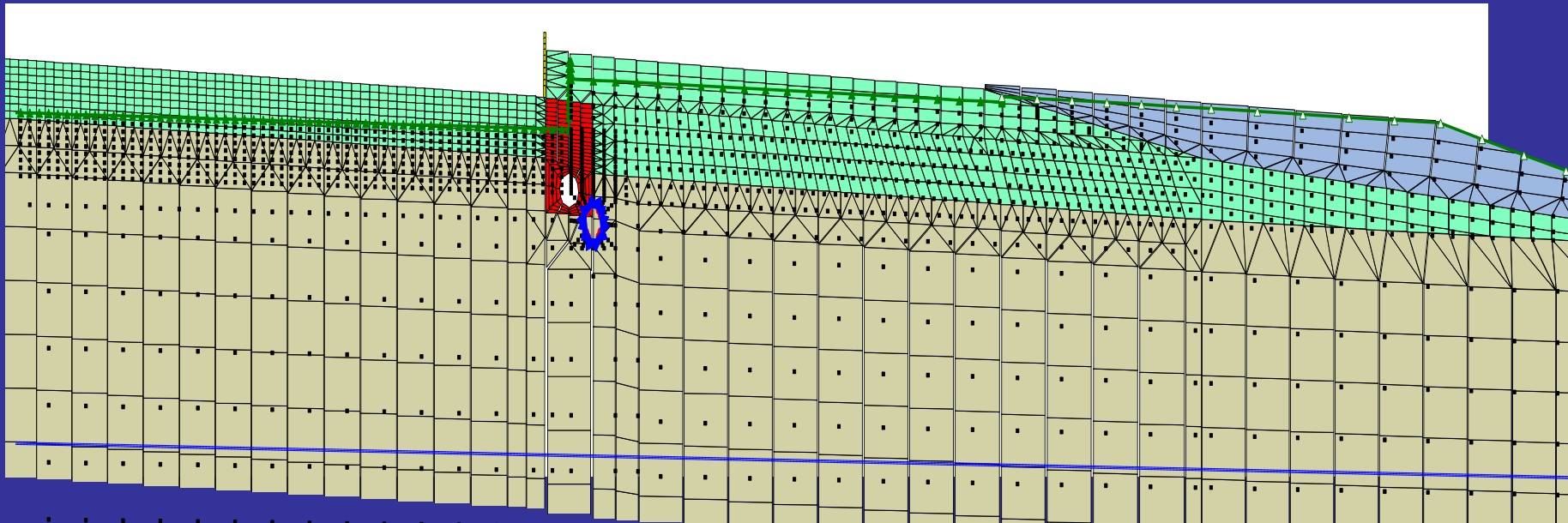
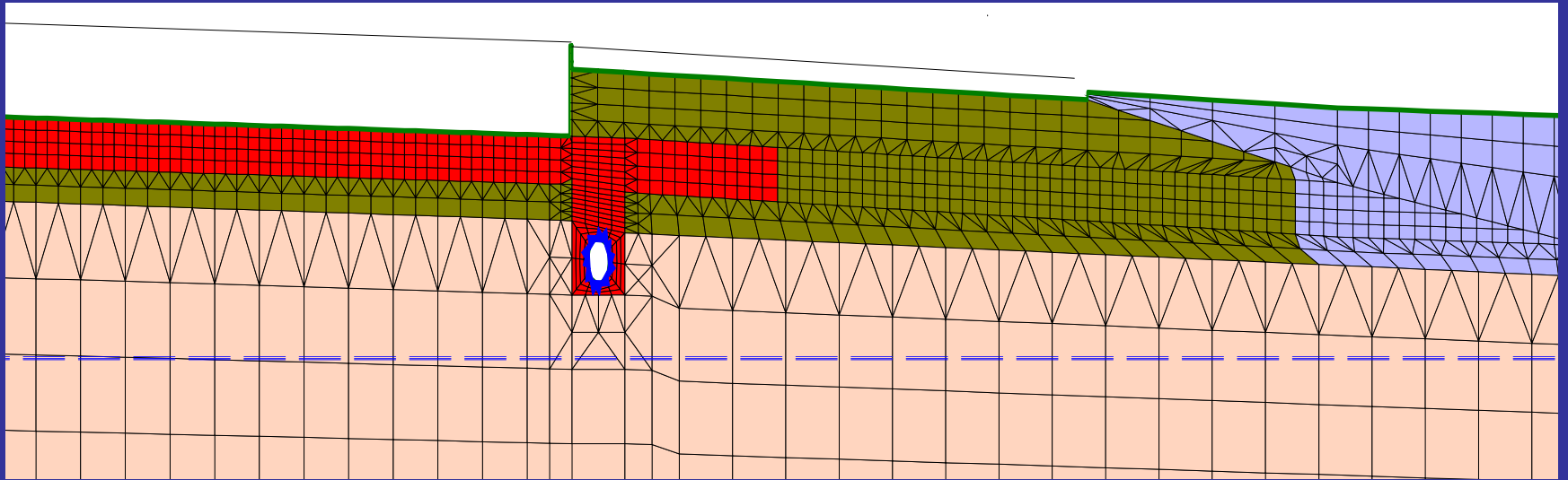
# Tempe Cell and Pressure Plate Extraction



# Estimate Hydraulic Conductivity Function



# Evaluating Current Drainage Designs



# Applications

## ■ Design

- Evaluating Current Drainage Designs
- M-E Design

# Seasonal Pore Suction Resistance Factors

Material	% Saturation		Suction (kPa)
	*Mean (summer)	SD	
Mn/ROAD Class 3	74	6.0	0.81
Mn/ROAD Class 4	60	6.0	8.36
Mn/ROAD Class 5	54	4.0	5.11
Mn/ROAD Class 6	33	4.0	3.46

\*difference is significant, n=418

- Generated From Mn/ROAD Test Sections
- Used as MnPAVE default values (Basic Level)

# MnPAVE

The screenshot shows the MnPAVE software interface with the 'Structure' panel active. The window title is 'MnPAVE - MnPAVE1.mpv'. The menu bar includes 'File', 'Edit', 'View', 'Window', and 'Help'. The toolbar contains icons for file operations and help. The main panel is titled 'Structure' and has three tabs: 'Basic', 'Intermediate', and 'Advanced'. The 'Basic' tab is selected.

**Default Structures:**

- HMA, Agg. Base, Eng. Soil
- HMA 1, HMA 2, Agg. Base, Eng. Soil
- HMA, Eng. Soil
- HMA, Agg. Base, Agg. Subbase, Eng. Soil
- HMA Overlay, Old HMA, Agg. Base, Eng. Soil
- User Defined

**Edit Structure:**

Layers	Material	Thickness (in.)
<input type="radio"/> 1	HMA	6
<input type="radio"/> 2	AggBase	6
<input type="radio"/> 3	Subbase	18
<input type="radio"/> 4	EngSoil	12
<input checked="" type="radio"/> 5	UndSoil	infinite

Design Mode: Basic

Units:  English,  SI

Finished Structure Go to Control Panel

**Material Type:**

- Hot-Mix Asphalt
- Aggregate Base
- Aggregate Subbase
- Engineered Soil
- Undisturbed Soil

**Material Subtype:**

- PG 58-34 [Select]
- Mn/DOT Class 5 [Select]
- Mn/DOT Select Granular [Select]
- Clay Loam [Select]
- Clay Loam [Select]

A yellow arrow points from a blue box labeled 'View Default Values' to the 'Grad' button in the Material Subtype section.

For Help, press F1

# MnPAVE

**Structure**

Basic Intermediate Advanced

**Gradation**

Material:

Sieve Size	Percent Passing
1 1/2" (37.5 mm)	100
1" (25.0 mm)	100
3/4" (19.0 mm)	95
3/8" (9.50 mm)	70
#4 (4.75 mm)	58
#10 (2.00 mm)	43
#40 (0.425 mm)	23
#200 (0.075 mm)	7
Not Used	
Not Used	

Bulk Specific Gravity (Gsb): 2.7

Bulk Density: 110 pcf

OK Cancel

**Mn/ROAD Class Material**

# MnPAVE

The screenshot shows the MnPAVE software interface with the 'Structure' tab selected. The interface includes a menu bar (File, Edit, View, Window, Help) and a toolbar. The main window is titled 'MnPAVE1.mpv' and contains several sections:

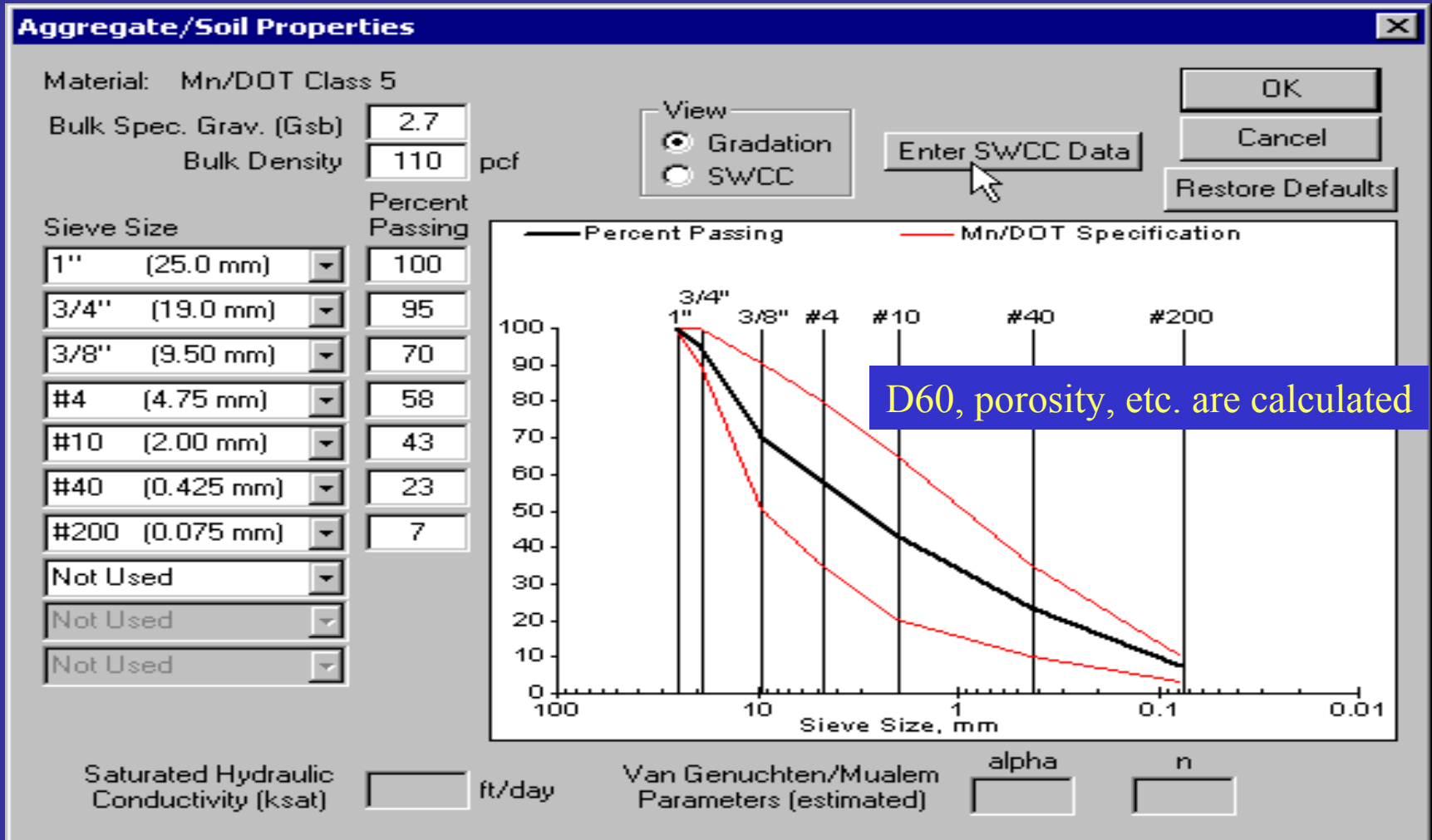
- Edit Structure:** A table with columns for Layers, Material, and Thickness (in.).

Layers	Material	Thickness (in.)
<input type="radio"/> 1	HMA	6
<input type="radio"/> 2	AggBase	6
<input type="radio"/> 3	Subbase	18
<input type="radio"/> 4	EngSoil	12
<input checked="" type="radio"/> 5	UndSoil	infinite
- Design Mode:** Set to 'Intermediate'.
- Units:** 'English' is selected.
- Finished Structure:** 'Go to Control Panel' button.
- Basic Tab:** Includes a 'View' section with 'Test Results' selected, and a 'Check box to enter test data' section.
- Advanced Tab:** Includes 'HMA Modulus', 'Agg. Test Type' (with 'Gradation' selected), 'Soil Test Type', and 'Other' (with 'Design Modulus, ksi' selected).
- Aggregate Section:** 'PG 58-34' is selected, and '19 M' is entered in a field.
- Agg. Moisture:** 'Wet' is selected.

A blue callout box with yellow text points to the 'Gradation' option in the 'Agg. Test Type' section, stating: "Select to input aggregate gradation".

For Help, press F1

# MnPAVE



# MnPAVE

**MnPAVE - MnPAVE1.mpv**

File Edit View Window Help

MnPAVE1.mpv

## Structure

Basic Intermediate Advanced

Design Mode

- Use values from Basic Design Level
- Use values from Intermediate Design Level
- Advanced mode (enter values now)

Parameter Shown Below

- Design Modulus, ksi
- Poisson's Ratio
- Seasonal Modulus Multipliers

Edit Structure

Layers	Material	Thickness (in.)
<input type="radio"/> 1	HMA	6
<input type="radio"/> 2	AggBase	6
<input type="radio"/> 3	Subbase	18
<input type="radio"/> 4	EngSoil	12
<input checked="" type="radio"/> 5	UndSoil	infinite

Design Mode: Advanced

Units

- English
- SI

Finished Structure  
Go to Control Panel

Import HMA Moduli from Basic

Import Other Moduli from Basic

Input Moisture Characteristics

	Fall	Winter	Early Spring	Late Spring	Summer
	1023	2615	1541	651.6	215.8
	22	50	6.6	15.4	18.7
	11.6	50	3.48	8.12	9.86
	6.4	50	50	4.48	5.44
	3.2	32	32	2.24	2.72

For Help, press F1

NUM

# MnPAVE

**Soil Water Characteristic Curve** [X]

Edit Help

Mn/DOT Class 5

Pressure (kPa)	Gravimetric Water Content (g/g)
0.001	0.1463
0.1	0.0988
10	0.0645
30	0.0517
101	0.0448
303	0.0039

OK

Cancel

Fit Method

- Brooks & Corey
- Fredlund & Xing
- Van Genuchten/Mualem

# Conclusion/ Current & Future Research

- Current drainage design and traditional soil mechanics methods are based on assumptions and design criteria which over simplify in situ conditions.
- Continue to develop and implement rational approach which incorporates unsaturated properties into the M-E and drainage design process.
- Continue to build extensive and comprehensive database of unsaturated material properties.
- Extend framework to recycled materials.

# Cooperating Universities and Researchers

- University of Florida, Gainesville (Dr. Bjorn Birgisson)
- University of Minnesota, Department of Soil, Water, and Climate (Dr. Satish Gupta)
- Recycled Materials Resource Center (RMRC), University of New Hampshire (Defne Apul, Drs. Eighmy and Gardner)
- Lakehead University, Thunder Bay (Dr. Sai Vanapalli)

# More Information

- **Unsaturated Properties of Engineered Materials Research**
  - [http://mnroad.dot.state.mn.us/research/MnROAD\\_Project/me\\_group/UnsatProperties.asp](http://mnroad.dot.state.mn.us/research/MnROAD_Project/me_group/UnsatProperties.asp)
- **MnPAVE (Download M-E Design Software)**
  - <http://mnroad.dot.state.mn.us/research/mnpave/mnpave.asp>
- **M-E Design Implementation Resources**
  - <http://mnroad.dot.state.mn.us/research/mnpave/meresource.asp>
- **Recycled Materials in Pavements**
  - <http://www.rmrc.unh.edu/>
- Ruth Roberson ([ruth.roberson@dot.state.mn.us](mailto:ruth.roberson@dot.state.mn.us)) or (651) 779-5214