

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



January 2003

*TRB COMMITTEE A2K06
SUBSURFACE DRAINAGE*

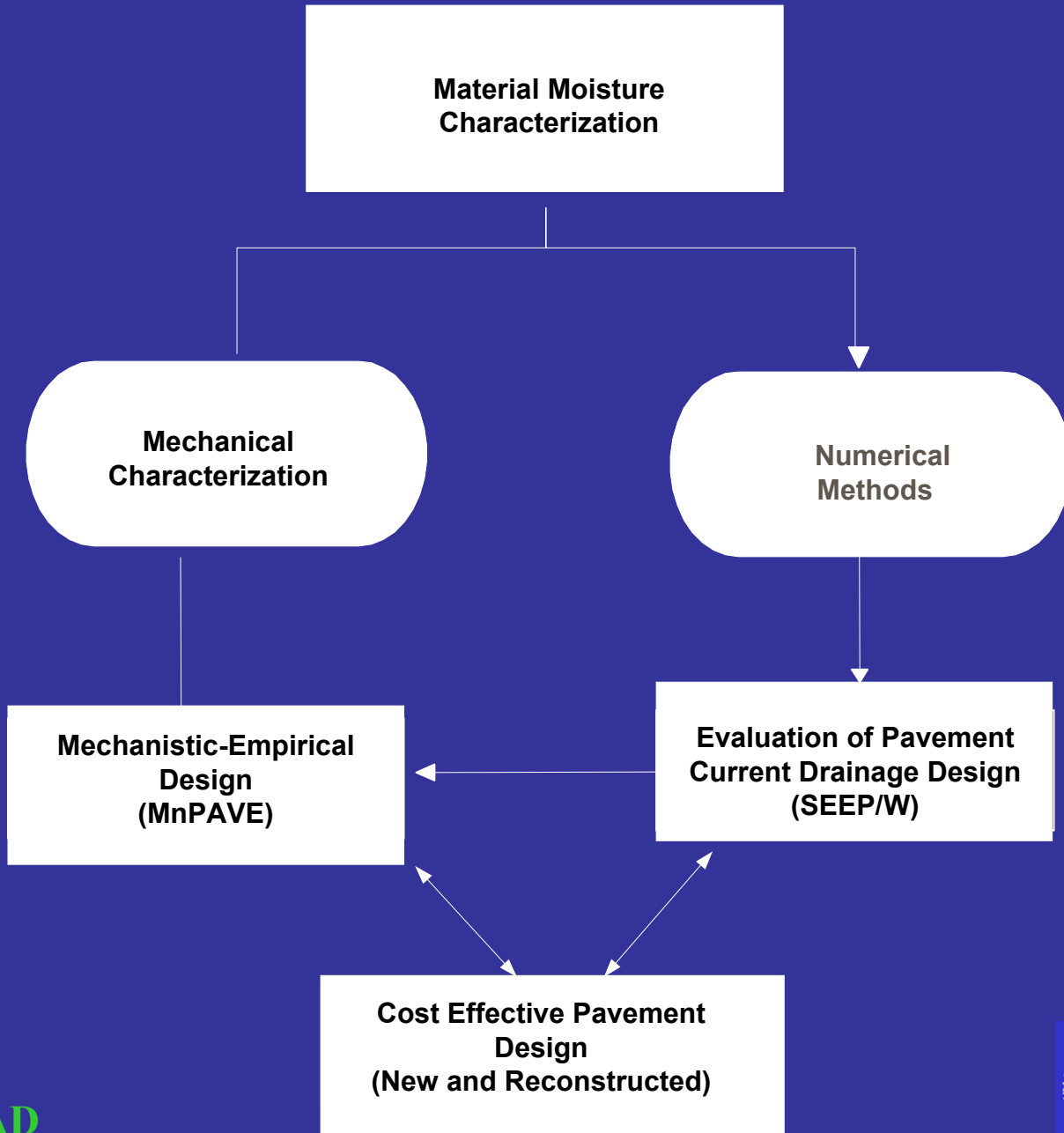
Ruth Roberson

Acknowledgments

- Local Road Research Board (LRRB)

Special Thanks

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



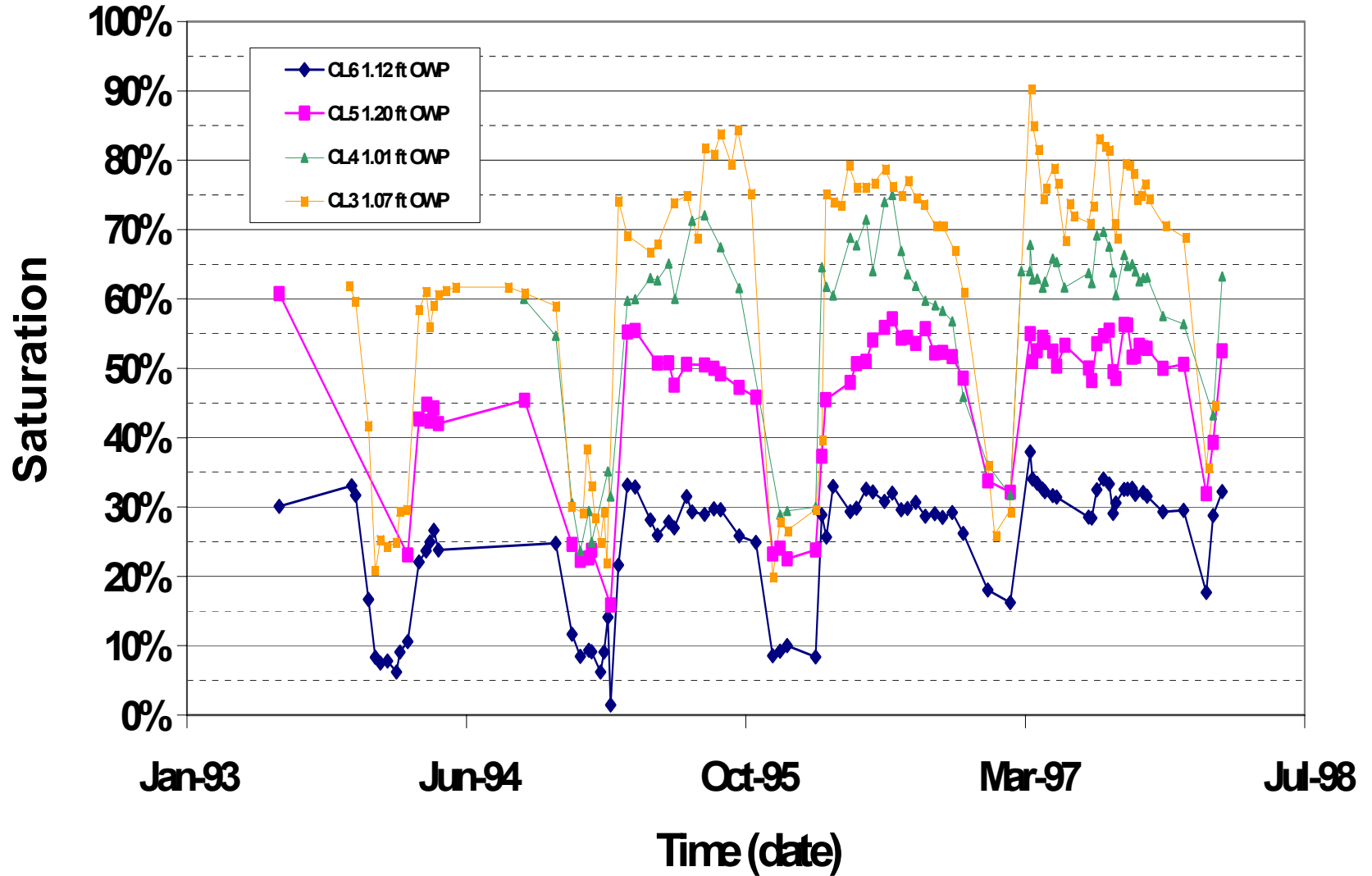
Objective

Linking Material Moisture Characteristics to
Design Parameters

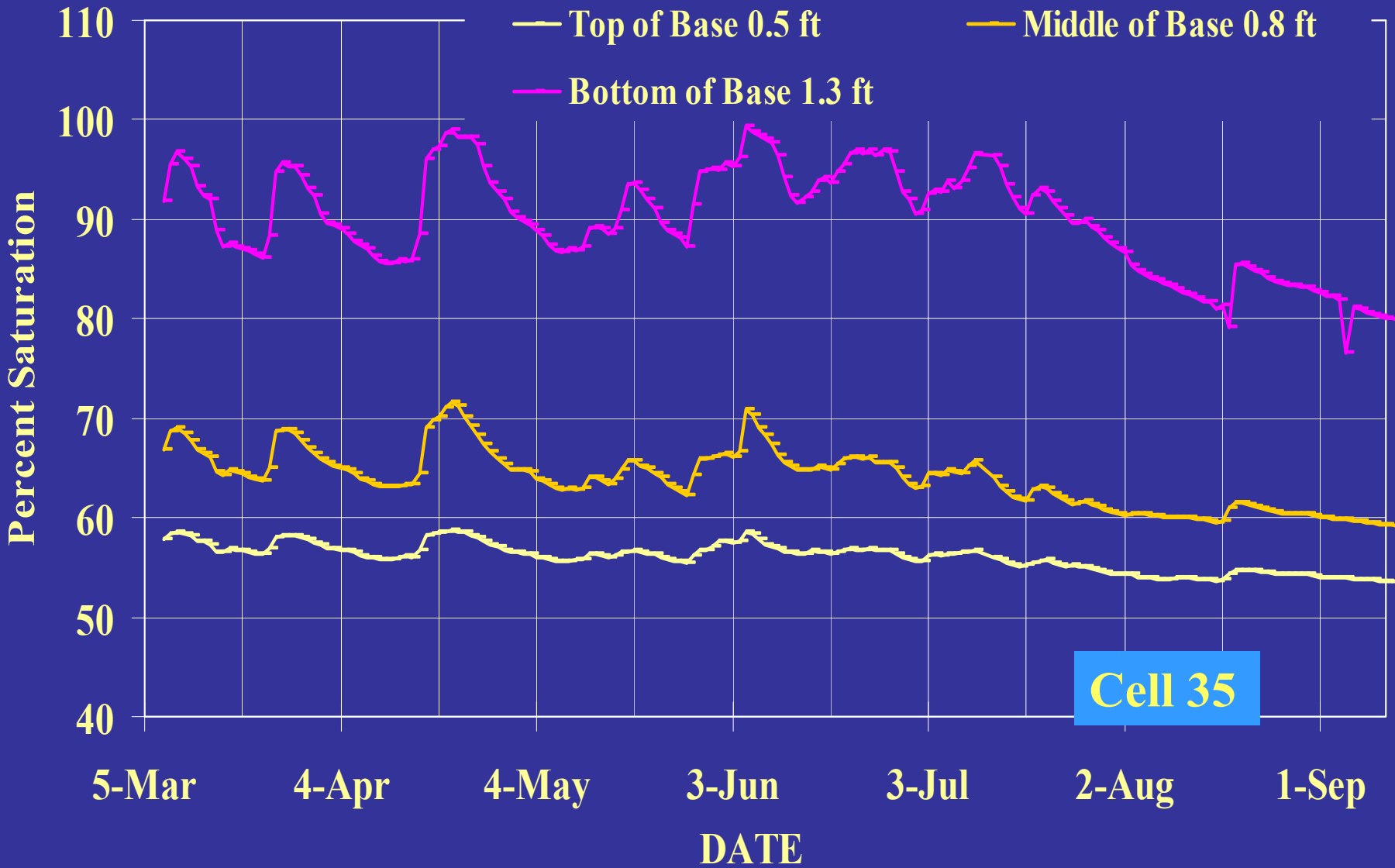
Material Characterization for M-E and Drainage Design

- 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

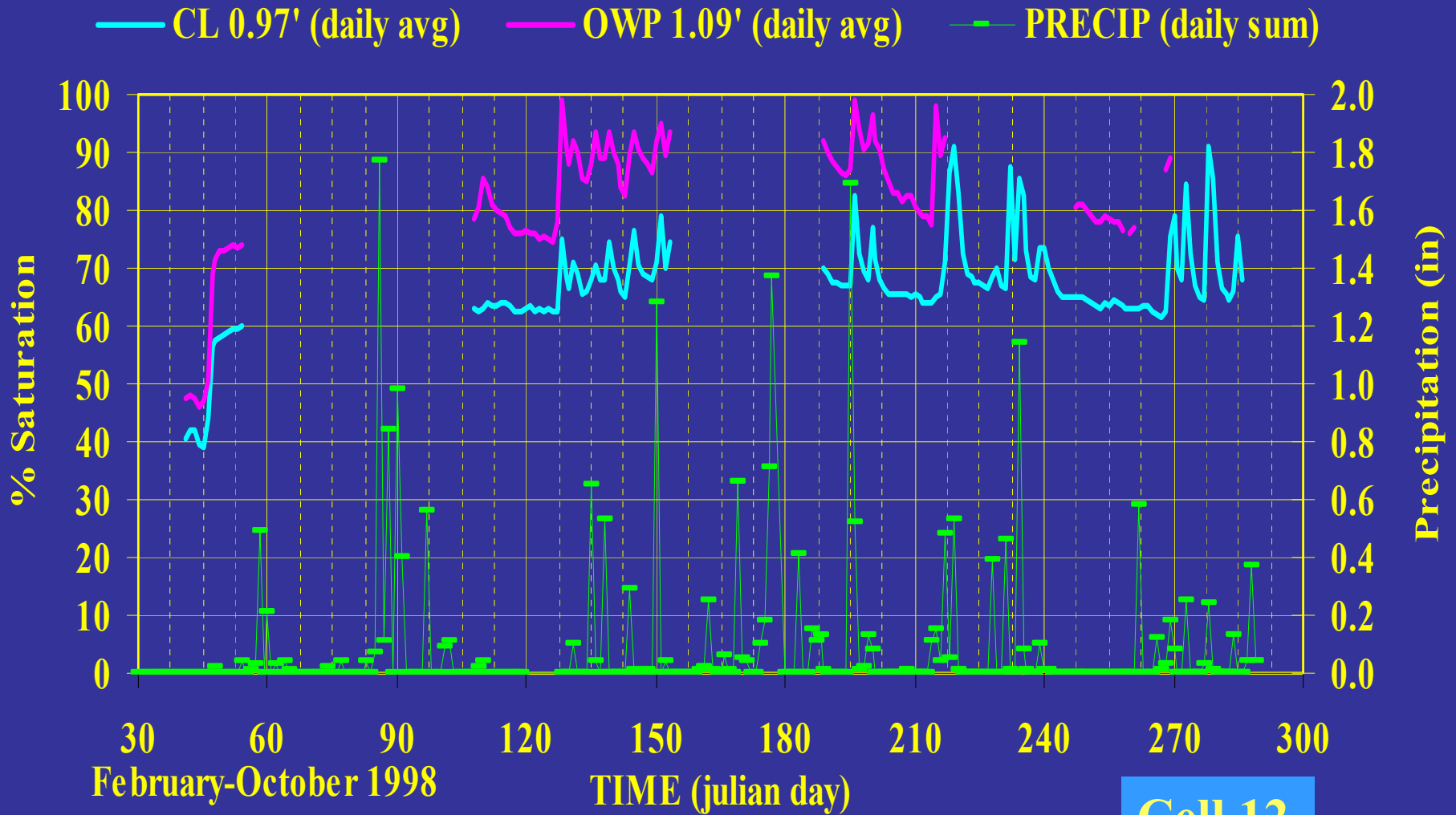
Mn/ROAD Seasonal Moisture Content



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

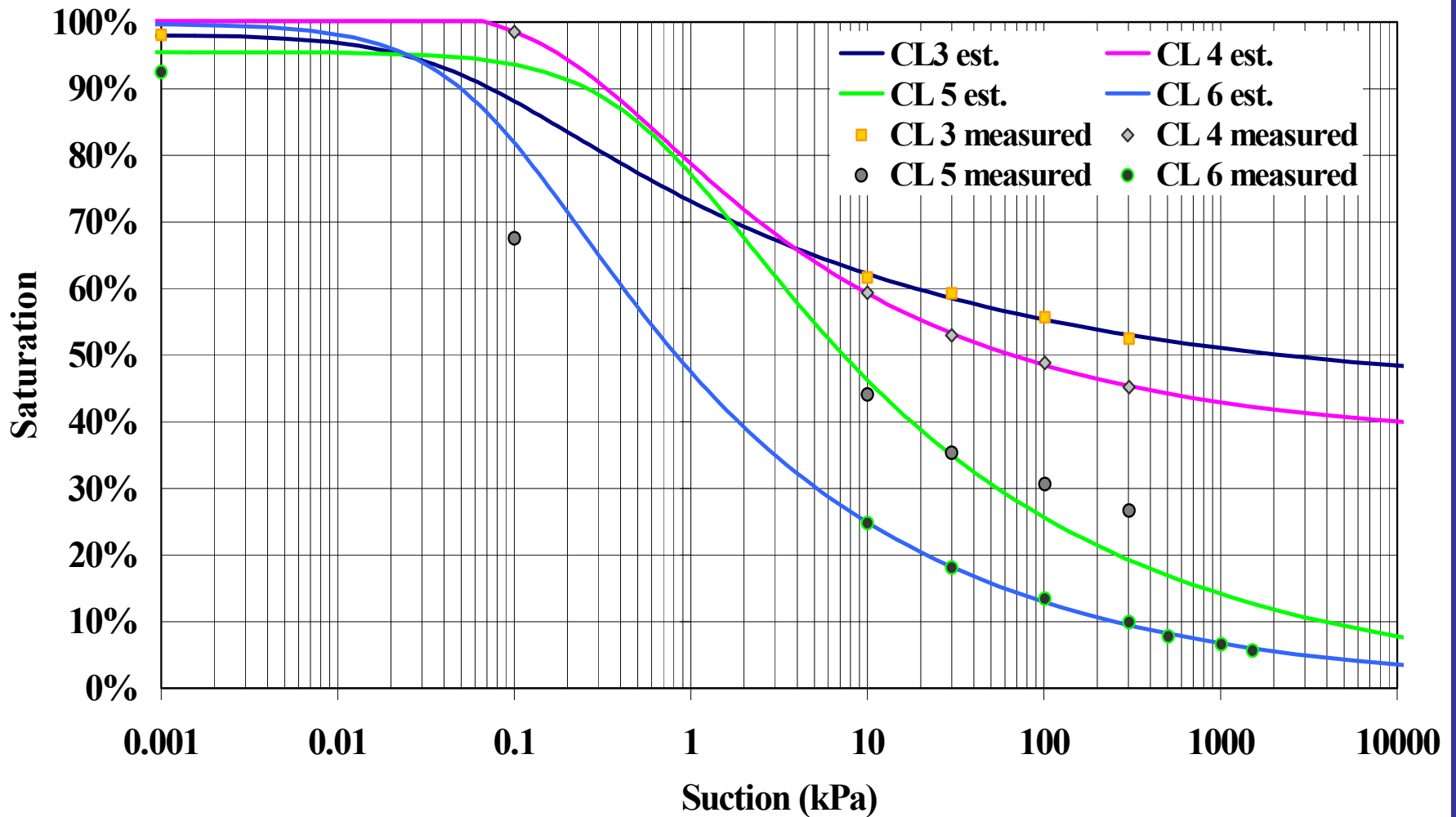
- **Flux is the volume flow rate per unit area ($\text{cm}^3/\text{sec}/\text{cm}^2$).**
- **Saturated conditions: flux is proportional to the gradient and the hydraulic potential is independent of the conductivity.**
- **Unsaturated conditions: flux remains proportional to the hydraulic gradient but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

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

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

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

Soil Water Characteristic Curve

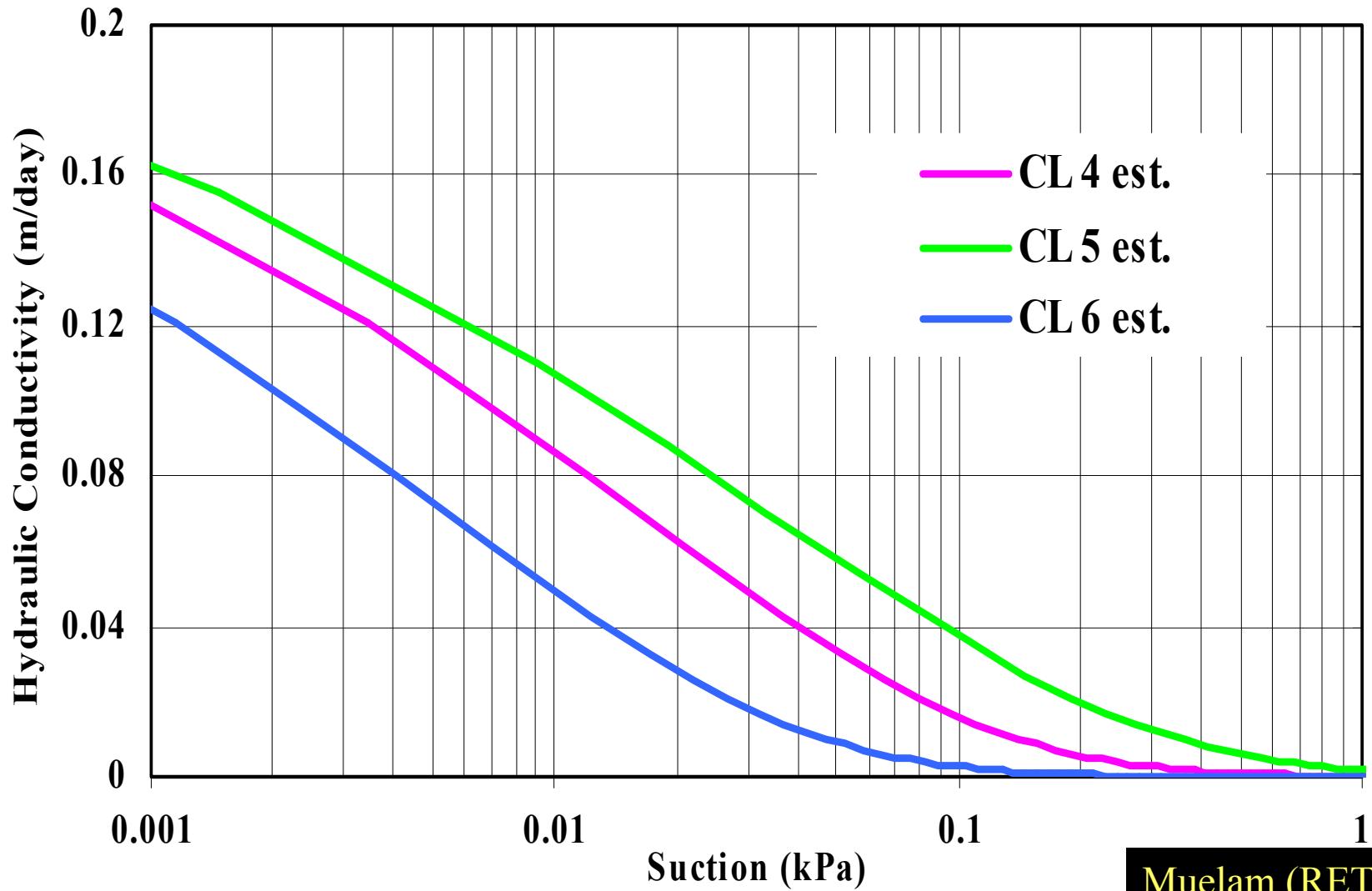


Van Genuchten fit (RETC)

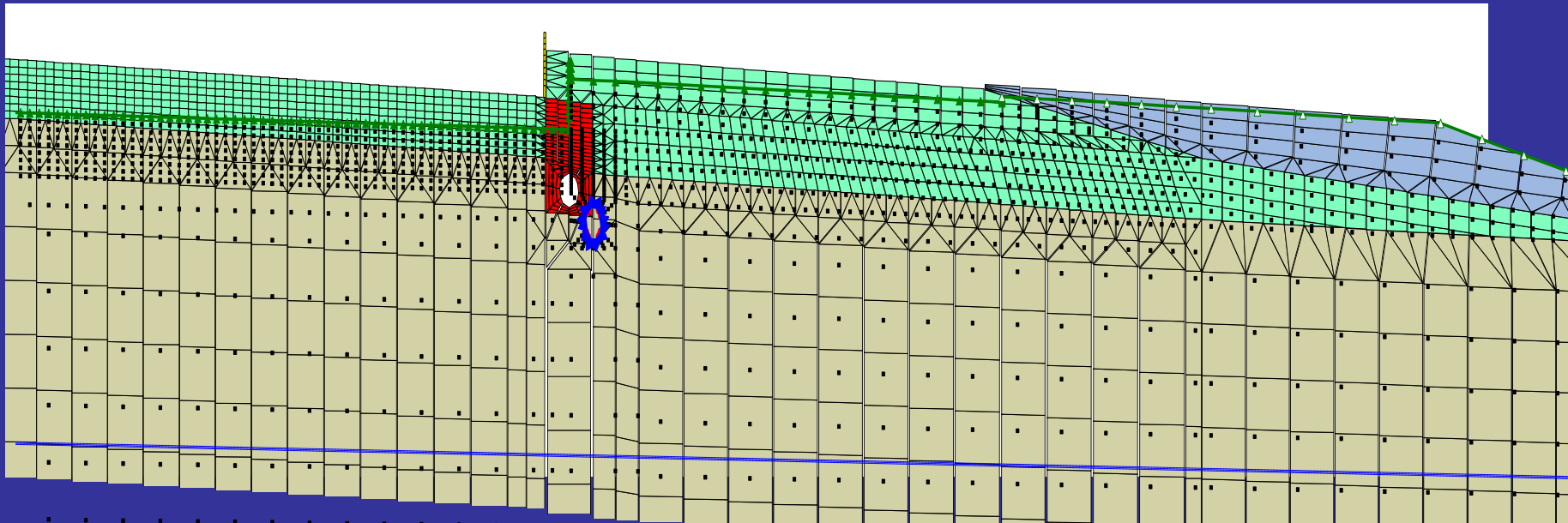
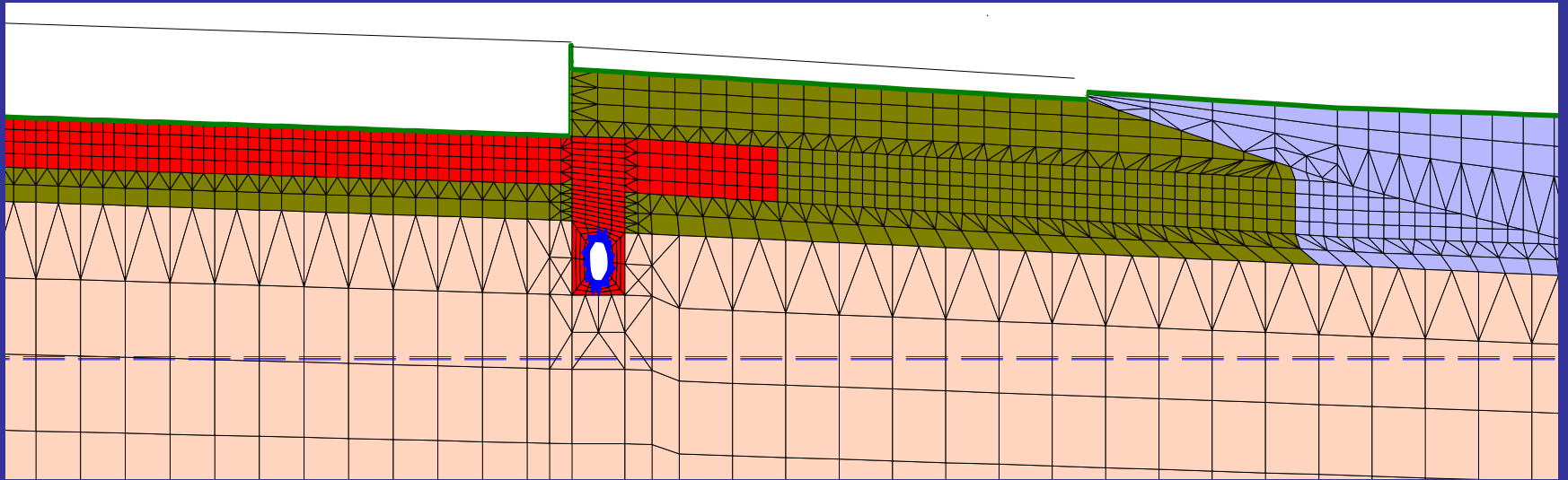
Tempe Cell and Pressure Plate Extraction



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 following components:

- Window Title:** MnPAVE - MnPAVE1.mpv
- Menu Bar:** File, Edit, View, Window, Help
- Toolbar:** Standard file operation icons (New, Open, Save, Print, etc.)
- Structure Panel:**
 - Structure:** MnPAVE1.mpv
 - Structure:** [Color-coded bar]
 - Design Mode:** Basic
 - Units:** English (selected), SI
 - Finished Structure:** Go to Control Panel
- Basic Tab:**
 - Default Structures:** Six radio buttons with corresponding color-coded diagrams and labels: HMA, HMA 1, HMA 2, HMA, HMA Overlay, and User Defined.
 - Material Type:** Hot-Mix Asphalt, Aggregate Base, Aggregate Subbase, Engineered Soil, Undisturbed Soil.
 - Material Subtype:** PG 58-34, Mn/DOT Class 5, Mn/DOT Select Granular, Clay Loam, Clay Loam.
 - Select Buttons:** A column of buttons labeled "Select" next to the subtypes.
 - Grad Button:** A button labeled "Grad" with a mouse cursor pointing to it.

For Help, press F1

View Default Values

MnPAVE

MnPAVE - MnPAVE1.mpv

File Edit View Window Help

MnPAVE1.mpv

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

For Help, press F1

MnPAVE

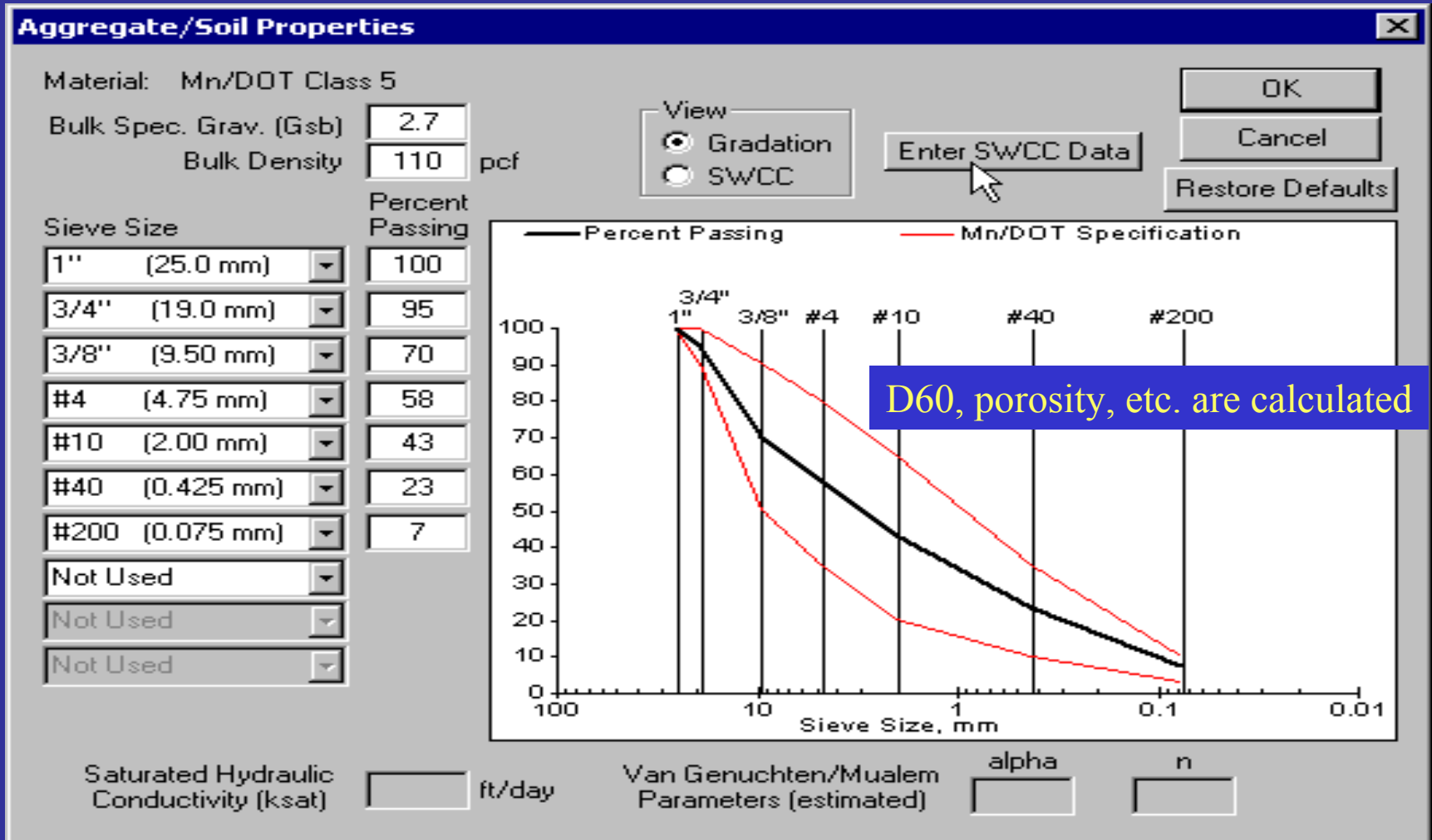
The screenshot shows the MnPAVE software interface with the 'Structure' tab selected. The interface includes a menu bar (File, Edit, View, Window, Help) and a toolbar. The main window is titled 'MnPAVE1.mpv' and contains several panels:

- 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 radio buttons for 'Test Results' (selected) and 'Resistance Factors'. A note says 'Check box to enter test data. Uncheck to use Basic defaults.' Below this are sections for 'HMA Modulus', 'Agg. Test Type' (with radio buttons for 'Lab Mr., ksi', 'R-Value', 'DCP,mm/blow', and a highlighted 'Gradation' button), 'Soil Test Type' (with radio buttons for 'Lab Mr., ksi', 'R-Value', 'DCP,mm/blow'), and 'Other' (with radio buttons for 'Design Modulus, ksi' and 'Poisson's Ratio').
- Intermediate Tab:** Includes a 'PG 58-34' field with a 'Select' button, a checked checkbox next to a '19' value with an 'M' unit, and an unchecked checkbox.
- Advanced Tab:** Includes 'Agg. Moist' radio buttons for 'Dry' and 'Wet'.

A blue callout box with yellow text points to the 'Gradation' button, stating: 'Select to input aggregate gradation'. At the bottom, it notes 'Optimum = Fall conditions, Wet = Late Spring conditions'.

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

- **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) or (651) 779-5214