




MnPAVE - SPTC1.mpv

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MPV SPTC1.mpv




# MnPAVE


## Mn\DOT Flexible Pavement Design


### Mechanistic-Empirical Method


Version 5.0



Project Information

 Climate

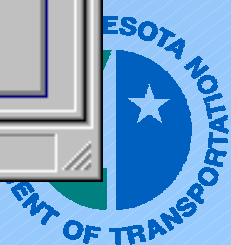
 Structure

 Traffic

ESAL  Load Spectra

For Help, press F1

NUM



# Climate

Basic | **Advanced**

Climatic Divisions

User Defined

Seasons  
East Central Division

Days Pavement Temp. (°F)  
 Weeks

Fall (Standard) 91 49

Winter (Frozen) 102 17

Early Spring (Base Thaw) 14 37

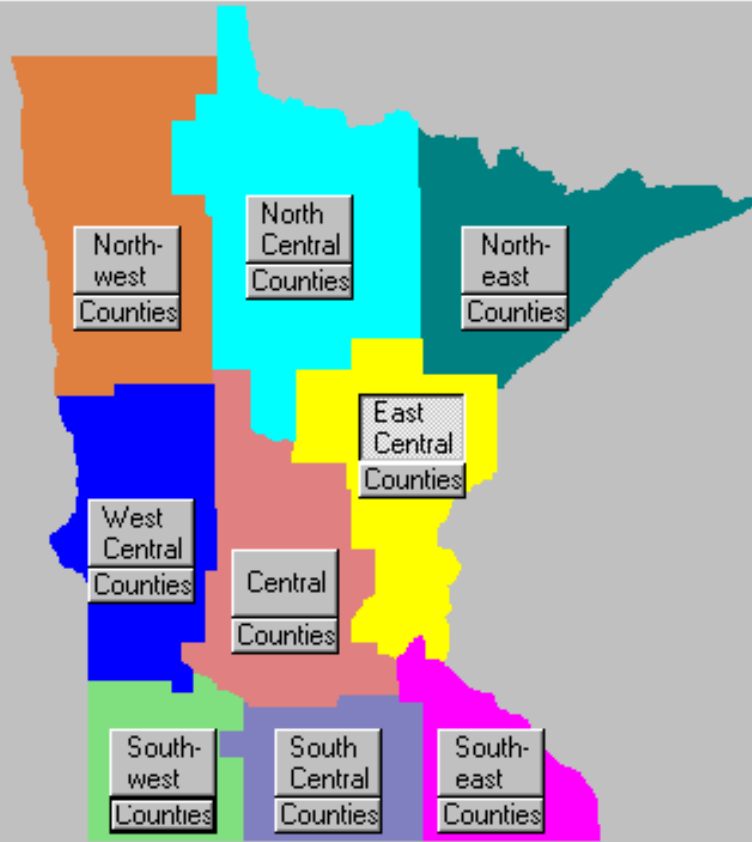
Late Spring (Soil Thaw) 65 59

Summer (High Temp.) 93 78

Units

English  
 SI

Finished Environ.  
Go to Control Panel



# Structure

Overburden Calculation

- View
- Thickness Values
  - Coefficient of Variation

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	30
<input checked="" type="radio"/> 5	Bedrock	infinite

Design Mode: Basic

- Units
- English
  - SI
- Finished Structure  
Go to Control Panel

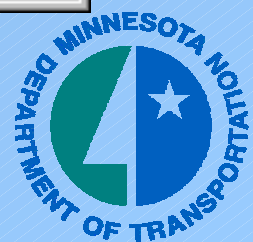
Basic Intermediate Advanced

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  
Agg. Base  
Eng. Soil  
Bedrock
-  User Defined

Material Type	Material Subtype
Hot-Mix Asphalt	PG 58-28 <input type="button" value="Select"/>
Aggregate Base	Mn/DOT Class 5 <input type="button" value="Select"/>
Aggregate Subbase	Mn/DOT Select Granular <input type="button" value="Select"/>
Engineered Soil	Clay Loam <input type="button" value="Select"/>
Bedrock	<input type="button" value="Select"/>

Edit HMA Dynamic Modulus Equation

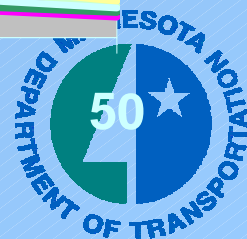
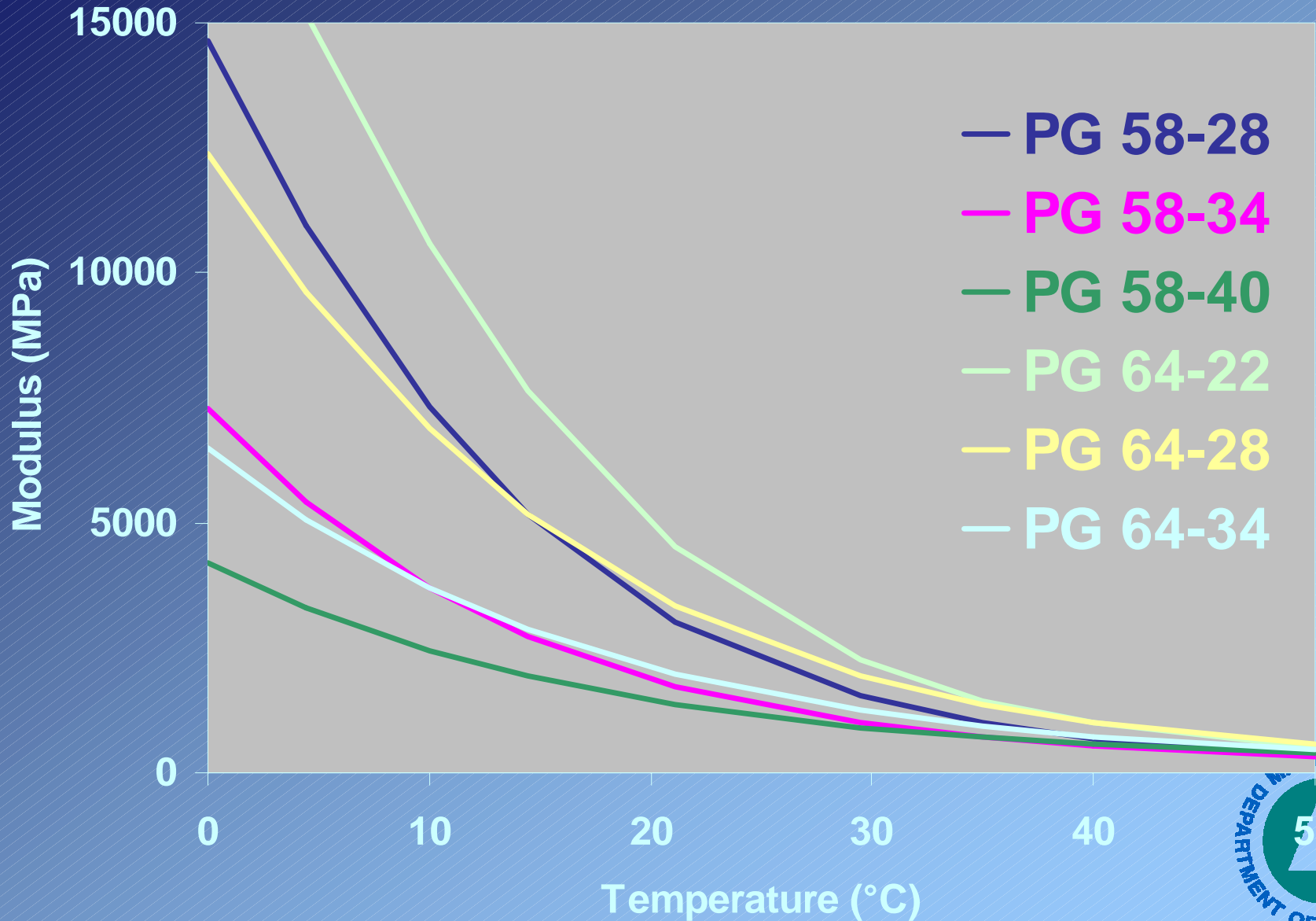


# Witczak's Dynamic Modulus Equation

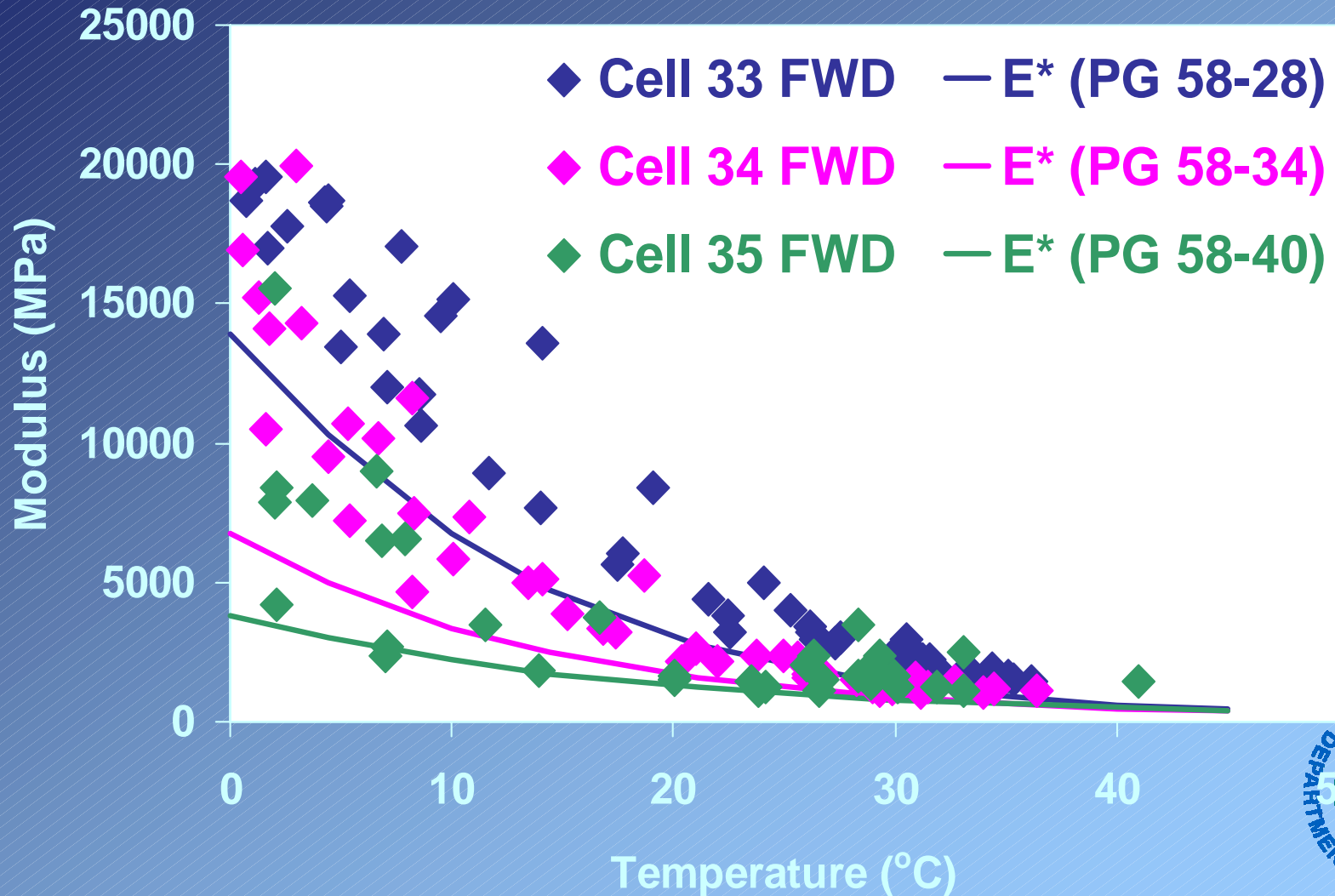
- Binder viscosity
- Effective binder content
- Aggregate gradation
- Loading frequency

$$\log E = a_0 + a_1 p_{200} + a_2 (p_{200})^2 + a_3 p_4 + a_4 V_a + a_5 \frac{V_{beff}}{V_{beff} + V_a} + \frac{a_6 + a_7 p_4 + a_8 p_{3/8} + a_9 (p_{3/8})^2 + a_{10} p_{3/4}}{1 + e^{(a_{11} + a_{12} \log f + a_{13} 2 \log \eta)}}$$

# Calculated HMA Dynamic Modulus



# Backcalculated Modulus vs. Witczak Dynamic Modulus



 **ESAL**

Axle Type

- ESAL
- Custom Axle

Axle Configuration

Tire Pressure  psi

Axle Weight  lbs.

Wheel Weight  lbs.

Traffic

- Lifetime
- First Year  (Calculated)

Design Life (years)

Annual Growth Rate (%)

Units

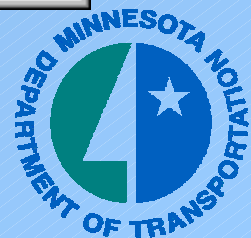
- English
- SI

Finished Traffic  
Go to  
Control Panel

Mohr-Coulomb Failure Criterion

	Axle Weight (lbs.)	Tire Pressure (psi)	Wheel Spacing (in.)
Heaviest Single Tire Axle	<input type="text" value="22000"/>	<input type="text" value="100"/>	
Heaviest Dual Tire Axle	<input type="text" value="28000"/>	<input type="text" value="100"/>	<input type="text" value="13.5"/>

Restore Mn/ROAD Defaults





Basic Intermediate **Advanced**

Traffic Input

First Year AADT

Direction Factor

Lane Factor

Design Life (years)

Annual Growth Rate (%)

Units

English

SI

Finished Traffic  
Go to  
Control Panel

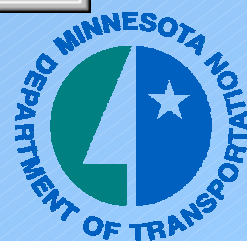
Axes

	Dual Dual	Dual Tandem	Dual Tridem	Steer	Single Single	Single Tandem	Single Tridem	Note: Loads that cause overlap are disabled.
Include View	<input checked="" type="checkbox"/> <input type="radio"/>	<input checked="" type="checkbox"/> <input type="radio"/>	<input type="checkbox"/> <input type="radio"/>	<input checked="" type="checkbox"/> <input type="radio"/>	<input type="checkbox"/> <input type="radio"/>	<input type="checkbox"/> <input type="radio"/>	<input type="checkbox"/> <input type="radio"/>	

Number of Loads Expected During Design Life

Dual	Tire Pressure	<input type="text" value="100"/> psi	Wheel Spacing	<input type="text" value="13.5"/> in.	
Load Class (kips)					
1 - 3	175550	19 - 21	85563	37 - 39	0
3 - 5	231596	21 - 23	36162	39 - 41	0
5 - 7	221571	23 - 25	12022	41 - 43	0
7 - 9	204485	25 - 27	6635	43 - 45	0
9 - 11	239235	27 - 29	2374	45 - 47	0
11 - 13	258322	29 - 31	0	47 - 49	0
13 - 15	258755	31 - 33	0	49 - 51	0
15 - 17	256610	33 - 35	0	51 - 53	0
17 - 19	182093	35 - 37	0	53 - 55	0
				71 +	0

Total Number of Selected Axes



**SPTC1.mpv**

**Output**  Life  Damage

Traffic Type: ESAL Total Repetitions: 1000000

Expected Life

Damage	Failure Mode
0.89	Fatigue (Mn/ROAD)
0.86	Fatigue (Finn)
3.04	Rutting (Mn/ROAD)
0.26	New Rutting

Adjust Materials (in.)

HMA: PG58-28  (in.)

AggBase: Cl.5

Subbase: SelGr

EngSoil: CL

Bedrock:

Recalc

Units:  English  SI

Go Back to Control Panel

Seasons | Reliability | Batch Mode

Seasonal Results

- Seasonal contribution to total damage
- Maximum strains for selected axle
- Allowed repetitions for selected axle
- View other output for selected axle

Selected Axle: ESAL 18000 lbs.

Fatigue Model:  Mn/ROAD  Finn

Rutting Model:  Mn/ROAD  New Mn/ROAD

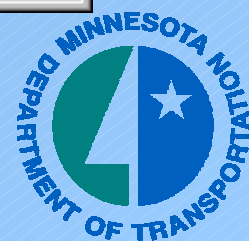
Percent of Total Damage

Weekly HMA Modulus

Season	Early Spring	Late Spring	Summer	Mode
Fall	9.1	0.2	0.9	Finn Fatigue
Winter	12.9	0.1	0	Mn/ROAD Rutting
Spring	38.5	51.4	39.4	
Summer	47.6			

Export Damage Data

Export Details for Selected Axle



**Output**  Life  Damage

Traffic Type: ESAL  
 Total Repetitions: 1000000

Expected Life	
Damage	Failure Mode
0.89	Fatigue (Mn/ROAD)
0.86	Fatigue (Finn)
3.04	Rutting (Mn/ROAD)
0.26	New Rutting

Adjust Materials (in.)

HMA: PG58-28	6
AggBase: Cl.5	6
Subbase: SelGr	18
EngSoil: CL	30
Bedrock:	infinite

Recalculate

Units:  English  SI  
 Go Back to Control Panel

Seasons | Reliability | Batch Mode

- Seasonal Results
- Seasonal contribution to total damage
  - Maximum strains for selected axle
  - Allowed repetitions for selected axle
  - View other output for selected axle

Fatigue Model:  Mn/ROAD  Finn  
 Rutting Model:  Mn/ROAD  New Mn/ROAD

Note: Negative values indicate tension.

Weekly HMA Modulus  Include Overburden Pressure

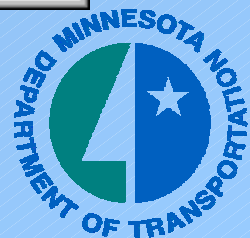
Fall	Winter	Early Spring	Late Spring	Summer	Mode
-147.4	-20.95	-68	-98.77	-211.4	X Strain@Bottom
7.959	9.628	4.298	4.191	9.698	Stress1@Middle
540.5	36.42	30.67	363.8	367.8	Z Strain@Top
350.3	42.36	30.67	372.5	427.6	Z Strain@Top
< 1 >	< 1 >	< 1 >	< 1 >	< 1 >	Week

Export Damage Data  
 Export Details for Selected Axle

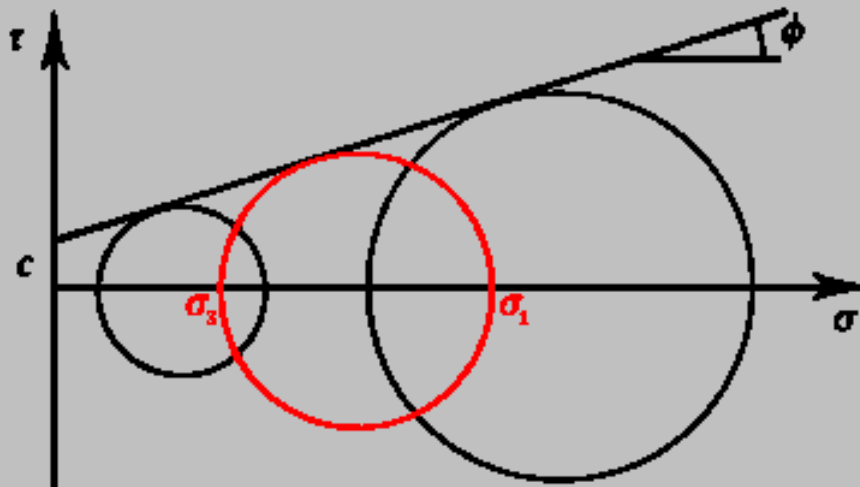
Selected Axle: ESAL 18000 lbs.

Evaluation Location: 1

Mode Units  
 Stress: psi (compression is positive)  
 Strain: microstrains  
 Deflection: mils (down is positive)



## Mohr-Coulomb Criterion



OK

Cancel

Material: Mn/DOT Class 5

c  psi

φ  °

Restore Default Values

$$\sigma_1 < \sigma_{1 \text{ critical}} = \sigma_3 \times \tan^2 \left( 45 + \frac{\phi}{2} \right) + 2c \times \tan \left( 45 + \frac{\phi}{2} \right)$$

Where:

$\sigma_{1 \text{ critical}}$  = Maximum allowed stress at middle of aggregate base

$\sigma_1, \sigma_3$  = Principal stresses due to maximum axle load

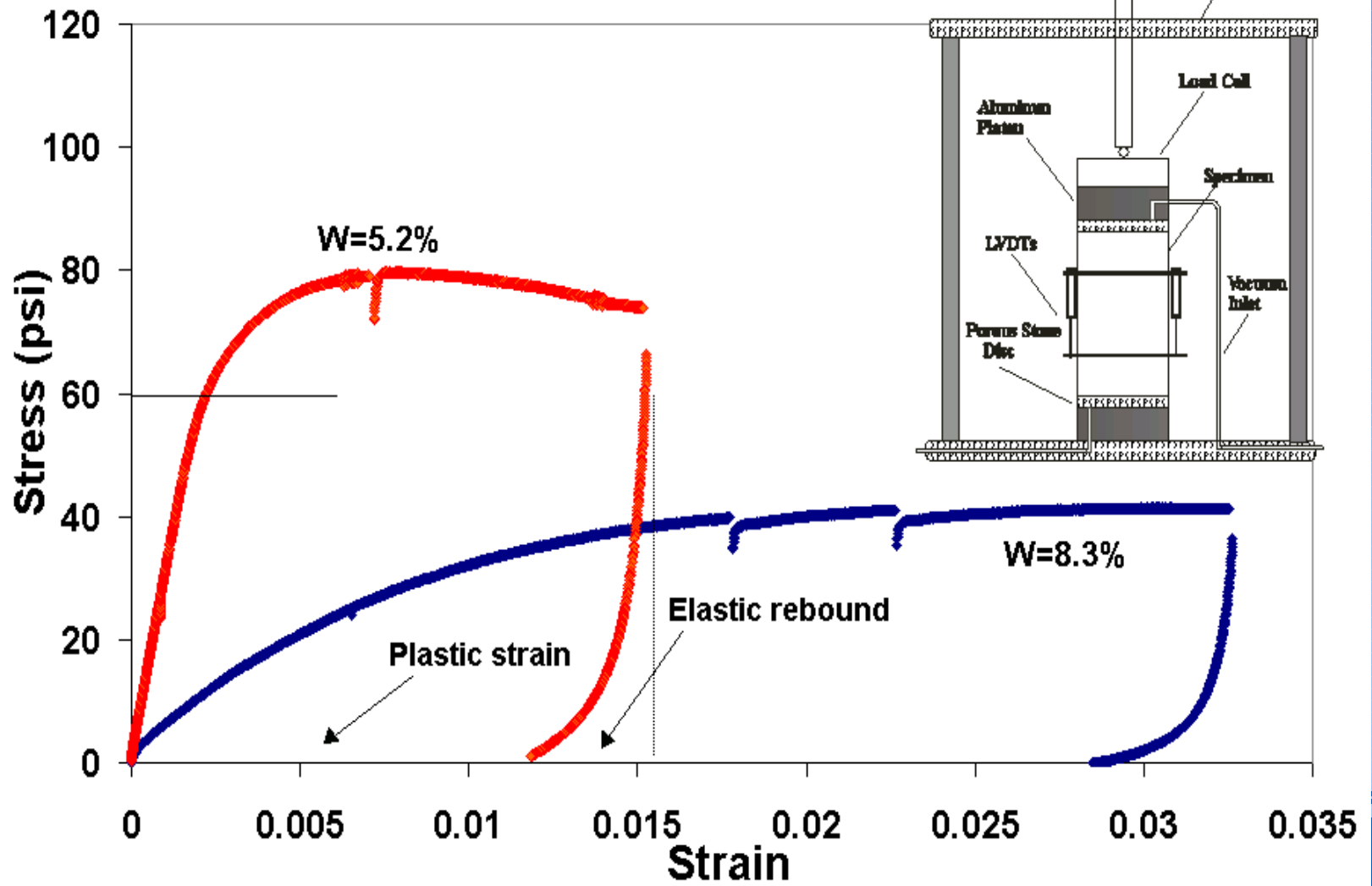
$\phi$  = Friction angle of granular material (from triaxial test)

$c$  = Cohesion of granular material (from triaxial test)

Note:

Currently all default values are derived from tests performed on Class 5 aggregate. Values for other materials will be added when testing is complete.

# Triaxial Stenght Test on Class 5 Material



# MnPAVE Mohr-Coulomb Results

Mohr-Coulomb Results
✕

Material: AggBase: Cl.5

Location: Middle of layer

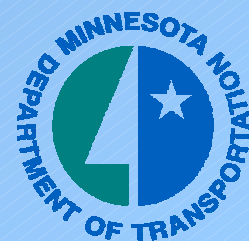
Adjust Layer 1 Thickness to Meet Requirements

$c$   psi

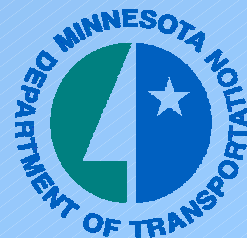
$\phi$   °

Close

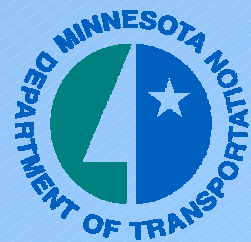
	Current Thickness	Required Thickness	
Layer 1 Thickness (in.)	<input style="width: 50px;" type="text" value="4"/>	<input style="width: 50px;" type="text" value="5.5"/>	
$\sigma_1$ psi	<input style="width: 50px;" type="text" value="24.95"/>	<input style="width: 50px;" type="text" value="18.2"/>	<input type="checkbox"/> Always show Mohr-Coulomb results
$\sigma_3$ psi	<input style="width: 50px;" type="text" value="0"/>	<input style="width: 50px;" type="text" value="0"/>	<input type="checkbox"/> Only show if material fails
$\sigma_1$ critical psi	<input style="width: 50px;" type="text" value="19.77"/>	<input style="width: 50px;" type="text" value="19.77"/>	



- **Transfer Function Calibration**
  - Compared MnPAVE with R-value design and Soil factor design methods:  
**Current MnPAVE is conservative.**
  - **Simple calibration for rutting using MnROAD**

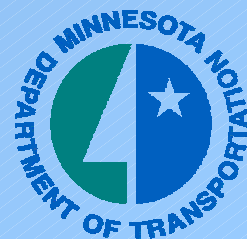


- **User Manual: Draft**

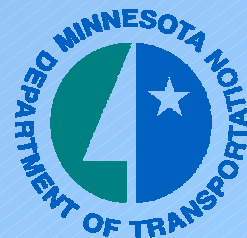


# Future Work

- Continue calibration of transfer functions.
  - Should use Witczak's equation to calculate  $E^*$  of bituminous mixture: binder effects

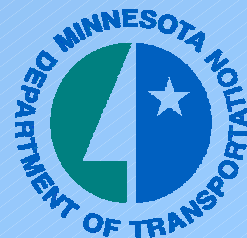


- **Improve the base and subgrade Mr table**
  - MnROAD CI5, CI3, taconite tailings, MnROAD Subgrade soils.
  - Convert R-value to Mr using laboratory data.
  
- **Implement Mohr-Coulomb failure criteria: prevent catastrophic failure**
  - Obtain a minimum HMA thickness



# Timeframe

- User training Oct. 2001
- Incorporate user feedback, calibrated MnPAVE  
Feb 2002
- M-E design adopted as Mn/DOT's procedure  
Dec 2002
- Evaluate AASHTO 2002,  
incorporate features as needed  
<http://www.2002designnguide.com/>  
Dec 2003



# Thank you.

- Questions?

