



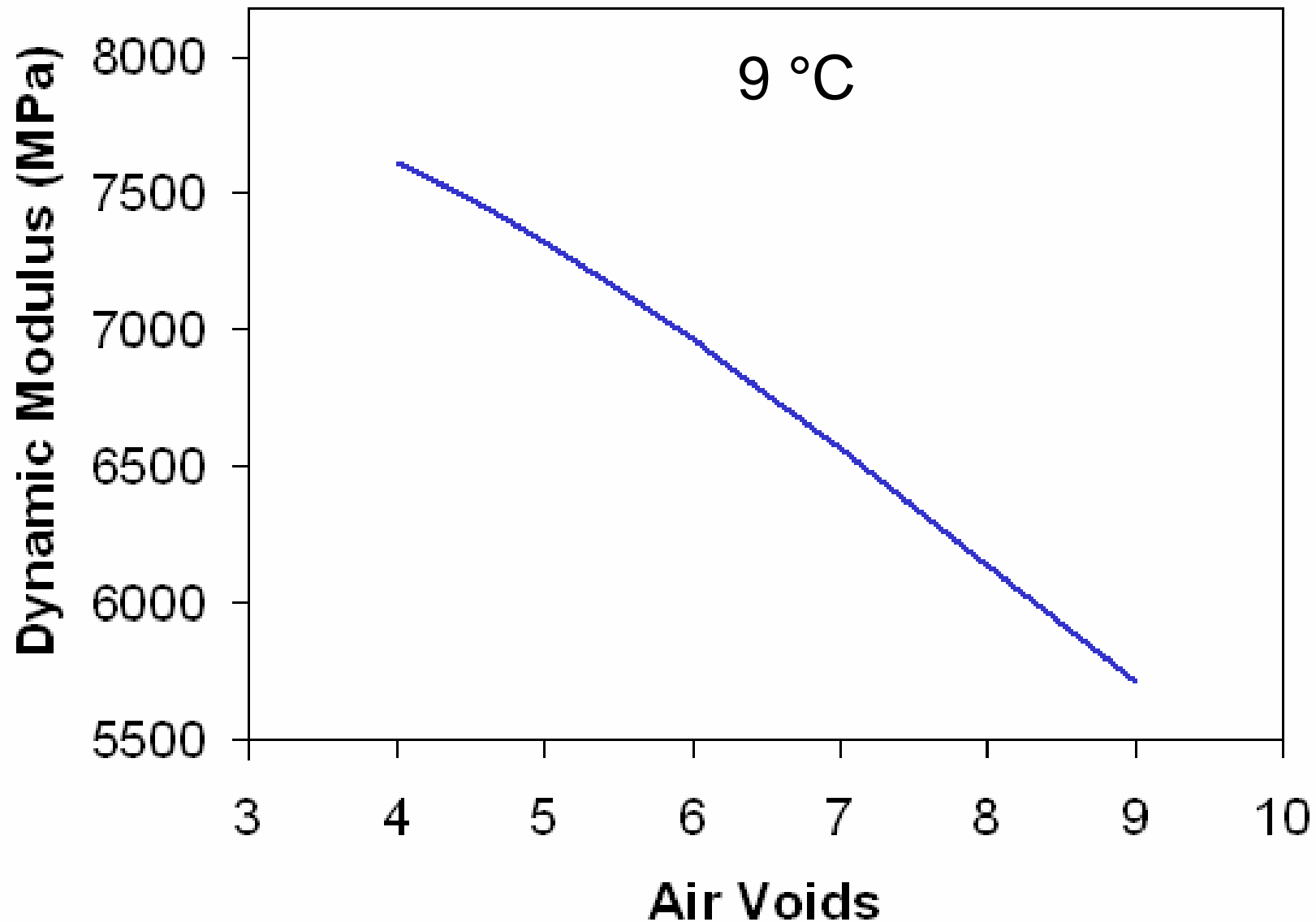
Performance Models

Pavement Design Systems and Pavement Performance Models
March 22-23, 2007 - Reykjavik, Iceland

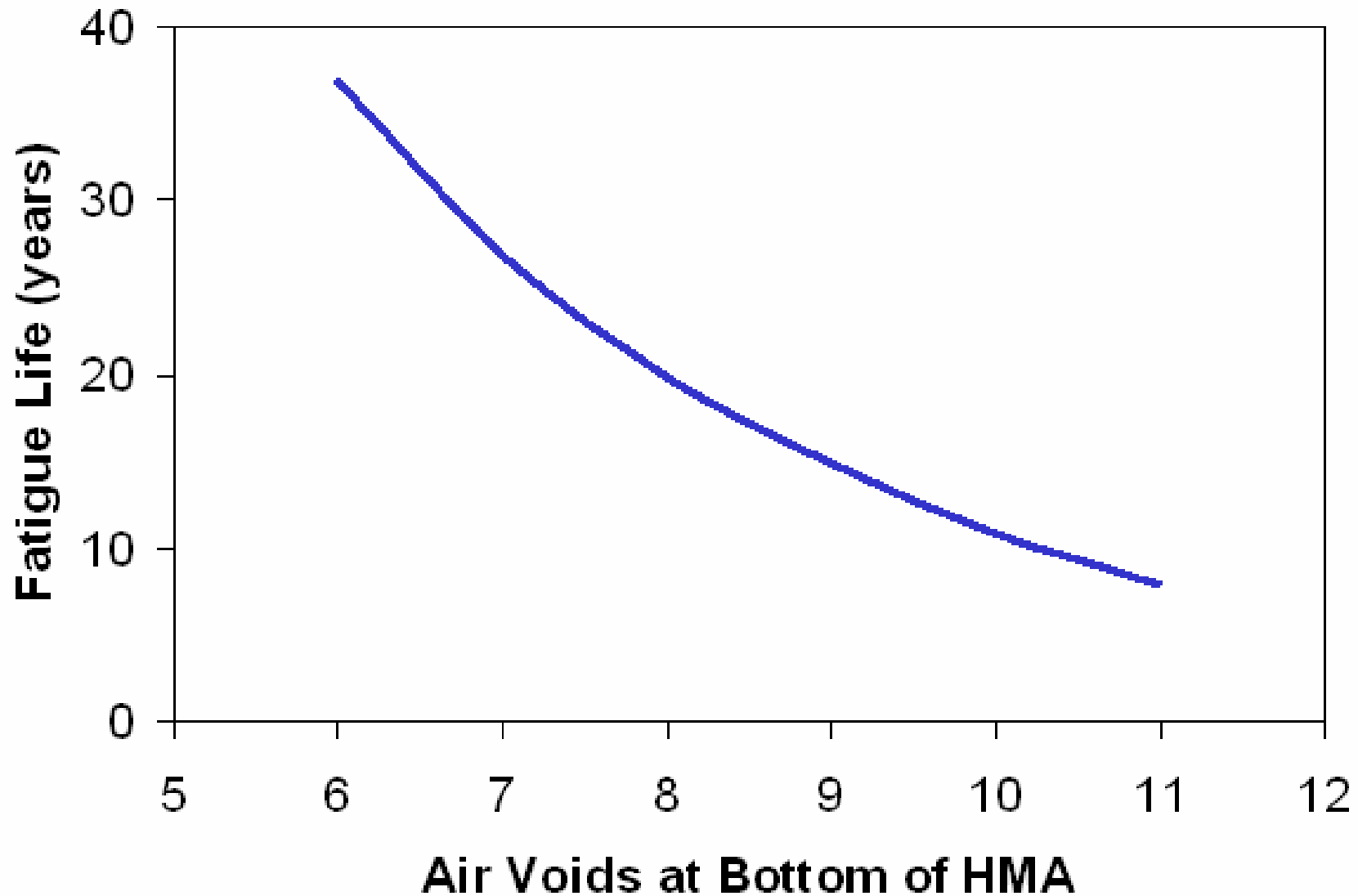
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Effect of Air Voids on Dynamic Modulus



Effect of Air Voids on Fatigue Life



Validation/Calibration Process

1. Compare MnPAVE output with current procedure and experience
2. Analyze reasonableness of predicted performance, adjust if necessary
3. Compare MnROAD performance



MnPAVE – Calibration

- Fatigue and rutting transfer functions
- Not many failures in Minnesota
- Preliminary calibration based on R-Value designs



Miner's Hypothesis

$$Damage = \sum_{i=1}^k \sum_{j=1}^m \frac{n_{season_i, load_j}}{N_{season_i, load_j}}$$

Where:

n = applied load repetitions

N = allowed load repetitions

k = total number of seasons

m = number of load configurations

Damage ≥ 1 indicates failure



Transfer Functions: Fatigue

Fred N. Finn/Asphalt Institute model

$$N = C \times S \times (4.32 \times 10^{-3}) \varepsilon^{-3.291} E^{-0.854}$$

Where

N = Allowed load repetitions for fatigue

S = Shift factor*

ε = Tensile strain at bottom of HMA

E = HMA dynamic modulus (MPa)

C = correction factor based on air voids and binder content

*** Preliminary MnPAVE shift factor of 92.6 is based on calibration with existing R-Value designs.**



Transfer Functions: Rutting

Calibrated with existing R-Value designs

$$N = 0.00618 \varepsilon^{-2.5592}$$

Where

N = Allowed load repetitions for rutting

ε = vertical strain at top of subgrade



R-Value Fatigue Calibration (2002)

Normalized Repetitions

failed

not failed

$$N = C \times S \times (4.32 \times 10^{-3}) \varepsilon^{-3.291} E^{-0.854}$$

- ◆ R-Value
- Soil Factor
- + Mn/ROAD (Current ESALs)
- Reconstructed
- Fatigue Transfer Function

Mainline

Low Volume Road

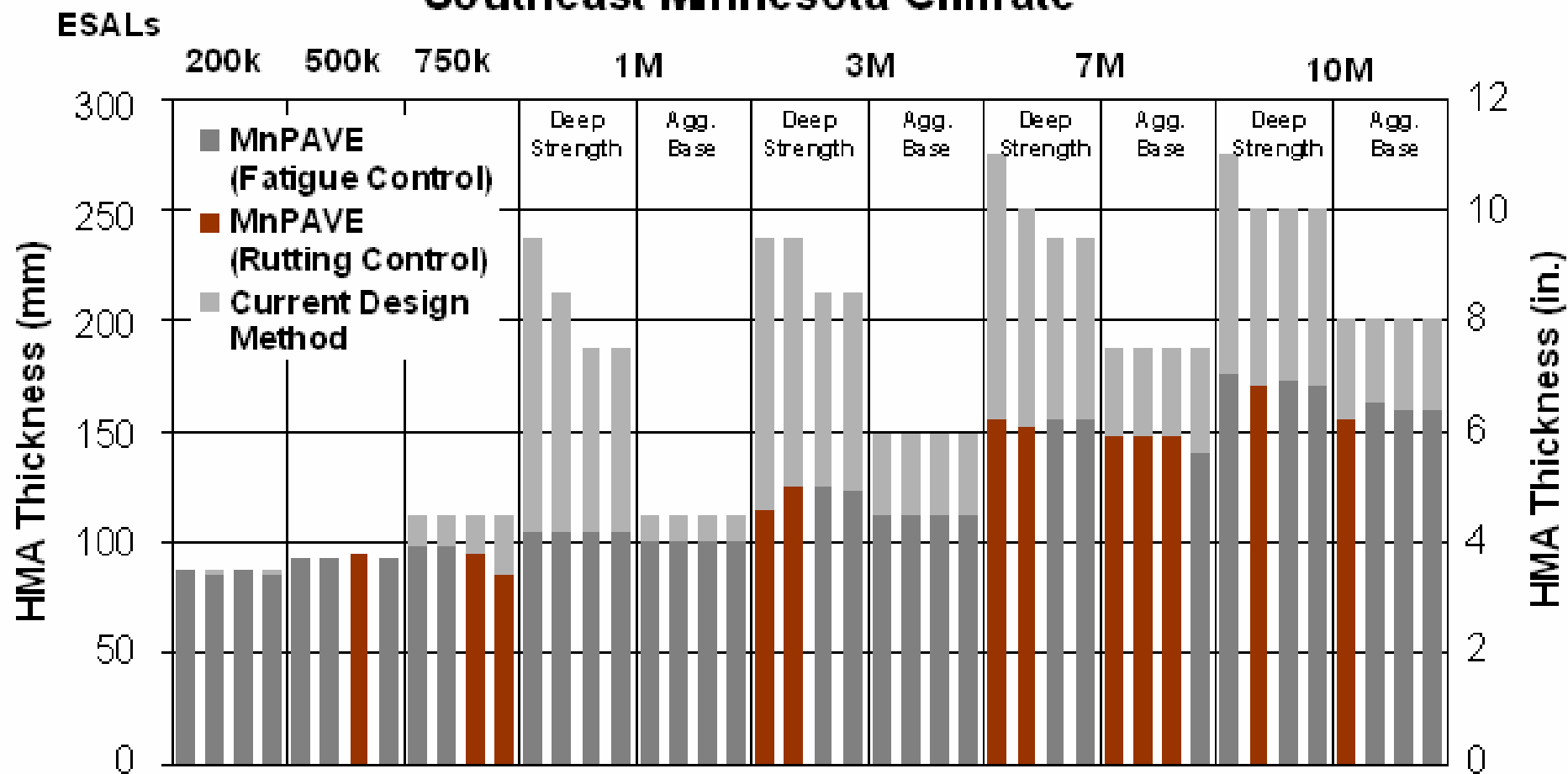
Thicker



Thinner

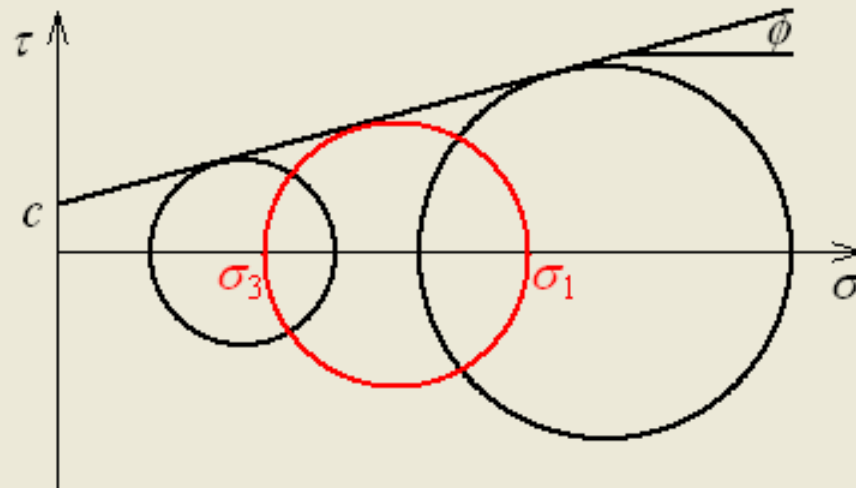


MnPAVE & R-Value HMA Thickness Southeast Minnesota Climate



MnPAVE - Mohr-Coulomb Criterion

Print Window Help



OK

Cancel

Material: Mn/DOT Class 6

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

c kPa

ϕ °

Where:

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

σ_1, σ_3 = Principal stresses due to maximum axle load

c = Cohesion of granular material (from triaxial test)

ϕ = Friction angle of granular material (from triaxial test)

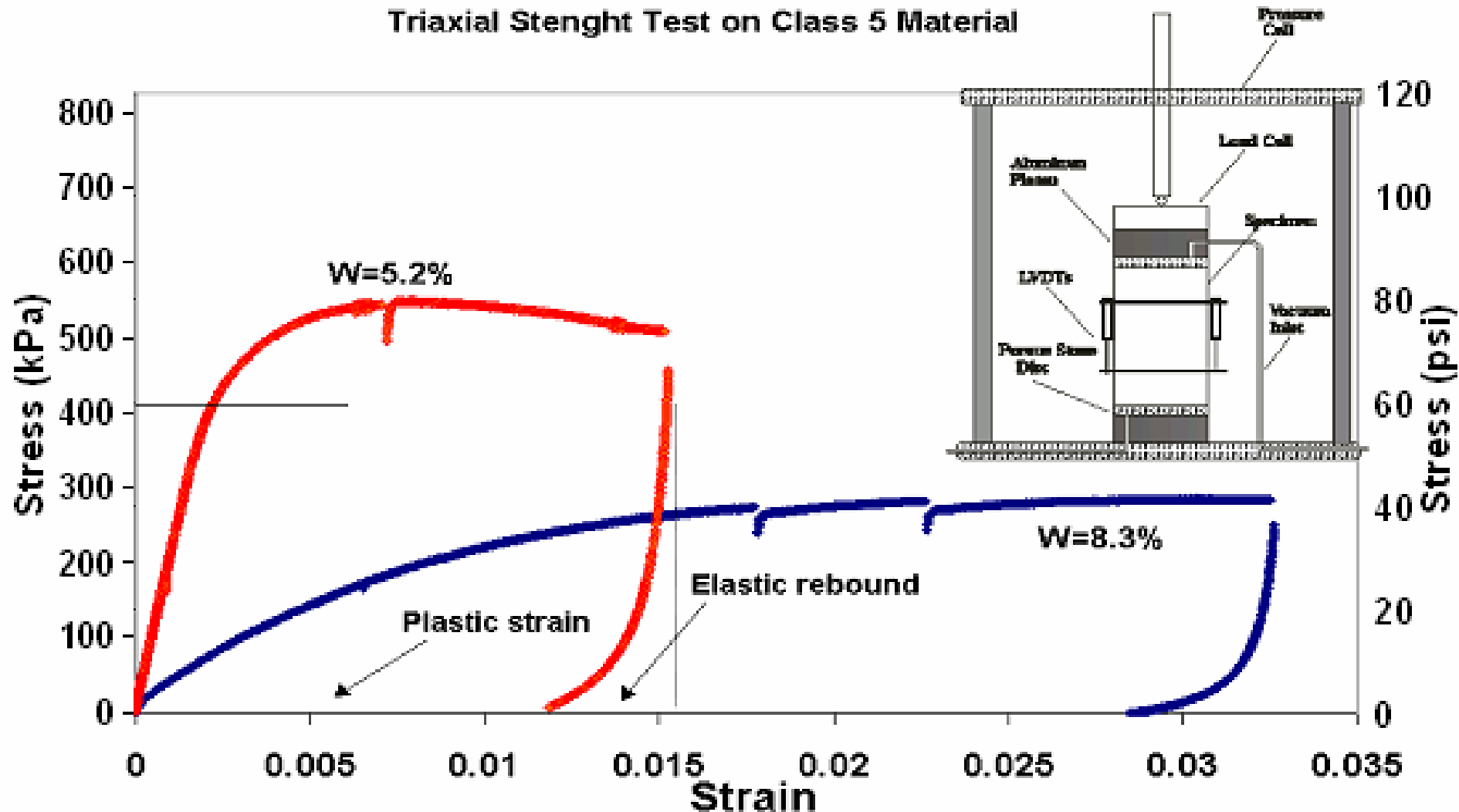
Note:

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 Test

Allowable stress criteria for aggregate base

Triaxial Stenght Test on Class 5 Material



MnPAVE Mohr-Coulomb Results

Material: AggBase: Cl.5

Location: Middle of layer

c

 psi

ϕ

 °

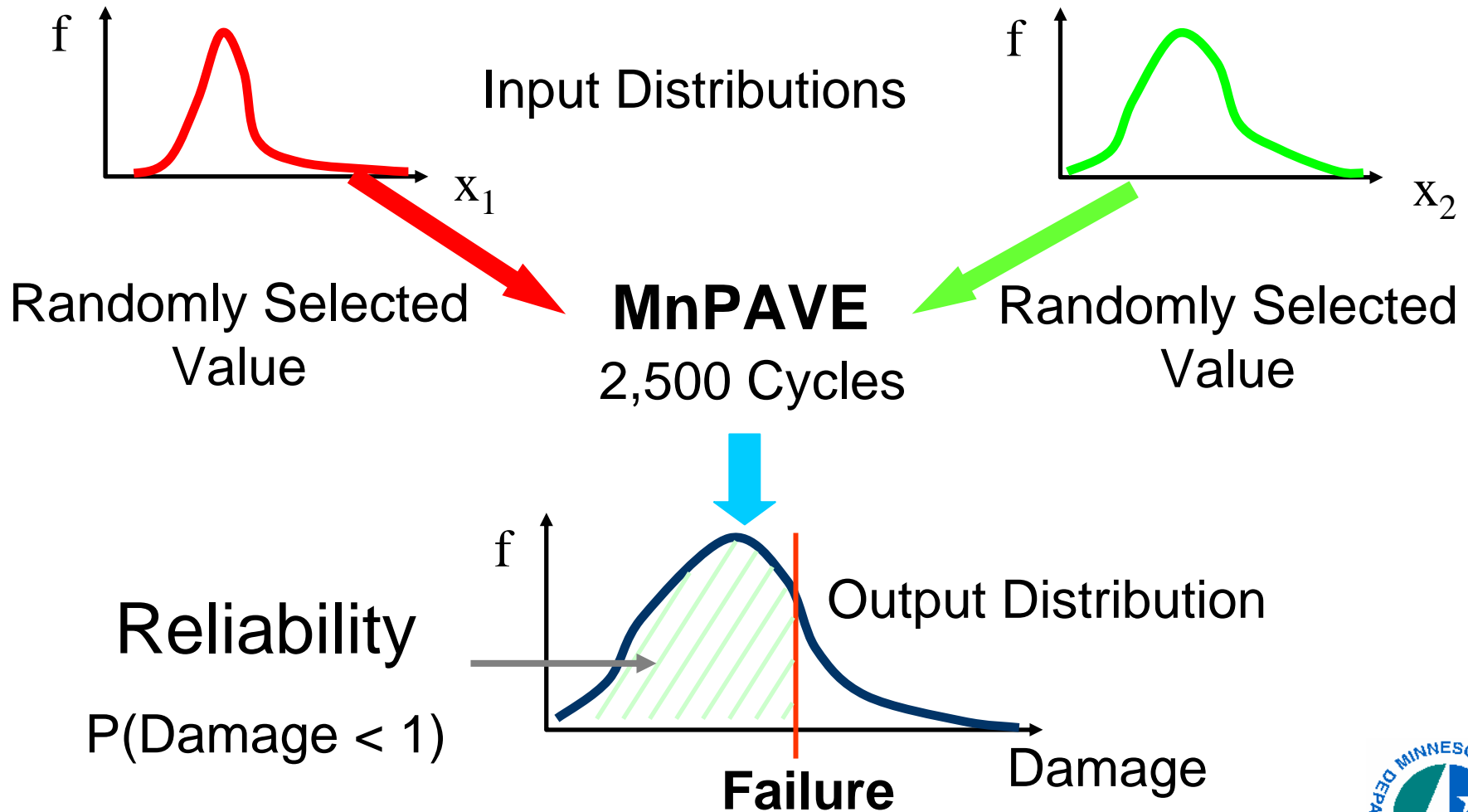
Adjust Layer 1 Thickness to Meet Requirements

Close

	Current Thickness	Required Thickness
Layer 1 Thickness (in.)	4	5.5
σ_1 psi	24.95	18.2
σ_3 psi	0	0
σ_1 critical psi	19.77	19.77

☐ Always show Mohr-Coulomb results
☒ Only show if material fails

Monte Carlo Simulation



Overlay Design

MnPAVE - MnPAVE1

File Edit View Window Help

MnPAVE1

→ Output ☒ Life ☐ Damage

Traffic Type: ESAL Total Repetitions: 3,000,000

Expected Life

Years: Fatigue 22

☐ Rutting is present in old HMA

Adjust Materials

	H (in.)
HMA: PG 58-34	2
Old: PG 58-34	4
AggBase: CL5	12
EngSoil: CL	24
UndSoil: CL	

Recalculate

Units: ☒ English ☐ SI

Go Back to Control Panel

Basic | Batch Mode | Reliability

Spring Axle Load Limit

PSR: 1.971 Age, yrs: 20

Percent of Total Damage

Fall	Winter	Early Spring	Late Spring	Summer
16.3	0.1	2.5	25.4	55.7

MnPAVE Fatigue

Export: ☒ Design Summary ☐ Damage Details

Export to File

For Help, press F1

Lukanen Report: Pavement Performance Prediction Models 1992

$$PSR = PSR_{initial} - e^{(a-b \times c^t)}$$

Where:

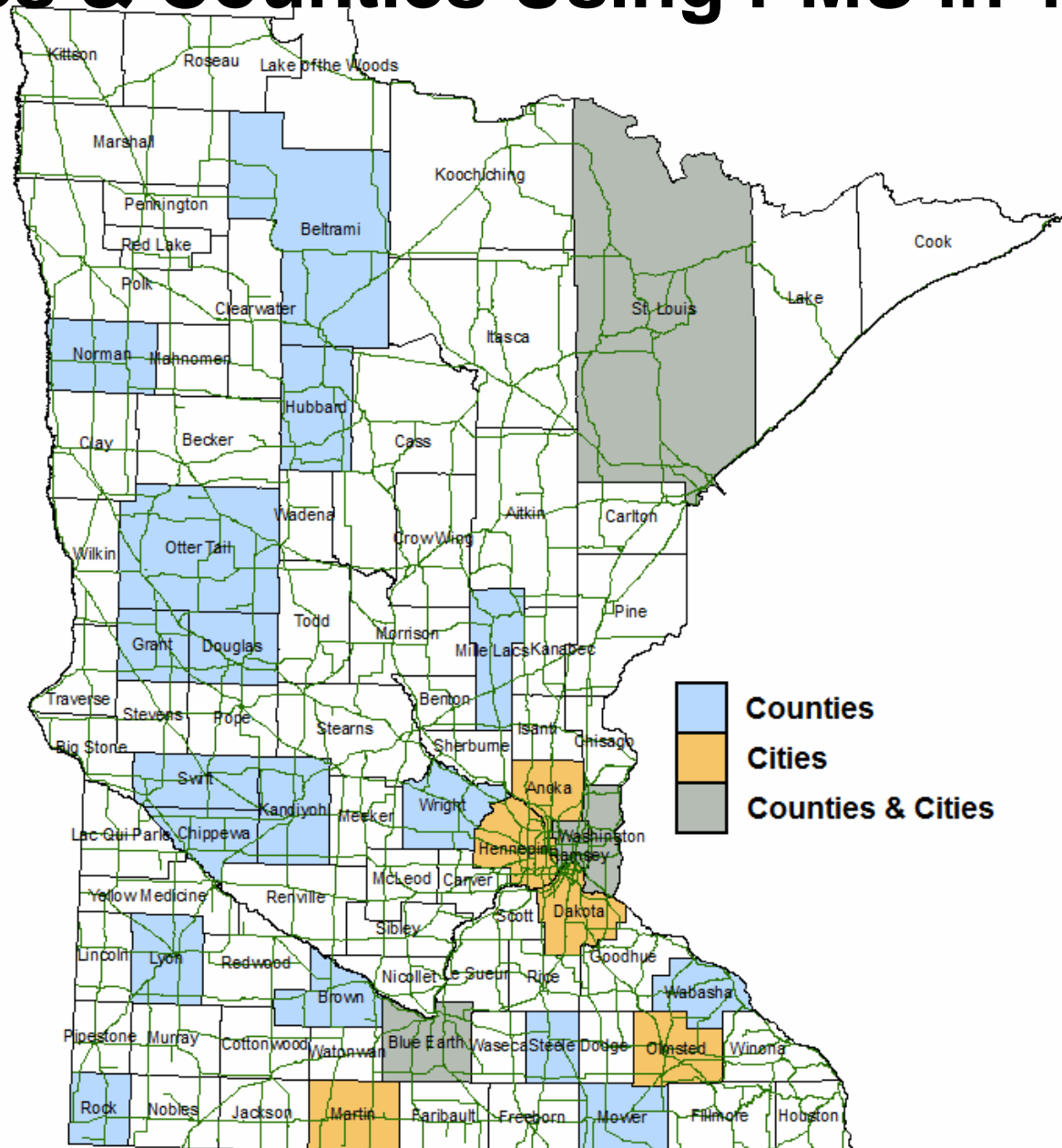
$$t = \ln\left(\frac{1}{Age}\right)$$



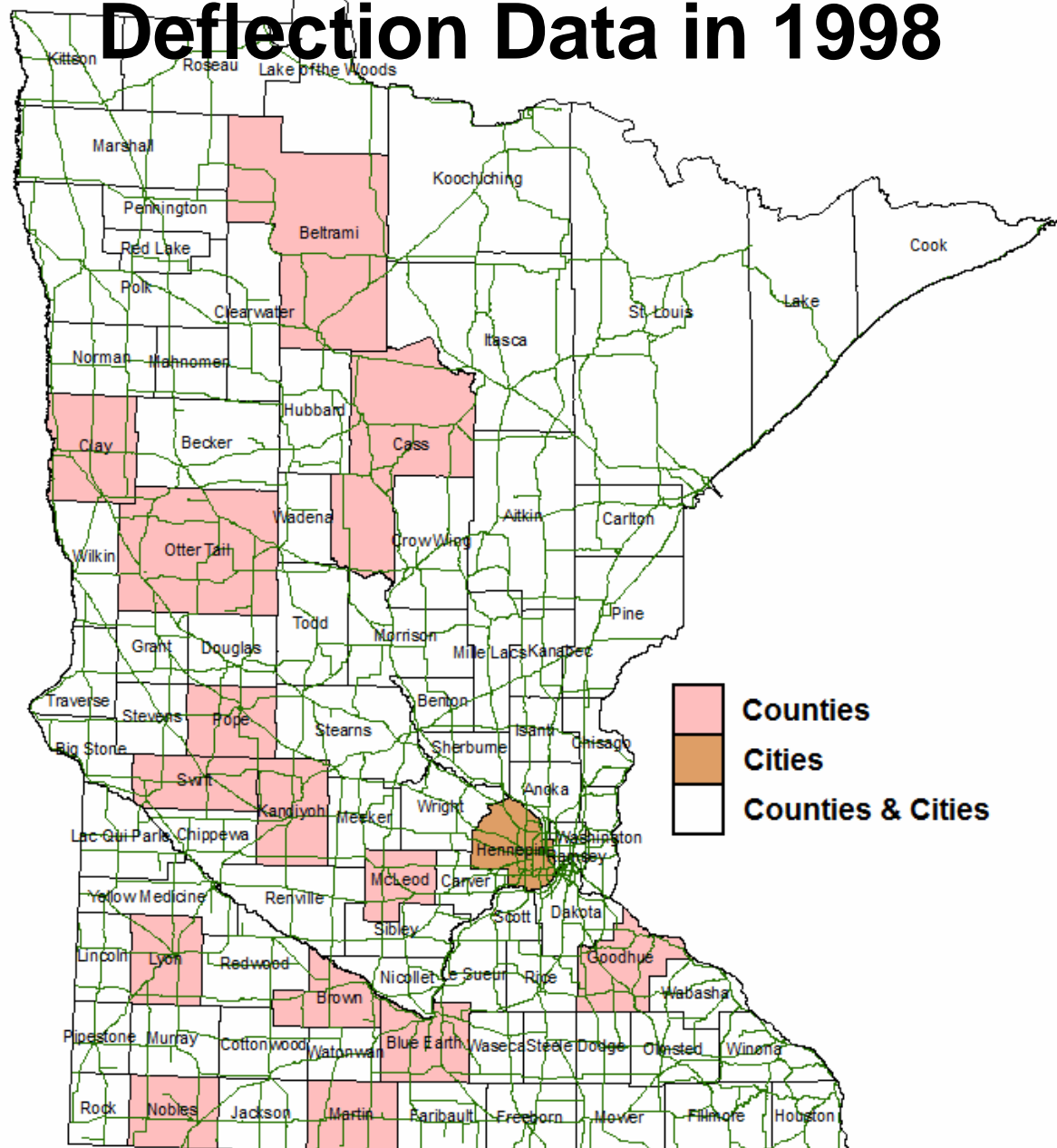
LRRB 828



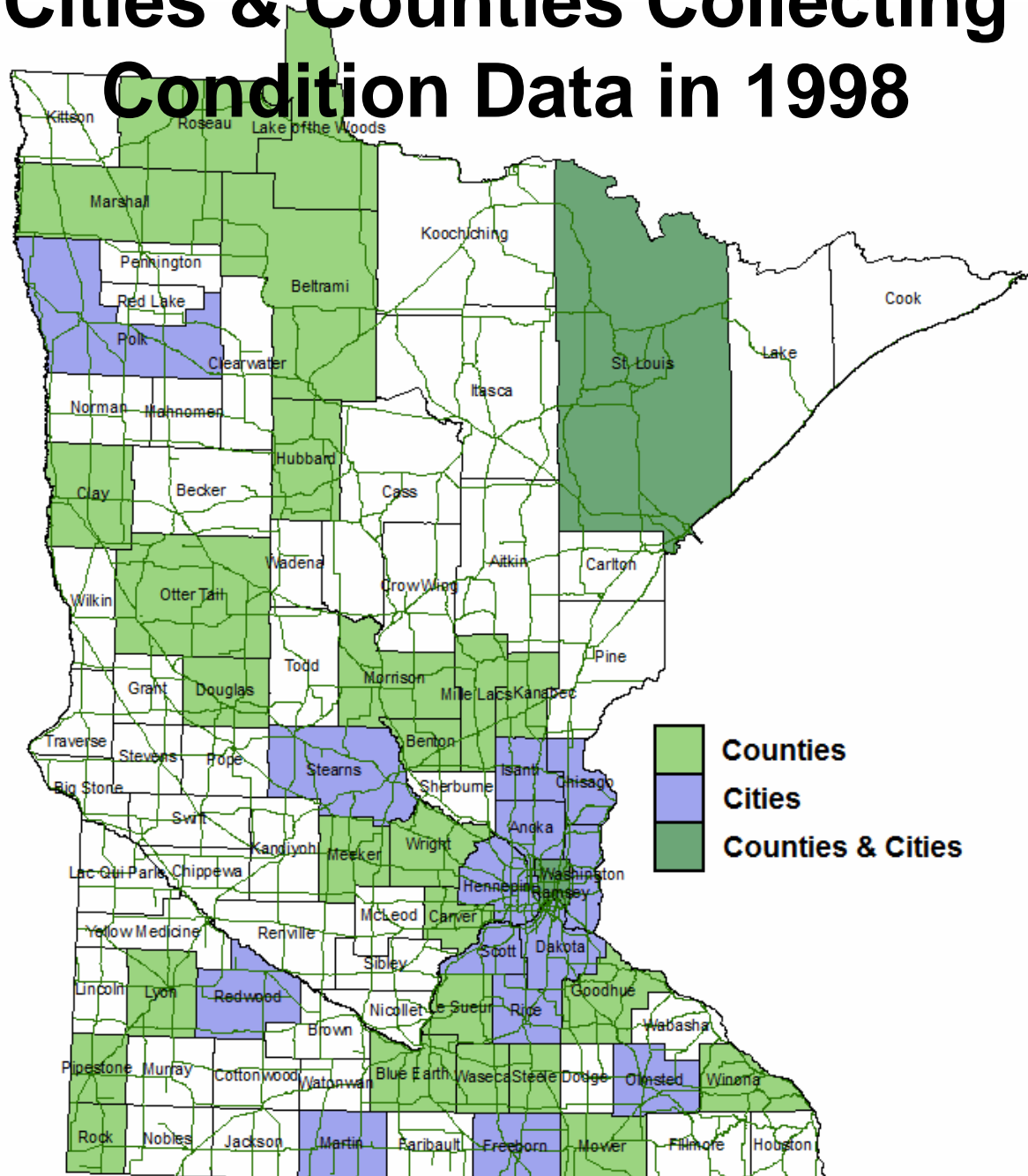
Cities & Counties Using PMS in 1998



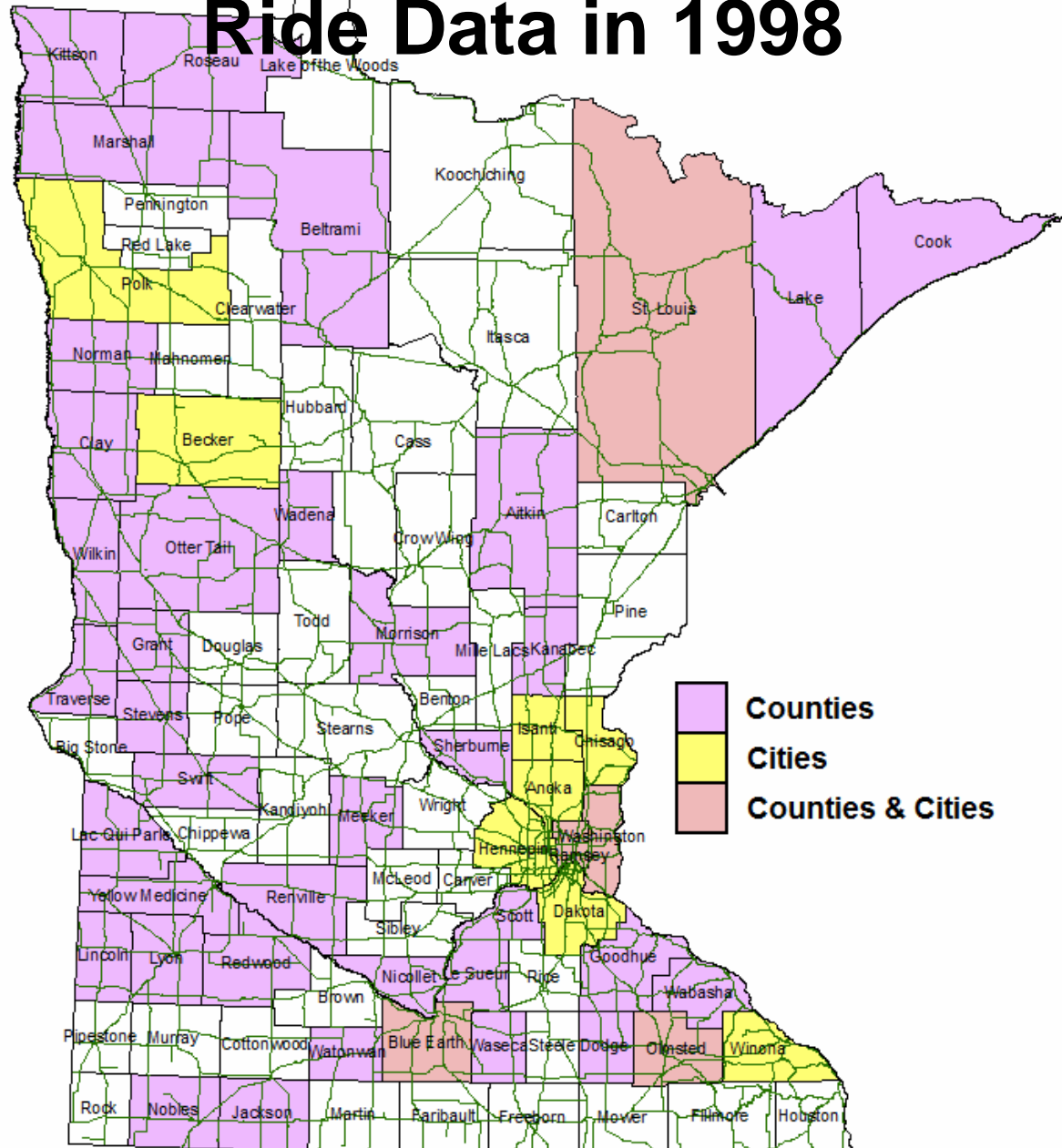
Cities & Counties Collecting Deflection Data in 1998



Cities & Counties Collecting Condition Data in 1998



Cities & Counties Collecting Ride Data in 1998



Other Development Tools

- GIS – Geographic Information System
 - Roads
 - Soils
 - Groundwater
- MPS – Materials Performance System
 - Soil and Aggregate Test Results
 - Pavement History
 - FWD
 - Traffic



Future Work

- Refine transfer functions
- Expand procedure to cover rehabilitation
 - Overlays
 - CIR
 - Rubblization
- Performance specifications
- Further work needed to characterize modified base gradations, select granular, Superpave, etc.





Questions

www.mrr.dot.state.mn.us

