Determination of in Place Elastic Layer Modulus

Transportation Research Board Annual Meeting

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Session #295

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LTPP

LONG TERM Pavement PERFORMANCE

Outline

1. Introduction: Project Objectives
2. Project Phases
3. Backcalculation Process
4. Application and Use of Backcalculation Results: Some Examples
5. Final Comments

Project Title

Backcalculation of the Long Term Pavement Performance Program Deflection Data:

Determination of In Place Elastic Layer Modulus: Backcalculation Methodology and Procedures

Project Objectives

1. Select appropriate methods/tools and perform backcalculation of all deflection basin data in the LTPP database.

2. Integrate **most accurate or representative** backcalculated layer modulus values into computed parameter tables in LTPP.

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Project Phases

I. Selection of methods/tools and demonstrate those methods to estimate in place elastic layer moduli.

- Most accurate?
- Most representative?

II. Execution of the methods/tools from Phase I to backcalculate elastic layer moduli for all LTPP test sections.

Backcalculation Challenges

- Correctly simulate the pavement structure – given the assumptions of elastic layered theory.
- Limited layers.
- Results are a composite value – not intact individual layer modulus values.
- No unique set of elastic layer moduli for a deflection basin.

LTPP Projects Selected for Phase I Demonstration

Pavement Type	New Construction	Rehabilitation	Seasonal Sites
Rigid	North Carolina SPS-2	Oklahoma SPS-6, selected sections	Utah, 49-3011
Flexible	Iowa & Wisconsin SPS-1, selected sections	Mississippi SPS-5, selected sections	Georgia, 13-1005

- LTPP sites selected to include as many of the different site and design features as possible in demonstration.

Phase I Hypotheses

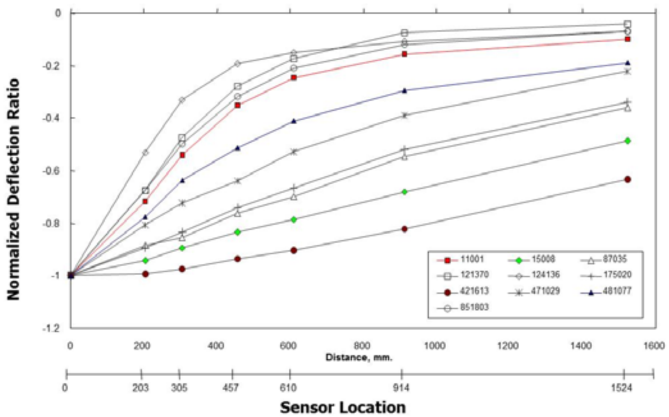
1. Backcalculation packages result in the same set of elastic layer modulus values.

2. Backcalculated elastic layer modulus values are correlated to but have a bias related to laboratory measured modulus values.

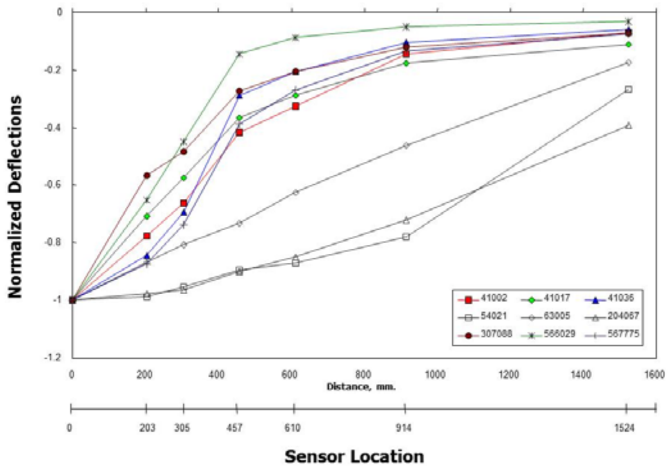
Phase I: Some Findings

Hypothesis 1

1. For deflection basins consistent with elastic layer theory:
   - Hypothesis was accepted.

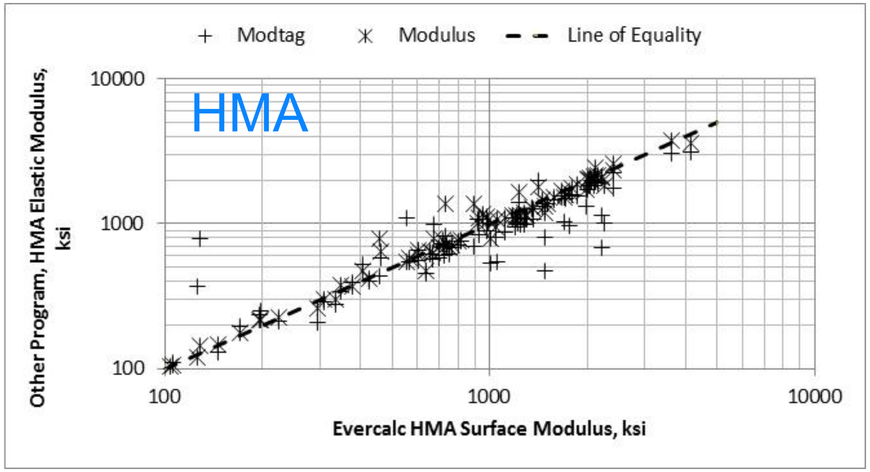


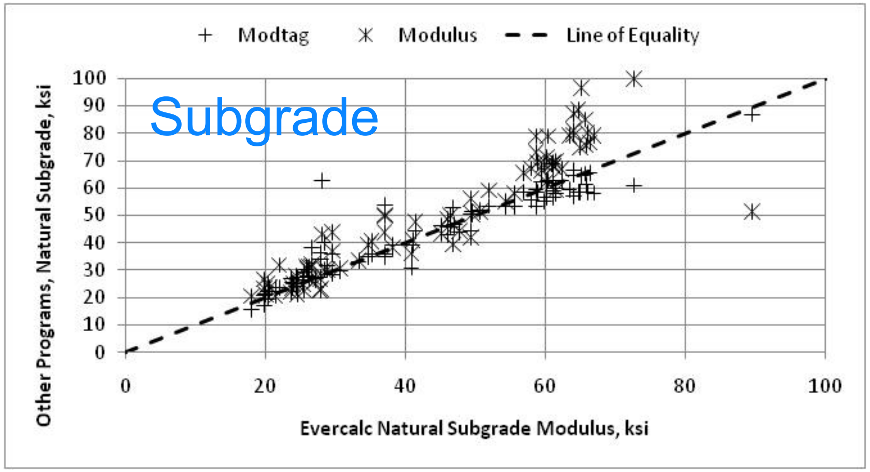
2. For deflection basins diverging from elastic layer theory:
   - Hypothesis was rejected.

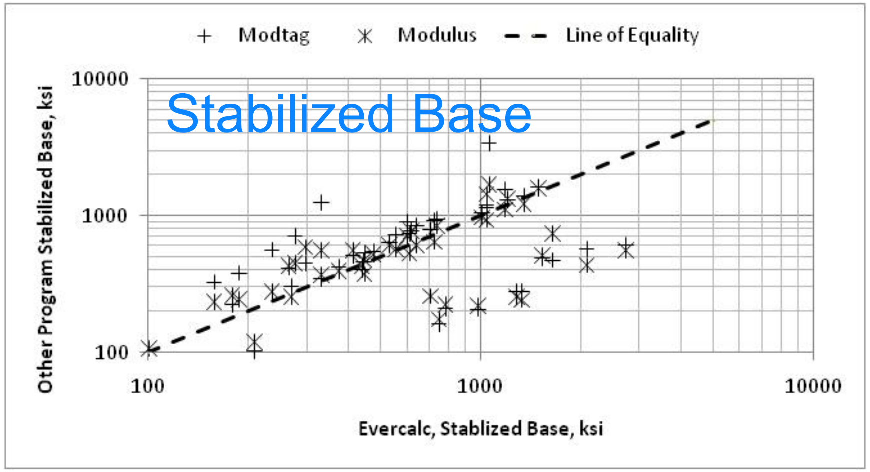


Phase I: Some Findings

- Evercalc and Modcomp resulted in similar elastic layer modulus values for many of the case study sites.







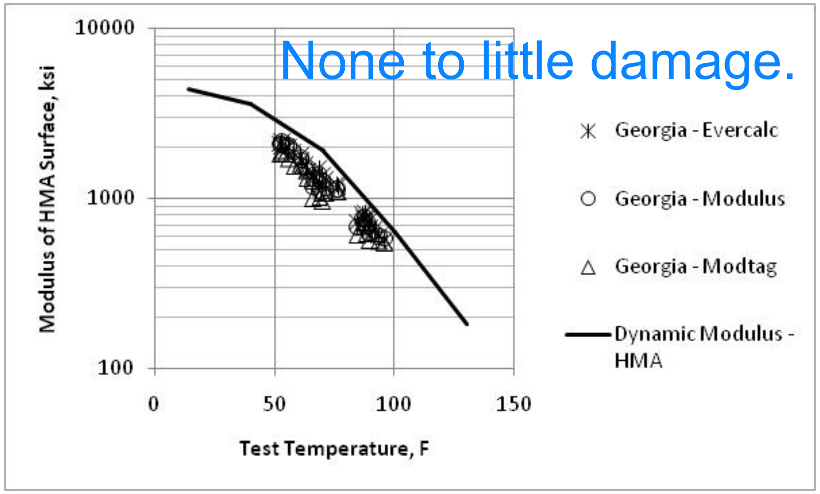
Phase I: Some Findings

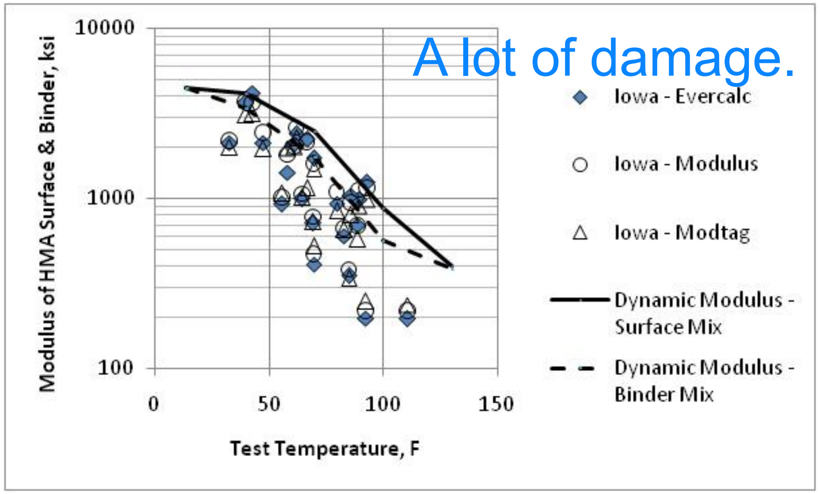
Average c-factor: Ratio between laboratory measured resilient modulus and backcalculated elastic modulus values for subgrade soils.

Backcalculation Program	Average c-Factor	Standard Deviation
Evercalc	0.35	0.136
Modcomp	0.36	0.146
Modulus	0.41	0.266

Phase I: Some Findings

- MEPDG damage concept confirmed or supported from backcalculated layer modulus.





Going Forward in Phase II

1. Use ***Evercalc*** as the primary backcalculation program for both flexible and rigid pavements.

2. Use ***Best Fit*** method for rigid pavements.

3. Use ***Modcomp*** for backup program for problem basins.

Phase II Overview

LTPP Experiments	HMA Surface	PCC Surface
Total GPS Sections	931	313
Total SPS Sections	1,194	695
Total	2,125	1,008
Total Basins Available	5,847,770	
Total Basins Analyzed	5,662,494	

Nearly 97 percent of all deflection basins can be and were used in backcalculation process.

Phase II: Defining Success

Based on RMSE and backcalculated modulus value

Criterion	Acceptable	Atypical	Error or Unacceptable
RMSE	≤3.0	≤3.0	>3.0
	and	and	or
Modulus value (by material type)	Within Acceptable range limits	Outside acceptable but within atypical limits	Outside Atypical range limits

Acceptable	Atypical	Error

Phase II: Success Rate

Over 76 percent of all deflection basins resulted in acceptable or Atypical elastic layer modulus.

Result	Total Number of Drops	Percent of Total Drops
Drops	5,662,494	100
Unacceptable Results	1,350,680	23.9
Atypical Results	2,494,628	44.1
Acceptable Results	1,817,186	32.1
Total Acceptable & Atypical Results	4,311,814	76.1

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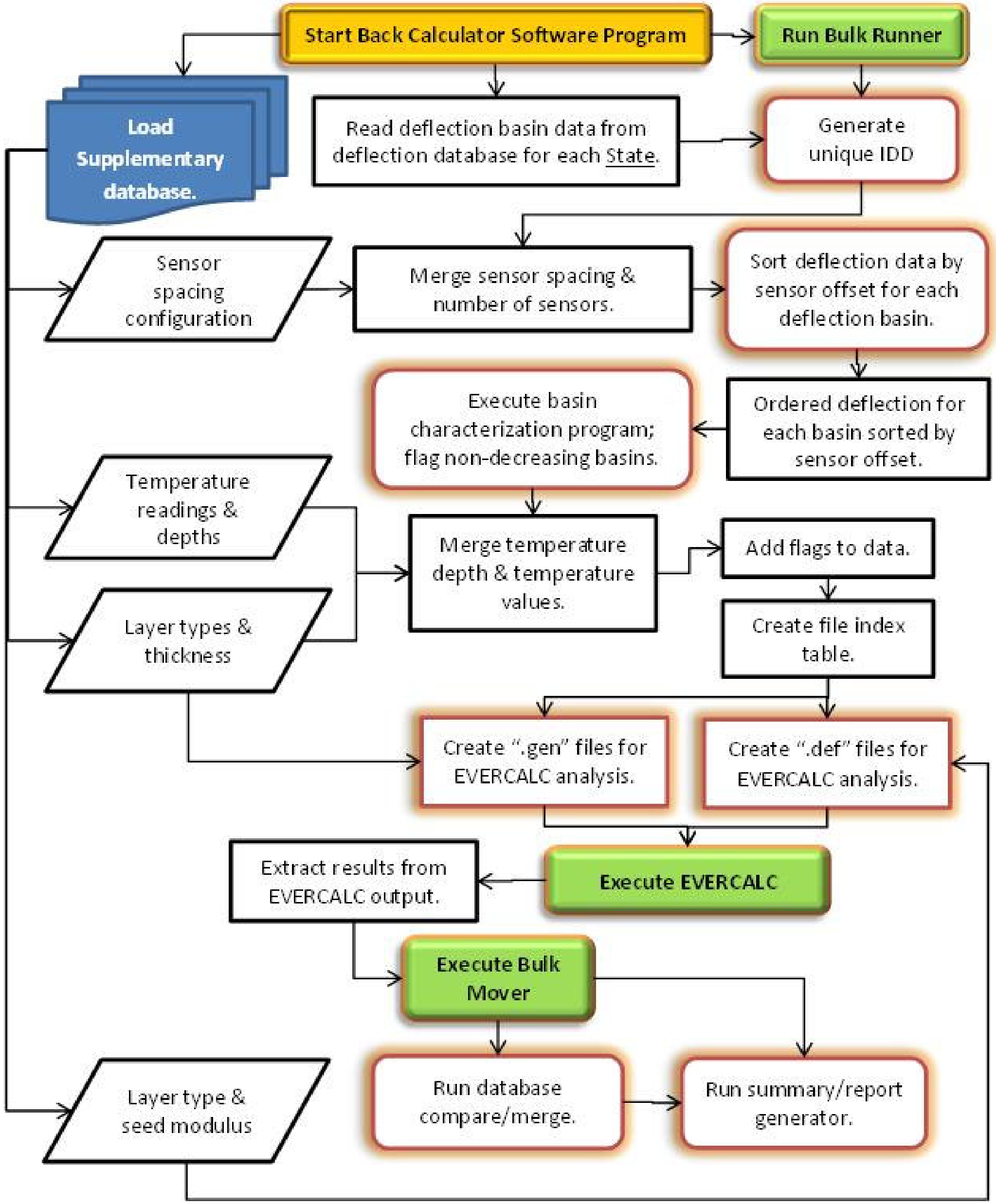
Phase II Goal

- Automate the process to make the process less dependent on the user so that others can use the tools and procedures to recreate the results.



Automated Procedure

- Software Packages:
  - EVERCALC/MODCOMP
  - BEST FIT, bonded and unbonded simulations
- Back Calculator:
  - Standalone software program
  - Bulk processing & filtering deflection data
  - Executing software packages
  - Post-processing/interpreting results
  - Generating reports and summaries

Bulk Runner

Bulk Mover

Computed Parameter Tables

Layer Structure Information	Backcalculated Modulus Values	
	Individual Basins	**Summary for Test Day**
1. Section Information	1. Elastic layer moduli from EVERCALC/MODCOMP	1. Elastic layer moduli from EVERCALC/MODCOMP
2. Structures, EVERCALC	2. Elastic layer moduli from BEST FIT	2. Elastic layer moduli form BEST FIT
3. Structures, BEST FIT	3. Load transfer efficiency from BEST FIT	3. Load transfer efficiency from BEST FIT
	All results included in CPTs	**Only results defined as acceptable and Atypical included in CPTs**

Tables storing the backcalculated modulus values are organized by agency for optimizing computational needs.

Mapping Layers

- Kept layers same across programs
- EVERCALC – 5 layers
- MODCOMP – 7 layer capability (> 5 layers not needed in project)

Overlay	Overlay (if applicable)
HMA-1	Existing HMA
HMA-2	
HMA-3	
Base	Base + Subbase
Subbase	
Subgrade	Weathered sublayer
	Infinite sublayer

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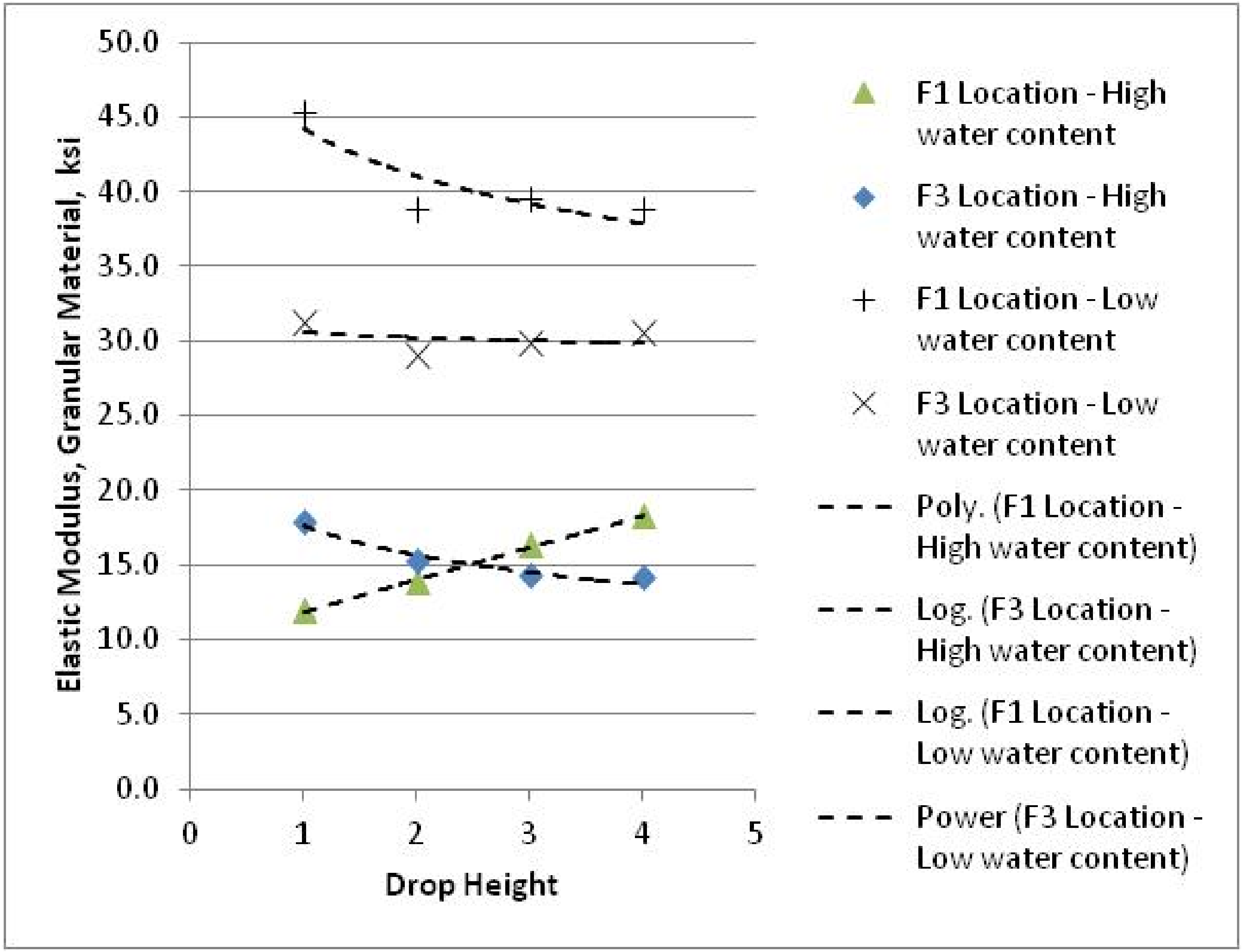
Importance of Water Content

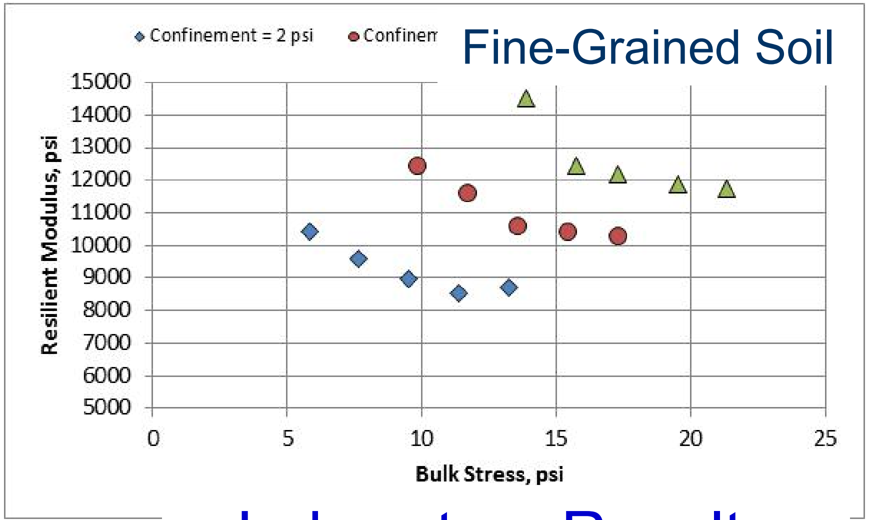
Material condition of unbound layers is important, as designated by the BC values.

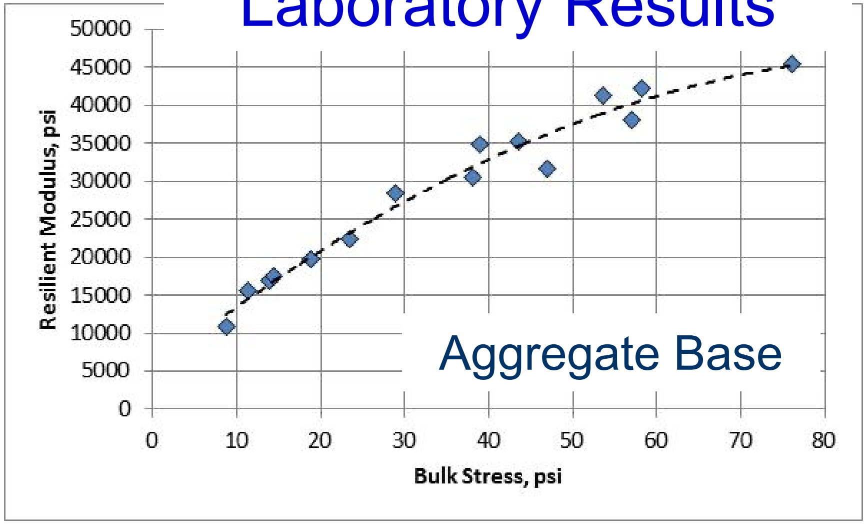


LTPP LONG TERM Pavement PERFORMANCE

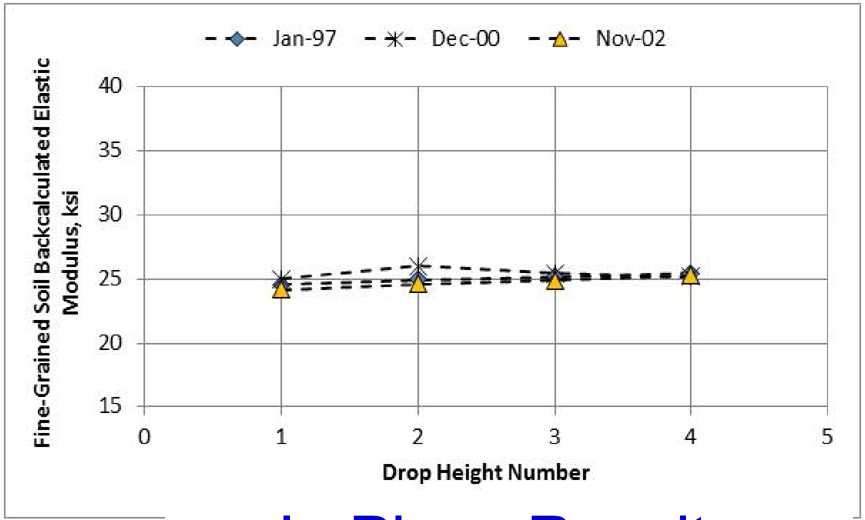
Stress Sensitivity

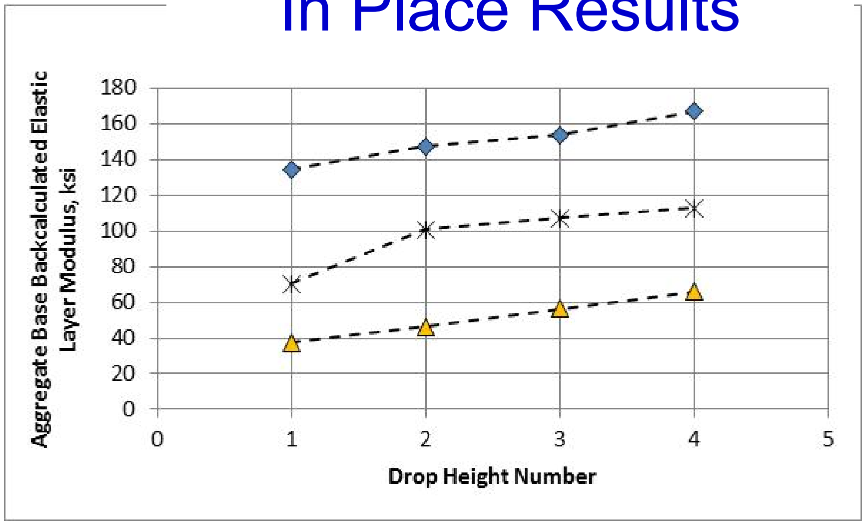
Laboratory Results



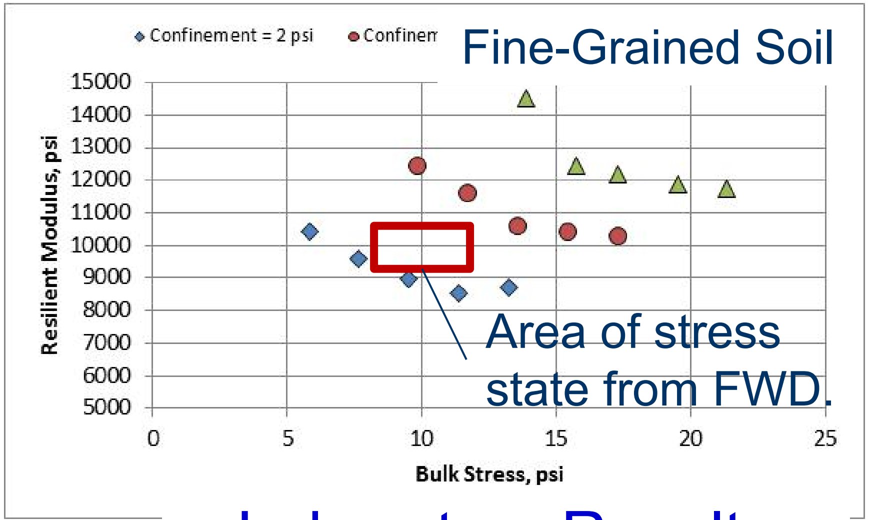


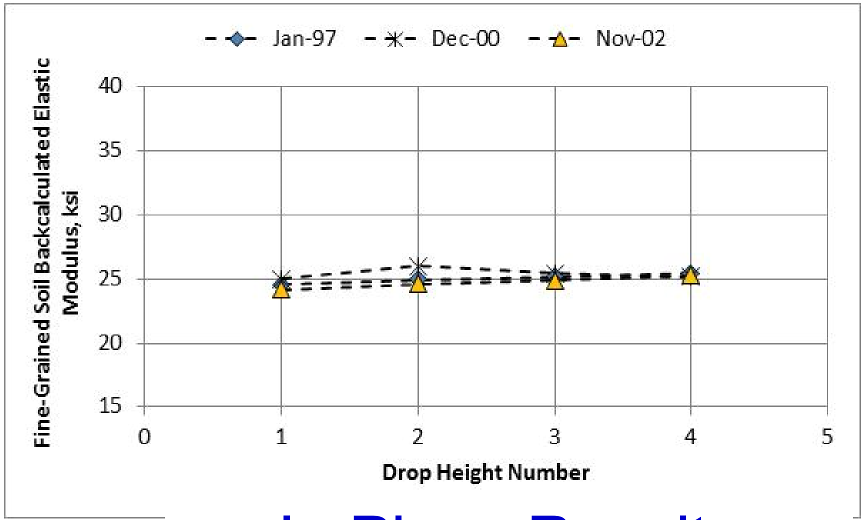
In Place Results



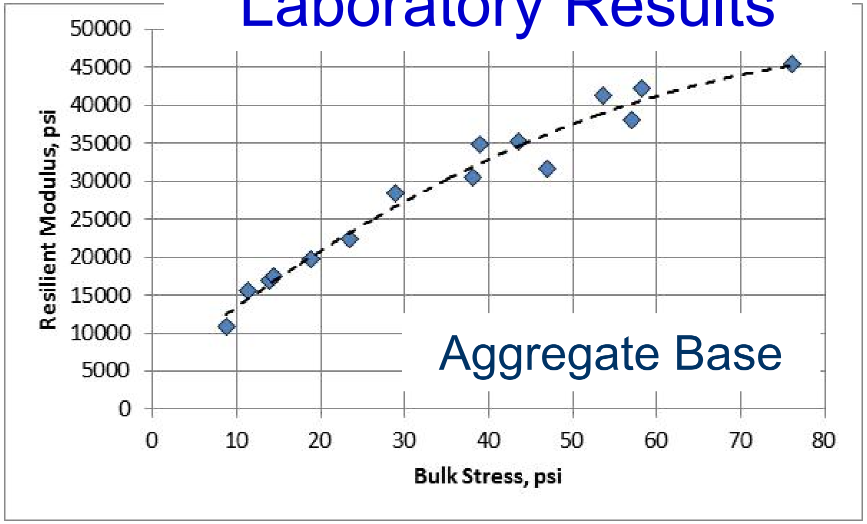


Stress Sensitivity

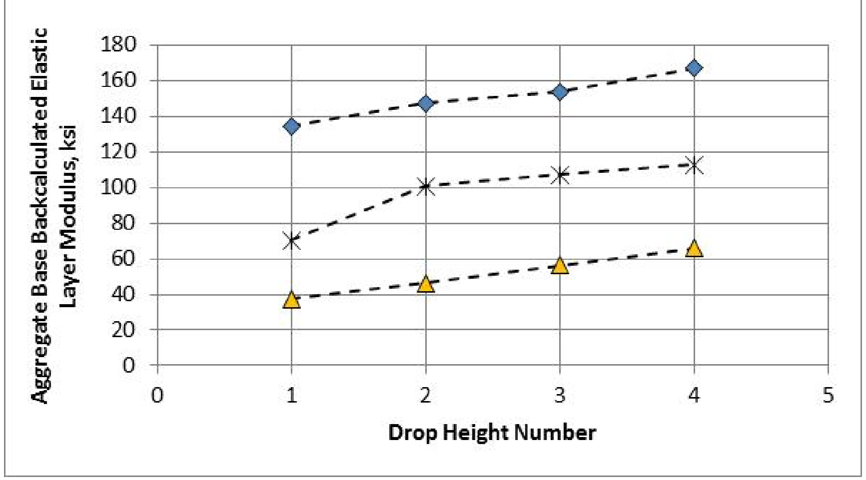




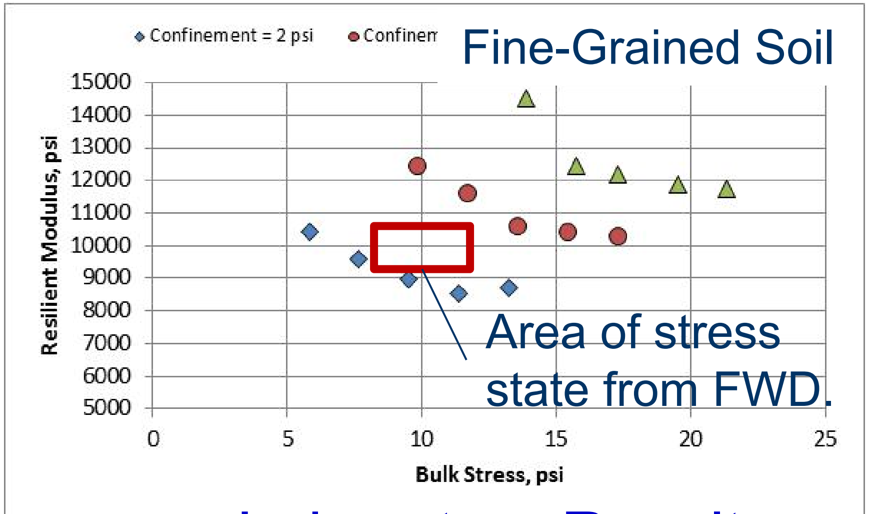
Laboratory Results

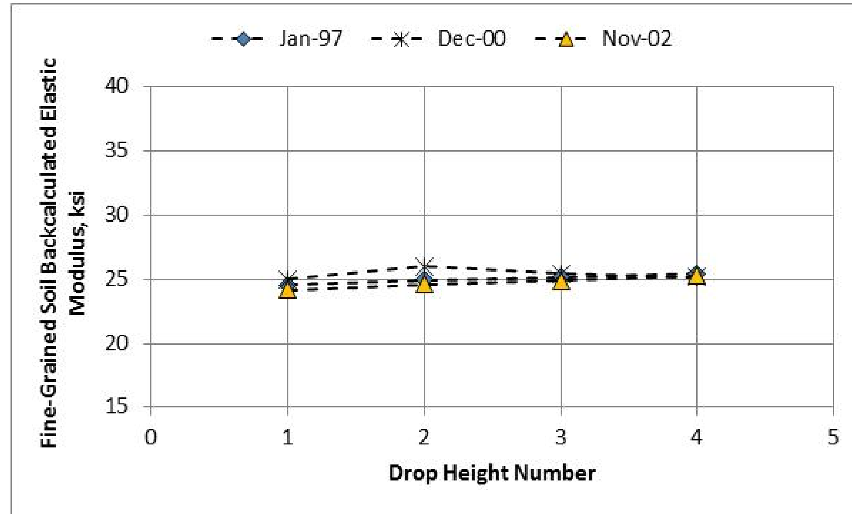


In Place Results



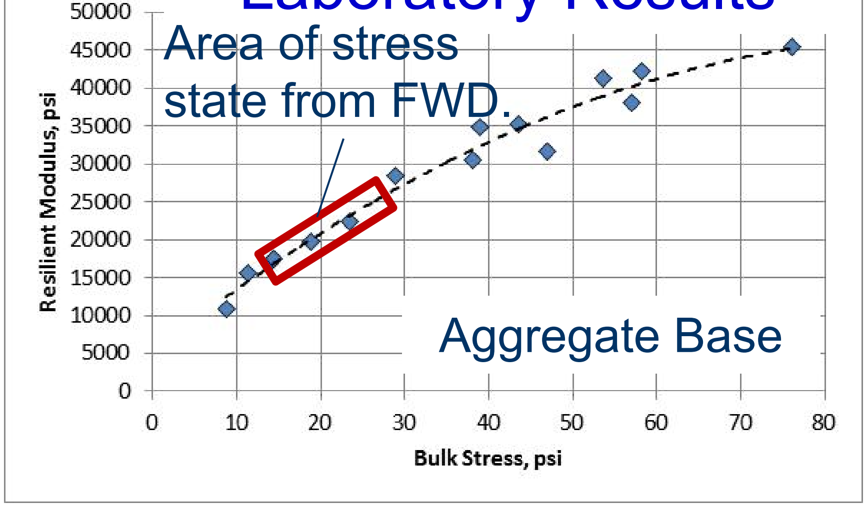
Stress Sensitivity

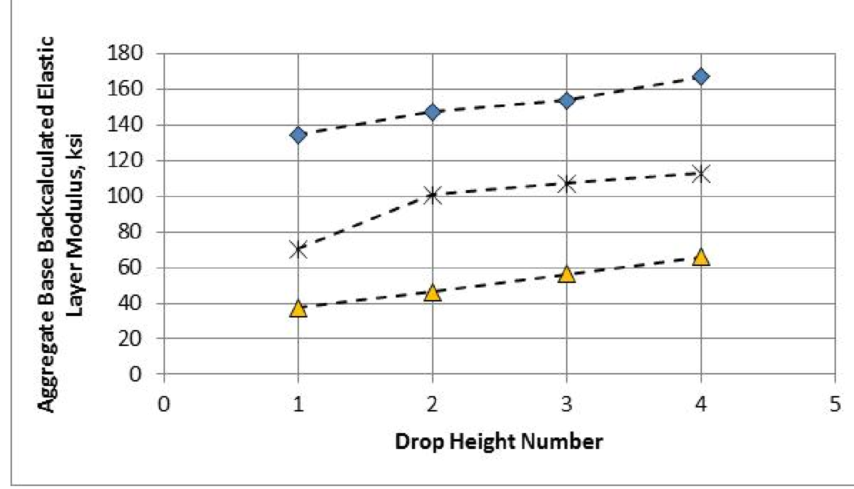




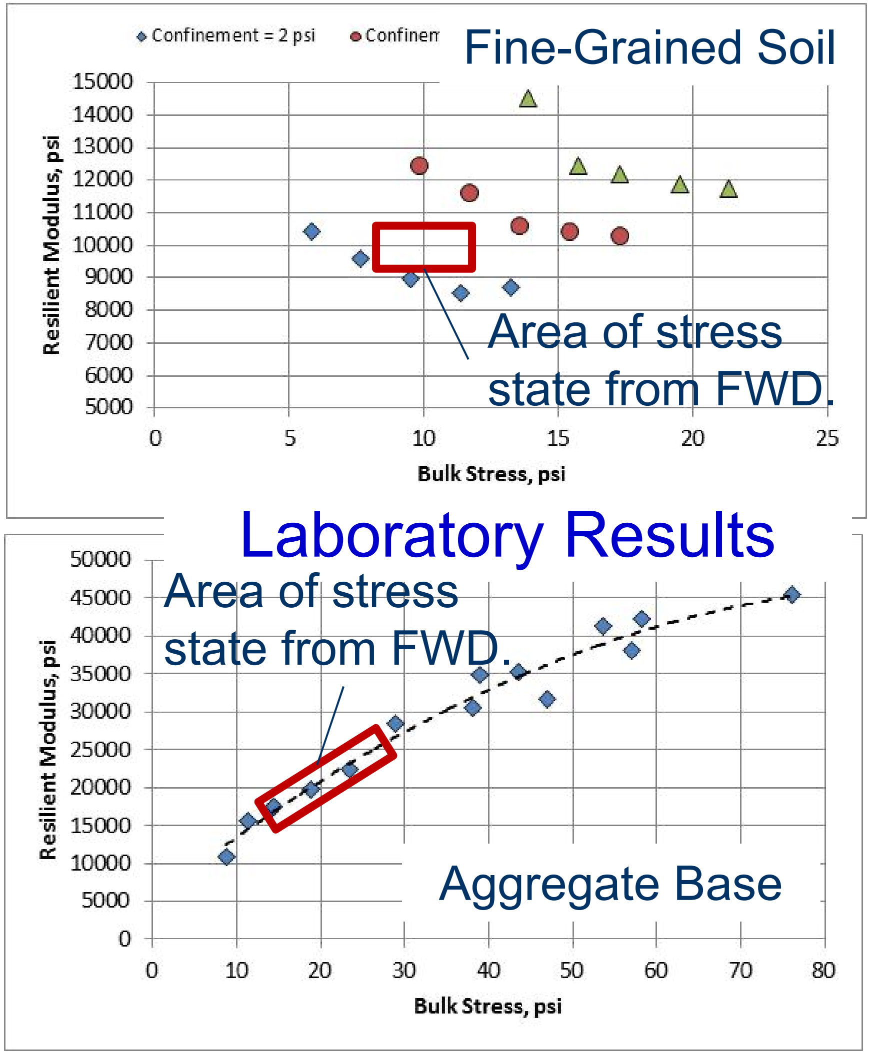
Laboratory Results

In Place Results





Stress Sensitivity

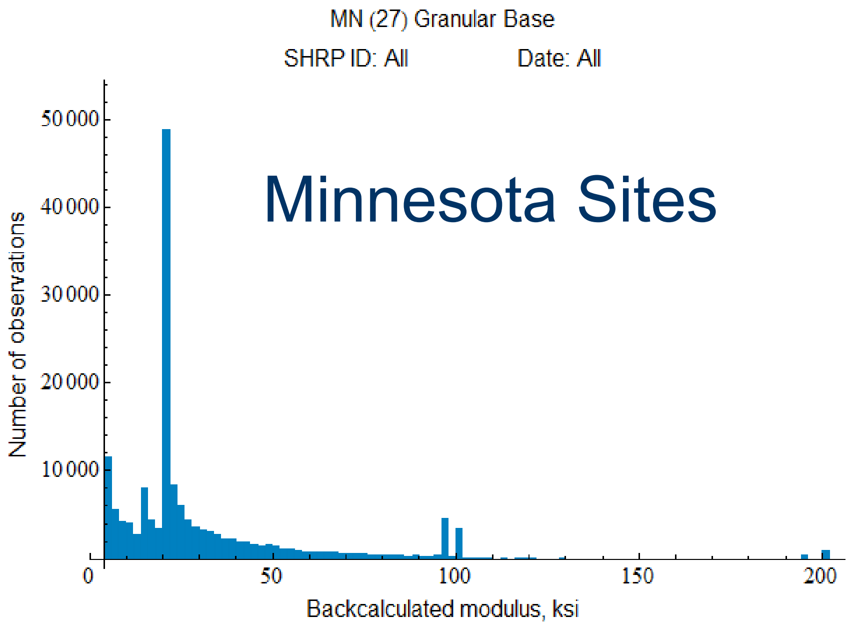


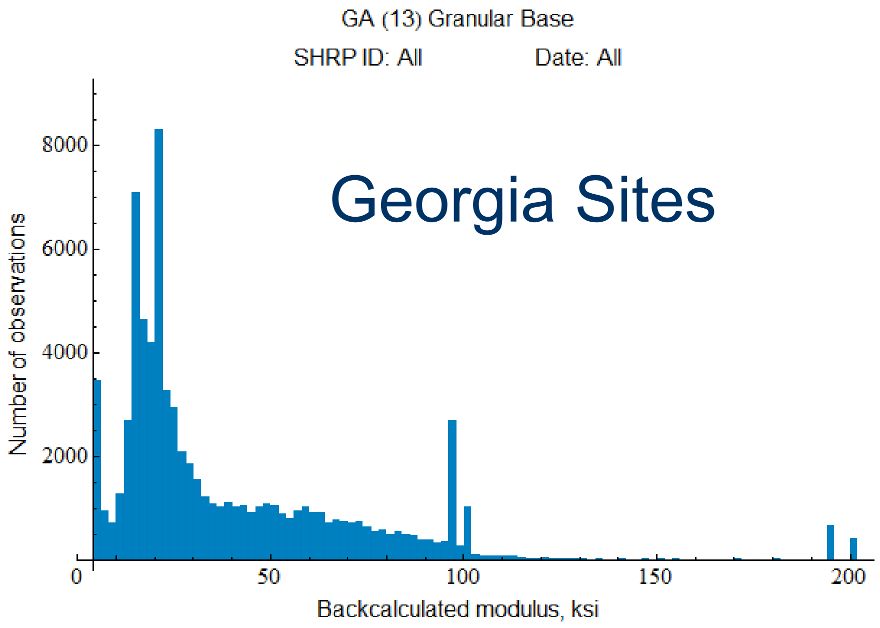
Backcalculation data show stress sensitivity is much less important in comparison to the physical condition of unbound layers.

For rehabilitation design, 4 drops probably not necessary.

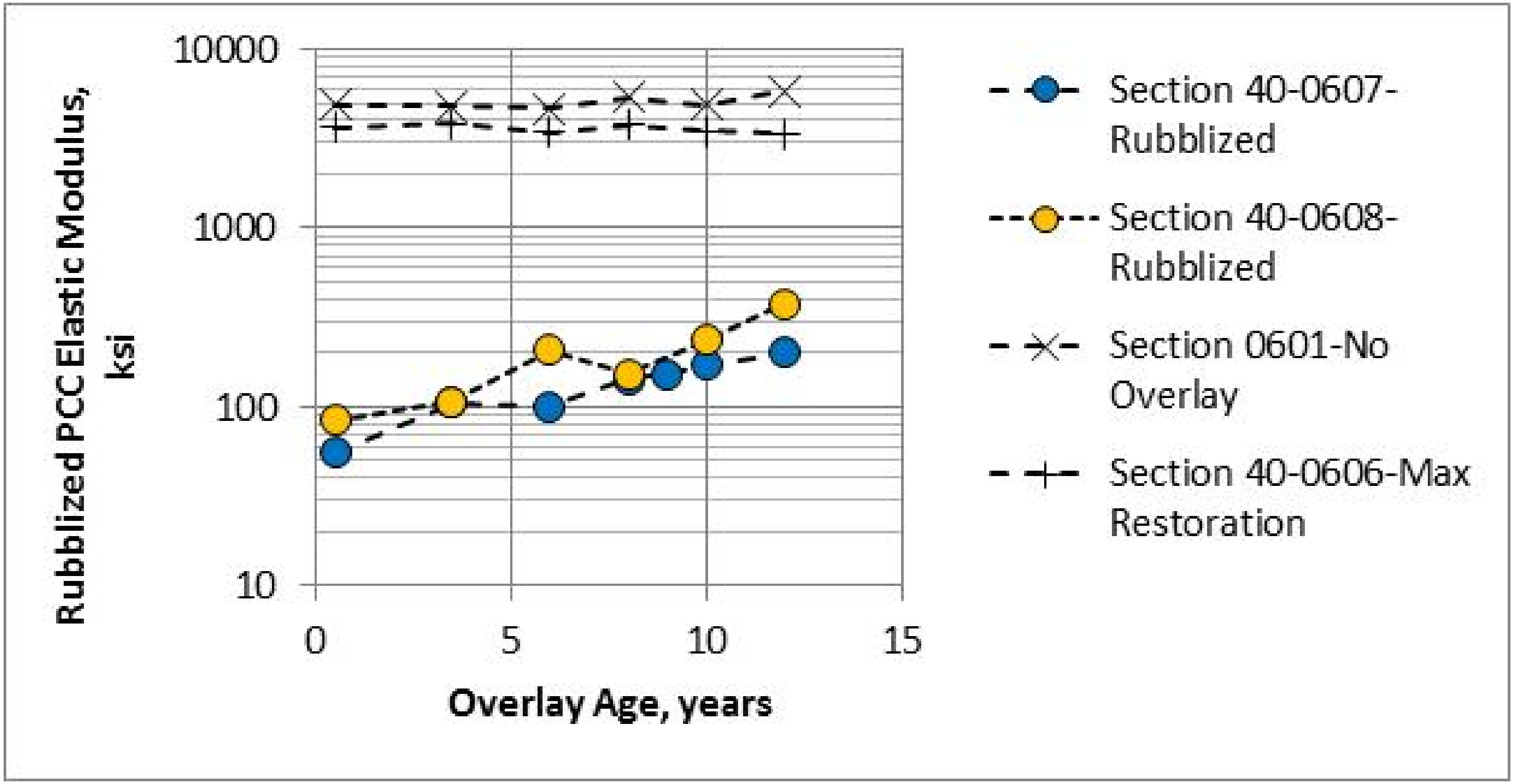
Establish Default Values

Backcalculated modulus values can be used to assist in establishing or confirming default values.





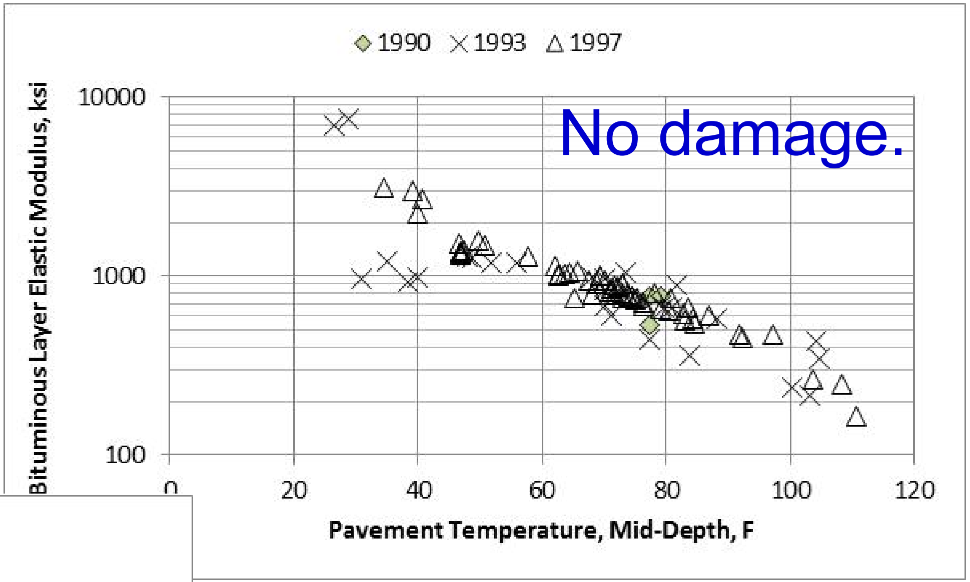
Healing or Time Effects?

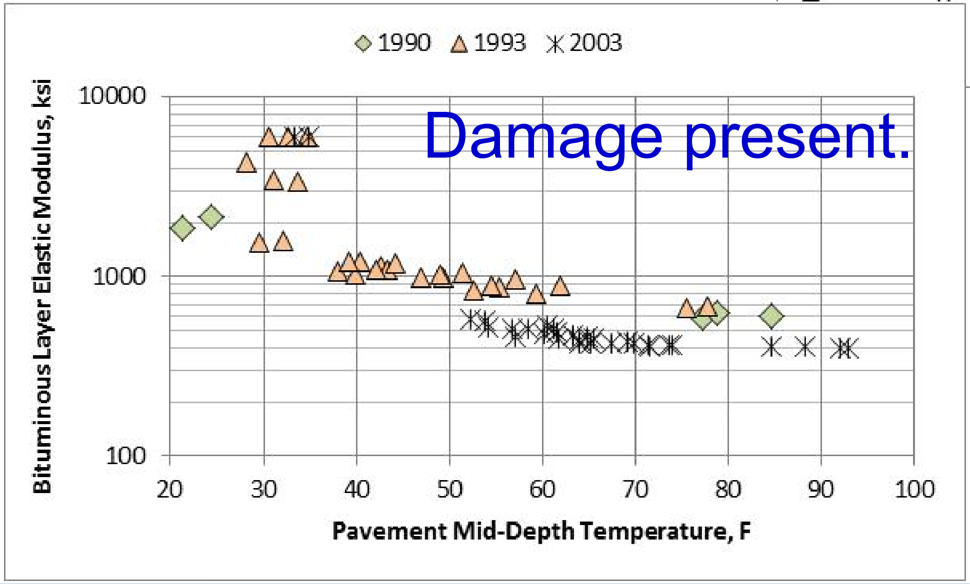


Modulus values steadily increasing over time for the rubblized test sections.

In Place Damage Assessment

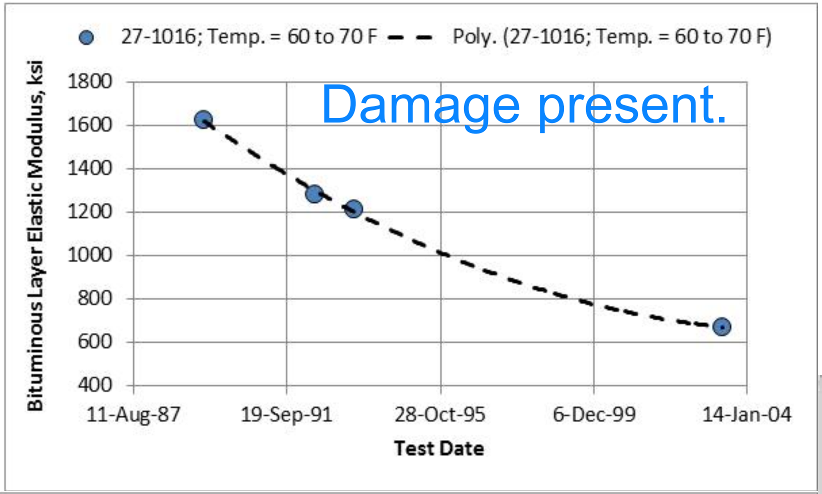
Using backcalculated modulus data to estimate in place damage for rehabilitation design.



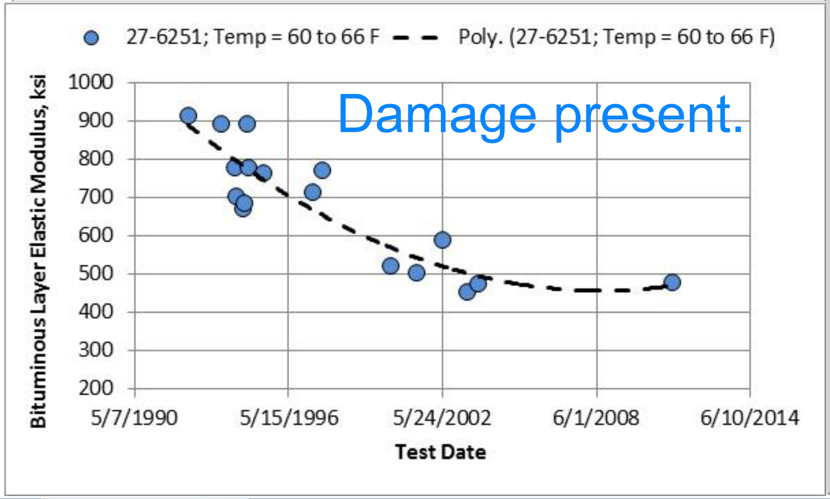


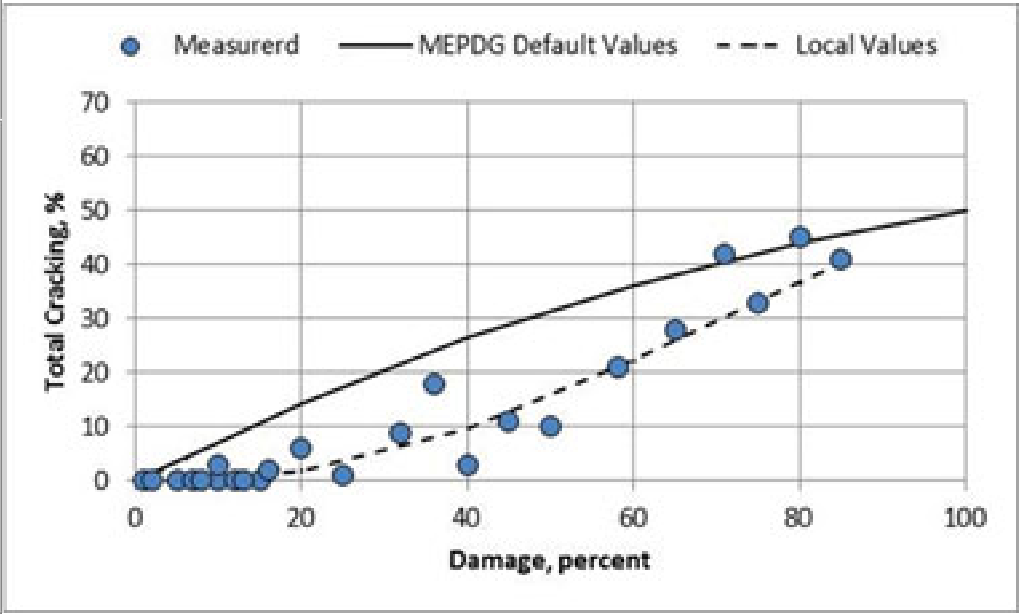
Damage defined as the ratio between backcalculated elastic modulus and lab measured values.

Use in Calibration: Cracking Transfer Functions



In place damage related to the amount of fatigue cracking for estimating the coefficients of the fatigue cracking transfer function.





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Some Final Comments

1. Nearly 97 percent of the measured deflection basins in the LTPP database are considered good in terms of elastic layer theory.

2. Over 76 percent of deflection basins resulted in elastic layer moduli considered acceptable; results from many deflection basins were on the borderline.

3. Deflection testing and calculated in place elastic moduli provide valuable information & data.

4. Use of 4 drop heights is probably not necessary for rehabilitation designs.

Some Final Comments

5. There are many applications of the backcalculated data in day to day rehabilitation designs.
   a) Determine the change in the PCC modulus over time for different repair techniques.
   b) Determine difference in responses for different design strategies and/or materials.
   c) Confirm MEPDG hypothesis that damage softens material – which can be estimated from deflection basin tests.
   d) Estimate coefficients of fatigue cracking transfer function between damage and amount of cracking.
   e) Confirm use of in place damage index to plan/schedule rehabilitation or preventive maintenance.

Questions