RUSS COLLEGE of Engineering and Technology

Incorporating Chemical Stabilization of the Subgrade into Flexible Pavement Design

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Presentation Outline

- **Background**
- Flexible Pavement Design/Analysis
- In-Situ Methods to Determine Layer Coefficient and modulus
- Results

Background

Incorporating Chemical Stabilization of the Subgrade in Pavement Design and Construction Practices

- Principal Investigator: Shad Sargand, Ohio University.
- Co Authors
  - Issam Khoury (OU)
  - Jayson Gray (OU)
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- State Job No. 134659
- Start date: February 27, 2012
- Completion date: September 30, 2014 (31 months)

Background

Research Objectives

- Evaluate the longevity and durability of chemically stabilized subgrade soils
- Examine the modulus or stiffness as determined by DCP and FWD data.
- Use finite element modeling to determine the level and nature of stresses and strains on untreated subgrade under the stabilized subgrade layer.
- Determine how the design of a flexible pavement should be modified when the subgrade is chemically stabilized.

Background

Research Objectives

- Compare and contrast the AASHTO 93 procedure to the procedure recommended by Chou et al (2004).
- Review the mix design properties of chemically stabilized subgrade soils currently used by ODOT. Conduct an analysis to determine what thickness and minimum strength of chemically stabilized layer is necessary for construction and pavement design purposes.

Background

Test Sites

- Chemical Stabilization Type
  - Lime
  - Cement
- Varying Age
  - Study Durability
- State Wide
  - Various Soil Types
- Volume Distribution
  - Interstate/US-Highway/State Route
- Minimum 20 Sites

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Flexible Pavement Design/Analysis

AASHTO Pavement Design Guide

- 1993 AASHTO Guide for the Design of Pavement Structures

$$\log_{10}(W_{18}) = Z_R \times S_o + 9.36 \times \log_{10}(SN+1) - 0.20 + \frac{\log_{10}\left[\frac{\Delta PSI}{4.2-1.5}\right]}{0.40+\frac{1094}{(SN+1)^{5.19}}} + 2.32 \times \log_{10}(M_R) - 8.07$$

Where

$$SN = a_1 D_1 + a_2 D_2 m_2 + a_i D_i m_i \ldots$$

and a_i is the layer coefficient

typical values:

Asphalt surface course – 0.44

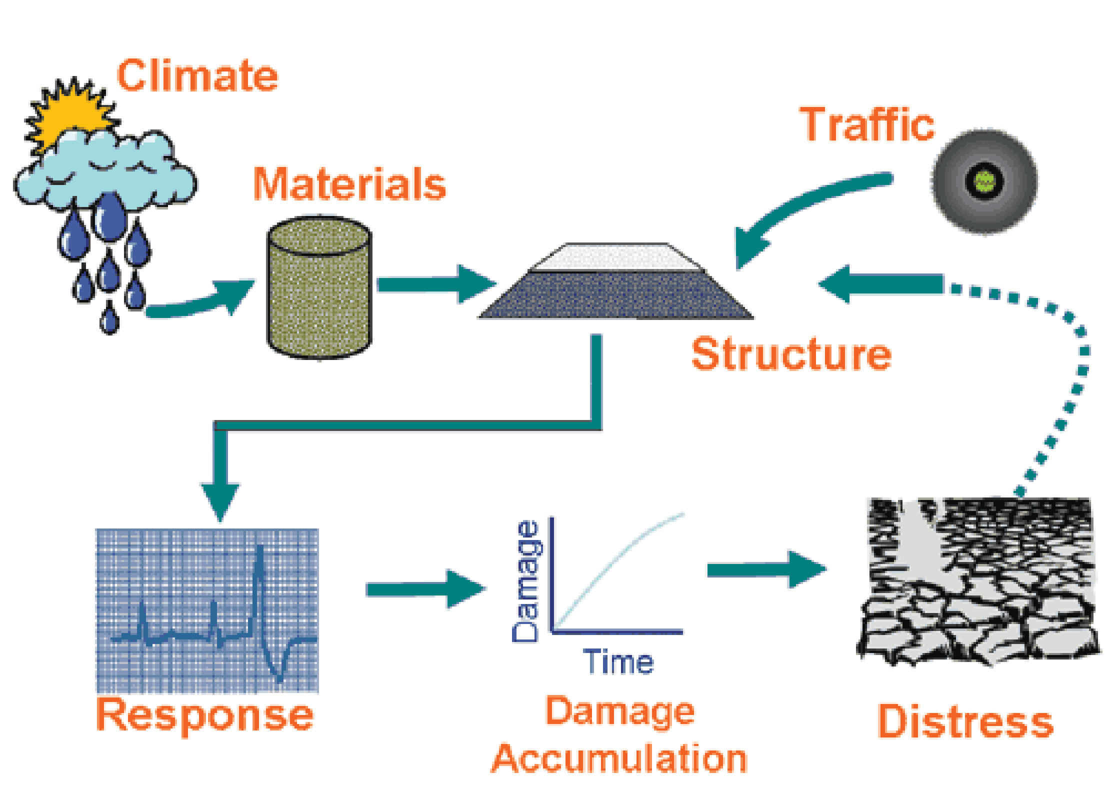
Aggregate Base – 0.14

Aggregate subbase course – 0.11 [AASHTO, 1993].

Flexible Pavement Design/Analysis

Mechanistic/Empirical Pavement Analysis

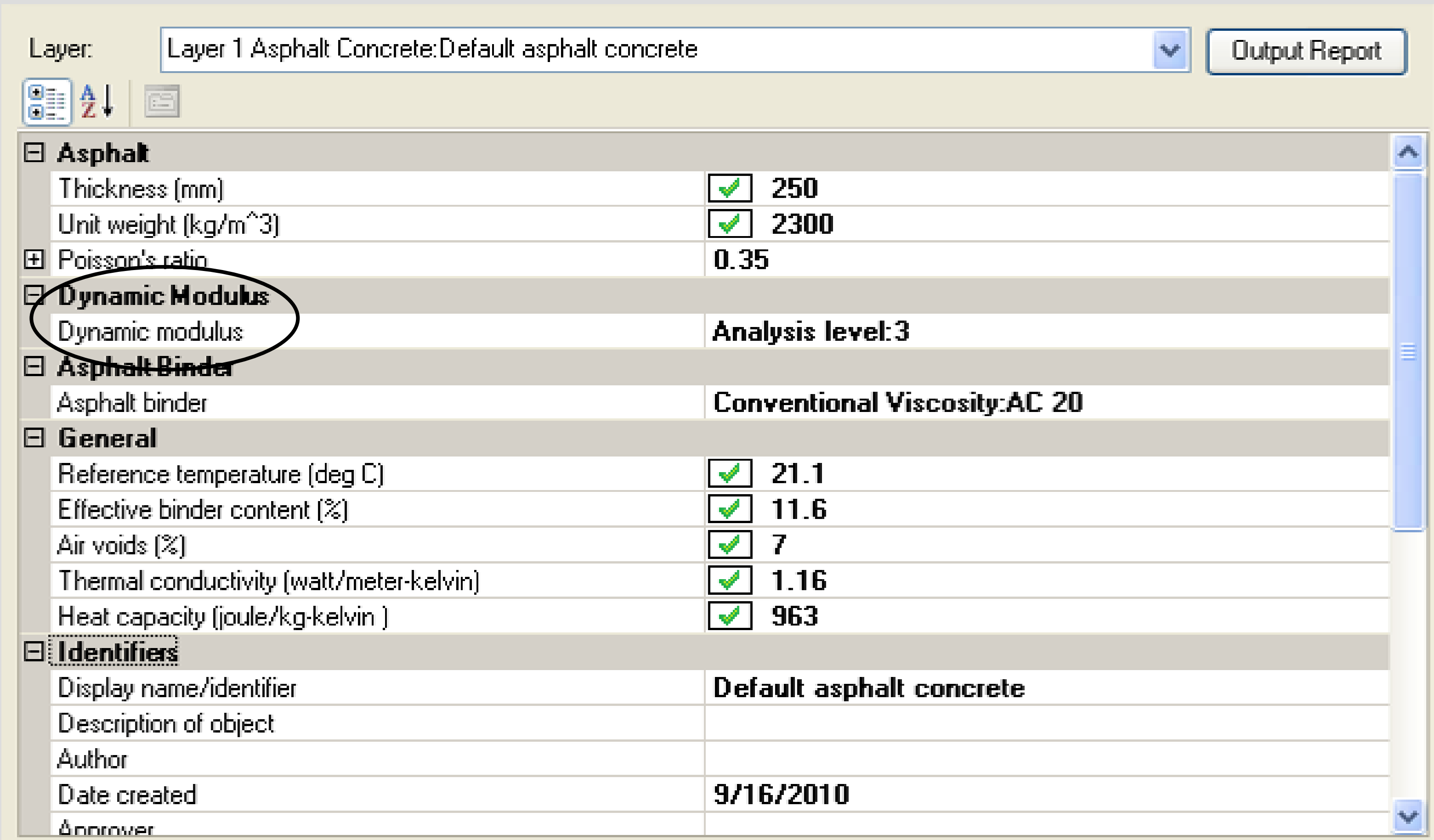
- Material mechanical properties and traffic loadings are used to calculate stress and strain
- Transfer functions are used to predict pavement distresses
- Predicted distresses are compared to allowable
- Reliability of trial section is determined



Flexible Pavement Design/Analysis

Mechanistic/Empirical Pavement Analysis

- Modulus is one of the material properties used by AASHTO software to predict stress/strain



Presentation Outline

- Background
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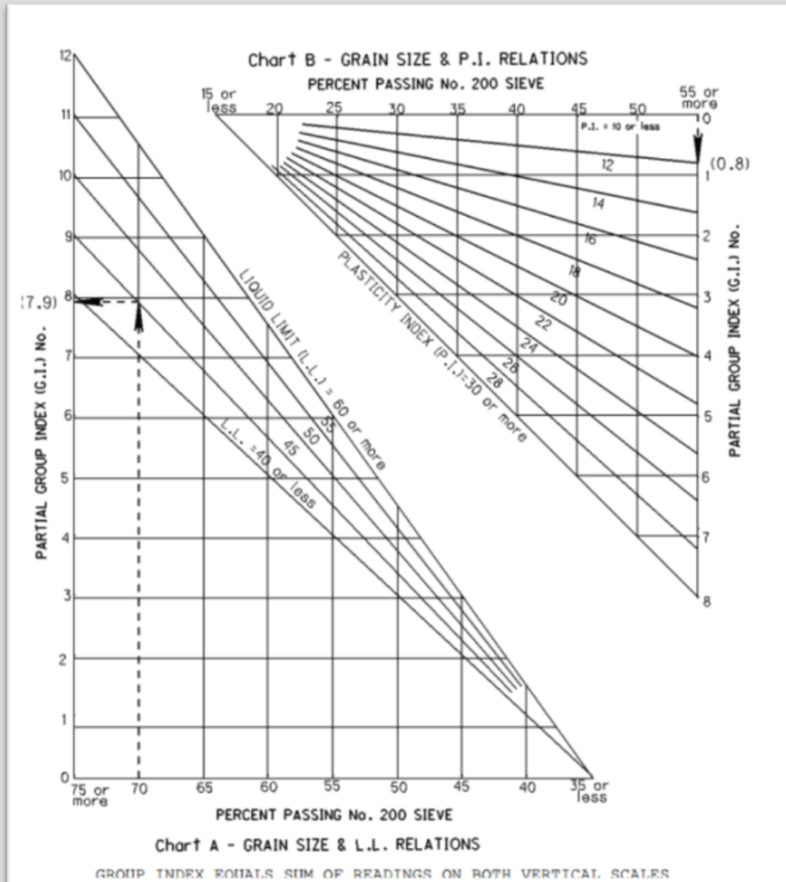
- **In-Situ Methods to Determine Layer Coefficient and modulus**
- Results

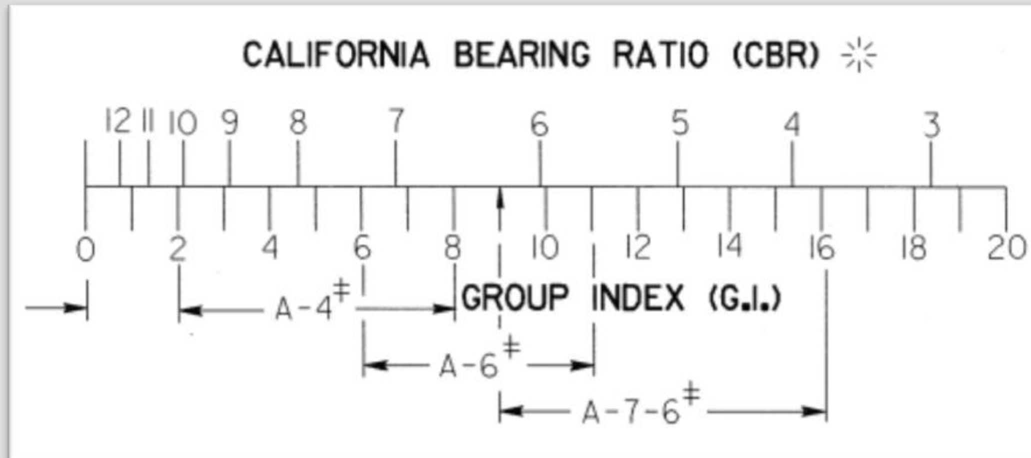
In-Situ Methods

- Soil Boring
- Coring
- Dynamic cone penetrometer (DCP)
- Portable seismic properties analyzer (PSPA)
- Falling weight deflectometer (FWD)

In-Situ Methods

Soil Boring / Group Index





M_R (soil) = 1200 x CBR

In-Situ Methods

Coring

Coring Rig

Cores provide pavement thickness, samples for lab testing, and access for testing of base/subgrade

Measuring Pavement Thickness

In-Situ Methods

Dynamic Cone Penetrometer (DCP)

Determining thickness and strength/stiffness of base/subgrade layers with DCP

In-Situ Methods

Analysis of DCP data

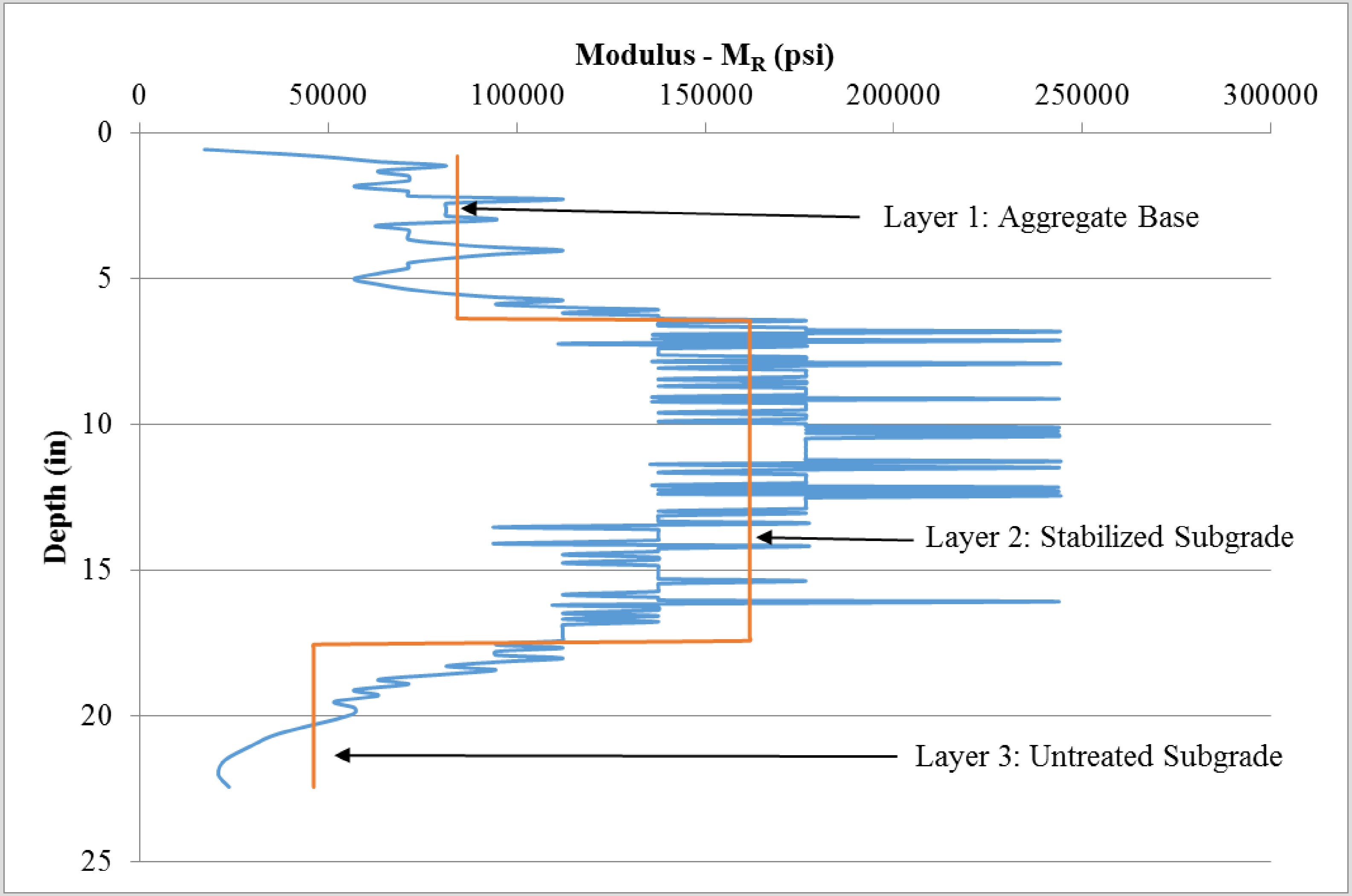
- Step 1 – Noise Reduction
  - Disregard any blows with depth change less than 0.04 inches.
- Step 2 - Conversion to CBR / M_R
  - $CBR = \frac{292}{PR^{1.12}}$
  - $M_R = 1200 * CBR$
- Step 3 – Identify Uniform Layers
  - $A(x) = \int_0^x R dx$
  - $R_a = \frac{\int_0^a R dx}{a}$
  - $A_a(x) = Ra * x$
  - $Z(x) = A(x) - Aa(x)$

PR – Penetration Rate (Depth per Blow)
CBR – California Bearing Ratio
M_R – Resilient Modulus
R - Resilient Modulus
A(x) – Cumulative Area
R_a – Average Response
$A_a(x)$ – Cumulative Average Area
Z(x) – Difference of Area and Average Area

*Wu & Sargand (2007)

In-Situ Methods

DCP – Identify Uniform Layers



In-Situ Methods

DCP Analysis

- <u>Step 4 Determine Structural Number (Layer Coefficient)</u>

B. K. Roy (2007)

$$DCPN_i = SN_i \, X \, T_i$$

where

$DCPN_i$ = i^th layer DCP number

BR_i = i^th layer blow rate

T_i = i^th layer thickness

$$SN_i = \frac{DCPN_i}{38.98}$$

where

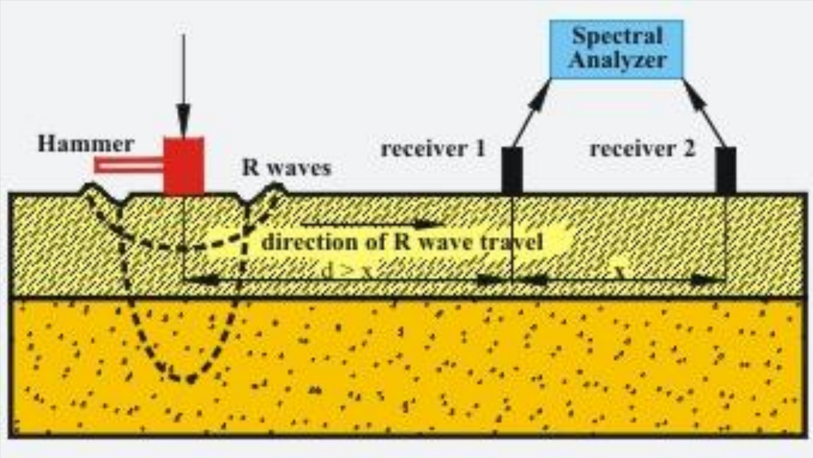
SN_i = i^th layer structural number

In-Situ Methods

Portable Seismic Pavement Analyzer (PSPA)

- Seismic Analysis

  Determination of surface layer modulus by analysis of the surface waves generated by an impact load



$$E = 2(\rho \times V_S^2)(1 + \upsilon)$$

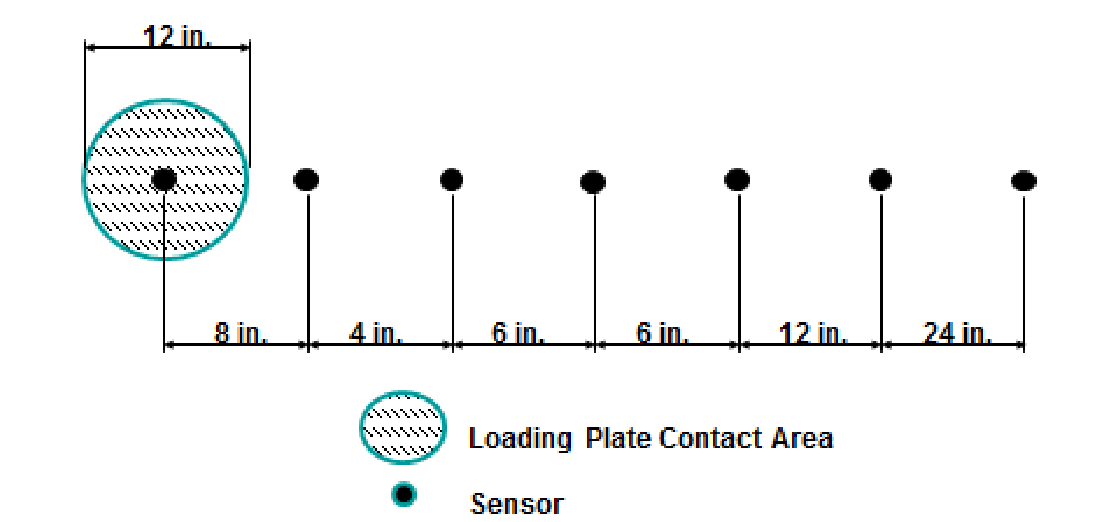
*http://www.ndt.net/article/ndtce2009/papers/69.pdf

In-Situ Methods

Deflection Based

Falling Weight Deflectometer (FWD)

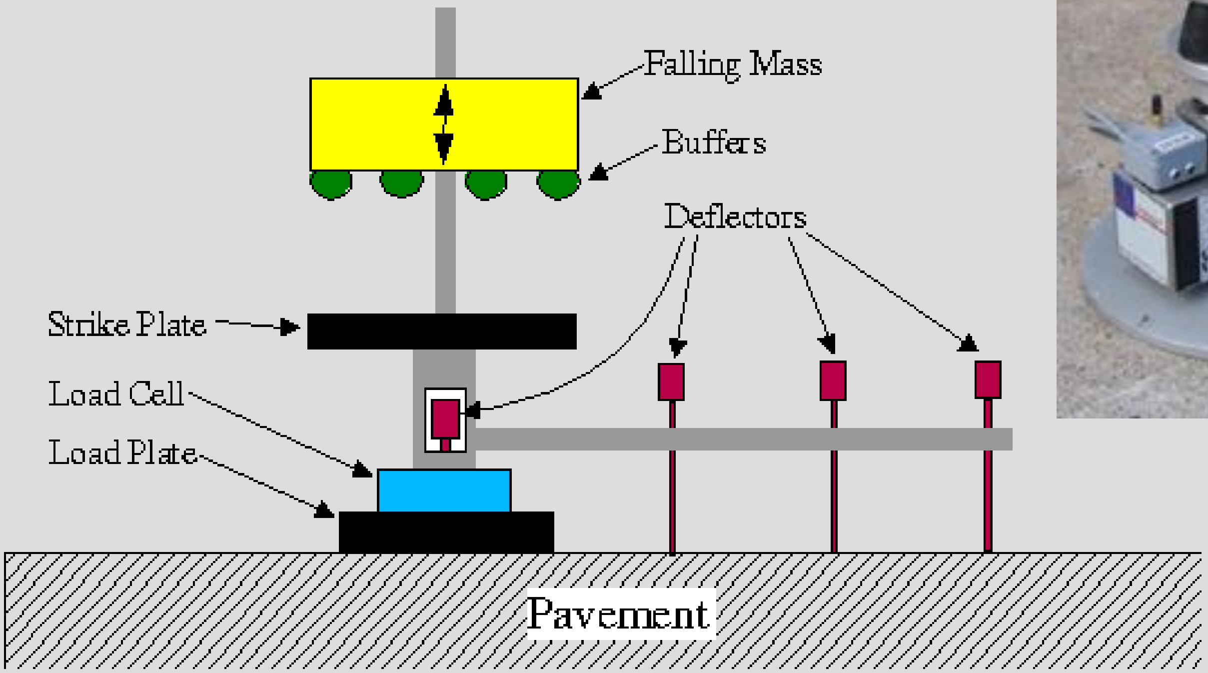
FWD sensor configuration



In-Situ Methods

Deflection Based

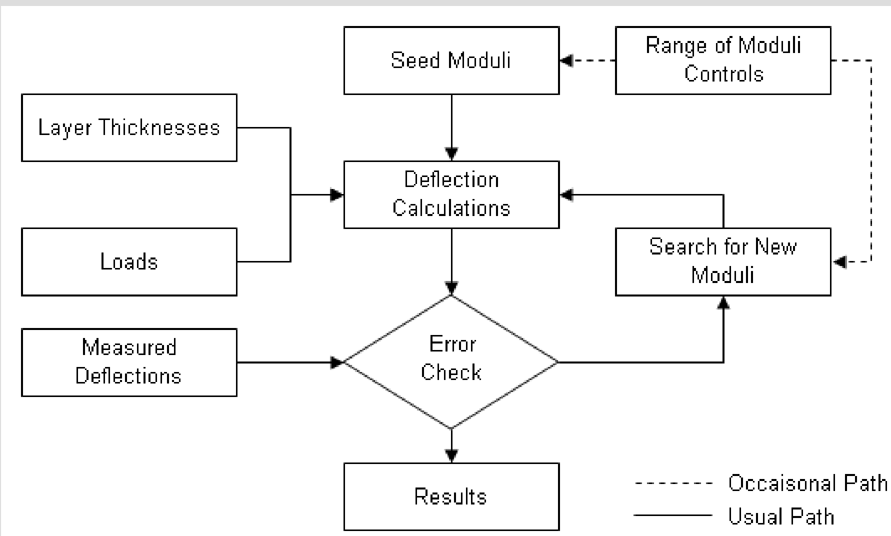
Lightweight Falling Weight Deflectometer (LFWD)

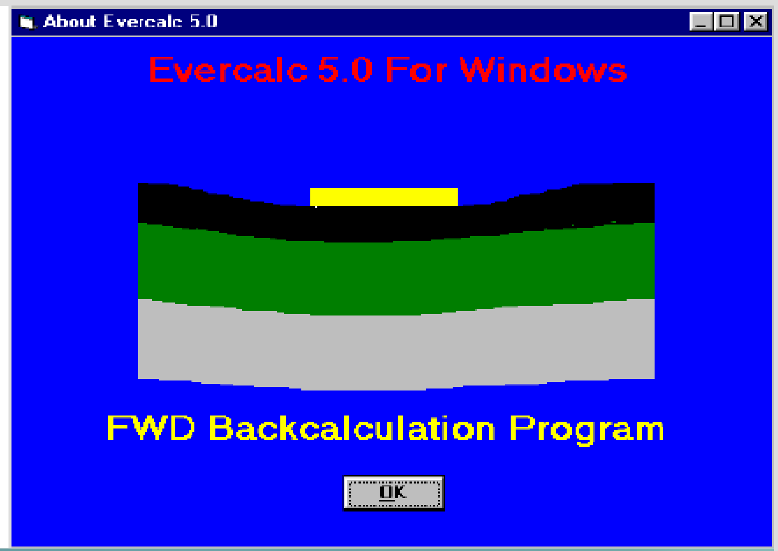


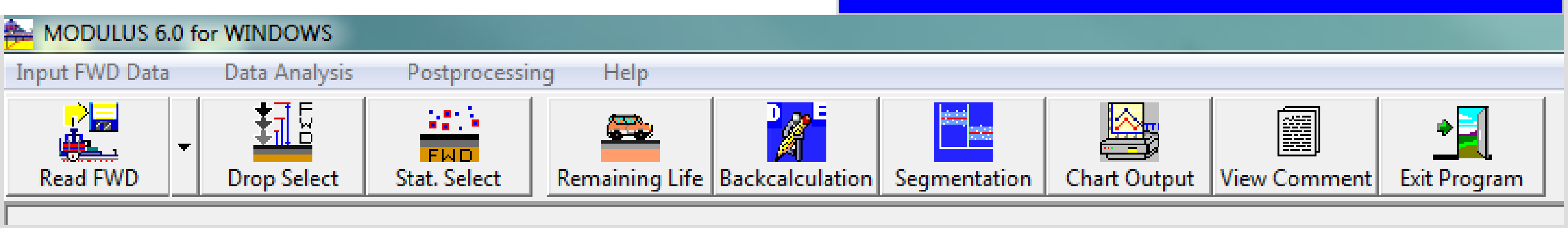
In-Situ Methods

Deflection Based

Determination of modulus of all pavement layers using backcalculation software such as MODULUS 6.0, EVERCALC, etc.







In-Situ Methods

Deflection Based

Determination of Structural Number (layer coefficient)

[AASHTO Section 5.4.5]

$$Design\ M_R = \mathrm{C}\left(\frac{0.24P}{d_r r}\right)$$

Where P = applied load, pounds
d_r = deflection at distance r from the center of the load, inches
r = distance from the center of the load, inches
C = a correction factor. The recommended C = 0.33

$$d_o = 1.5pa\left[\frac{1}{M\sqrt{1+\left(\frac{D}{a}\sqrt[3]{\frac{E_P}{M_R}}\right)^2}} + \frac{1-\frac{1}{\sqrt{1+\left(\frac{D}{a}\right)^2}}}{E_P}\right]$$

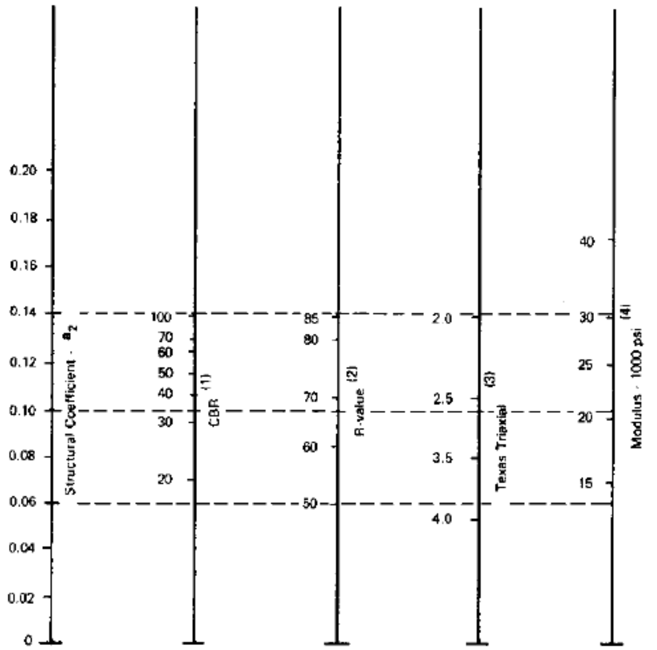
Where d_0 = deflection measured, in inches, at the center of the load plate adjusted to a standard temperature of 68°F
p = NDT load plate pressure, psi
A = NDT load plate radius, inches
D = total thickness of pavement layers above subgrade, inches
M_R = subgrade resilient modulus, psi

$$SN_{eff} = 0.0045D\sqrt[3]{E_P}$$

In-Situ or Lab Method

Modulus Based

Determination of Structural Number (layer coefficient) for Aggregate Base [AASHTO Section 2.3.5]



(1) Scale derived by averaging correlations obtained from Illinois.
(2) Scale derived by averaging correlations obtained from California, New Mexico and Wyoming.
(3) Scale derived by averaging correlations obtained from Texas.
(4) Scale derived on NCHRP project (3).

Figure 2.6. Variation in Granular Base Layer Coefficient (a_2) with Various Base Strength Parameters (3)

$$a_2 \cong 0.249\left(\log_{10} E_{base}\right) - 0.977$$

E_{base} in psi

(AASHTO, 1993)

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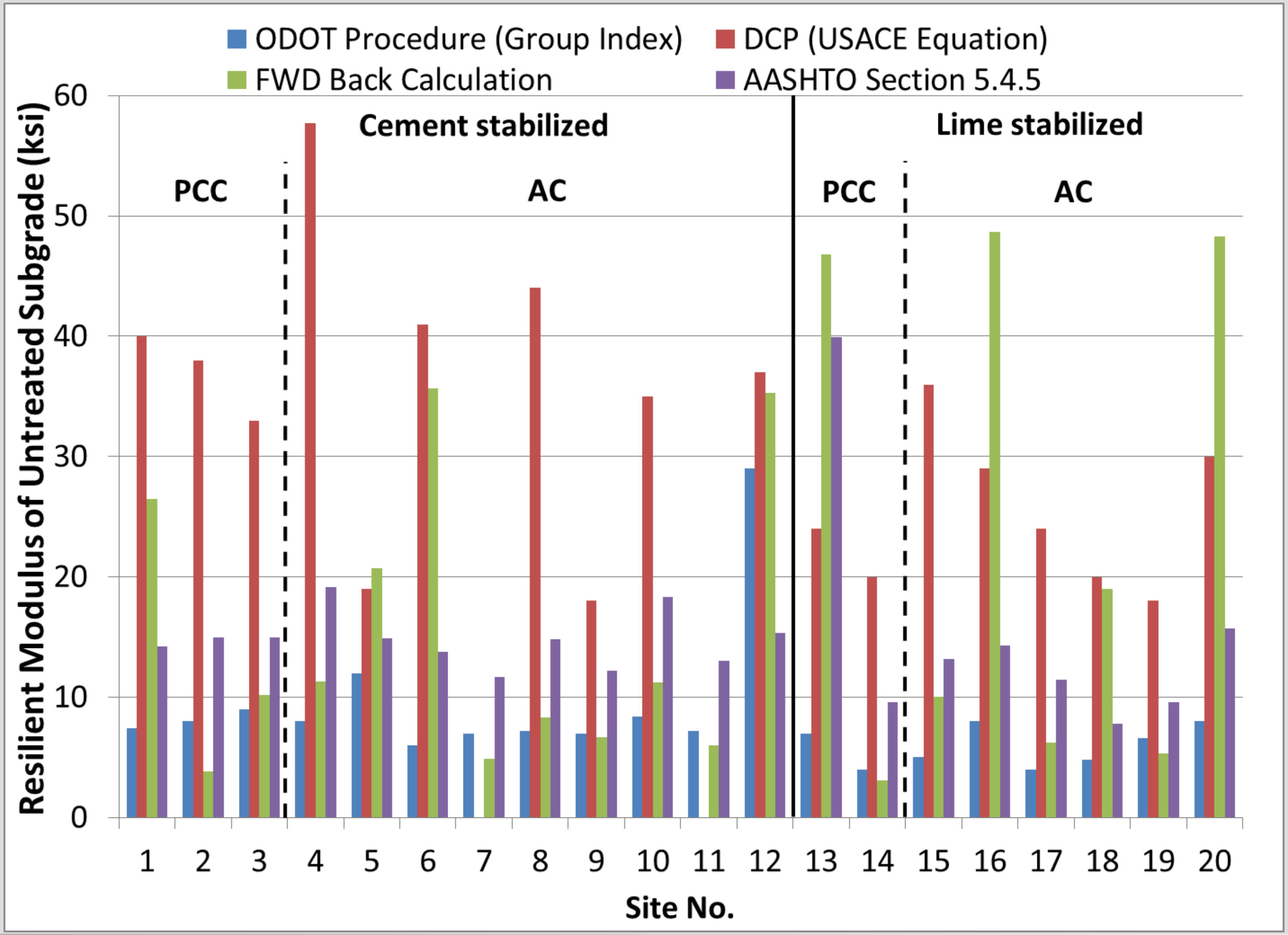
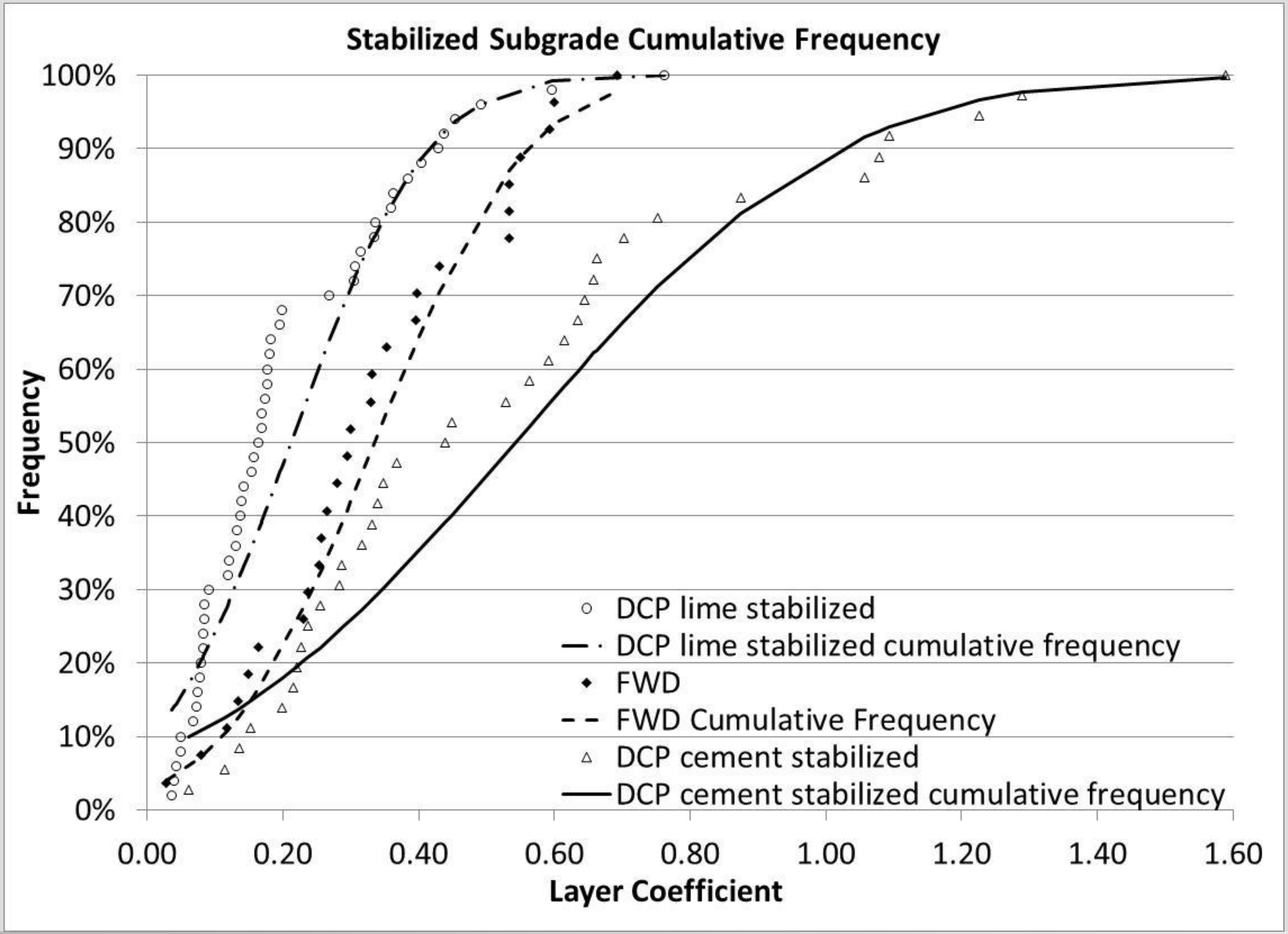
Results Untreated Subgrade

Modulus



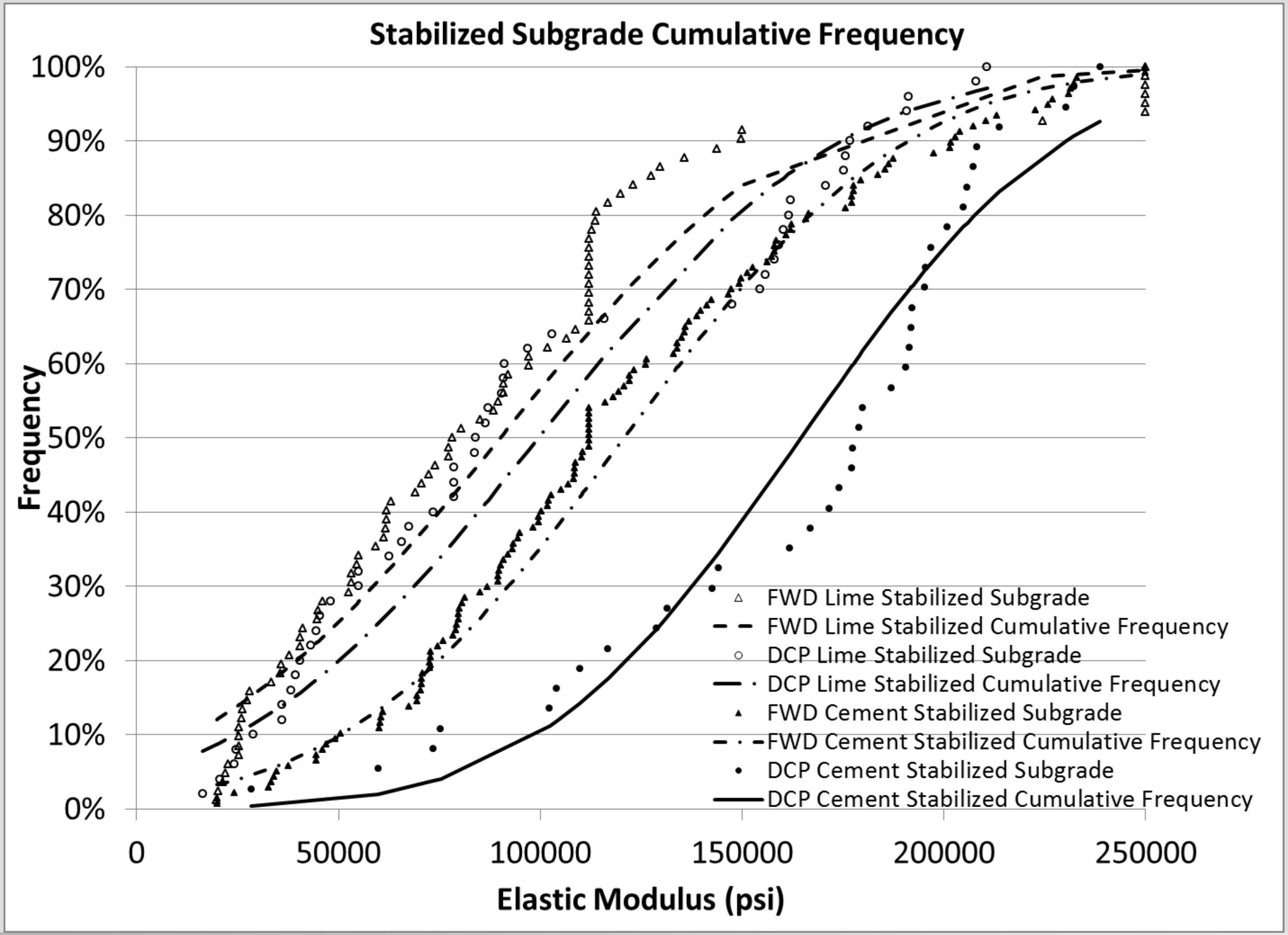
Results Stabilized Subgrade

Layer Coefficient



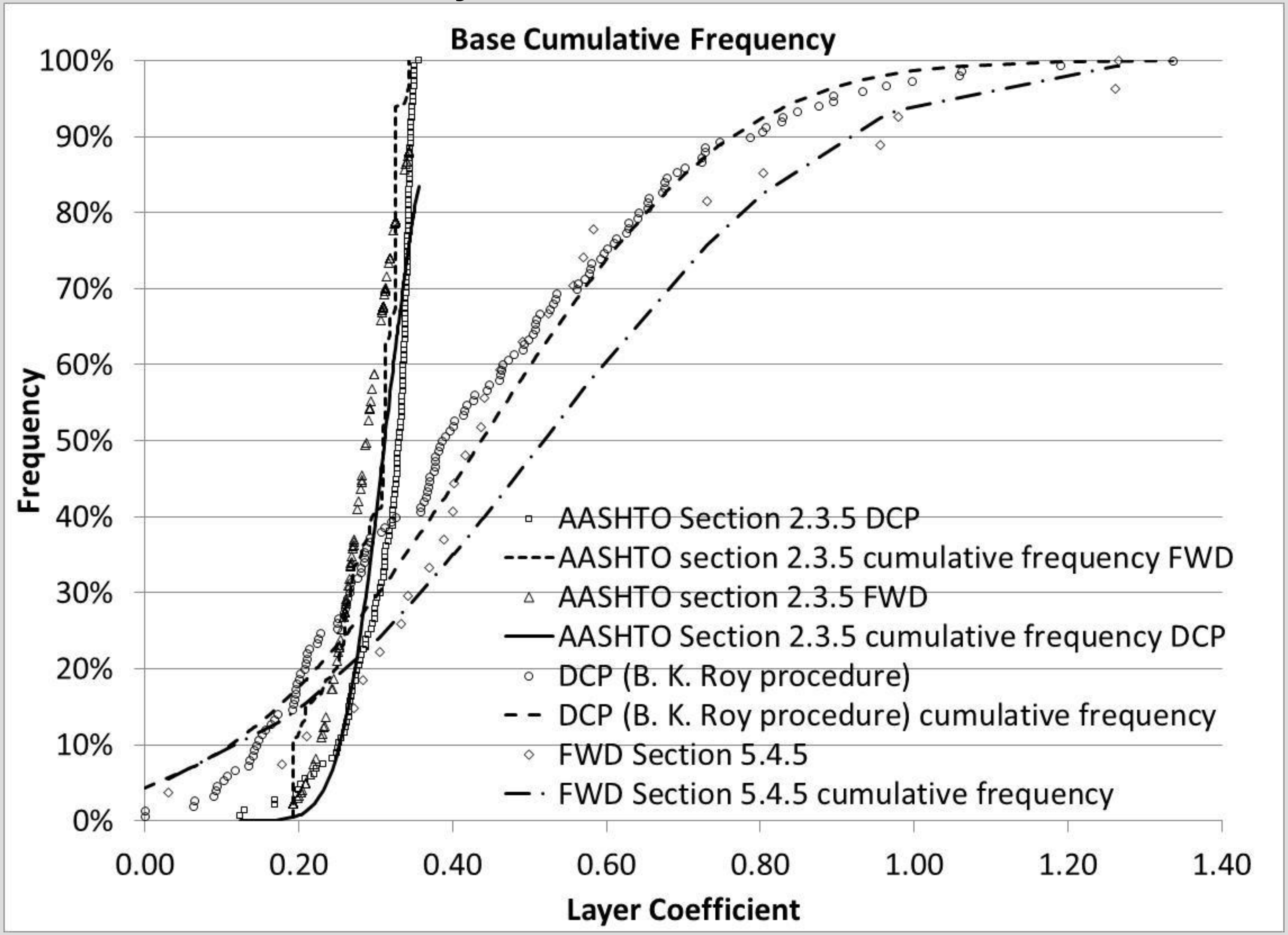
Results Stabilized Subgrade

Modulus



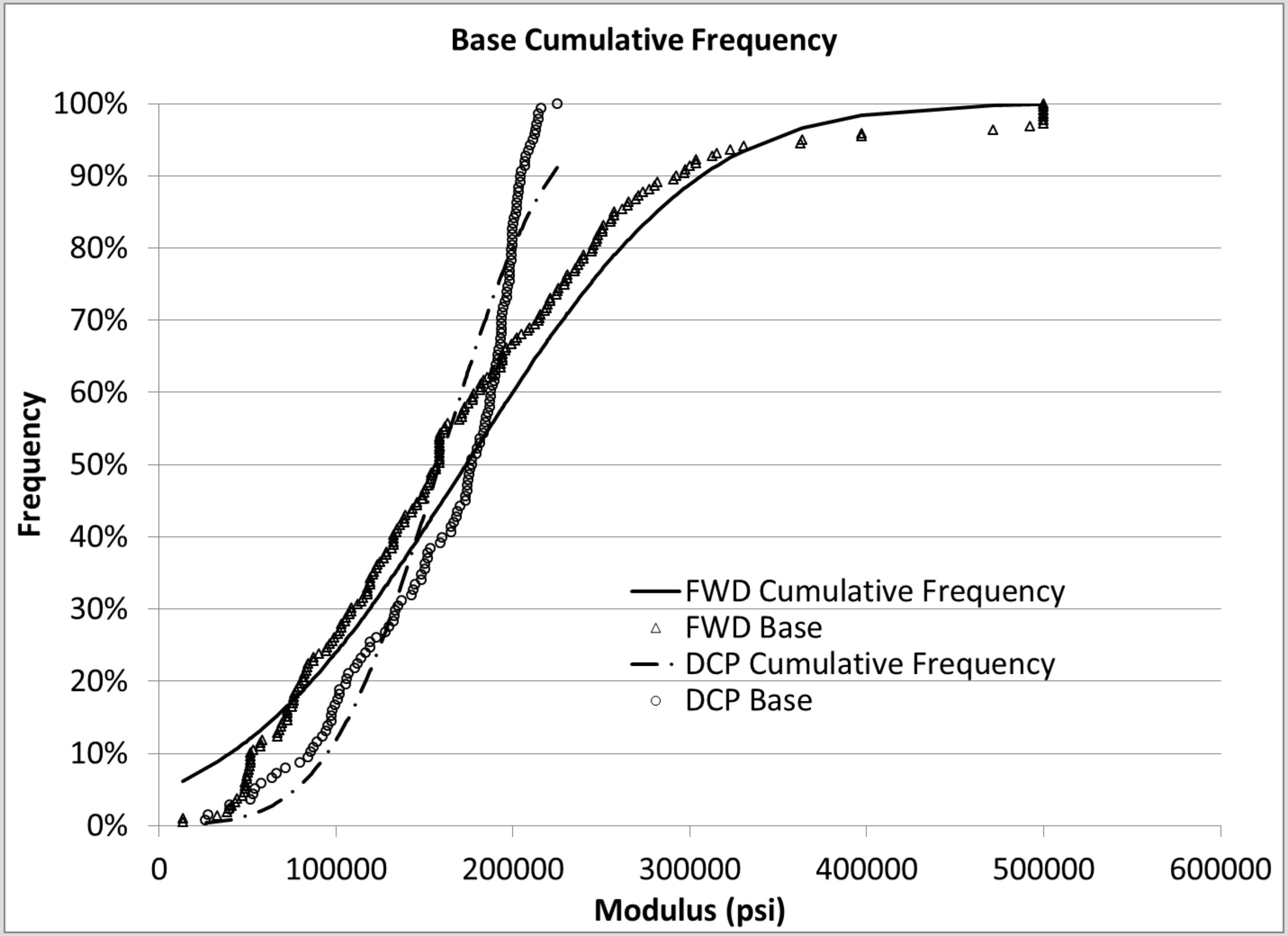
Results Aggregate Base

Layer Coefficient

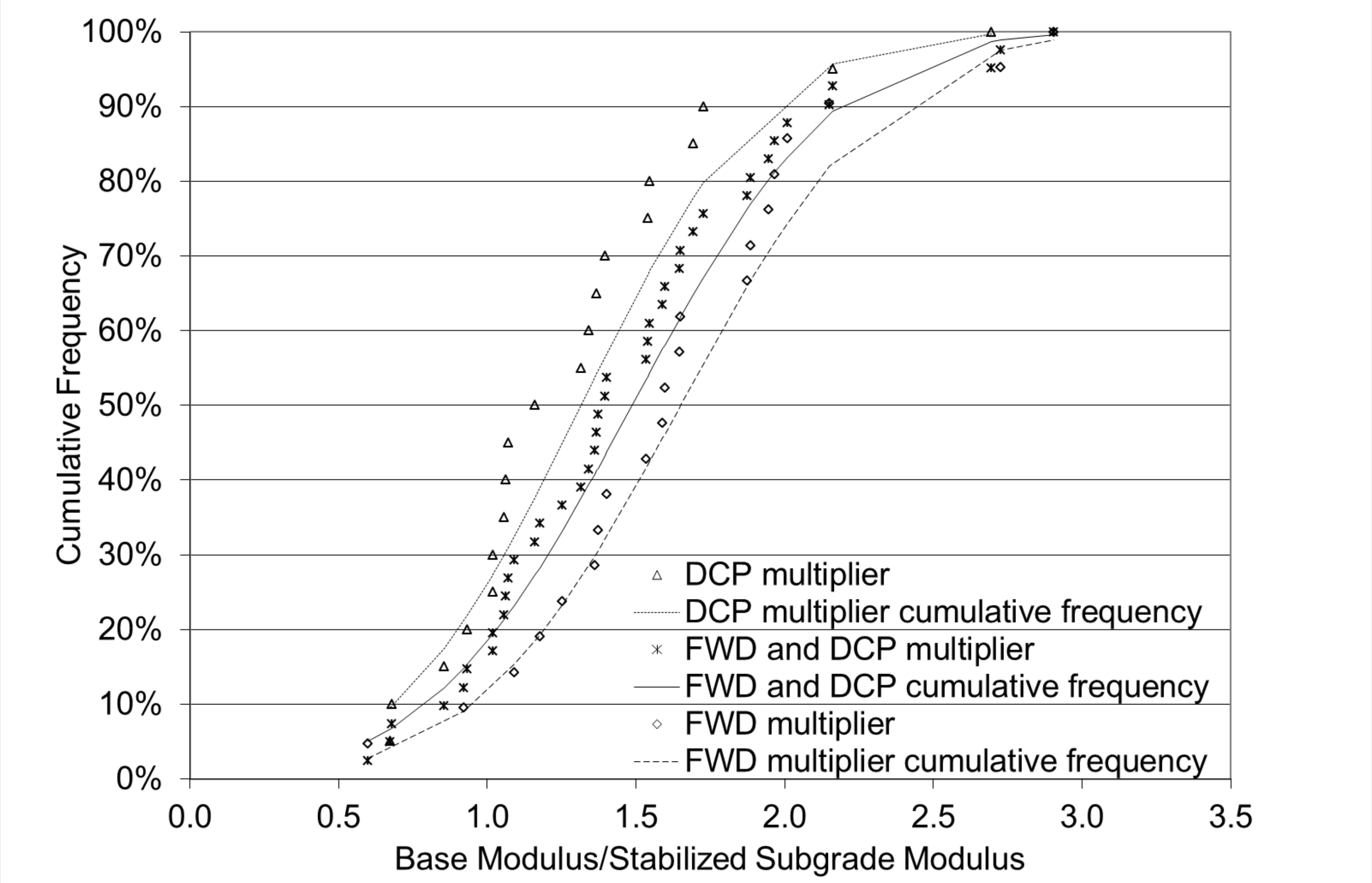


Results Aggregate Base

Modulus



Results Stabilized Subgrade and Aggregate Base



Conclusions

- As borne out by FWD and DCP measurements, both cement stabilization and lime stabilization resulted in significant long term increases in the modulus of the stabilized subgrade relative to the unstabilized subgrade,
- Current construction procedures will effectively chemically stabilize approximately 85% of the design thickness for cement, and 80% for lime.
- The modulus and stiffness of the base is increased because it is confined by the stabilized soil underneath and the pavement on top.

Conclusions

- The significant increase in the modulus of the base and stabilized subgrade may justify decreasing the thickness of flexible pavement layer. However, there are other factors to be considered in the final pavement design which can also impact pavement performance.

- Final report available at: http://www.dot.state.oh.us/Divisions/Planning/SPR/Research/Pages/Publications.aspx

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http://www.ohio.edu/orite/