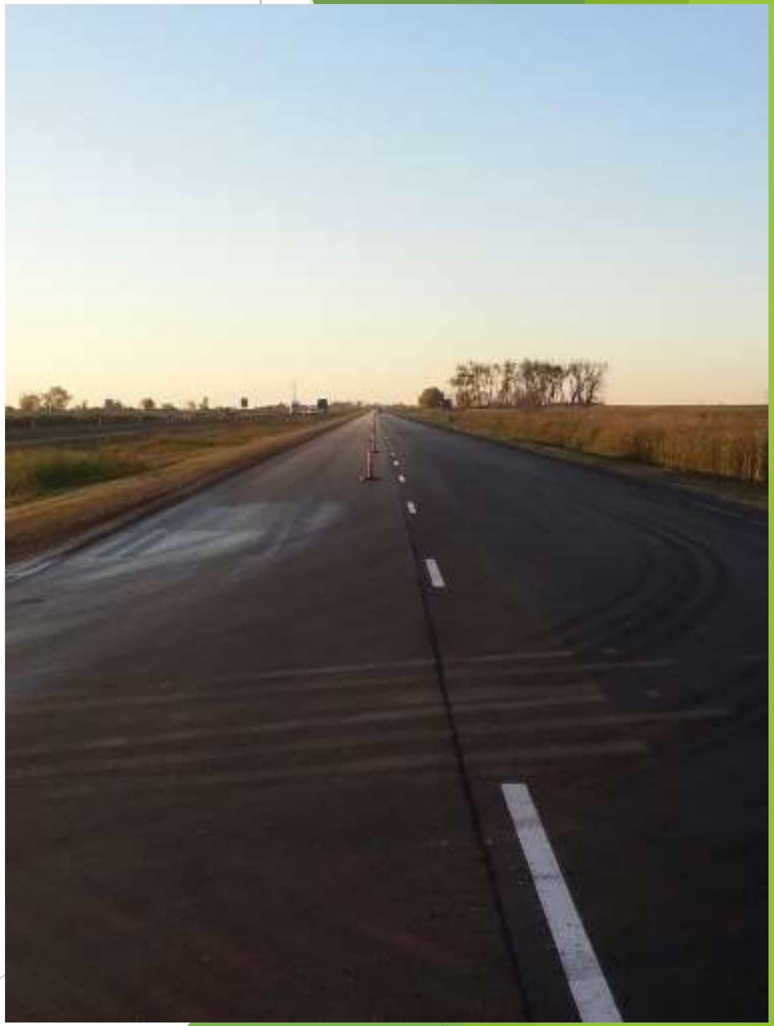
2015 North Dakota Asphalt Conference

April 1, 2015
Bismarck, ND

Ken Swedeen
Dakota Asphalt Pavement Association

Pavement Design

- A highway pavement is a structure consisting of superimposed layers of processed materials above the natural soil subgrade. The primary function of a pavement is to distribute applied vehicle loads to the subgrade in the ENVIRONMENT which it operates. It should due so minimizing distress and at an acceptable ride quality for it's design life.
- A highway pavement should also be maintainable, minimize impact on users and businesses while maximizing accessibility, be safe or have an acceptable skid resistance, and minimize environmental and aesthetic impacts including noise pollution and light reflectance. All of these additional requirements should be met in the ENVIRONMENT which it operates.



Pavement Design

- Placing an efficient, economical and effective pavement requires at least three important steps:
  - Accurate Assessment of Existing Conditions
    - Subgrade Support, Drainage, Environmental Conditions
    - Current Traffic and Future Traffic (Future Development)
    - Availability and Suitability of Materials (Specifications)
  - Selection of Proper Mix Type(s) & Materials (Construction)
  - Pavement Design - Layer and Thickness
    - Method verified academically
    - Method correlated/calibrated locally

Pavement Design

- Prior to 1962 designs were “locally” calibrated and highly subjective
  - Post WWI Truck Traffic and ADT Tripled (1919-1929)
  - Post WWII Truck Traffic and ADT Doubled Again (1945-1955)
  - Rapid transportation expansion – Rapid transport expansion
  - 1942 ushered in almost universal 18,000 lb. axle limits on "low pressure" pneumatic tires with 32,000 lb. tandem limits – war time recommendations became the standard ~~ *heavier axle loads on “softer” tires with tandem transports*
- AASHO in 1955 initiated a "Road Test" via the HRB (TRB) to construct, instrument and develop a road test resulting in engineered pavement design criteria
  - The 1962 AASHO Road Test was modeled on a completed road test initiated by WASHO from 1952-1954 in southern Idaho

Pavement Design

- The AASHO Road Test was built, constructed, analyzed and deliverables developed (AASHO Design Guide) in 1962
  - Constructed on a “green field” portion of the under construction Interstate 80 between Ottawa and LaSalle, IL, about 80 miles SW of Chicago
  - 34-inch avg. rainfall, 25-in. avg. snow, 76 deg. avg. mean summer, 27 deg. avg. mean winter temperatures; multiple freeze-thaw w/ avg. frost depth 28-in.
  - Glacial subgrade (a-6/a-7-6) 1-2 ft. depth soils on substratum of a-7-6 soils another 2 ft. thickness interspersed with sand/gravel lens
  - Special Embankment (3-ft.) MDC of A-6 (Groups 9-13); PI~11 to 15; LL~27 to 32; 80%-85% -#200
  - ONE climate zone, ONE subgrade, LIMITED variables, construction methods and vehicles representative of the 1950’s.
  - Cost was approximately $127 million (ND’s share was $122,085!)

AASHO Road Test 1956-1960

Near Ottawa, Illinois

Road test determined relationship between axle load and road damage

$$\frac{W_x}{W_{18}} = \left[\frac{L_{18} + L_{2s}}{L_x + L_{2x}}\right]^{4.79} \left[\frac{10^{G/\beta_x}}{10^{G/\beta_{18}}}\right] \left[L_{2x}\right]^{4.33}$$

Pavement Response to Load

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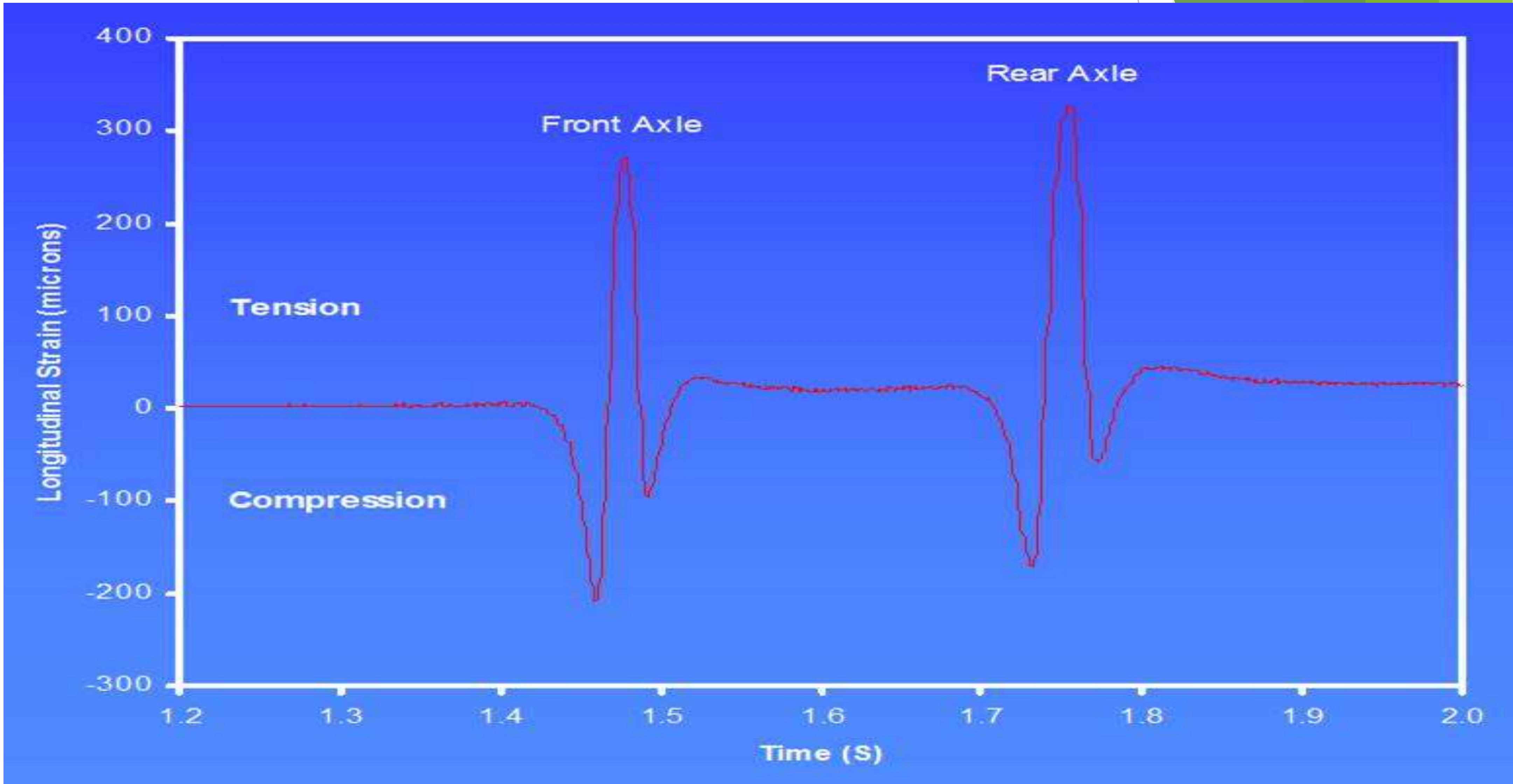
Strain at the Bottom of HMA



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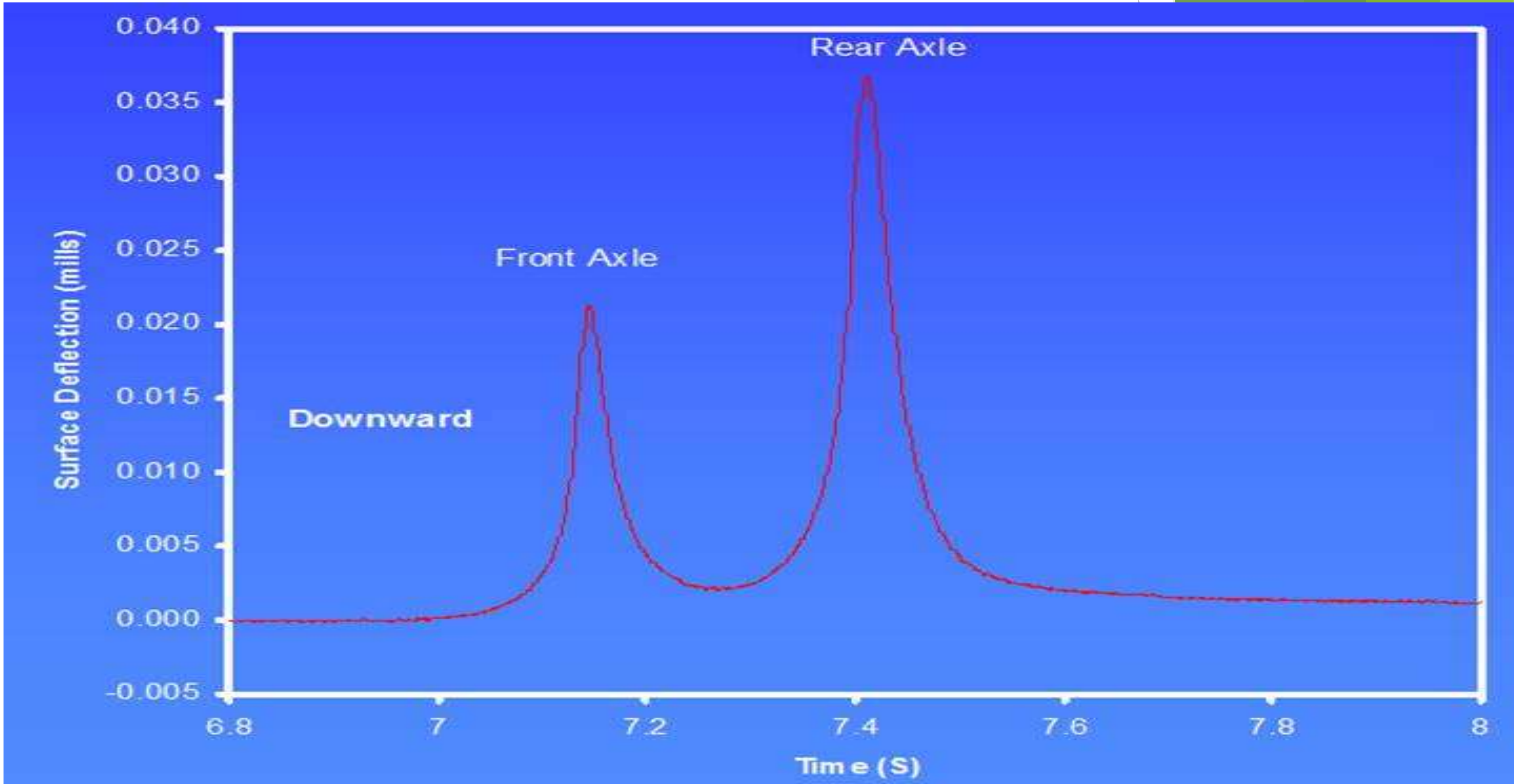
Pavement Deflection



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Relationship of Load to Damage

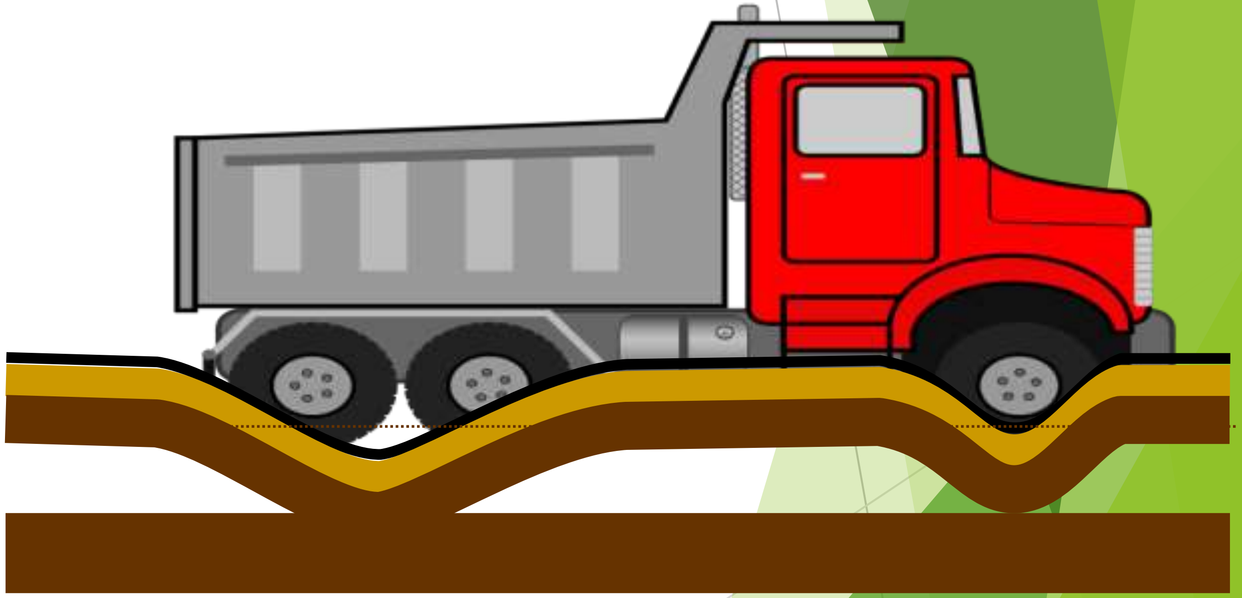
- Deflection *d* is proportional to axle group weight *W*

  $d \propto W$

- Damage *D* is proportional to 4^{th} power of deflection *d*

  $D \propto d^4$

  or $D \propto W^4$



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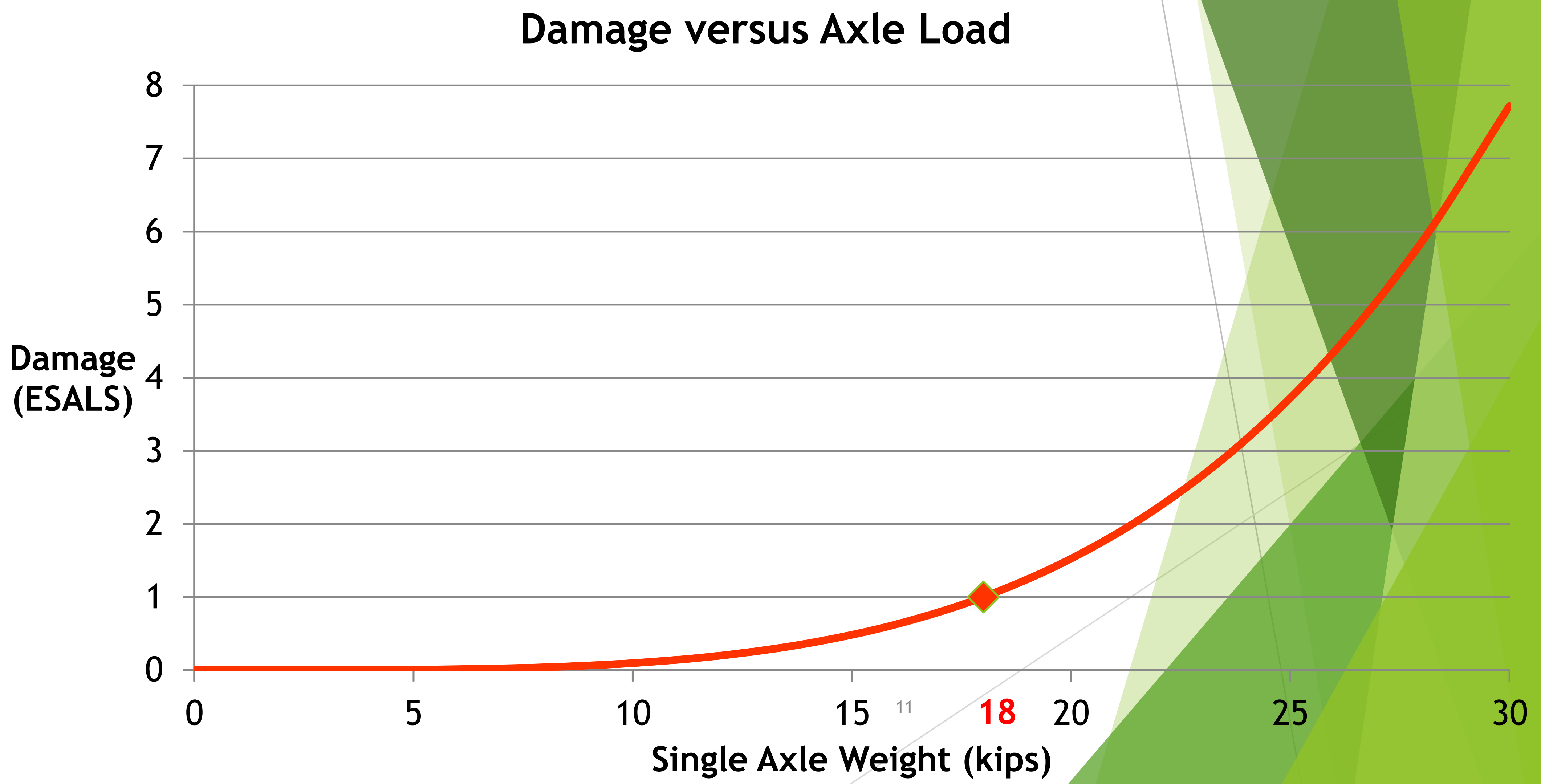
4th Power Damage Relationship



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Thickness Design Methods

- AASHTO Thickness Design
  - Used by most state DOTs
  - Based on structural number concept
- AASHTO MEP Design Guide
  - Future design method closing on ratification
  - Based on mechanistic design principles
- Asphalt Institute
  - SW-2
  - For pavements on highways, airports, HWL

Pavement Design

- Basic AASHTO 93/98 Pavement Design Guide
  - Determine the desired Terminal Serviceability (**p_t**)
  - Convert traffic volumes to number of Equivalent 18-kip Single Axle Loads (**ESAL**)
  - Determine the Structural Number (**SN**)
  - Determine Layer Coefficients (**a_i**)
  - Determine Moisture damage coefficients (**M_i**)
  - **Determine Reliability and Standard Deviate (S_0, Z_R)**
  - **Solve layer thickness equations for individual layer thickness**

Pavement Design
1993 AASHTO Design Guide

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

where: W_{18} = predicted number of 80 kN (18,000 lb.) ESALs

Z_R = standard normal deviate

S_o = combined standard error of the traffic prediction and performance prediction

SN = Structural Number (an index that is indicative of the total pavement thickness required)

= $a_1D_1 + a_2D_2m_2 + a_3D_3m_3 + \ldots a_i$ = ithlayer coefficient D_i = ithlayer thickness (inches) m_i = ith layer drainage coefficient

DPSI = difference between the initial design serviceability index, p_o, and the design terminal serviceability index, p_t

M_R = subgrade resilient modulus (in psi)

Pavement Design Serviceability

- Based on Present Serviceability Rating (PSR) of original AASHO Road Test
- Subjective rating by individual/panel
  - Initial/Post Construction
  - Through the life of pavement and effects of distress
- $0 < PSR < 5$
- $PSR < 2.5$ Poor or Unacceptable
- AASHTO 93 modified to Present Serviceability Index (PSI)
  - Correlated to physical measurements
  - Attempt to include distress factors as well as ride quality
  - Still empirical

Pavement Design Serviceability

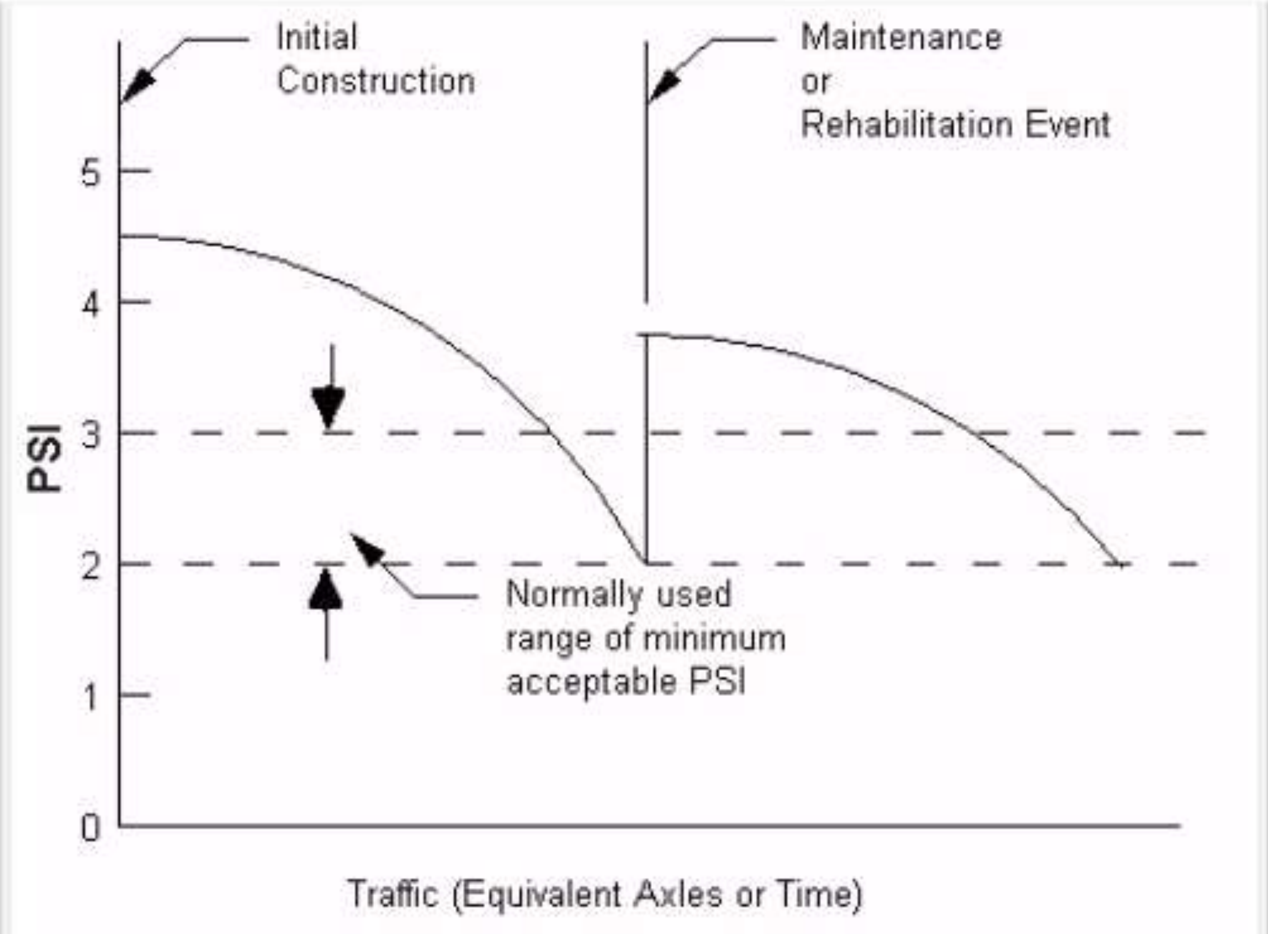


Figure 1. Concept of pavement performance using Present Serviceability Index (PSI) (Hveem and Carmany, 1948[2])

Pavement Design
Structural Number Concept

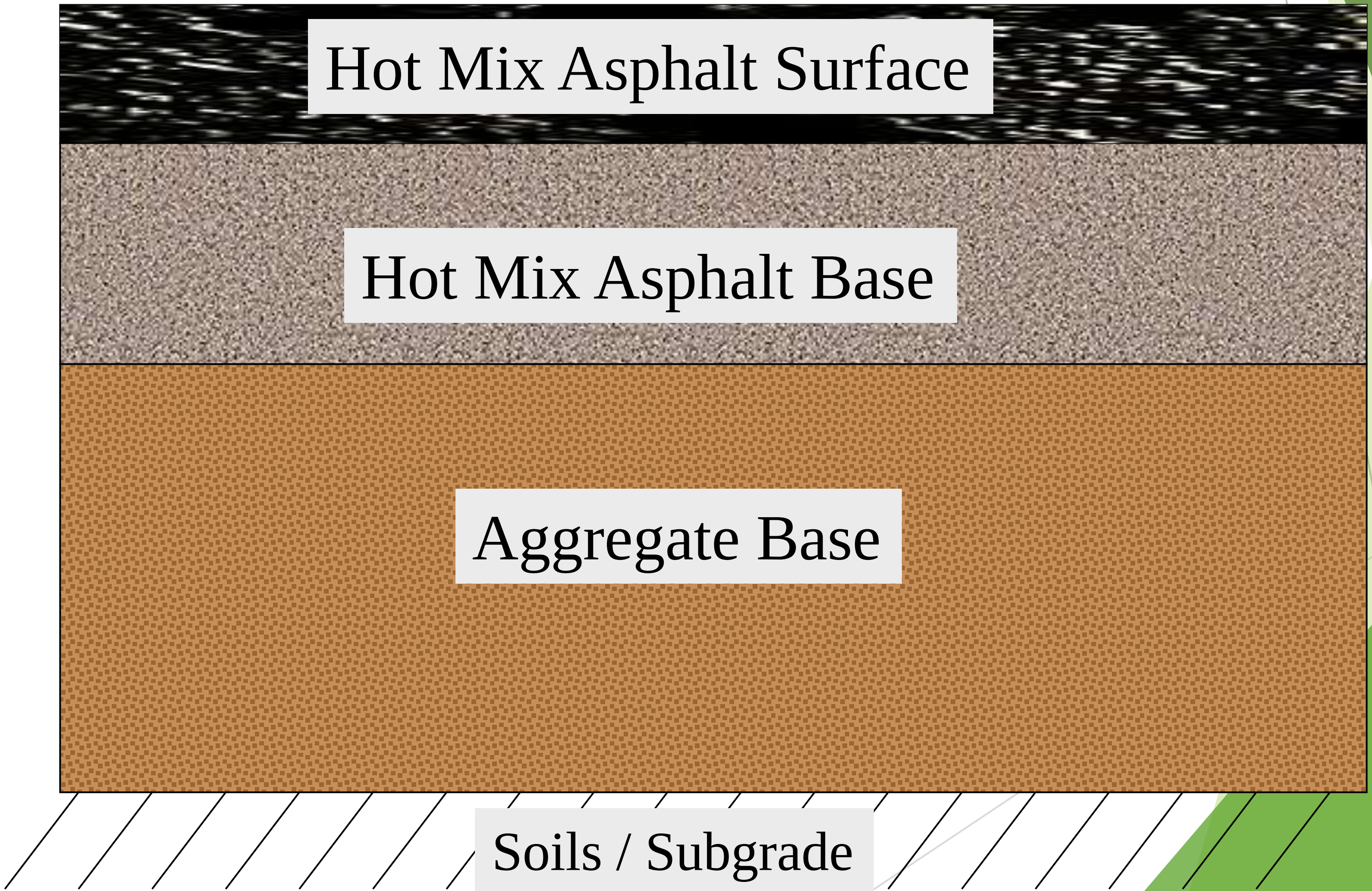
- Total structural number based on
  - number of equivalent loads over design period
  - subgrade support
- Structural number coefficients based on
  - Materials Type
  - Materials Condition
    - May be reduced for existing pavements with distress

$$SN = a_1D_1 + a_2D_2M_2 + a_3D_3M_3$$

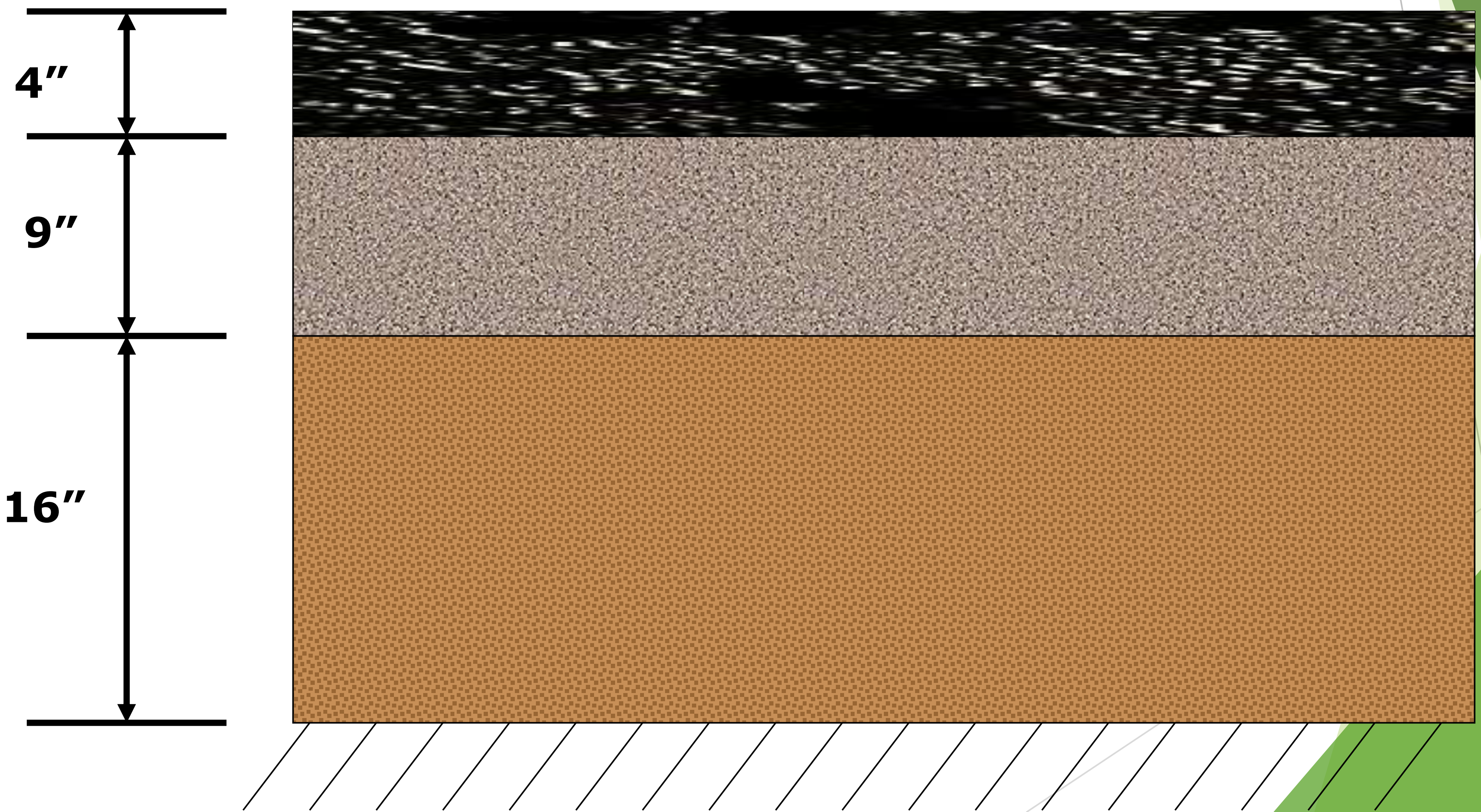
where:

- a_1, a_2, a_3 = structural-layer coefficients of the wearing surface, base, and subbase layers, respectively,
- D_1, D_2, D_3 = thickness of the wearing surface, base, and subbase layers in inches, respectively, and
- M_2, M_3 = drainage coefficients for the base and subbase, respectively.

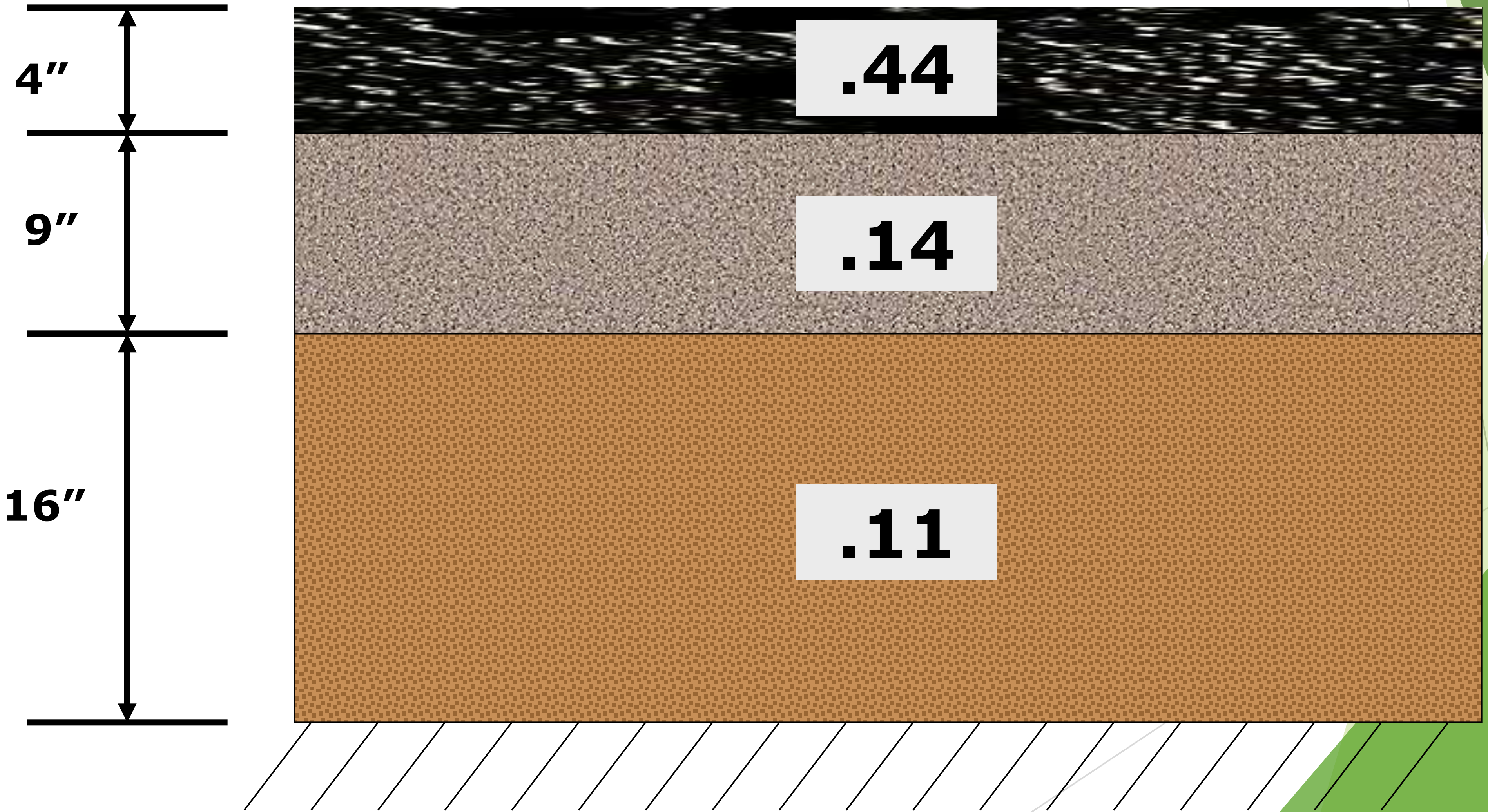
Pavement Design
Structural Number Concept



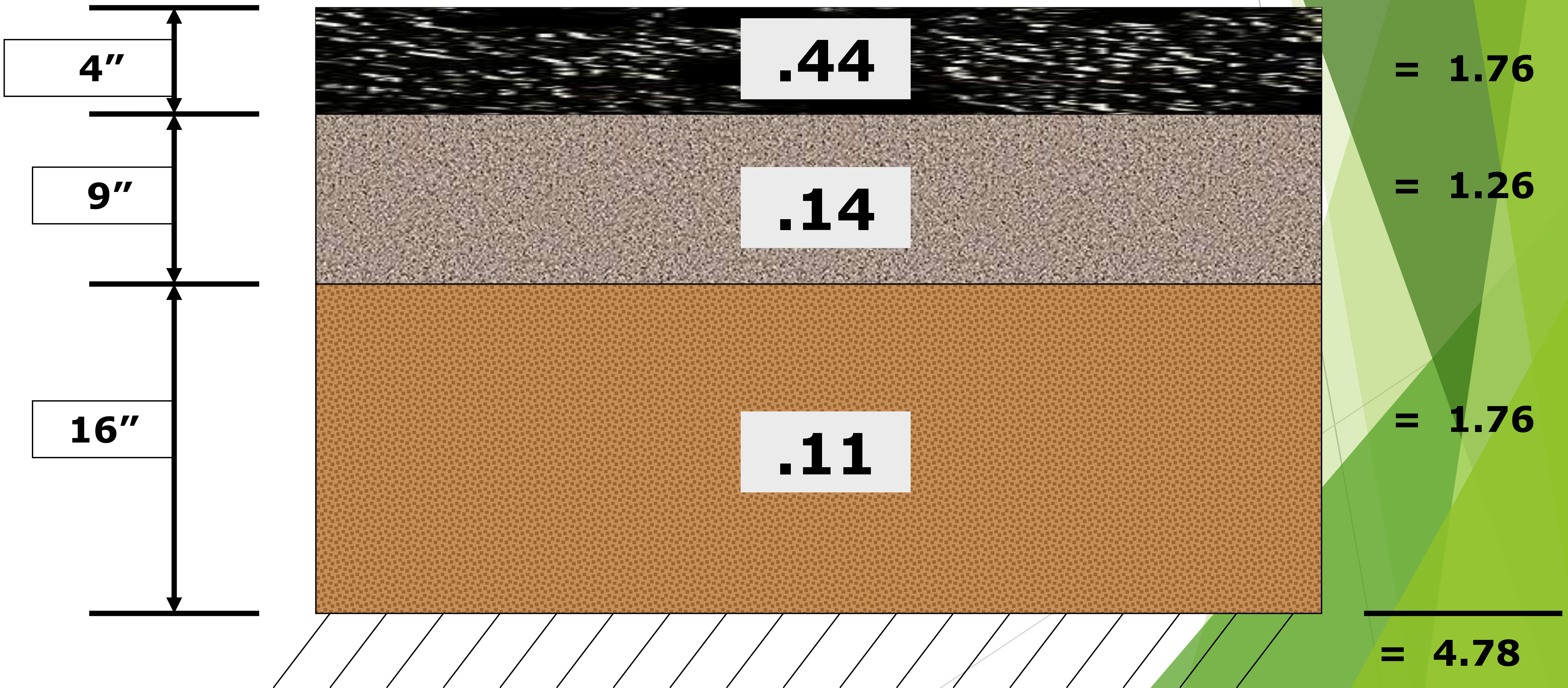
Pavement Design
Structural Number Concept



Pavement Design
Structural Number Concept



Pavement Design
Structural Number Concept



Pavement Design
Structural Number Concept

- The structural coefficient of a layer represents the relative strength of materials built into that layer

•ASPHALT CONCRETE STRUCTURAL COEFFICIENTS (a_i)	
Items 424, 442, 443, 446, 448, 826, 857, 859, 874 – AC Surface	0.43
Items 442, 443, 446, 448, 826, 857 – AC Intermed.	0.43
Items 301, 302 AC Base Course.	0.36
Item 304 – Aggregate Base	0.14
Item 320 – Rubblized Concrete	0.14

Ohio DOT Structural Coefficients (Example Only)

Pavement Design Reliability

"The reliability of the pavement design-performance process is the *probability* that a pavement section designed using the process will perform satisfactorily over the traffic and environmental conditions for the design period." (AASHTO, 1993[1])

AASHTO 93 Utilizes the *Reliability* concept to account for design uncertainty.
Reliability consists of two parts:

1. *Z_R or Standard Normal Deviate*: Desired probability of exceedance or a "miss". 5% Z_R ~~~~ *95% Reliability*
2. *S_O or Combined Standard Error*: Error in Traffic Prediction and/or Performance Prediction

Pavement Design Reliability

Table 1. Suggested Levels of Reliability for Various Functional Classifications (from AASHTO, 1993[1])

Functional Classification	Recommended Level of Reliability	
	Urban	Rural
Interstate and Other Freeways	85 – 99.9	80 – 99.9
Principal Arterials	80 – 99	75 – 95
Collectors	80 – 95	75 – 95
Local	50 – 80	50 – 80

Typical values of S_o used are 0.40 to 0.50 for flexible pavements and 0.35 to 0.40 for rigid pavements.

Pavement Design
Use AASHTO 93 Wisely -

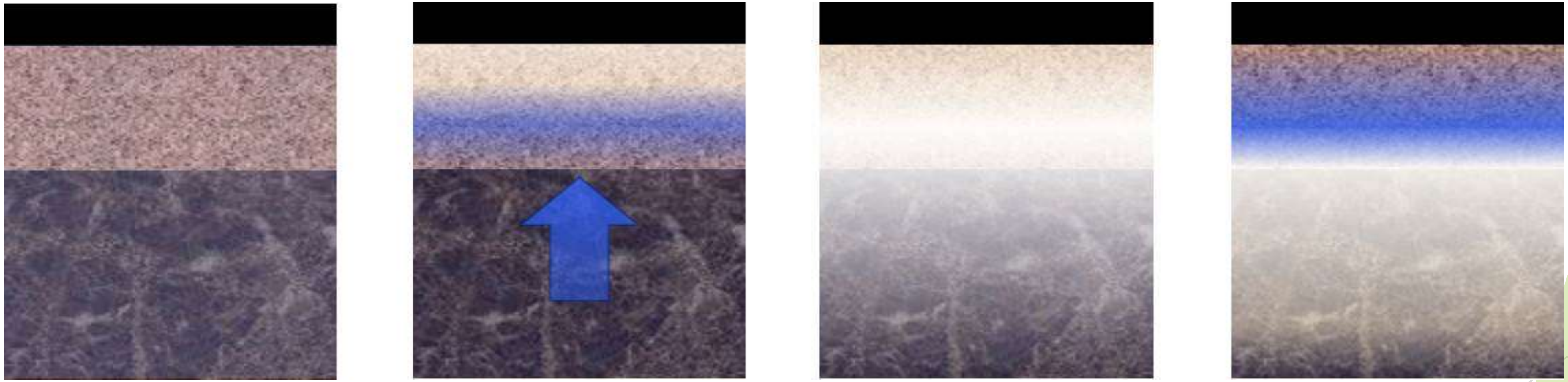
- Considerations AASHO Road Test – Significant Limitations
  - Specific & Limited Materials, Specific Environment
  - AASHO Road Test was a 2-year test….results projected for 20-year design life
  - All loading was identical and timely for 1955…no mixed loading, no radial tires
- When you utilize AASHTO 93, you have slept with AASHO Road Test
  - Extrapolating other subgrade support values to far different soils
  - Assuming the loading in AASHO road test can be extrapolated with 18k ESAL
  - Assuming similar environmental effects

Pavement Design
Use AASHTO 93 Wisely -

- Areas of Special Interest
  - Structural Coefficients
    - The NDDOT has 50-years of calibration on NDDOT mixes and performance on the SHS
    - New Materials?
  - Subgrade Support
    - Resilient Modulus (M_R) and Historical Significance with R-Value/CBR
    - Seasonal Impacts or "It's hard to describe -30 deg. F. unless you've been there"
  - Moisture & Drainage
    - A lower M_i with AASHTO 93=~ More Thickness….not necessarily More Strength
    - The NDDOT has 50+ years of performance (pavement management system), soil data and experience with ND's varied soils
  - Traffic
    - Accurate traffic data collection and classification a must
    - The S_0 has proven to be highly variable on historical studies (e.g. Alabama/NCAT, et. al.)

Pavement Design
Use AASHTO 93 Wisely – Case in Point

Spring Load Restrictions: Moisture in base and subgrade freezes and thaws top-down, causing moisture to be drawn upward and trapped during spring thaw



moist unfrozen	moist freezing	fully frozen	thawing weak
Summer	Fall	Winter	Spring

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Pavement Design
PaveXpress – A Design Tool

PaveXpress

- Functional
- AASHTO 93/98 Design Tool for Flexible & Rigid Pavements
- A scoping tool
- A “go to” for Pavement Resources

Pavement Design
PaveXpress – A Design Tool

Introduction

Welcome to PaveXpress, a scoping tool to help you create simplified pavement designs while taking into account key engineering inputs.

Resources

PaveXpress includes access to resources such as design guides from state DOTs and industry associations so you can build formal designs from its simple recommendations.

View Resources

Get Started

Click on the button below to launch the PaveXpress Scoping Tool and start creating your own designs, with options for both flexible and rigid pavement construction.

Launch

Pavement Design
PaveXpress – A Design Tool

PaveXpress

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Resources

The following resources accompany the PaveXpress Simplified Pavement Design Tool

- State DOTs
- State Asphalt Pavement Associations
- Parking Lot Design Guides

PaveXpress

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1 **Project Information**
Location, Roadway Classification and Pavement Type

2 **Design Parameters**
Specific Design Variables

3 **Traffic Data**
Traffic and Loading Data

4 **Pavement Structure**
Pavement Layer(s) Information

5 **Pavement Sub-Structure**
Base, Sub-Base and Subgrade

Calculated Design

Project Information

Project Name	2015 NDAC
Project Description	Cost Effective Transportation
Estimated Completion Year	2015

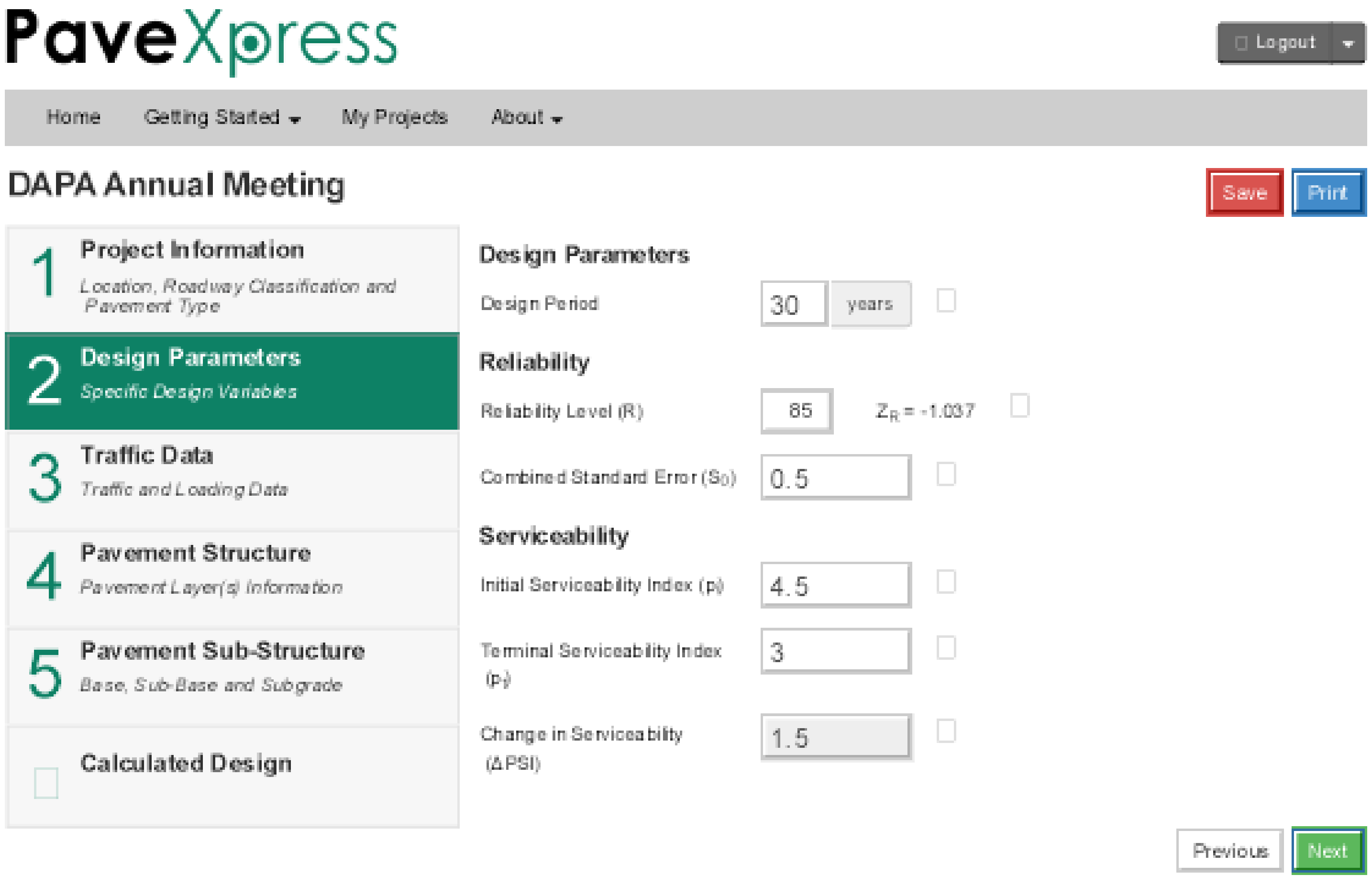
Location

State	South Dakota

Category

Roadway Classification	Arterials/Highway
Pavement Type	Flexible

Next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Traffic and Loading Data
4 Pavement Structure
Pavement Layer(s) Information
5 Pavement Sub-Structure
Base, Sub-Base and Subgrade
Calculated Design
Design Parameters
Design Period
30
years
Reliability
Reliability Level (R)
85
Z_R = -1.037
Combined Standard Error (S_0)
0.5
Serviceability
Initial Serviceability Index (p_i)
4.5
Terminal Serviceability Index (p_t)
3
Change in Serviceability (ΔPSI)
1.5
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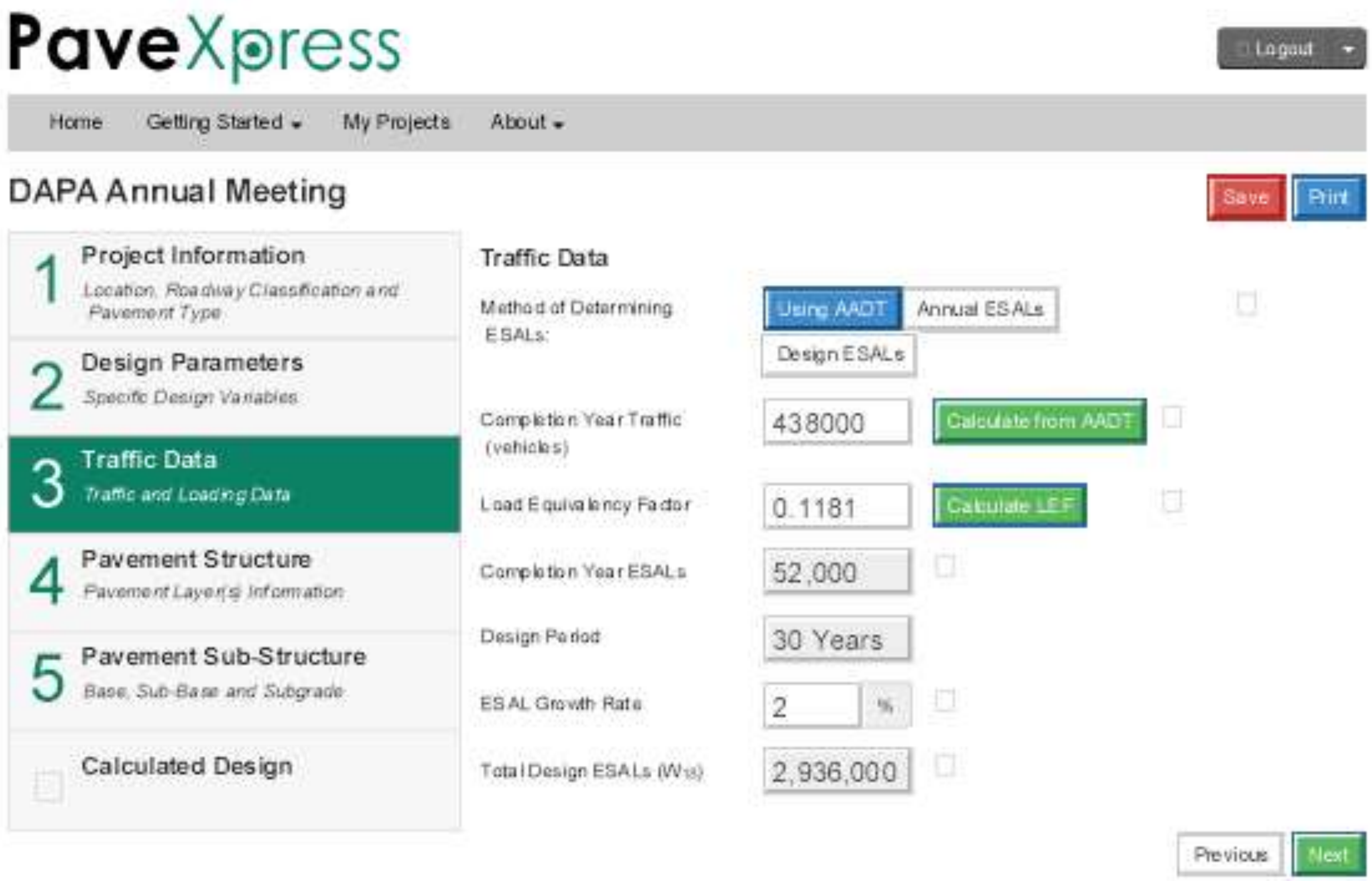
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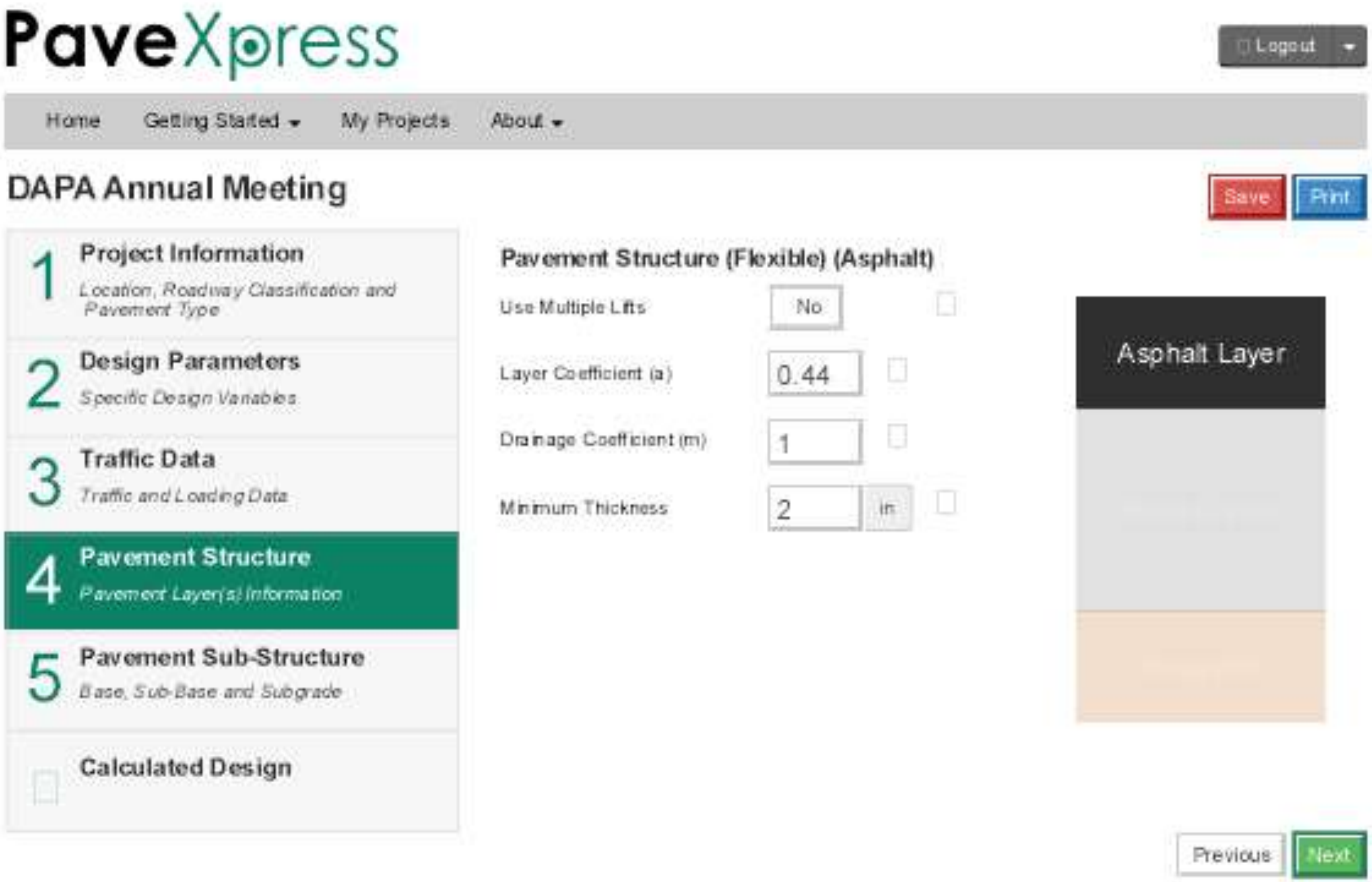
5 Pavement Sub-Structure
Base, Sub-Base and Subgrade
Calculated Design
Traffic Data
Method of Determining ESALs:
Using AADT
Annual ESALs
Design ESALs
Completion Year Traffic (vehicles)
438000
Calculate from AADT
Load Equivalency Factor
0.1181
Calculate LEF
Completion Year ESALs
52,000
Design Period
30 Years
ESAL Growth Rate
2
%
Total Design ESALs (W_{18})
2,936,000
Previous
Next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Pavement Layer(s) Information
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Base, Sub-Base and Subgrade
Calculated Design
Pavement Structure (Flexible) (Asphalt)
Use Multiple Lifts
No
Layer Coefficient (a)
0.44
Drainage Coefficient (m)
1
Minimum Thickness
2
in
Asphalt Layer
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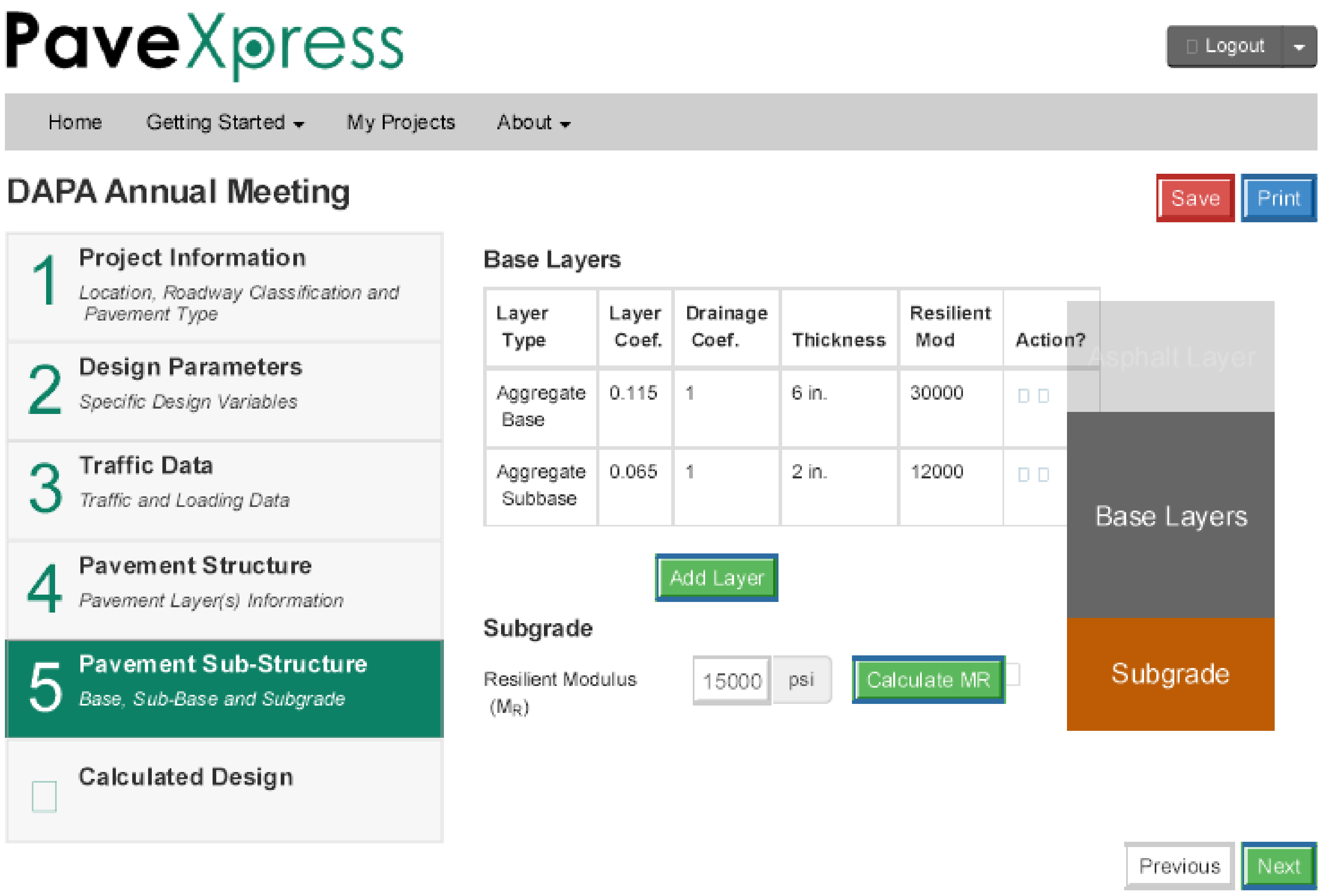
Next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Base, Sub-Base and Subgrade
Calculated Design
Base Layers
Layer Type | Layer Coef. | Drainage Coef. | Thickness | Resilient Mod | Action?
Aggregate Base | 0.115 | 1 | 6 in. | 30000
Aggregate Subbase | 0.065 | 1 | 2 in. | 12000
Add Layer
Subgrade
Resilient Modulus (MR)
15000 psi
Calculate MR
Asphalt Layer
Base Layers
Subgrade
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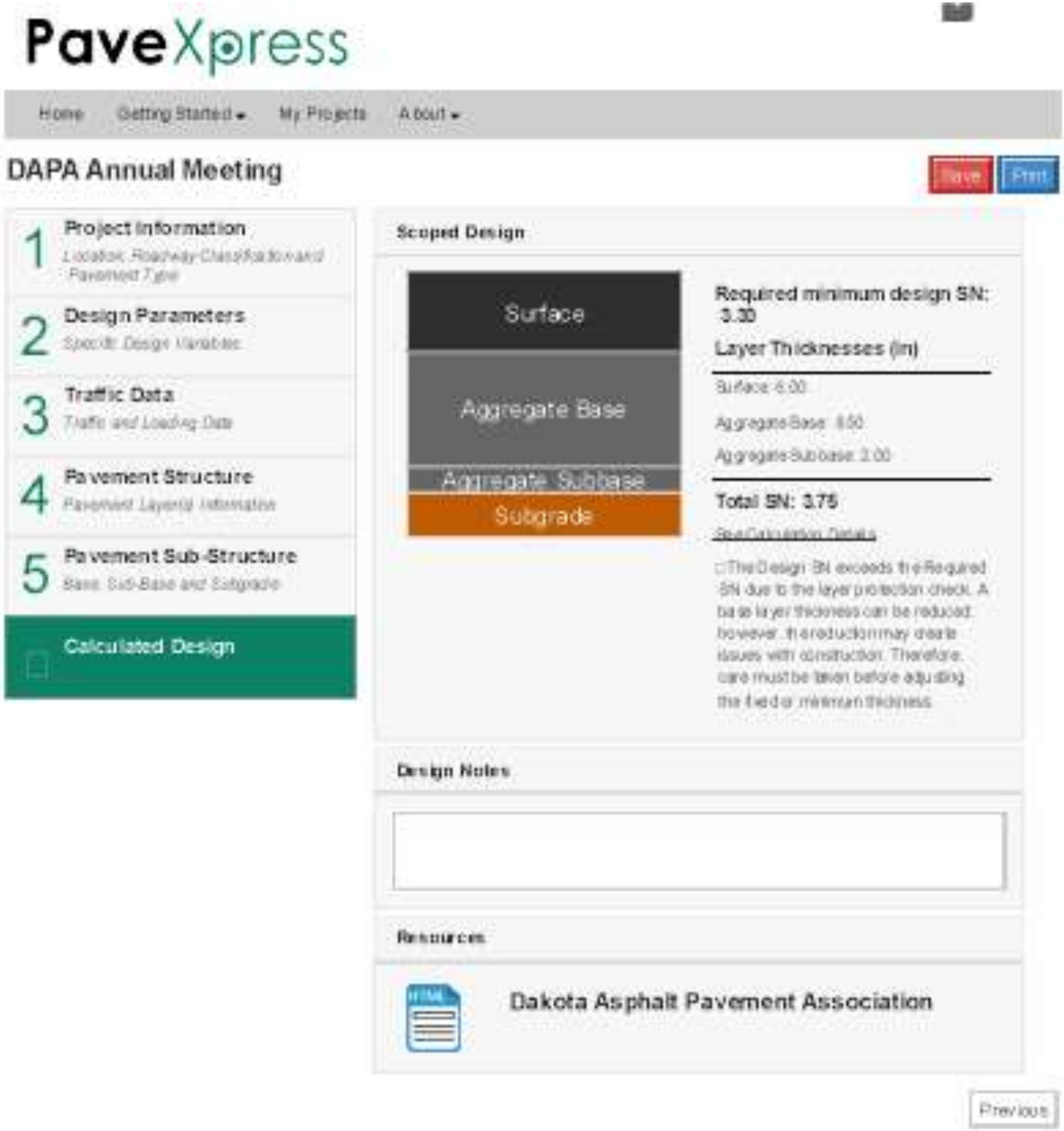

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5 Pavement Sub-Structure
Base, Sub-Base and Subgrade
Calculated Design
Scoped Design
Surface
Aggregate Base
Aggregate Subbase
Subgrade
Required minimum design SN: 3.30
Layer Thicknesses (in)
Total SN: 3.75
Design Notes
Resources
Dakota Asphalt Pavement Association
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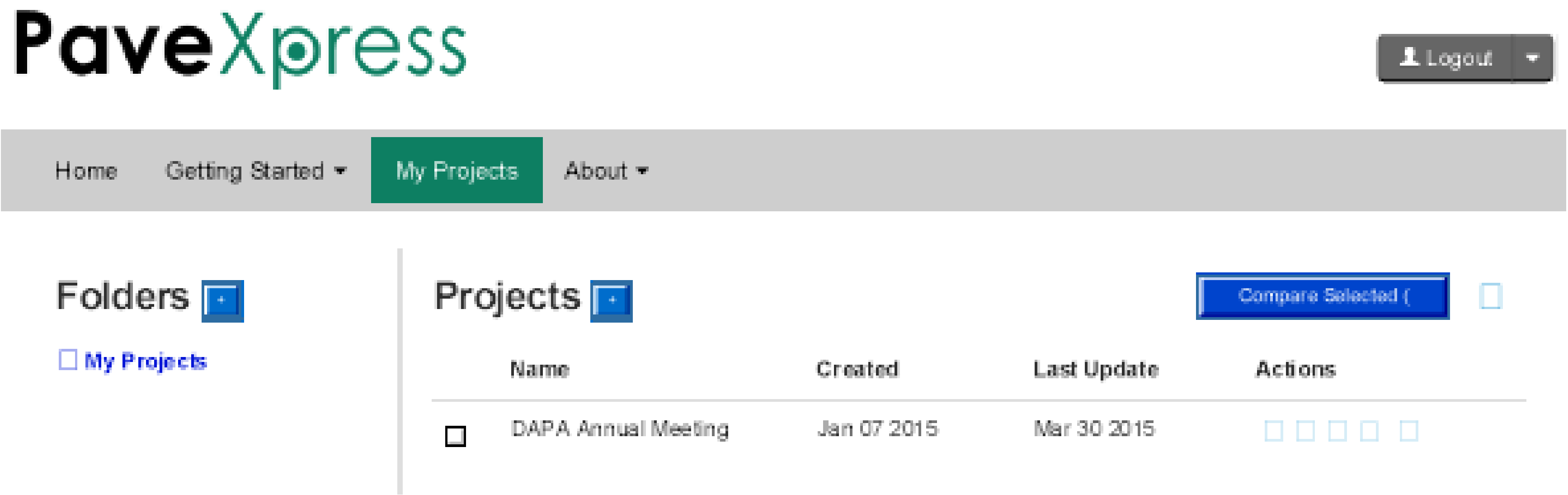
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About

The PaveXpress Scoping Tool is a simplified pavement design tool to help engineers and pavement decision-makers analyze pavement structures and create technically sound structural designs. Some of the tool's key features:

- Accessible via web and mobile
- Free, no cost to use
- Based on AASHTO pavement design equations
- User-friendly
- Share, save, and print project designs
- Interactive help and resource links

The PaveXpress Scoping Tool was developed by Pavia Systems, with generous sponsorship from the National Asphalt Pavement Association (http://www.asphaltpavement.org), the Asphalt Pavement Alliance (http://www.asphaltroads.org), and a consortium of state asphalt pavement associations.

SAPA State Asphalt Pavement Associations

NAPA NATIONAL ASPHALT PAVEMENT ASSOCIATION

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Pavement Design

- PaveXpress soon to be available seamlessly on revamped DAPA web page
- Adding other Pavement Resources to DAPA web page
  - Parking Lot Model Designs
  - Mixture and Binder Selection Guides
  - Bike Path and Pedestrian Path Recommendations
  - Asphalt Contracting Do’s and Don’ts
  - Quantity Take-off Tools
  - Compaction/PaveCool Tools
  - Expanded Bid Letting Announcements
  - Project Profiles and New Technology White Papers
  - Other Pavement and Instructional Resources
- **Expected Roll Out May 1, 2015**

Pavement Design

Questions???

Thank you!