Geosynthetics In Roadway Applications

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Geosynthetic-reinforced subgrade and base course, over range of subgrade strengths, both paved and unpaved surfaces

Accelerated Pavement Testing Lab

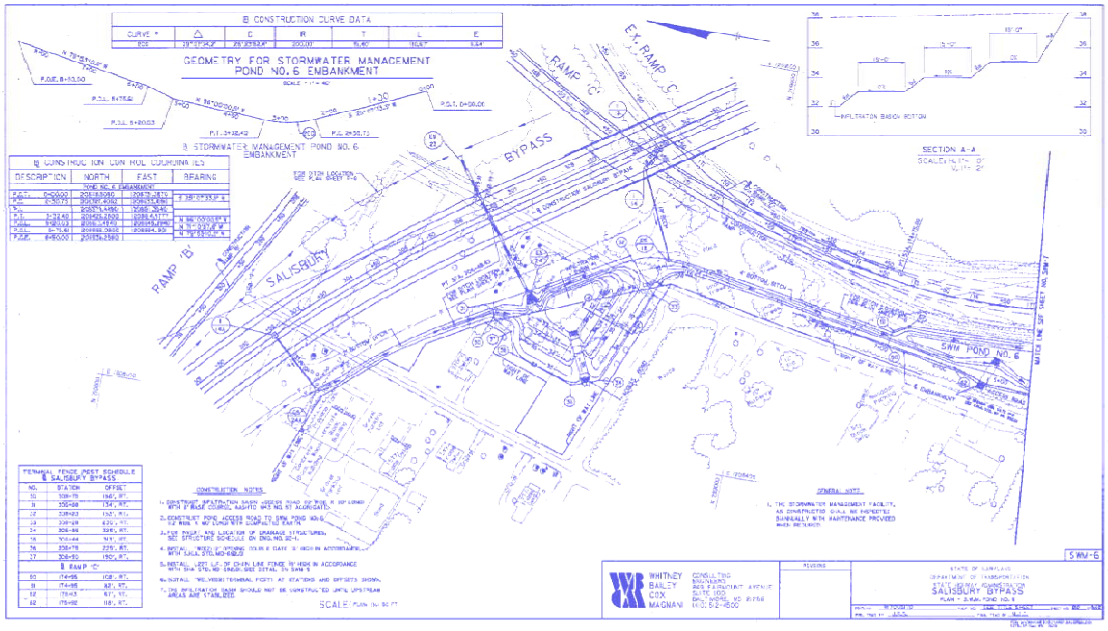
TRI Accelerated Pavement Tester

Cyclic Plate Load Test

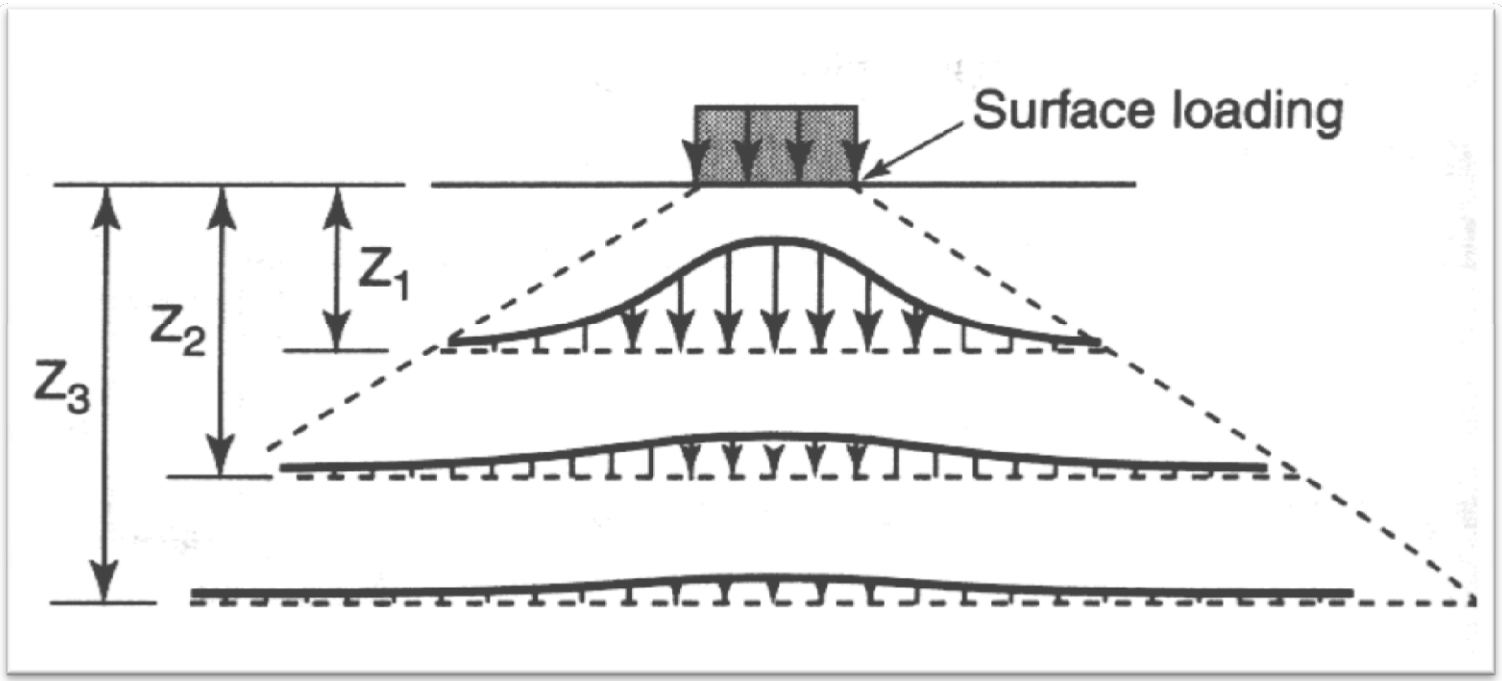
GEOSYNTHETICS IN ROADS

Pavement Design Objectives

- Smooth wearing surface for ride quality
  - Structural design
    - Stiffness/strength
    - Drainage
  - Material selection
  - Construction quality
- Safety
  - Friction
  - Drainage
- Economical
- Environment sensitivity
  - Pollution
  - Noise



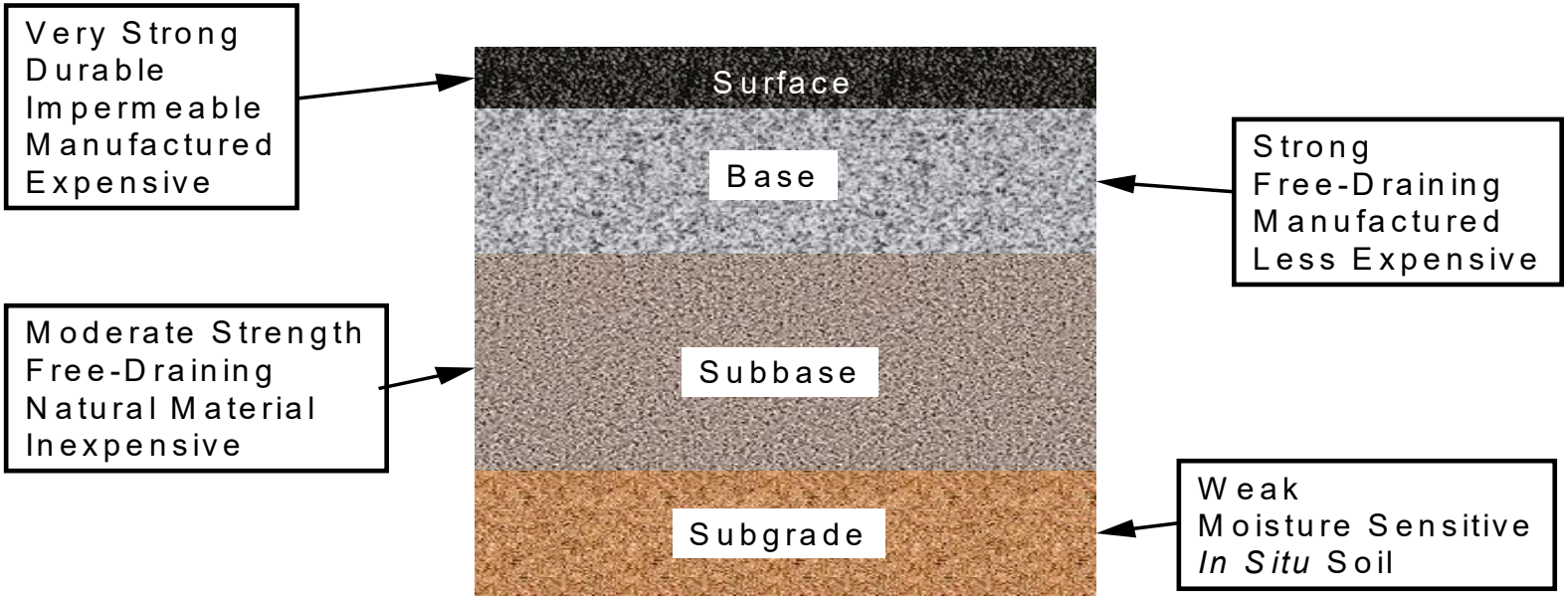
Structural Design Basics



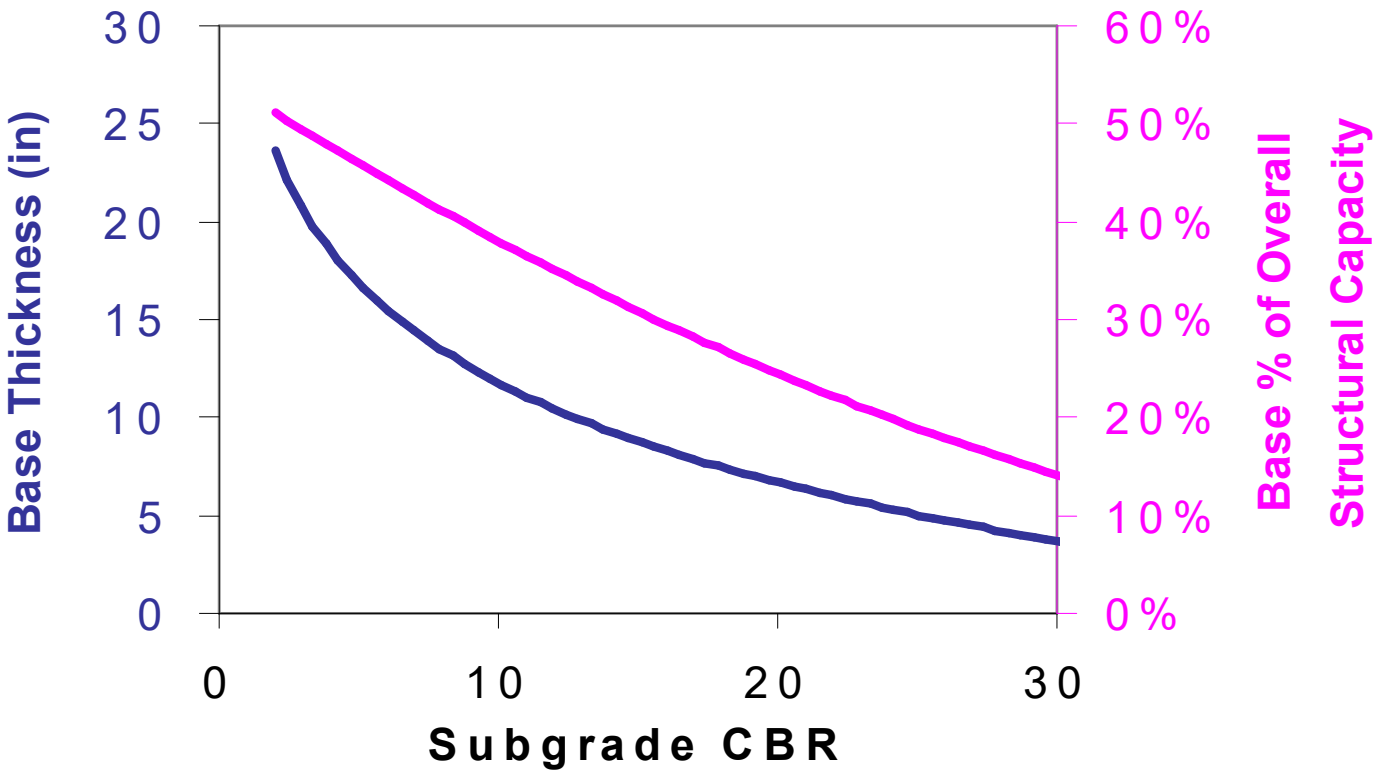
(Yoder and Witczak, 1974)

Limit stresses transferred to the subgrade

Layered Pavement System



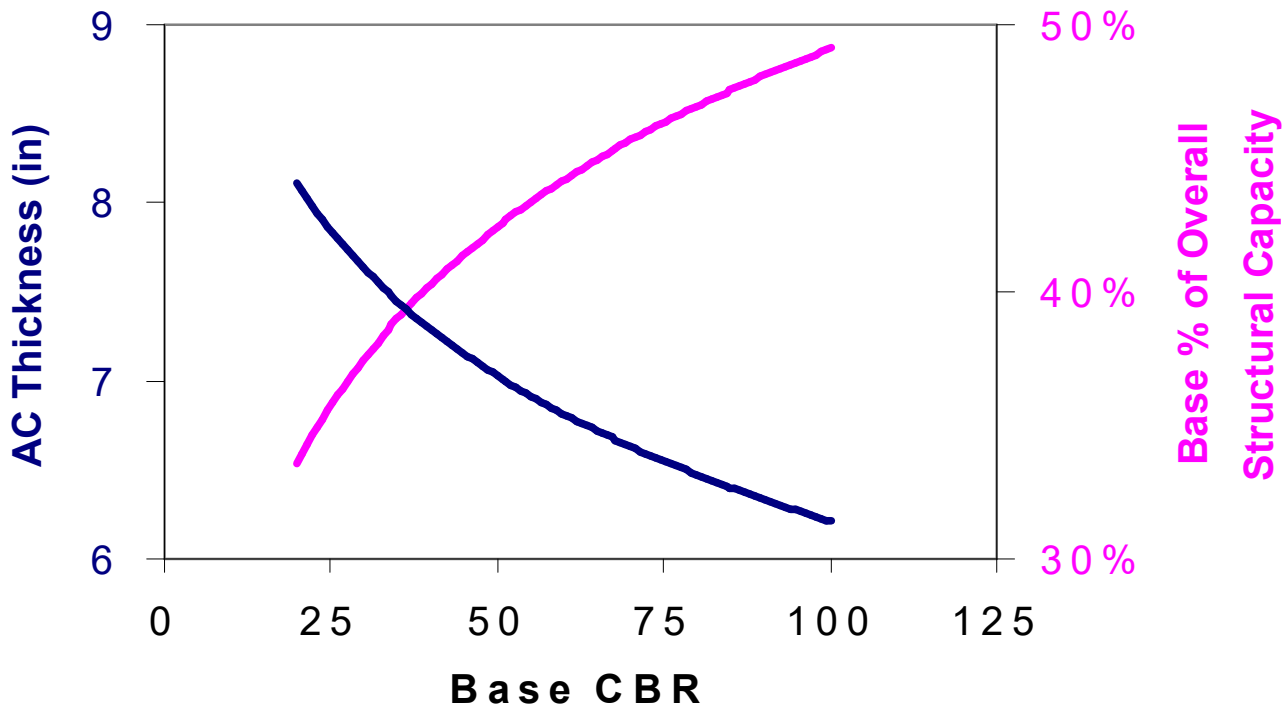
Effect of Subgrade Strength



Assumptions:

- **Flexible pavement**
- **'93 AASHTO**
- **10M ESALs**

Effect of Base Strength

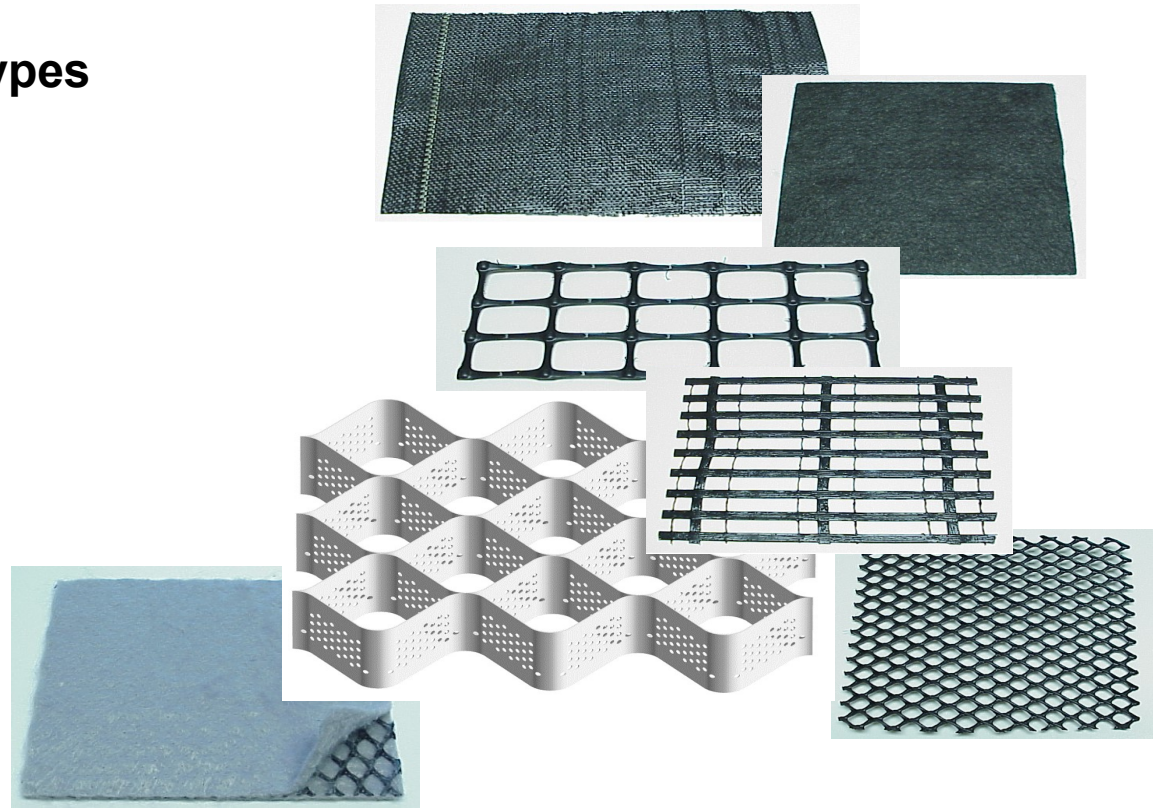


Assumptions:

- **Flexible pavement**
- **'93 AASHTO**
- **10M ESALs**
- **SG CBR=4**
- **Minimum AC thickness**

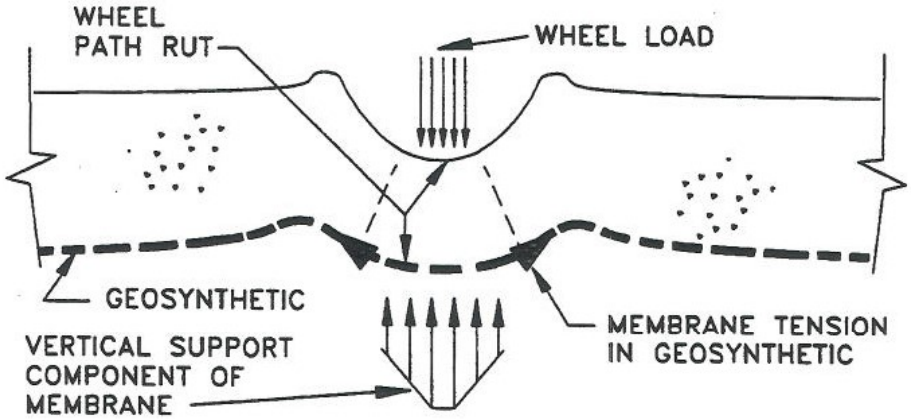
Geosynthetics in Pavements

- **Principal Geosynthetic Types**
  - Geotextiles
  - Geogrids
  - Geocells
  - Geonets
  - Geomembranes
  - Geocomposites
- **Geosynthetic Functions**
  - Stabilization
  - Reinforcement
  - Separation
  - Drainage
  - Filtration

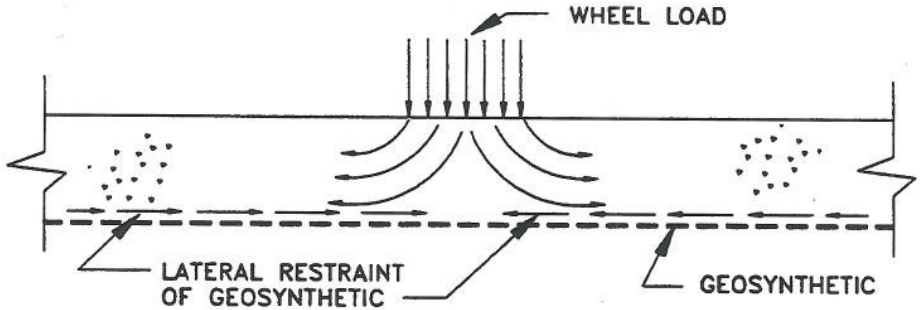


Stabilization Applications in Pavements

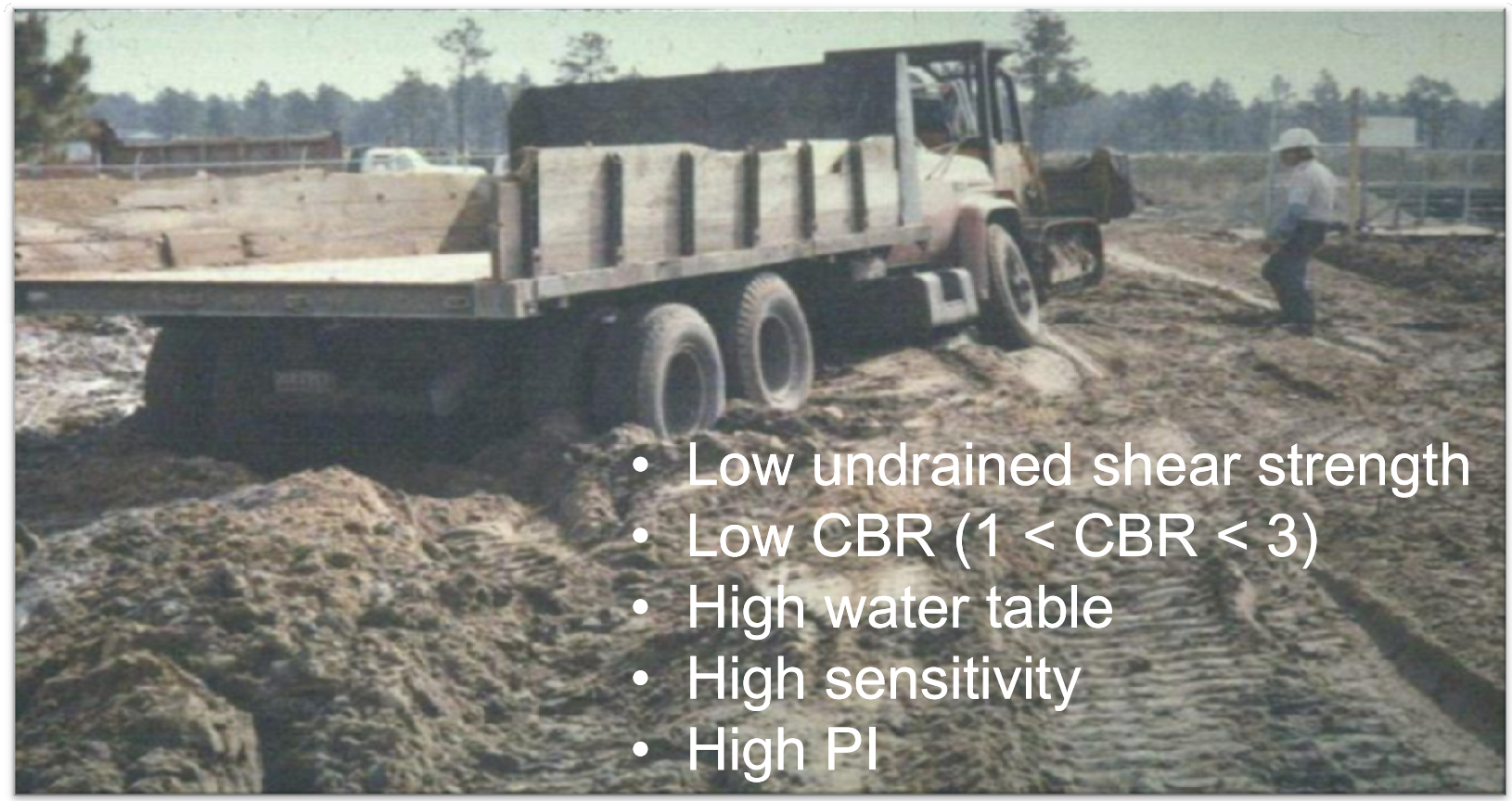
1) Softer subgrade



2) Firmer Subgrade



Subgrade Stabilization Application



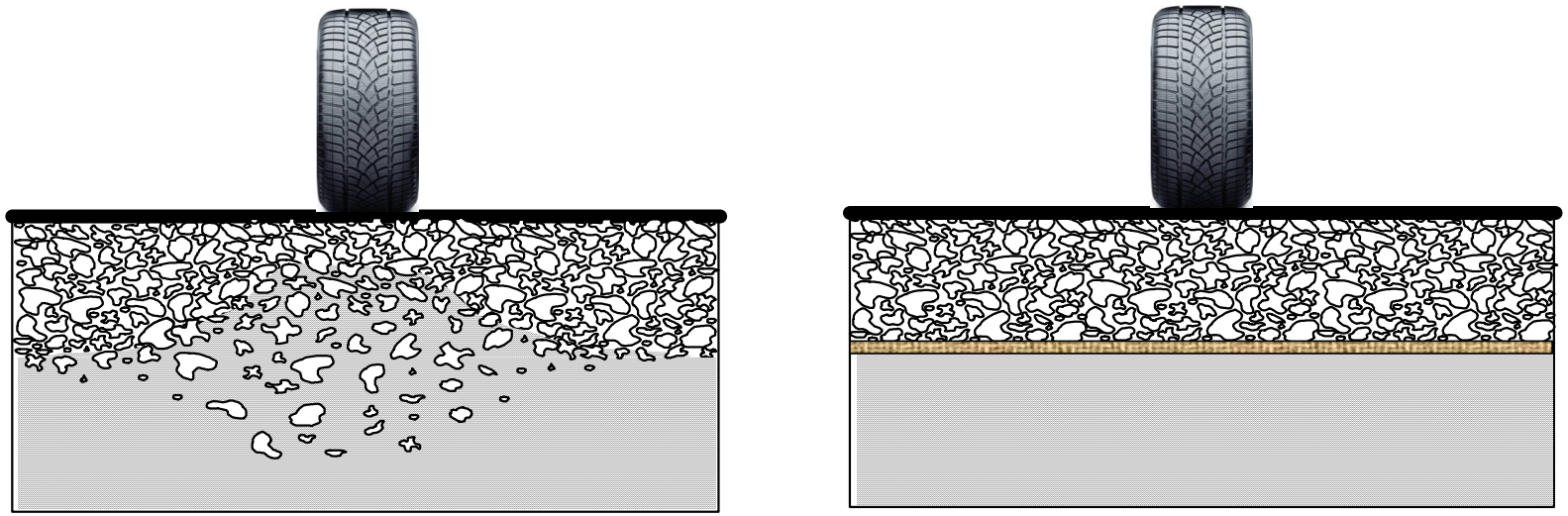
- Low undrained shear strength
- Low CBR (1 < CBR < 3)
- High water table
- High sensitivity
- High PI

Base Reinforcement Application

- Improve long-term load bearing capacity
- Improve structural support
- Geosynthetics incorporated into design of road structure
- Improve roadway longevity
- Tend to be lower volume roads
- CBR < 8

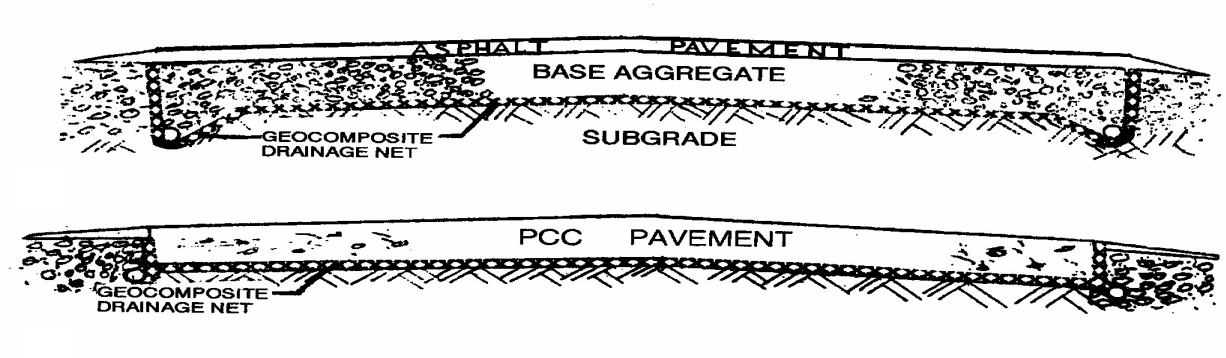
Geosynthetic Functions in Pavements

3) Separation

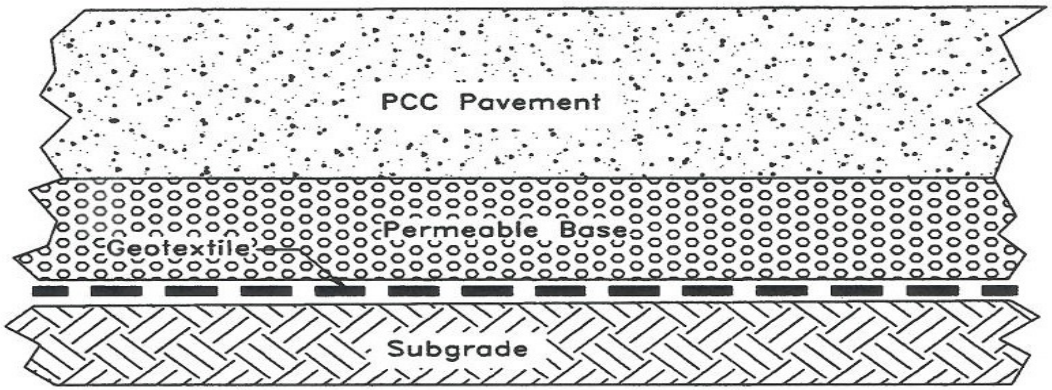


Geosynthetic Functions in Pavements

4) Drainage



5) Filtration



Matrix of Geosynthetic Functions

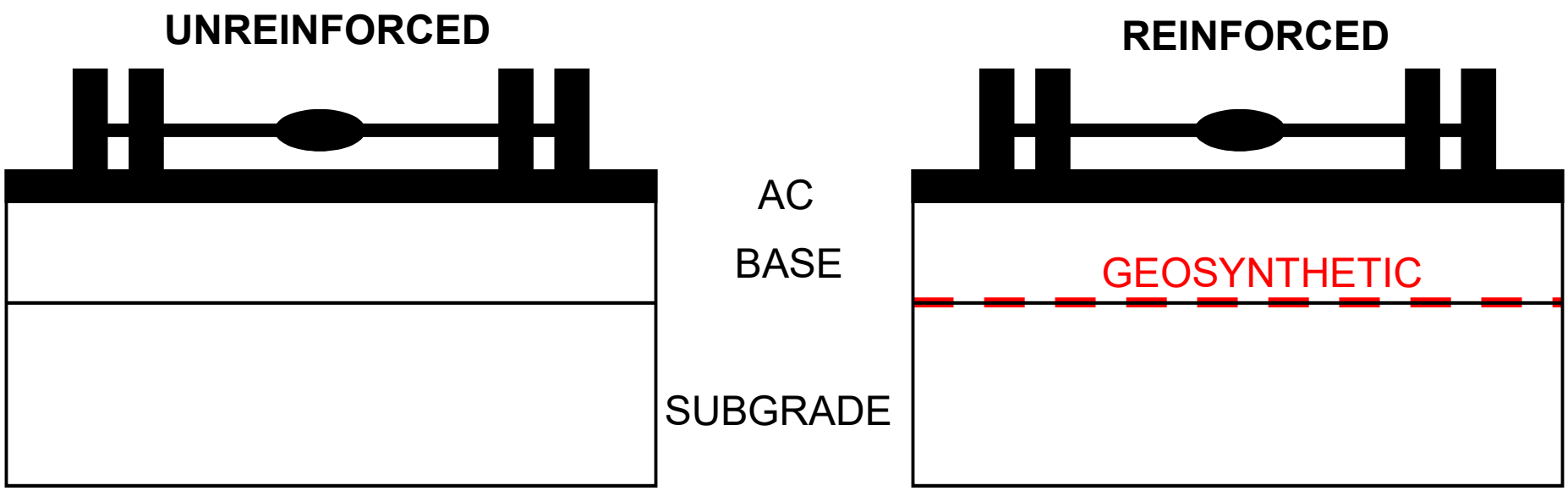
	Stabilization	Reinforcement	Separation	Drainage	Filtration
Geotextile	√	√	√		√
Geogrid	√	√			
Geocell	√	√			
Geonet				√	
Geopipe				√	
Geocomposite	√	√	√	√	√

Benefit Characterization

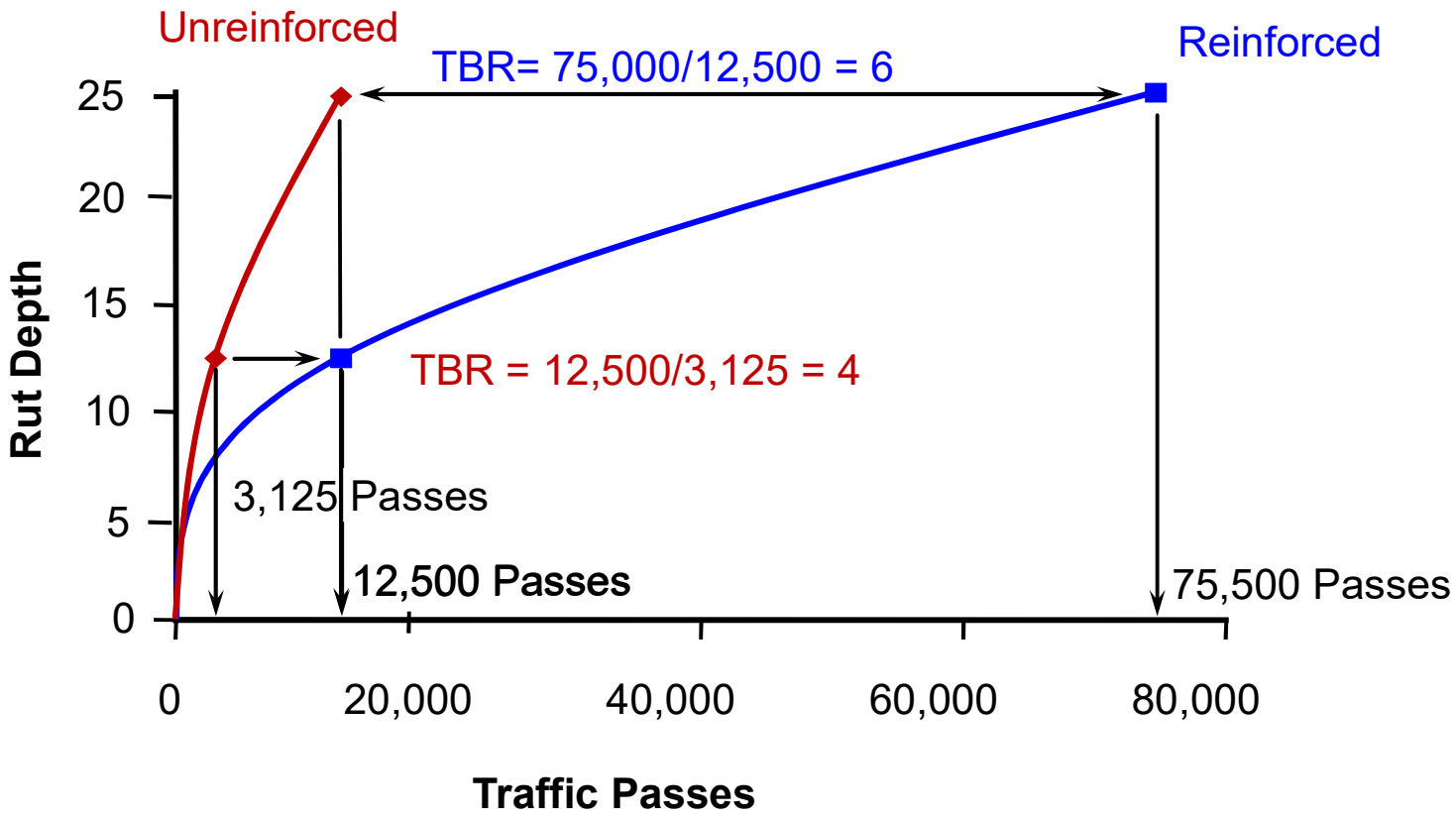
- Traffic Benefit Ratio (TBR)
- Base Course Reduction Factor (BCR)
- Layer Coefficient Ratio (LCR)

TBR

Comparison of equivalent pavement systems



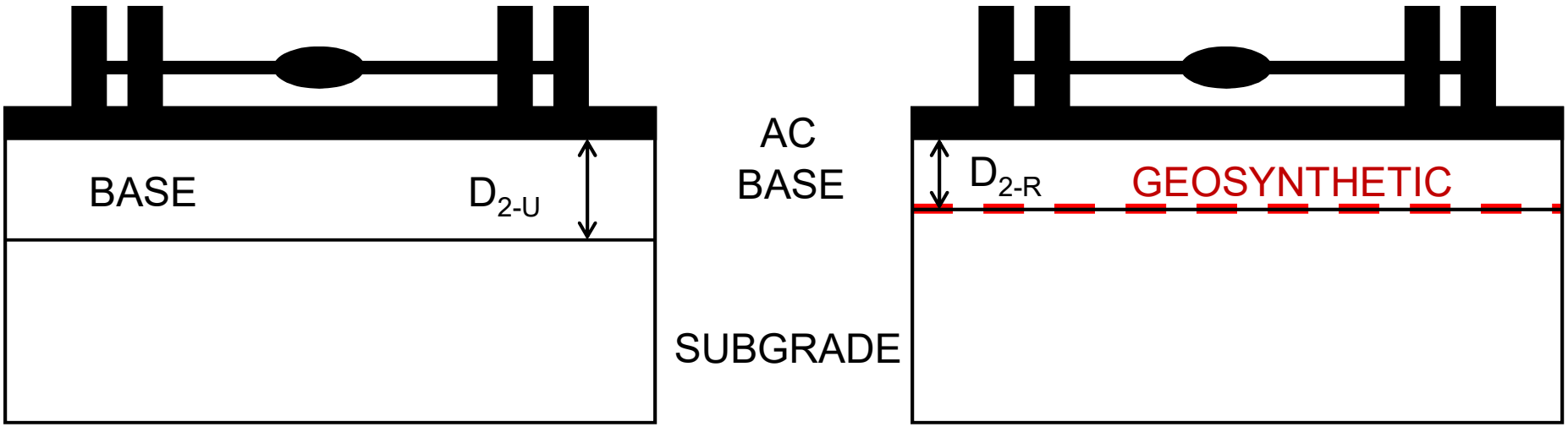
TBR Calculation



BCR

$$BCR = (D_{2\text{-}U} - D_{2\text{-}R})/D_{2\text{-}U}$$

Comparison of pavement systems with identical life

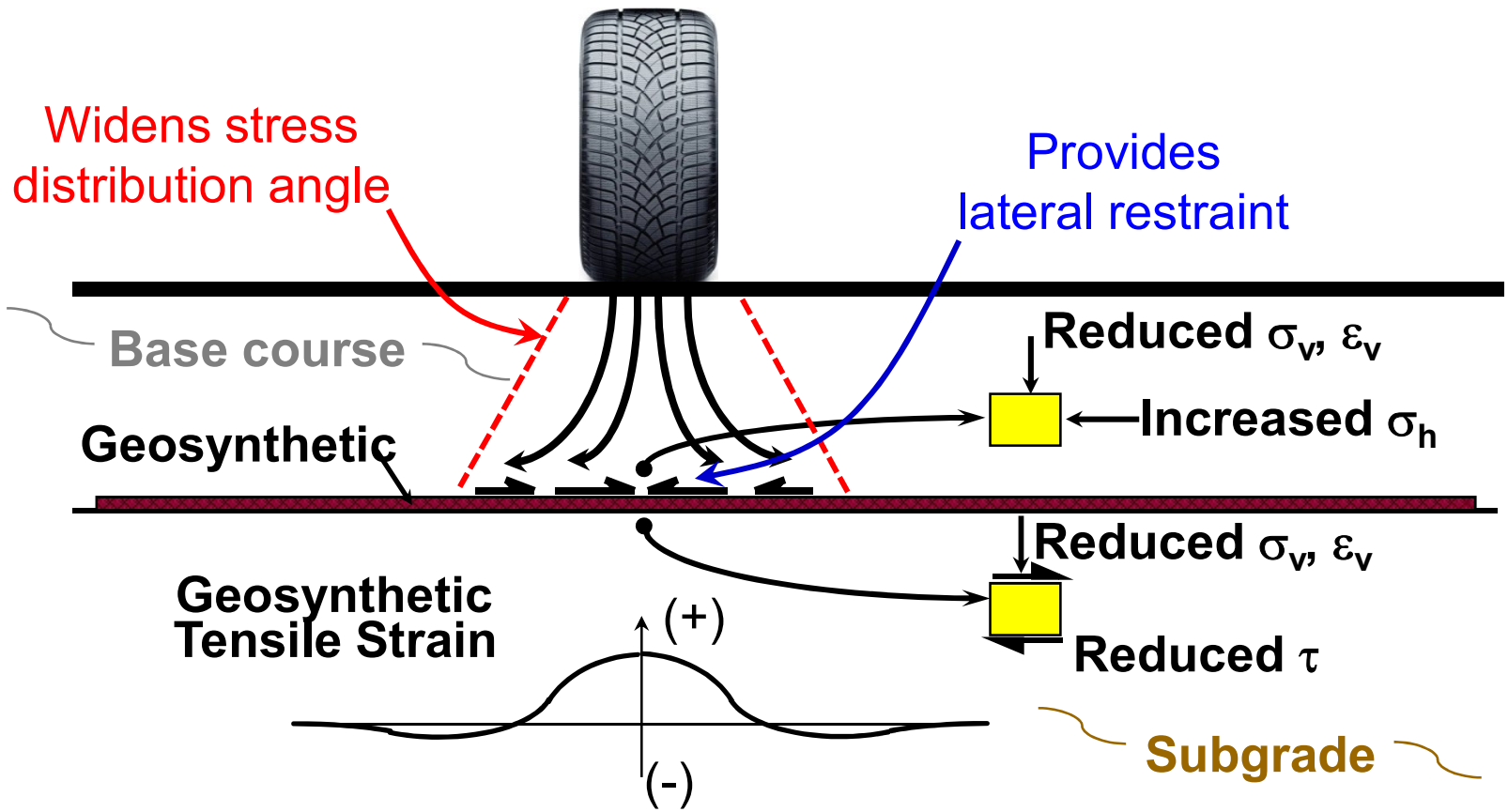


LCR

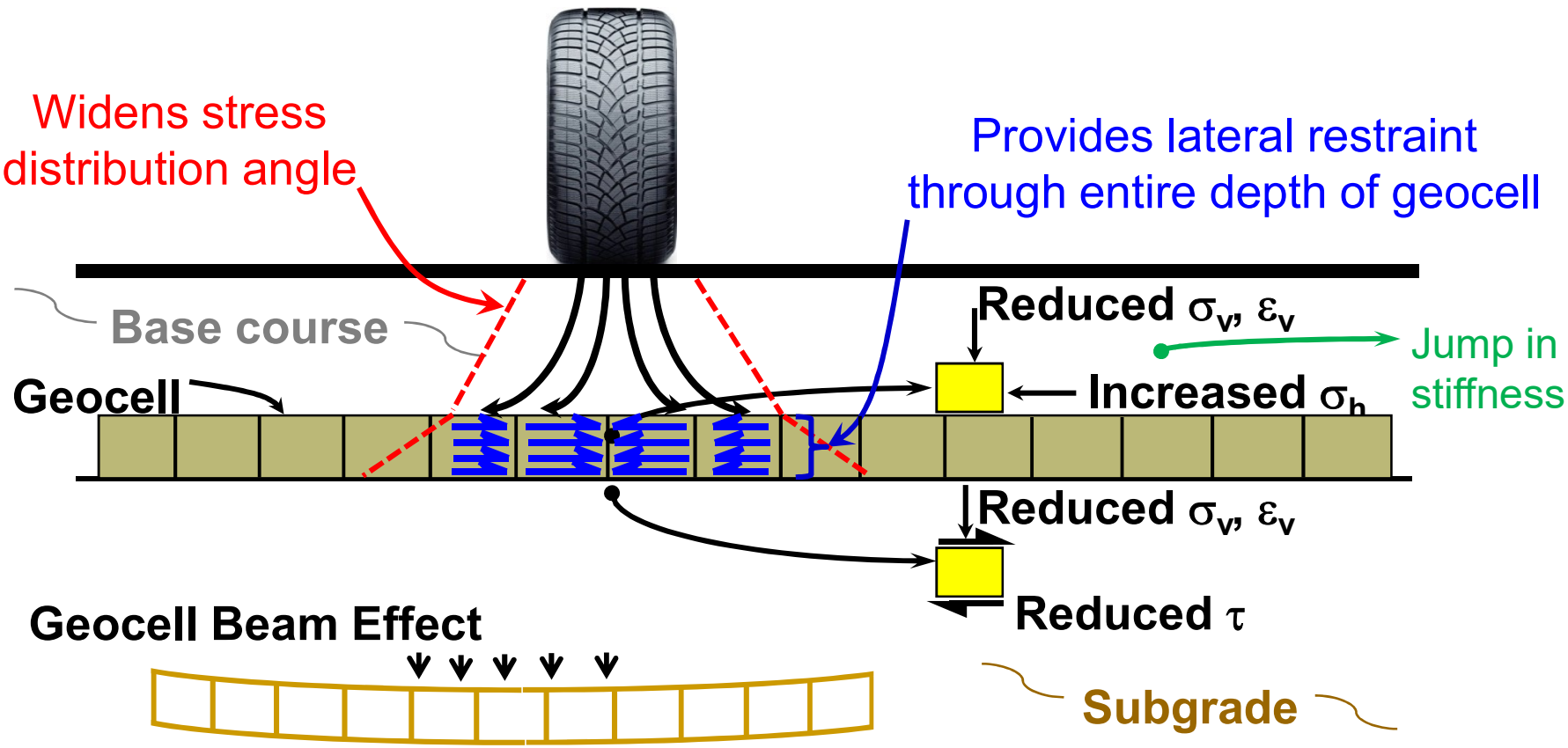
- Quantify the benefit of the geosynthetic in terms of modified thickness of the base aggregate
- AASHTO design equation

  $SN = D_1a_1 + D_2a_2m_2LCR + D_3a_3m_3$
- Using TBR –> back-calculate the benefit of geosynthetic in terms of equivalent section of equal performance by adjusting the thickness of the gravel using AASHTO equation
- Using BCR results directly –> LCR = 1/(1-BCR/100)

2D Geosynthetic Improvement Mechanisms



3D Geosynthetic Improvement Mechanisms



Performance Testing Methods

- Full-scale test sections
- Accelerated pavement testing
- Cyclic plate load tests
- Mechanistic material properties
  - Triaxial or resilient modulus tests
  - Small-scale mock-ups using standard materials

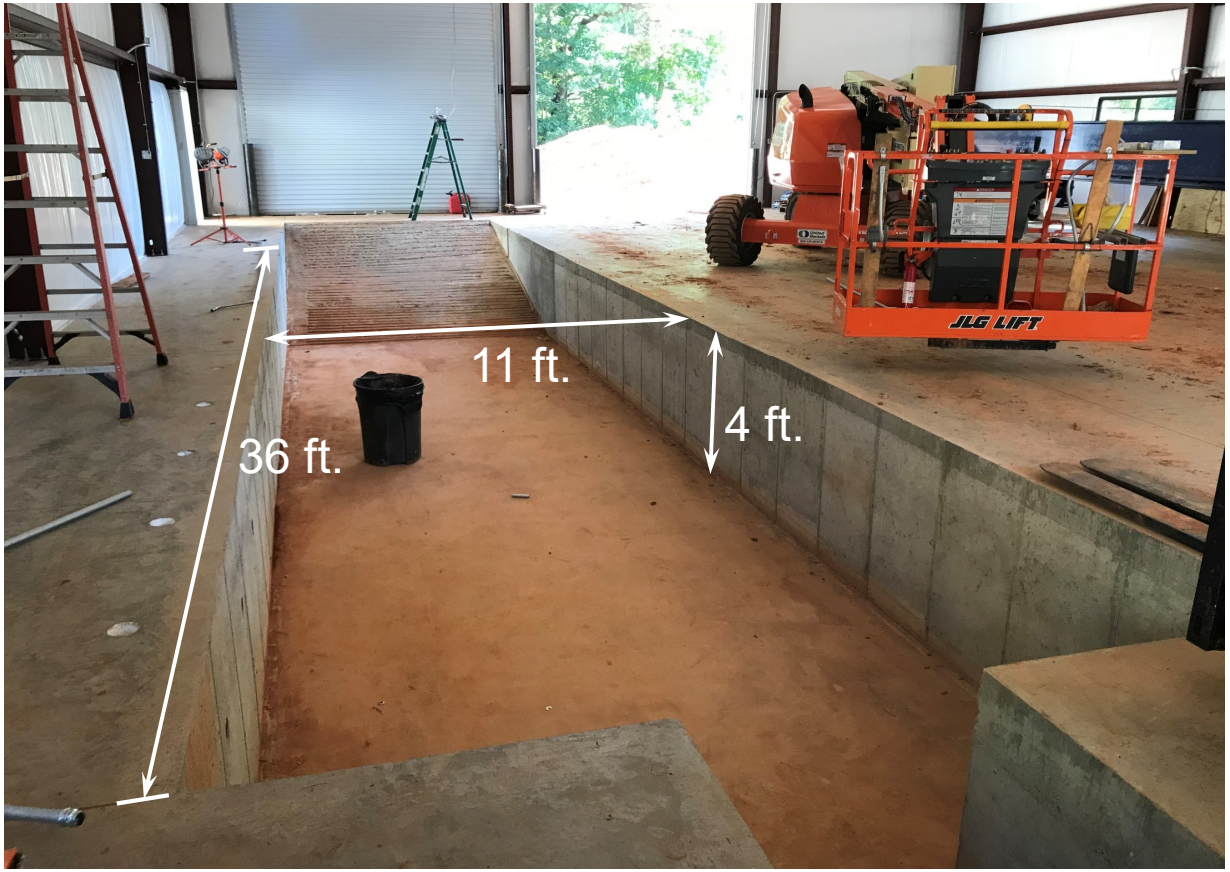
- Balance realism with cost/time/effort

MDT Large-Scale Lab Testing Project

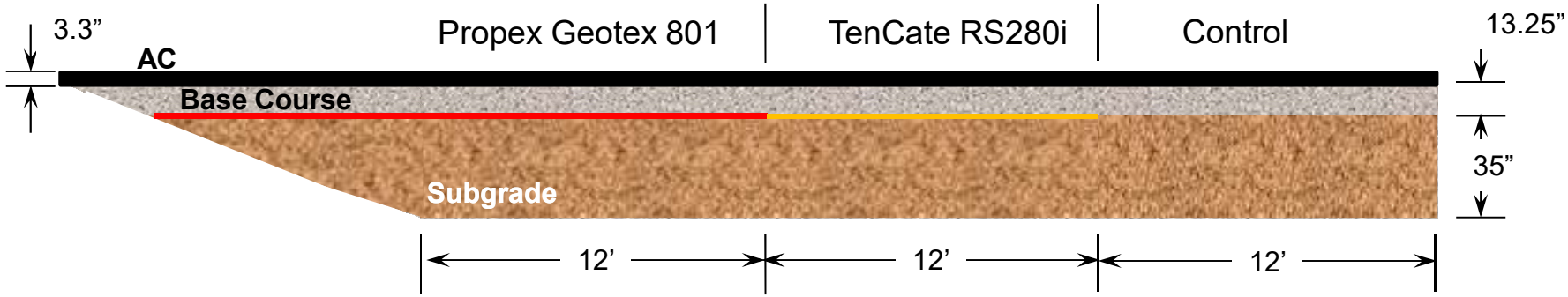
Objective: to determine the structural benefit of geotextiles in paved road application

- Benefit of reinforced test sections compared to a control
- Controlled testing using accelerated pavement tester
- Results used to with an analytical design tool for geosynthetic-reinforced roads

Controlled Test Area



Test Section Layout



Test Sections:

- Control (no geosynthetic)
- TenCate RS280i – woven textile
- Propex Geotex 801 – non-woven textile

Predicted response:

- 320k cycles to failure
- 900k cycles to failure
- 450k cycles to failure

Subgrade

Property	
Liquid Limit	40%
Plastic Limit	25%
Plasticity Index	15%
% passing #200 sieve	75.5%
Maximum dry unit weight†	15.9 kN/m^3
Optimum moisture content†	18.6%
Maximum dry unit weight‡	17.4 kN/m^3
Optimum moisture content‡	17.0%
R-value at 2.07 MPa (300 psi) exudation pressure	23.5

† determined using Standard Proctor method (ASTM D698)
‡ determined using Modified Proctor method (ASTM D1557)

Classification: CL, A-6

Target strength: CBR = 2.5%

Crushed Base Course

Property	
Specific gravity of fine mat'ls	2.653
Specific gravity of course mat'ls	2.631
Fractured face content (1+)	65%
% passing #200 sieve	4.6%
Maximum dry unit weight‡	136.9 pcf
Optimum moisture content‡	7.7%
CBR @ 95% Modified Proctor dry unit weight	100%
R-value at 2.07 MPa (300 psi) exudation pressure	72.5
L.A. Abrasion loss	18%
Micro-Deval loss	5.5%

‡ determined using Modified Proctor method (ASTM D1557)

- Brewer pit (Forsyth, MT)
- ¾-in. minus CBC
- SP, A-1-a

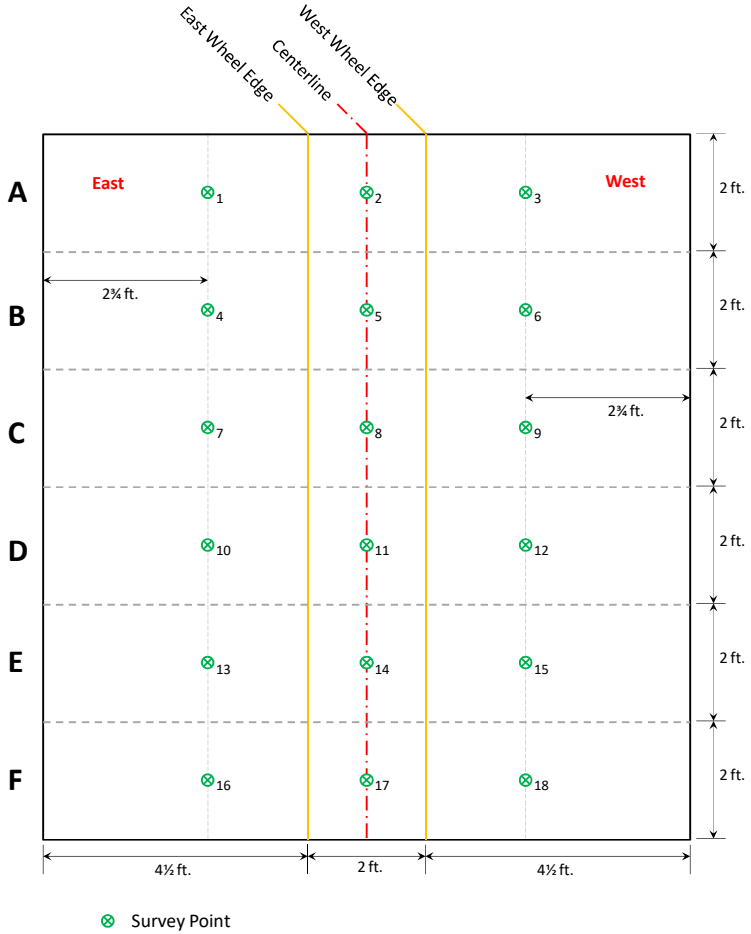
Hot-Mix Asphalt

- Material source: South Carolina
- PG grade of SC mix: 64-22
- Dynamic modulus testing to confirm similar properties to Montana hot-mix
- Surface C mix from SC

Construction QC Testing Plan

- Elevation and thickness – surveys
- In-situ shear strength (subgrade) – vane shear
- In-situ moisture content – oven
- Dynamic stiffness – LWD
- Strength – CBR and/or DCP
- Density – sand cone and/or nuclear density

Construction Surveys



18 points per layer per test section

Measurements in Each Test Section

Subgrade

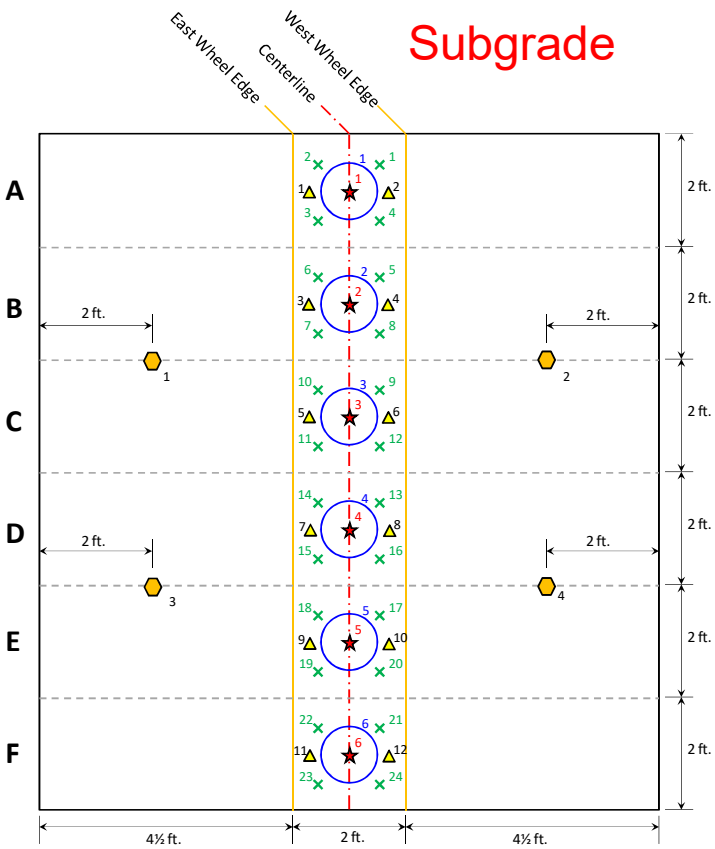
Measurement Type	Layer	Measurements per Layer
In-situ shear strength (vane)	All	24
Moisture content	All	12
Bearing strength (CBR)	All	2
Dynamic stiffness (LWD)	4, 5, 6	6
Strength (DCP)	Final	6
Unit weight (sand cone)	Final	4

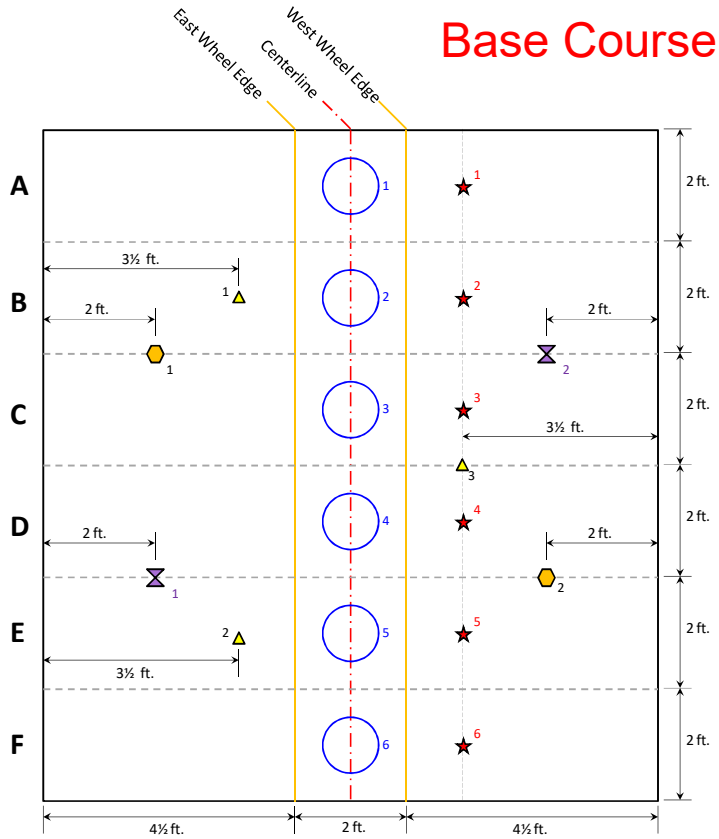
Measurements in Each Test Section

Base Course

Measurement Type	Layer	Measurements per Layer
Moisture content	All	3
Dynamic stiffness (LWD)	All	6
Strength (DCP)	Final	6
Unit weight (sand cone)	Final	2
Unit weight (nuclear densometer)	Final	2-4

Measurement Locations





Subgrade Construction

- Mix subgrade to target moisture content
- Compact small area using jumping jack
- Test vane shear strength, and adjust if necessary
- Install in pit
- Track in place with skid-steer
- Compact with drum compactor
- Conduct in-situ material testing
- Cover to minimize changes over time

Mixing Subgrade

Subgrade Prior to Compaction

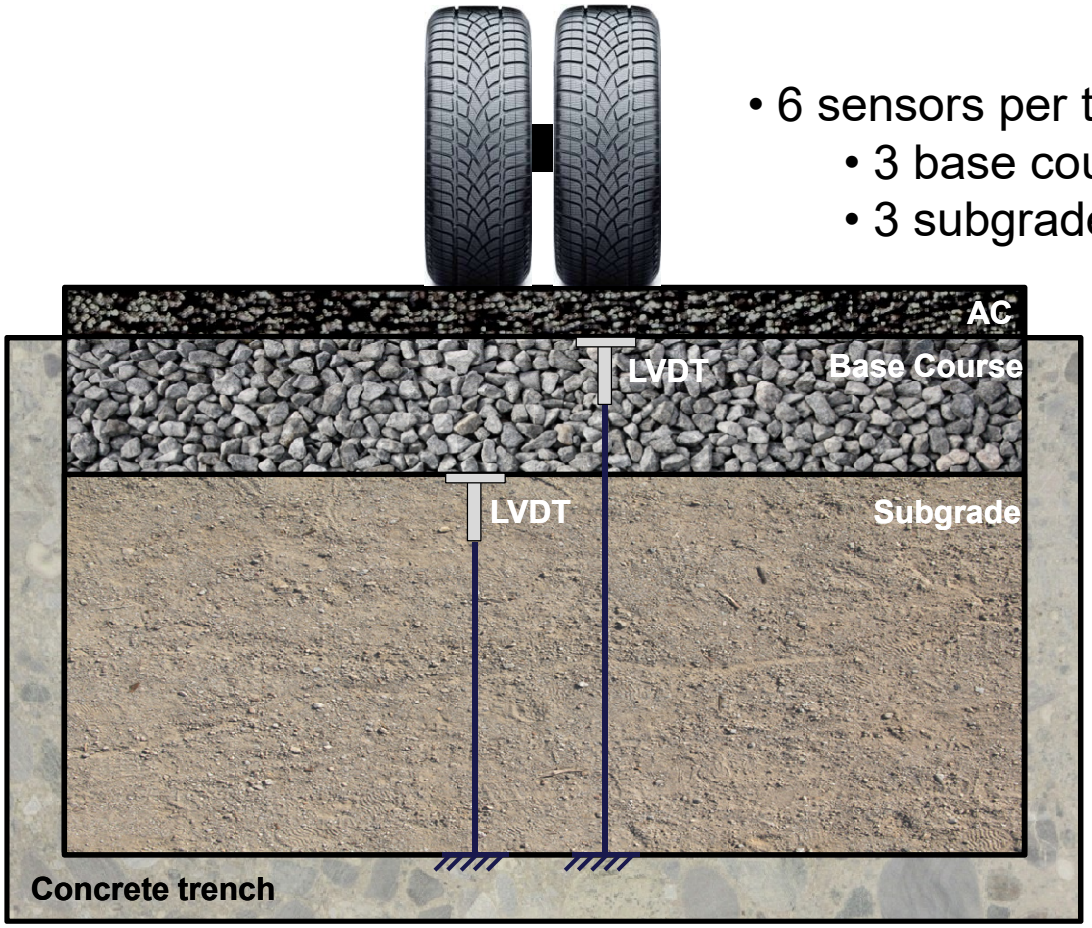
Compacting Subgrade

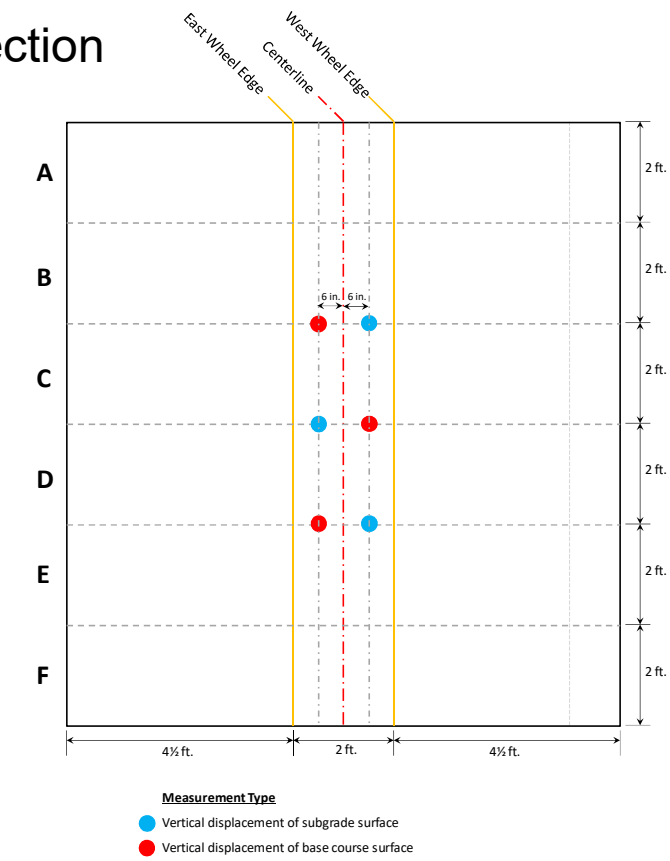
Leveling Final Subgrade Surface

Final Subgrade Surface

Instrumentation Layout

- 6 sensors per test section
  - 3 base course
  - 3 subgrade





Installing LVDT Anchor

Installing LVDT

Installing Geosynthetics

Installing Geosynthetics

Base Course Construction

<u>Procedure</u>:

- Mix to OMC
- Two layers ~ 6 in. thick
- Screed level
- Compact

Installing Base

Screeded Base

Compaction

Final Surface

*Density taken on surface met specification

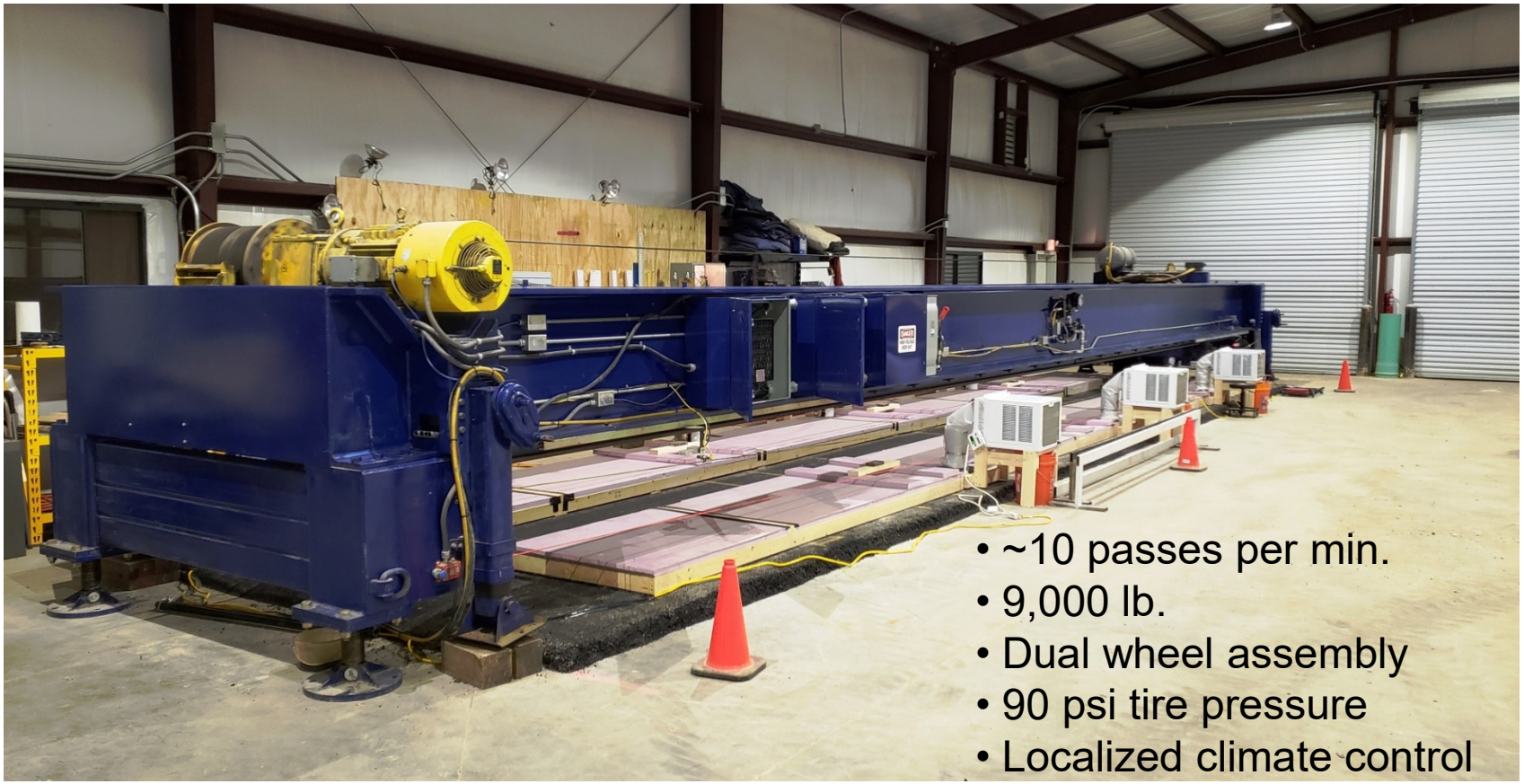
Asphalt Paving

- Single lift
- Target thickness = 3.0 in.
- +/- 0.15 in. tolerance
- Target density = 92%
- Nuclear density testing
  18 meas./test section

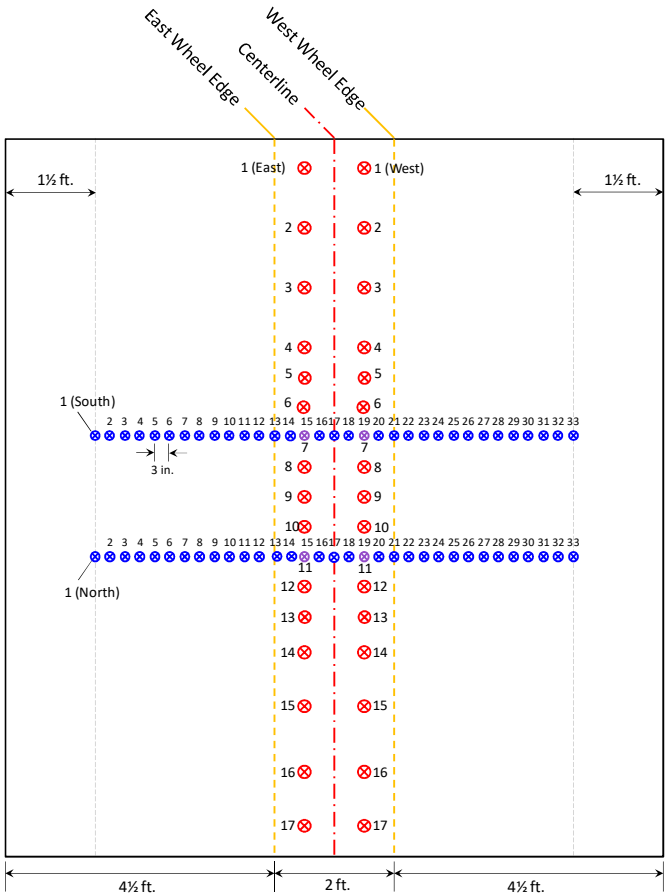
De-Constructing Asphalt

Final Surface

Accelerated Trafficking



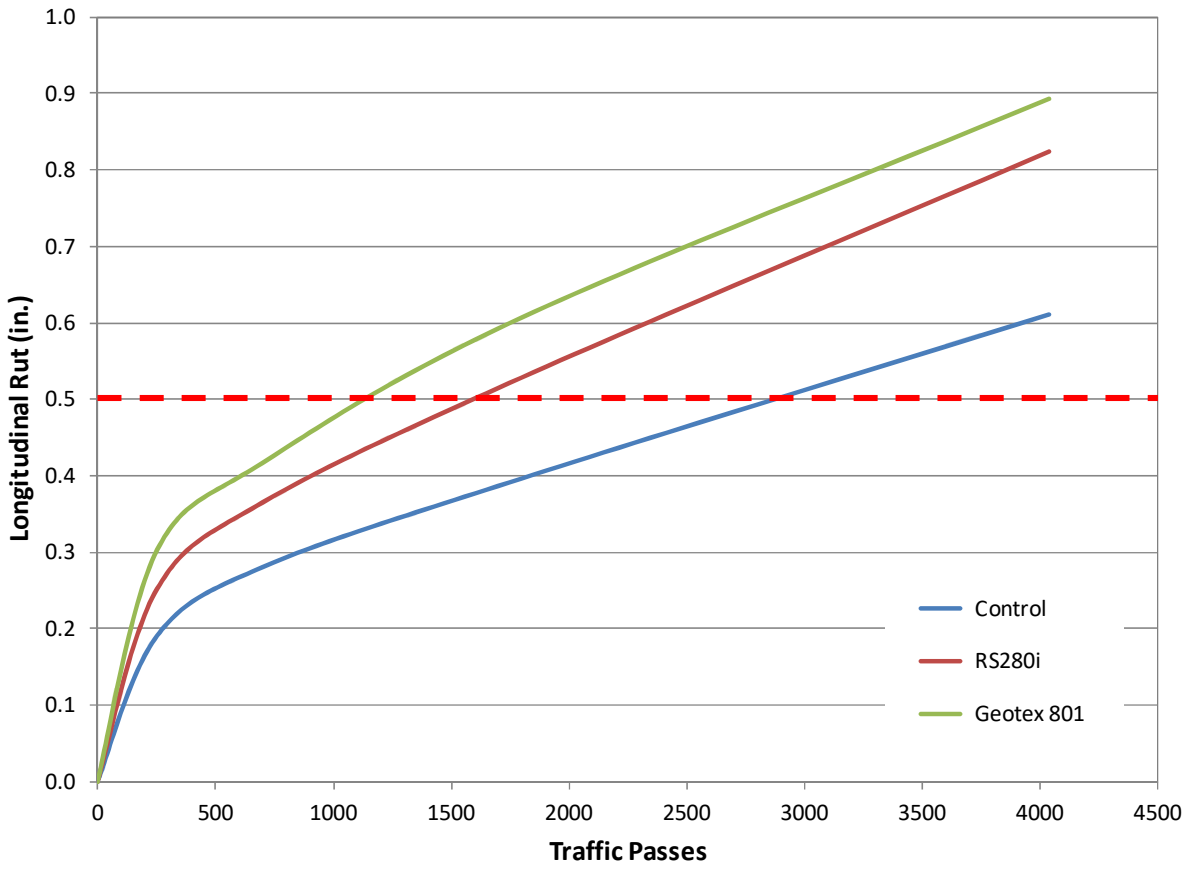
Surface Rut Measurements



Measurements in each test section:

- 34 measurements of longitudinal rut (17 per tire track)
- 2 transverse profiles

Longitudinal Rut Response

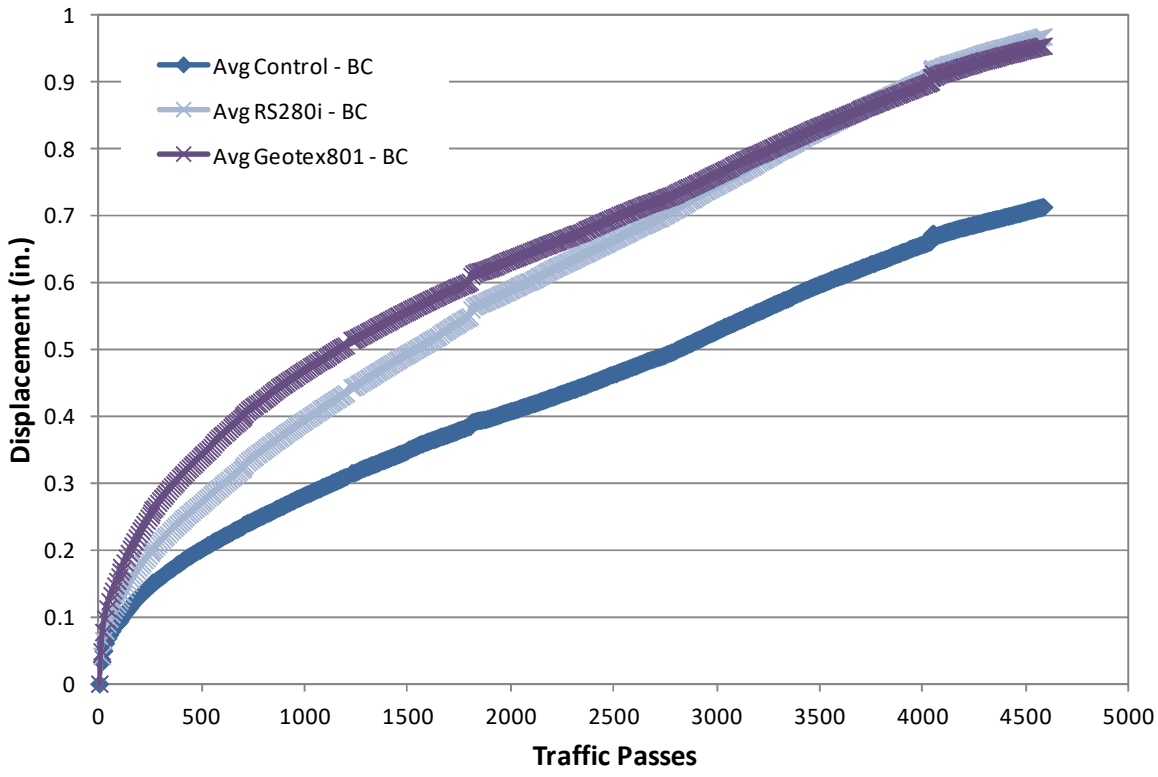


Primary observations:

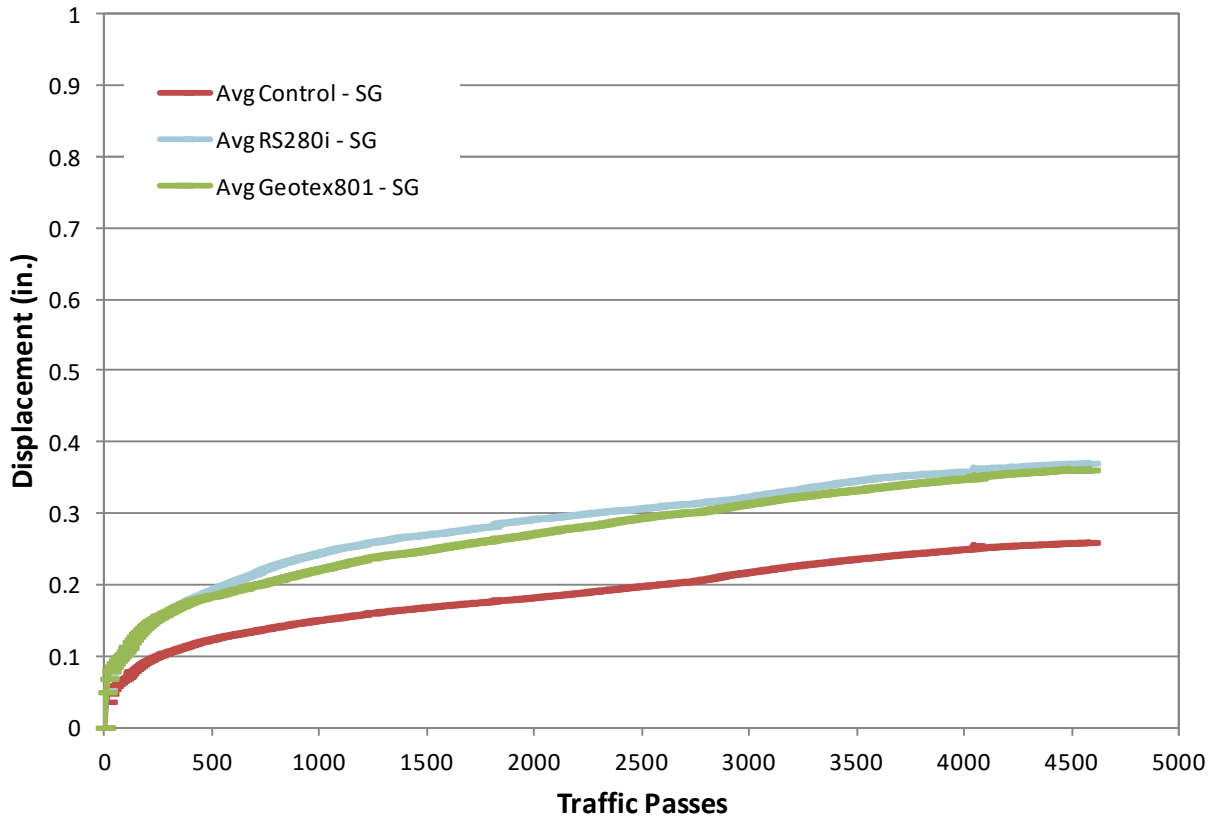
- Rapid rut accumulation
- Control performed best

Why?

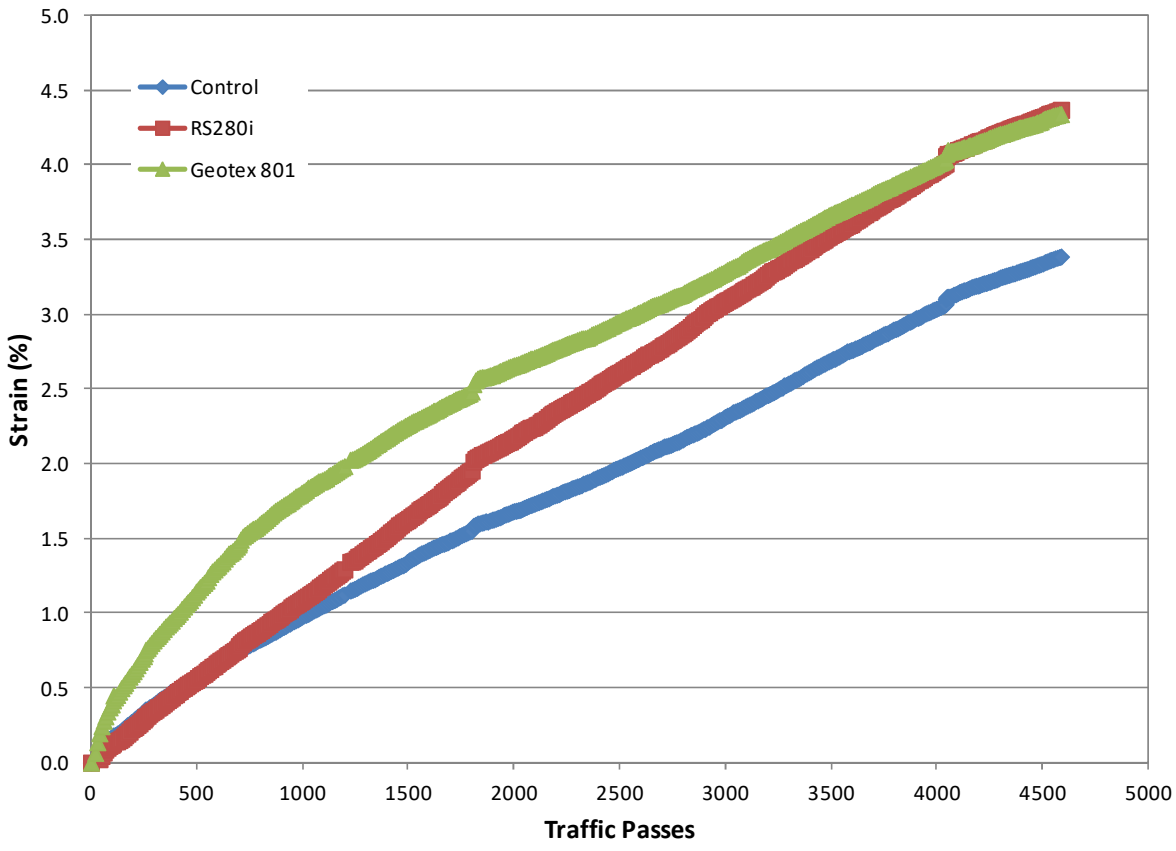
Avg Displacement of Base Surface



Avg Displacement of Subgrade Surface



Avg Strain in Base



Surface Profile

Why Large Strains in Base Course?

- Base compacted at optimum moisture content
- Was not part of QC plan to measure density of first layer
- First layer was too wet and did not get compacted properly
- Reluctance to distort subgrade surface with compaction equipment

Moving Forward

- Remove asphalt
- Remove base course
- Remove instrumentation
- Remove geosynthetics
- Re-level subgrade surface (removed ~1 in.)
- Rebuild base and asphalt layers

Base Course Construction Changes

- Compact below OMC
- Compact in 3 layers (versus 2)
- Allow to dry before next layer
- Compact using smaller equipment
  - Initial construction: 54 in. single drum (5.5 ton)
  - Reconstruction: 47 in. double drum (3 ton)

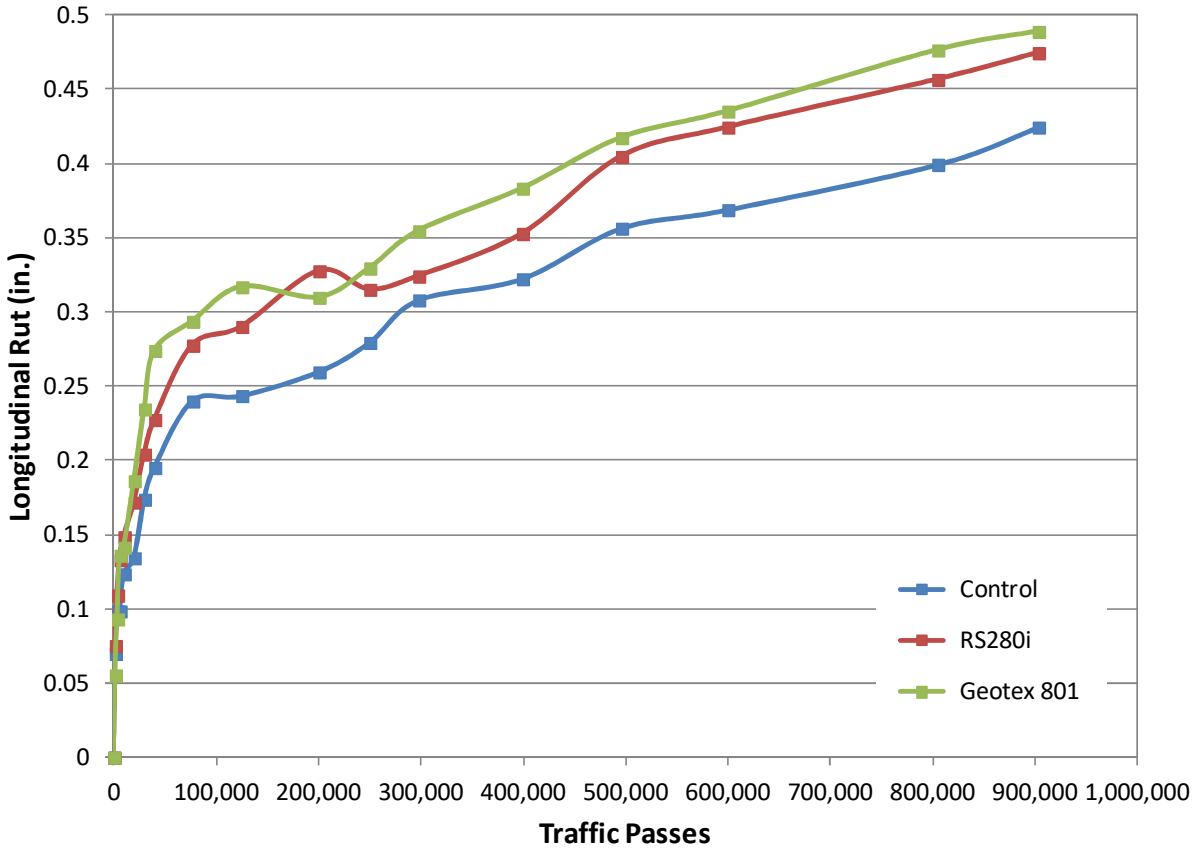
Base Construction Comparisons

Parameter	Phase I	Phase II
Thickness (in.)	13.4	13.3
Moisture content by layer* (%)	7.9 / 5.5	6.5 / 6.6 / 6.0
Dyn. Stiffness by layer* (MN/mm^3)	5.8 / 23.1	17.7 / 22.6 / 120.5
CBR from DCP (%)	17.7	73.4
Density by layer* (pcf)	138.8 (final layer only)	136.3 / 137.4 / 138.0

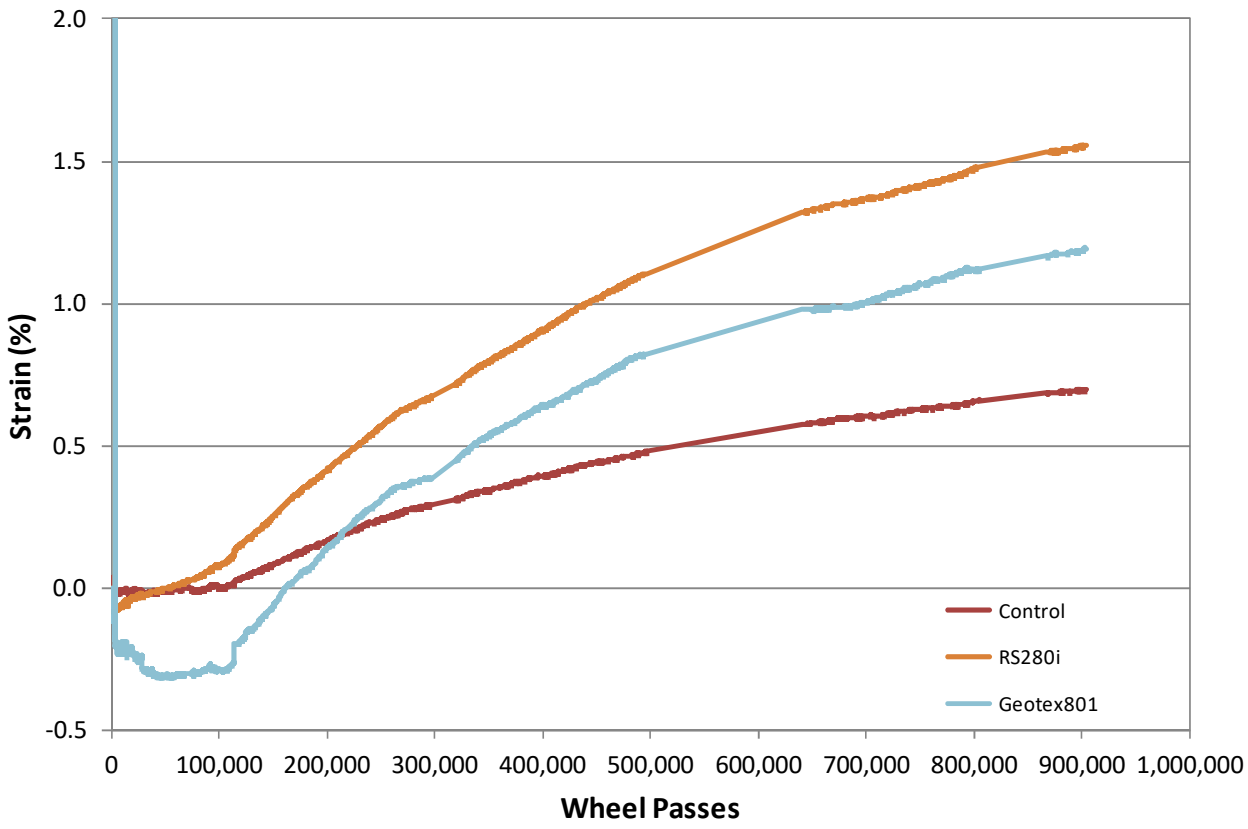
*Earlier numbers are associated with lower layers

Max. dry unit weight = 136.9 pcf
OMC = 7.7%

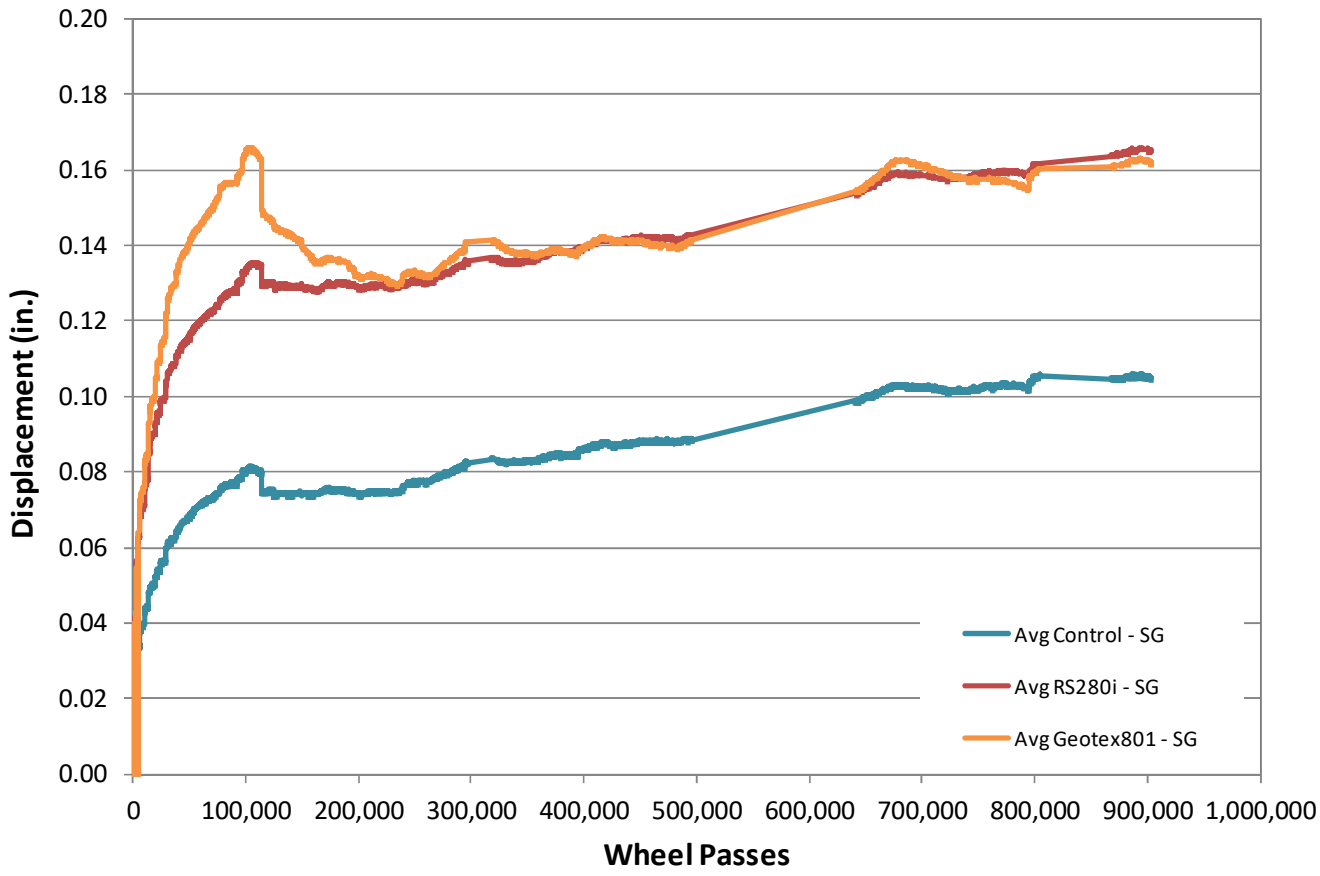
Longitudinal Rut Response (Ph. II)



Avg Base Course Strain



Avg Displacement of Subgrade Surface



Cross-Section Forensics

Possible Reasons for Ph. II Longevity

- Improved construction of base course
- Changes in subgrade <u>near the surface</u>
  - Decrease in moisture content (27.5→25.8%)
  - Increase in vane shear strength (108→142 kPa)
  - Increase in dynamic stiffness (4.0→6.2 MN/mm^3)
  - CBR from DCP (2.1→2.3%)
- Thicker asphalt layer (2.9→3.4 in.)

Summary and Conclusions

- All test sections performed similarly, showing no structural benefit of geotextiles in lab experiment
- Geotextiles will undoubtedly help maintaining integrity of base course over the life of the pavement
- Good compaction of base course layer is critical
- Introduction of water into pavement cross-section would likely change this result

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