Geogrid Reinforcement in Flexible Pavements

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Tensar International Corporation
October 6, 2010

ASCE American Society of Civil Engineers

REPORT CARD for america's INFRASTRUCTURE

SEARCH

★ HOME ★ REPORT CARDS ★ STATES ★ CATEGORIES ★ SOLUTIONS ★ TAKE ACTION ★ NEWSROOM ★

2009 Grades

Aviation	D
Bridges	C
Dams	D
Drinking Water	D-
Energy	D+
Hazardous Waste	D
Inland Waterways	D-
Levees	D-
Public Parks and Recreation	C-
Rail	C-
Roads	D-
Schools	D
Solid Waste	C+
Transit	D
Wastewater	D-

America's Infrastructure GPA: **D**

Estimated 5 Year Investment Need: **$2.2 Trillion**

The Infrastructure Roundtables

Read the Civil Engineering report on these events about the 5 Key Solutions

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Infrastructure in the News

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Take Our Poll

Five categories received D-. Which is the most urgent?

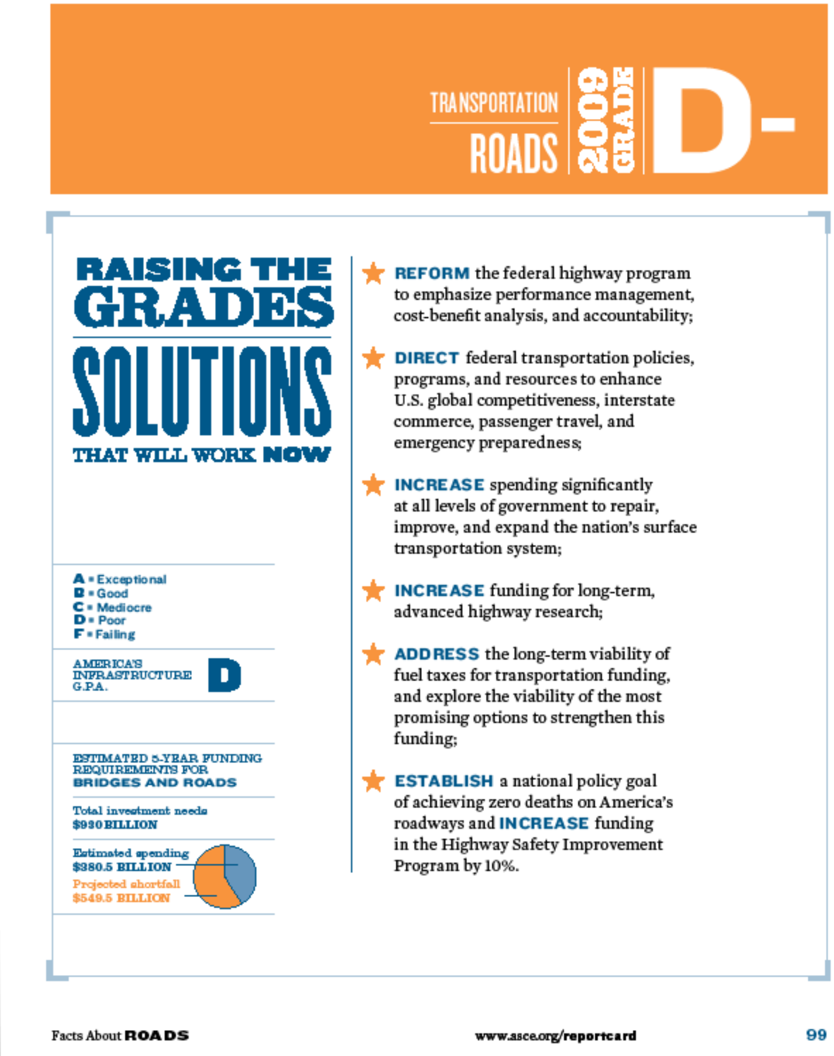
Drinking Water 54%

Inland Waterways 10%

Levees

Internet 100%

Our Roads



TRANSPORTATION

ROADS

2009 GRADE

D-

RAISING THE GRADES

SOLUTIONS THAT WILL WORK NOW

A = Exceptional
B = Good
C = Mediocre
D = Poor
F = Failing

AMERICA'S INFRASTRUCTURE G.P.A. D

ESTIMATED 5-YEAR FUNDING REQUIREMENTS FOR BRIDGES AND ROADS

Total investment needs
$930 BILLION

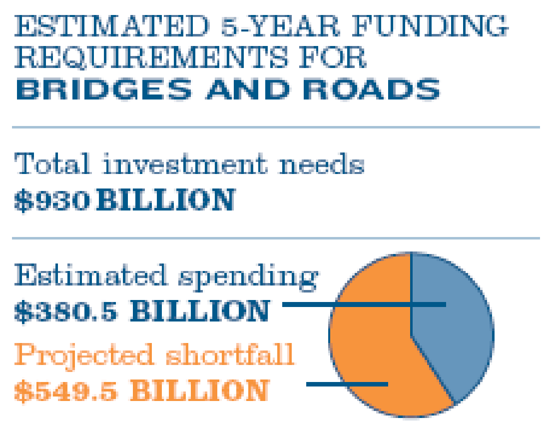
Estimated spending
$380.5 BILLION

Projected shortfall
$549.5 BILLION

- **REFORM** the federal highway program to emphasize performance management, cost-benefit analysis, and accountability;
- **DIRECT** federal transportation policies, programs, and resources to enhance U.S. global competitiveness, interstate commerce, passenger travel, and emergency preparedness;
- **INCREASE** spending significantly at all levels of government to repair, improve, and expand the nation's surface transportation system;
- **INCREASE** funding for long-term, advanced highway research;
- **ADDRESS** the long-term viability of fuel taxes for transportation funding, and explore the viability of the most promising options to strengthen this funding;
- **ESTABLISH** a national policy goal of achieving zero deaths on America's roadways and **INCREASE** funding in the Highway Safety Improvement Program by 10%.

Facts About **ROADS** www.asce.org/reportcard 99

- "33% of America's major roads are in poor or mediocre condition…"
- "The current spending level of $70.3 billion for highway capital improvements is well below the estimated $186 billion needed annually to substantially improve the nation's highways. "



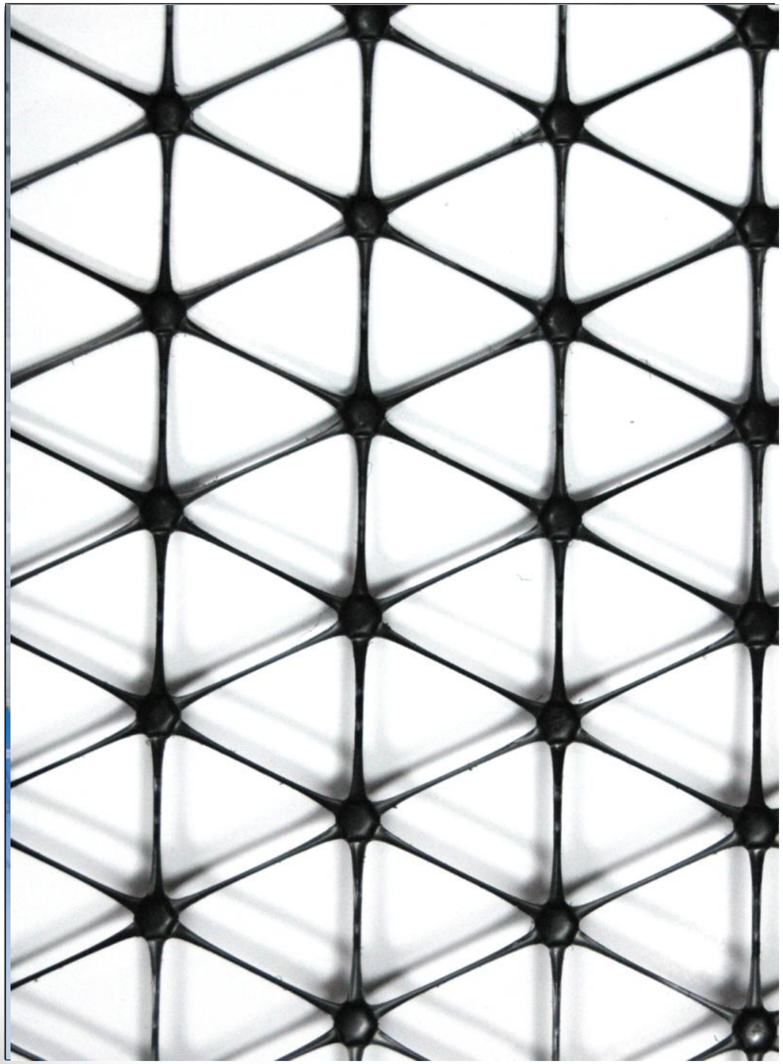
Source: infrastructurereportcard.com

Some Causes of Premature Road Failure

1. Weak Subgrade
2. Poor Drainage
3. Excessive Loading
4. Construction Errors
5. Material Failure
6. Unintended Use
7. Construction Damage to Subgrade
8. Regional Issues
    - Heaving, Thermal Cracking

Geogrid Introduction

Geogrid



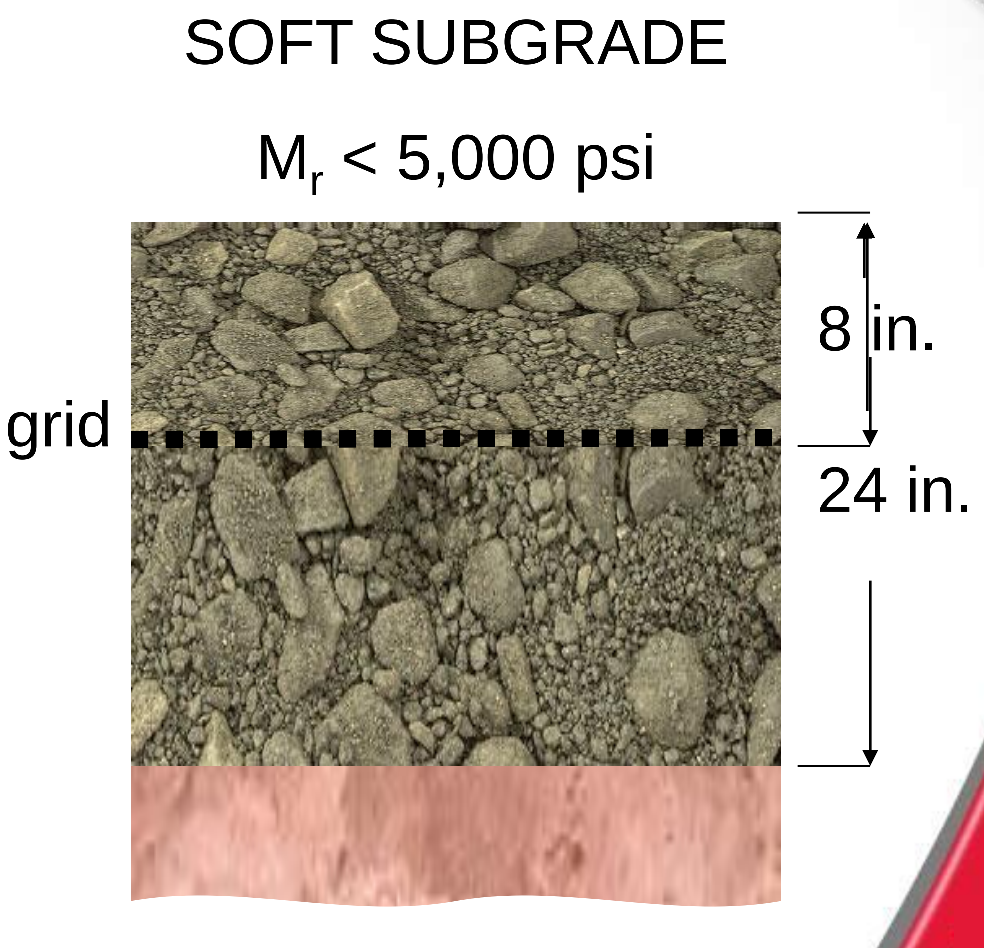
- Biaxial Geogrids
  - Extruded
  - Woven
  - Welded
  - Geogrid Composites
- Triaxial Geogrid
  - Extruded

Geogrid Reinforcement

- Subgrade Improvement
  - Undercut reduction in soft soils
  - Improved construction platform for road construction
  - Protection of sensitive subgrade soils

- Pavement Base Reinforcement
  - Stiffening of base aggregate layer
  - Reduction of pavement section
  - Extended life of pavement

SUBGRADE IMPROVEMENT

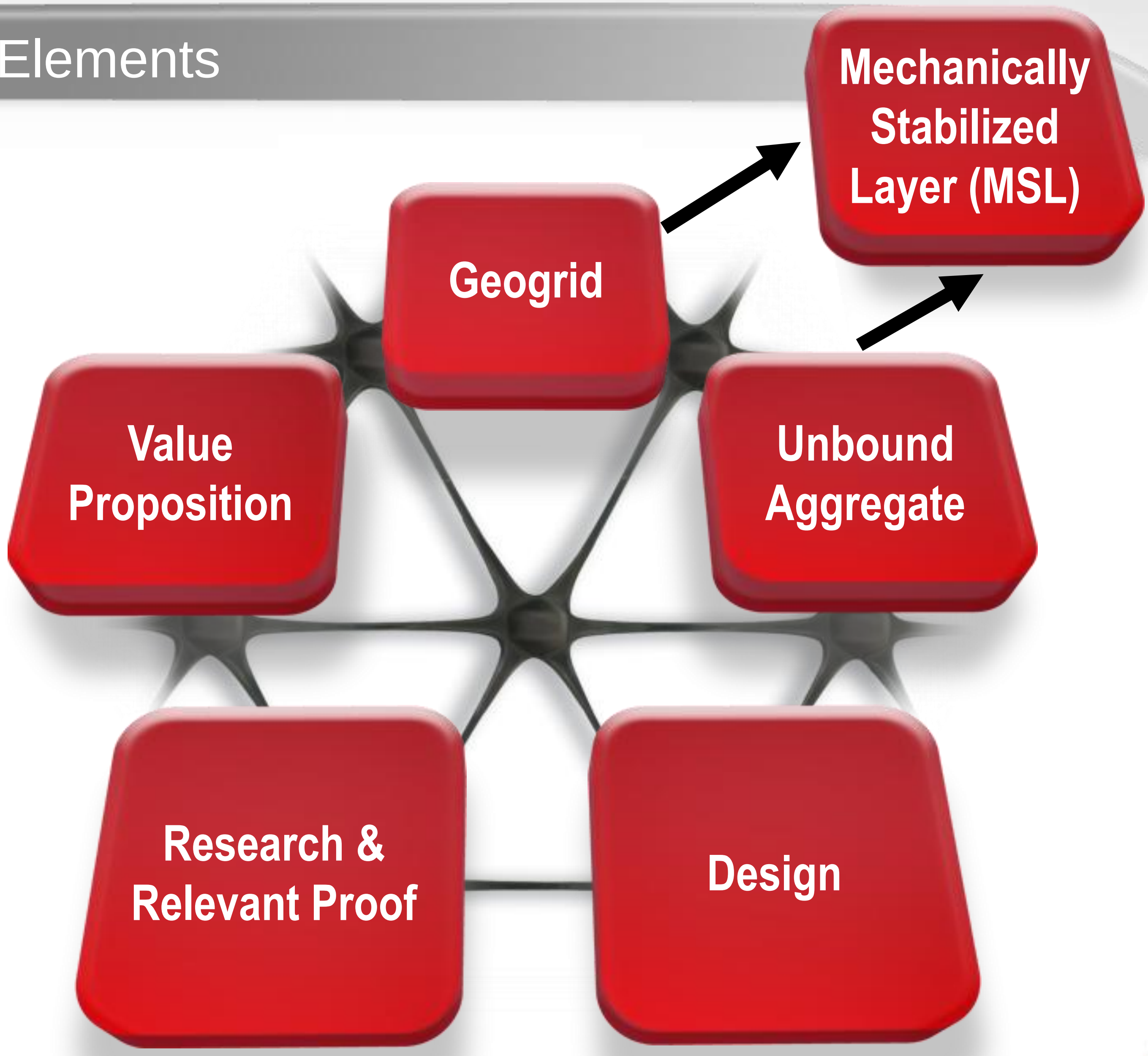


PAVEMENT BASE REINFORCEMENT

↑ LIFE : ↓ COST

grid

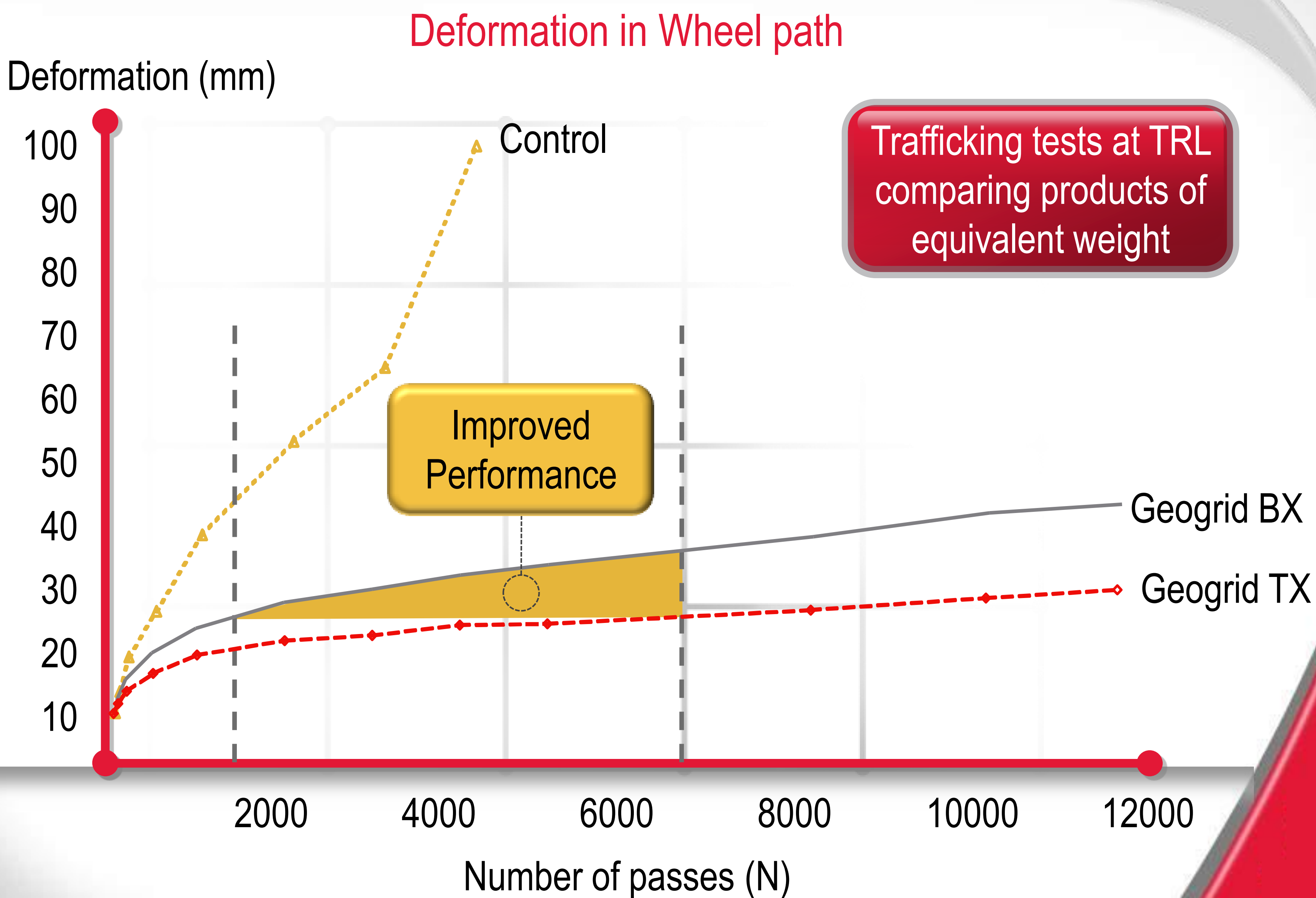
Design Elements



Geogrid Research

Full-scale Trafficking – TRL

Longer Design Life



Small-scale Trafficking

Performance Measured through Rutting Profiles

Aggregate Rutting Profiles

Unreinforced

3,000 axle passes

Geogrid BX

10,000 axle passes

Geogrid TX

10,000 axle passes

Subgrade Rutting Profiles - Unreinforced

Unreinforced

3,000 axle passes

Geogrid BX

10,000 axle passes

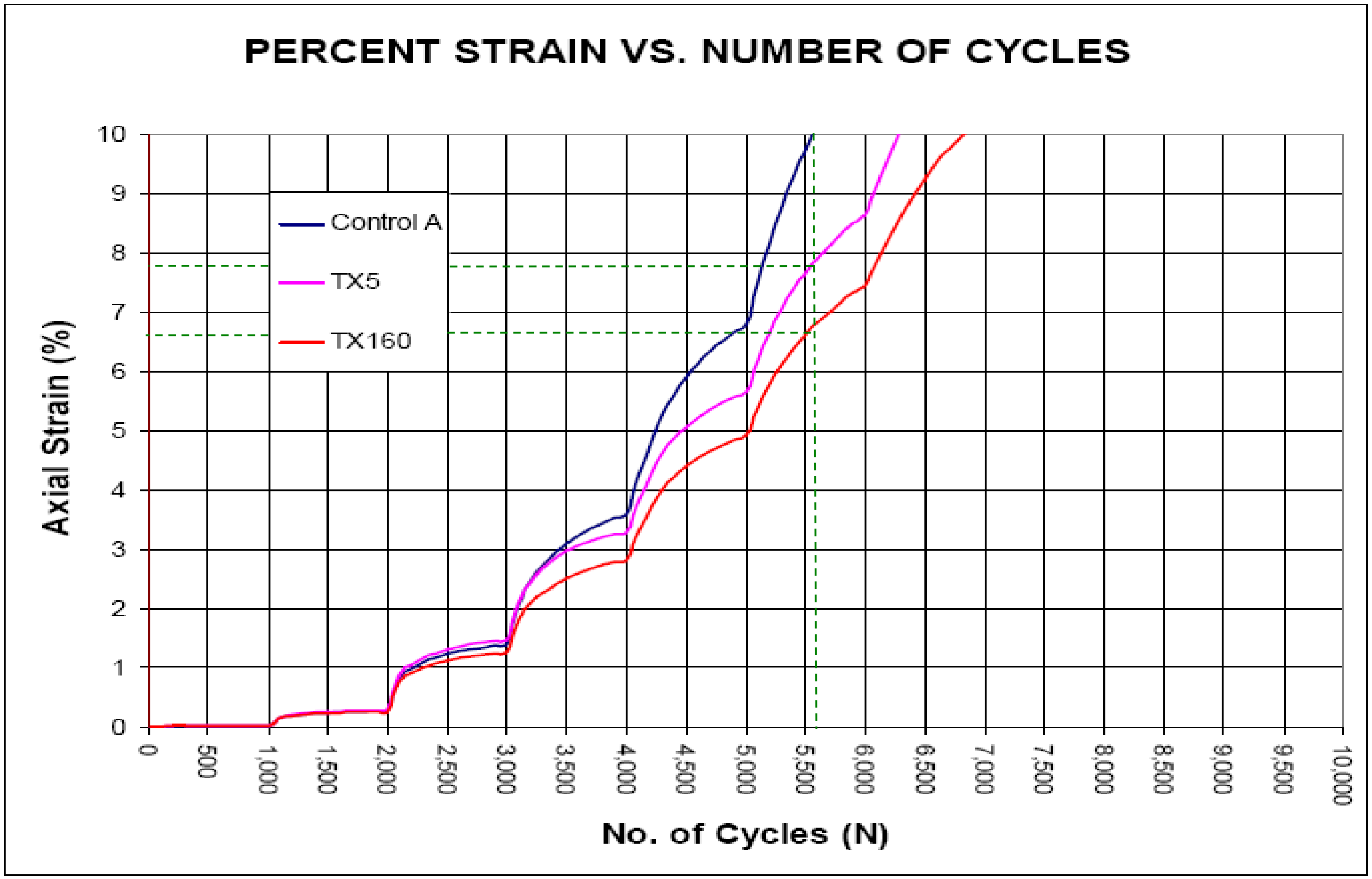
Geogrid TX

10,000 axle passes

Tri-Axial Cell Testing

Geogrid Placement

Multistage Repeated Load Tri-Axial Cell Testing



Multistage Repeated Load Tri-Axial Cell Testing

$$E = s/v$$

$$E_c = s/0.10 = 10s$$

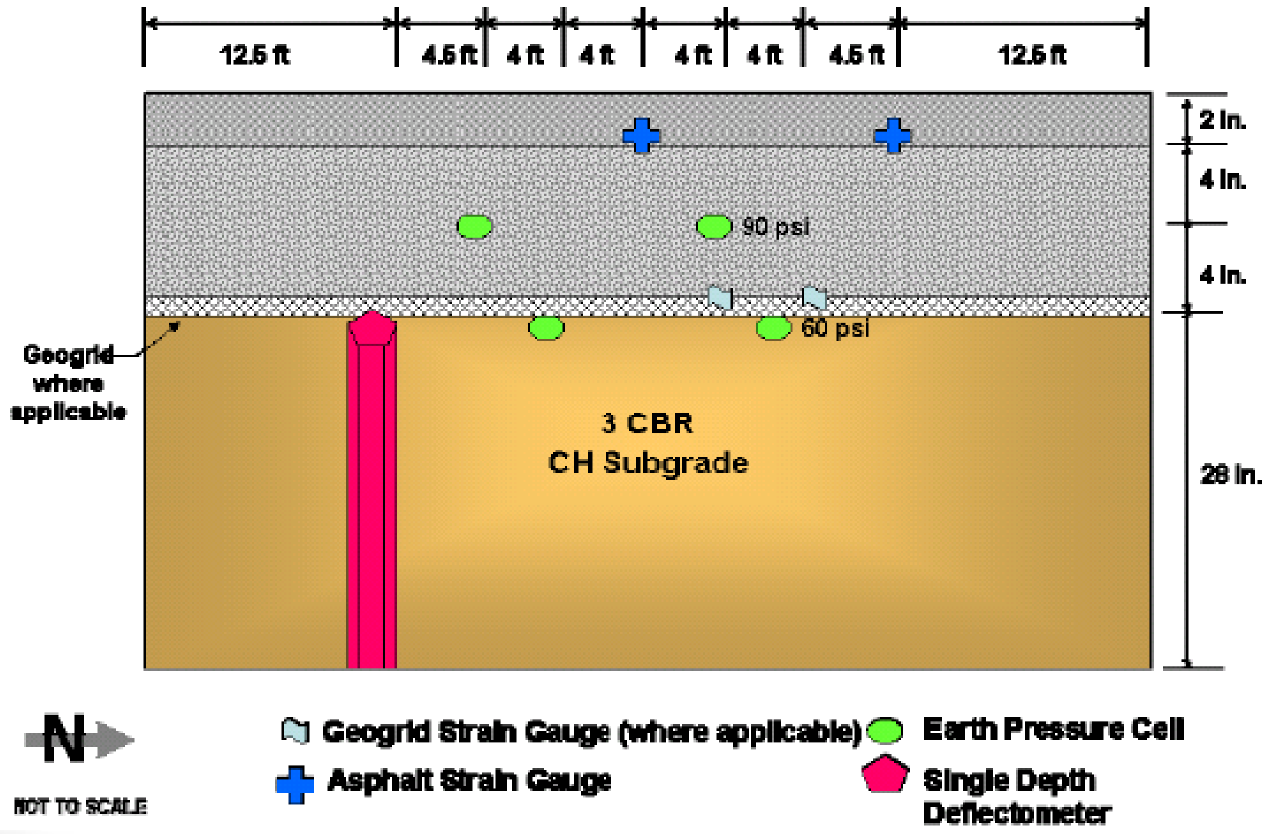
$$E_{TX5} = s/0.0775 = 13s$$

$$E_{TX160} = s/0.066 = 15s$$

Geogrid 1 = 30% modulus increase
Geogrid 2 = 50% modulus increase

U.S. Army Corps of Engineers Full Scale APT

U.S. Army Corps of Engineers Full Scale APT



U.S. Army Corps of Engineers Full Scale APT

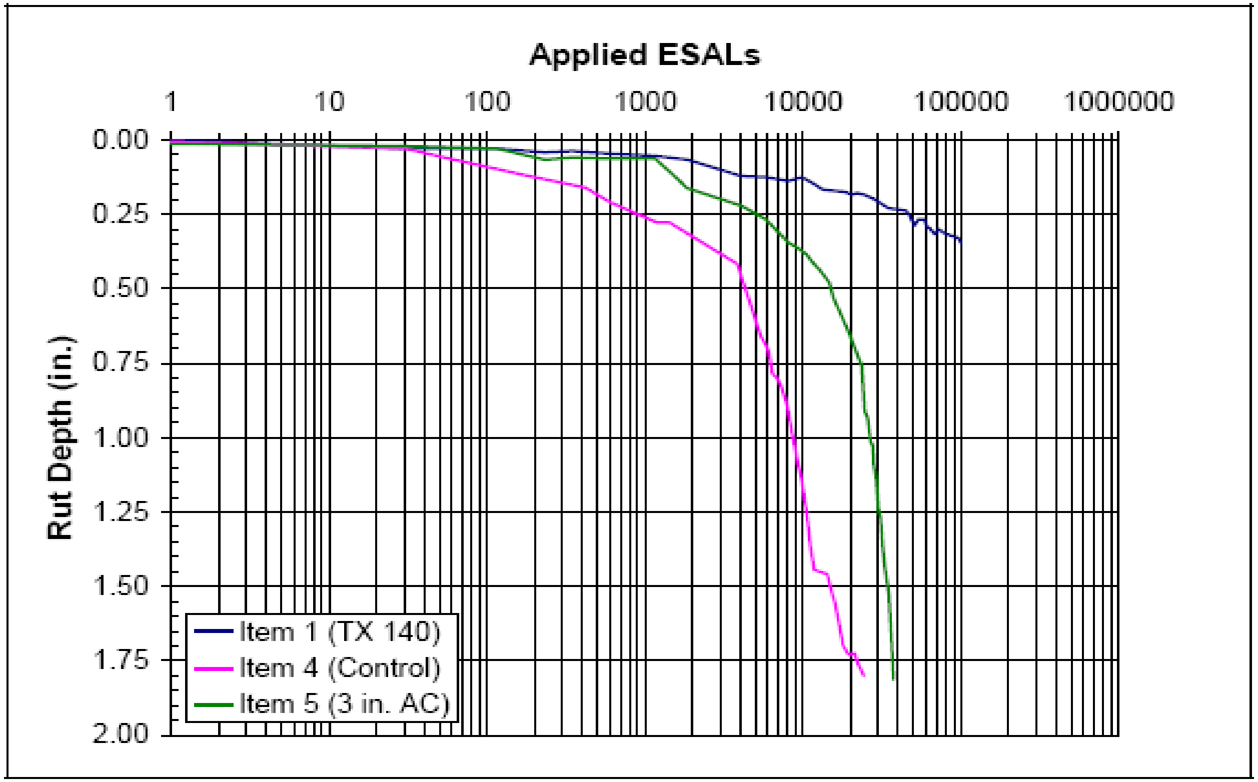


Figure 23. Accumulation of rutting at selected locations

Subgrade Stabilization

Design

Circa 1910



Geosynthetic Design Methods for Subgrade Stabilization

FHWA Geosynthetic Design and Construction Guidelines – 2008 Sections 5.4 and 5.5

FHWA Geosynthetic Design and Construction Guidelines

- Section 5.4 – Design Guidelines for the use of Geotextiles in Temporary and Unpaved Roads
  - 1977 Steward, et. al. (US Forestry Service)
- Section 5.5 – Design Guidelines for the use of Geogrids in Temporary and Unpaved Roads
  - 2003 Tingle and Webster (U.S.A.C.O.E.)
  - 2004 Giroud and Han
- A temporary or unpaved road may constitute improved subgrade or a construction platform for a permanent road

1977 - Steward, et. al. (U.S. Forestry Service)

- Geotextile Only
- Utilizes Bearing Capacity Factor - N_C
- Developed prior to the existence of biaxial geogrid

1977 - Steward, et. al. (U.S. Forestry Service)

"the following limitations apply:

- the aggregate layer must be

  a) compacted to CBR 80,

  b) cohesionless (nonplastic);

- vehicle passes less than 10,000;
- geotextile survivability criteria must be considered; and
- subgrade undrained shear strength less than about 90 kPa (CBR <3)"

Source: U.S.F.S. Steward, et. al. 1977

2003 - Tingle and Webster (U.S. Army Corps of Engineers)

- Modified Steward, et. al. for geogrids and geotextiles
- Utilizes Bearing Capacity Factor - N_C
- Identifies 3 performance mechanisms of geogrid

Geogrid Mechanisms

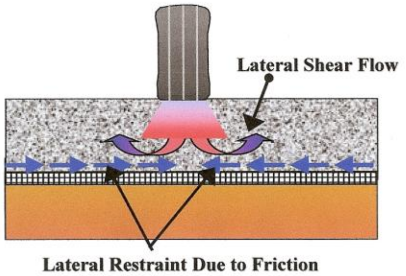


Figure 1. Lateral restraint reinforcement mechanism.

1. **<u>Lateral Restraint</u>**

   "Confinement"

   (true stability)

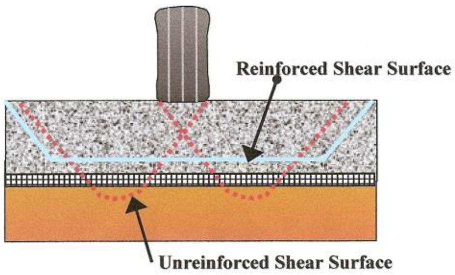


Figure 2. Improved bearing capacity reinforcement mechanism.

2. **<u>Improved Bearing Capacity</u>**

   "Snowshoe Effect"

   (load distribution)

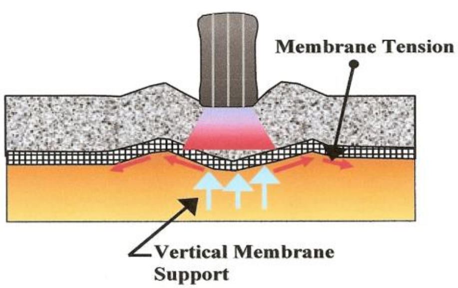


Figure 3. Tensioned membrane effect reinforcement mechanism.

3. **<u>Tensioned Membrane</u>**

   "Hammock Effect"

   (initial tension)

Source: U.S. Army Corps of Engineers ETL 1110-1-189

Geogrid Mechanisms

"In the early stages of research regarding geogrid reinforcement of pavement systems, the tensioned membrane effect was thought to be the primary reinforcement mechanism. However, subsequent investigations have shown that reinforcement benefits are obtained without significant deformation of the pavement section. Thus, lateral restraint has been identified as the primary reinforcement mechanism, followed by the improved bearing capacity concept and the tensioned membrane effect.

Source: U.S. Army Corps of Engineers ETL 1110-1-189

2004: Giroud and Han

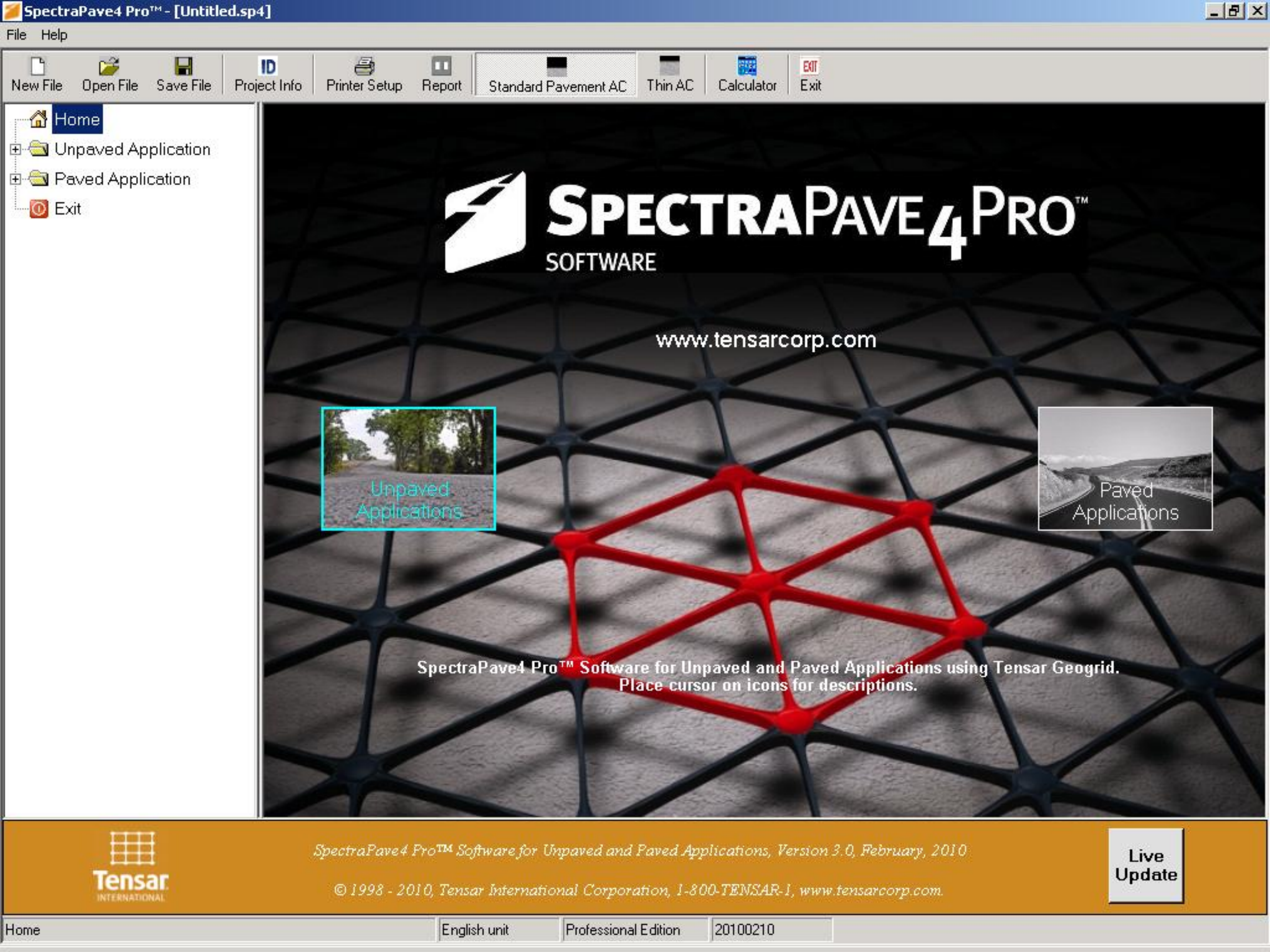
- Geogrid and geotextile
- Built on principles of Giroud and Noiray (1981) design method for geotextiles
- Individual geogrids must be empirically calibrated to formula
- Utilizes Bearing Capacity Factor – N_C
- Utilizes Bearing Capacity Mobilization Coefficient – *m*
- Utilizes Stress Distribution Angle - a

2004: Giroud and Han

"Due to their large apertures, geogrids may interlock with base course aggregate if there is an appropriate relationship between geogrid aperture size and aggregate particle size. While the degree of interlocking depends on the relationship between geogrid aperture size and aggregate particle size, the effectiveness of interlocking depends on the in-plane stiffness of the geogrid and the stability of the geogrid ribs and junctions. As a result of interlocking, the mechanisms of unpaved structure reinforcement are different for geotextiles and geogrids."

FHWA Design Guidelines Summary

- Only three (3) design methods detailed for soft subgrades
- Steward, et. al. only pertains to geotextiles
- Tingle and Webster built on Steward's study and developed geogrid performance mechanisms
- Giroud and Han introduce bearing capacity mobilization and stress distribution factors for geogrid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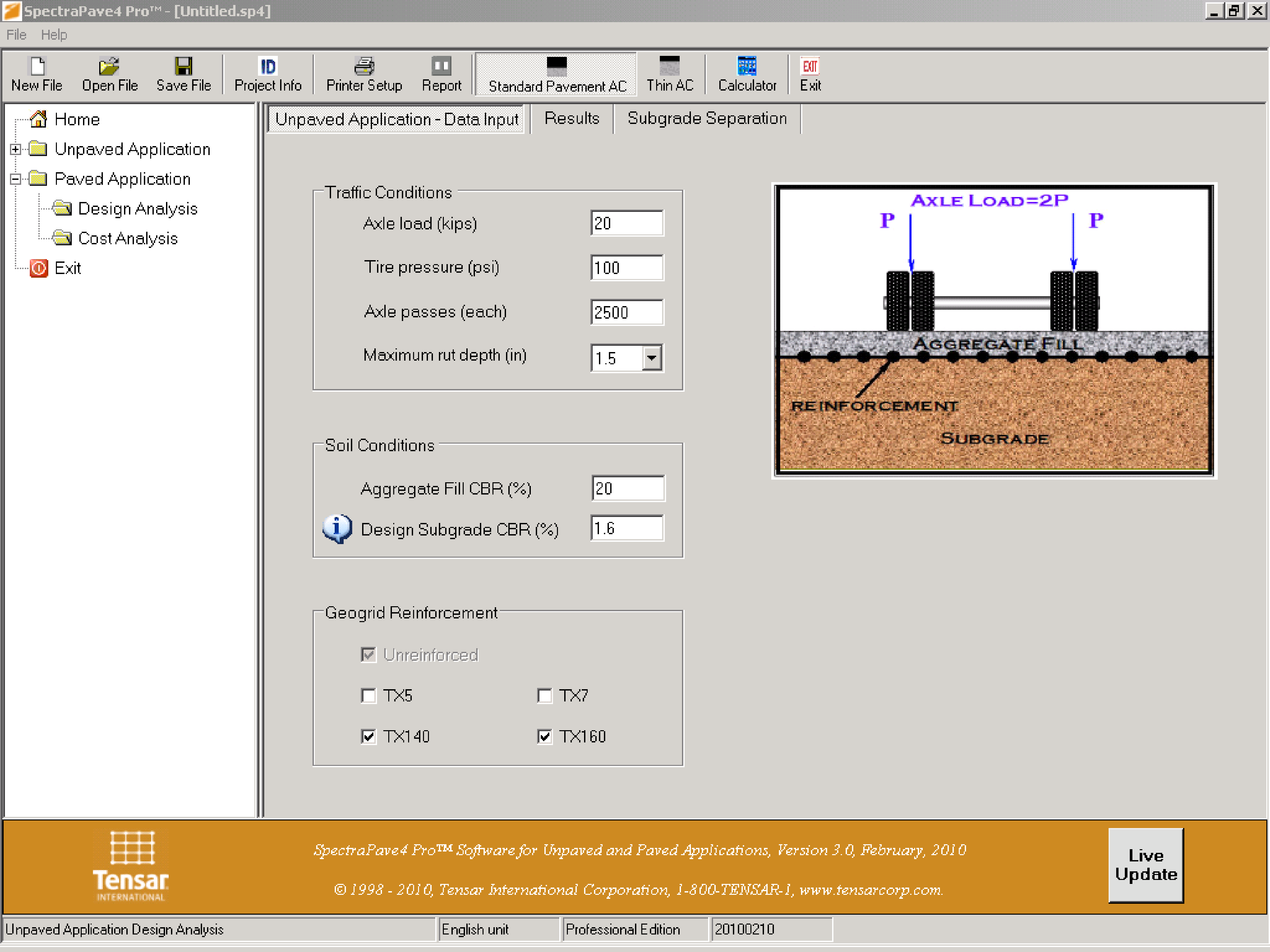
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Paved Application
Design Analysis
Cost Analysis
Exit
Unpaved Application - Data Input
Results
Subgrade Separation
Traffic Conditions
Axle load (kips) 20
Tire pressure (psi) 100
Axle passes (each) 2500
Maximum rut depth (in) 1.5
Soil Conditions
Aggregate Fill CBR (%) 20
Design Subgrade CBR (%) 1.6
Geogrid Reinforcement
Unreinforced
TX5
TX7
TX140
TX160
AXLE LOAD=2P
P
P
AGGREGATE FILL
REINFORCEMENT
SUBGRADE
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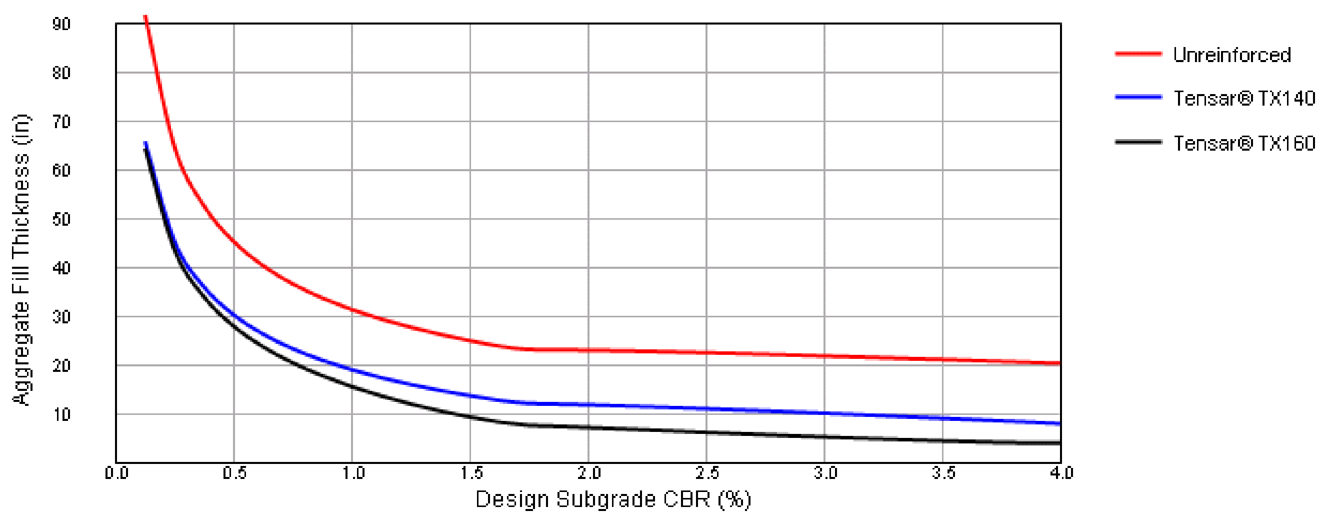
  - Cost Analysis
- Exit

Unpaved Application - Data Input | Results

Geosynthetic	Aggregate Fill Thickness (in)		Aggregate Fill Thickness Savings	
	Calculated	Required	(in)	(%)
Unreinforced	24.05	25	N/A	N/A
Tensar® TX140	12.9	13	12	48
Tensar® TX160	8.46	9	16	64

Click Here to Conduct Unpaved Application Cost Analysis

Click Here to Check Subgrade Separation



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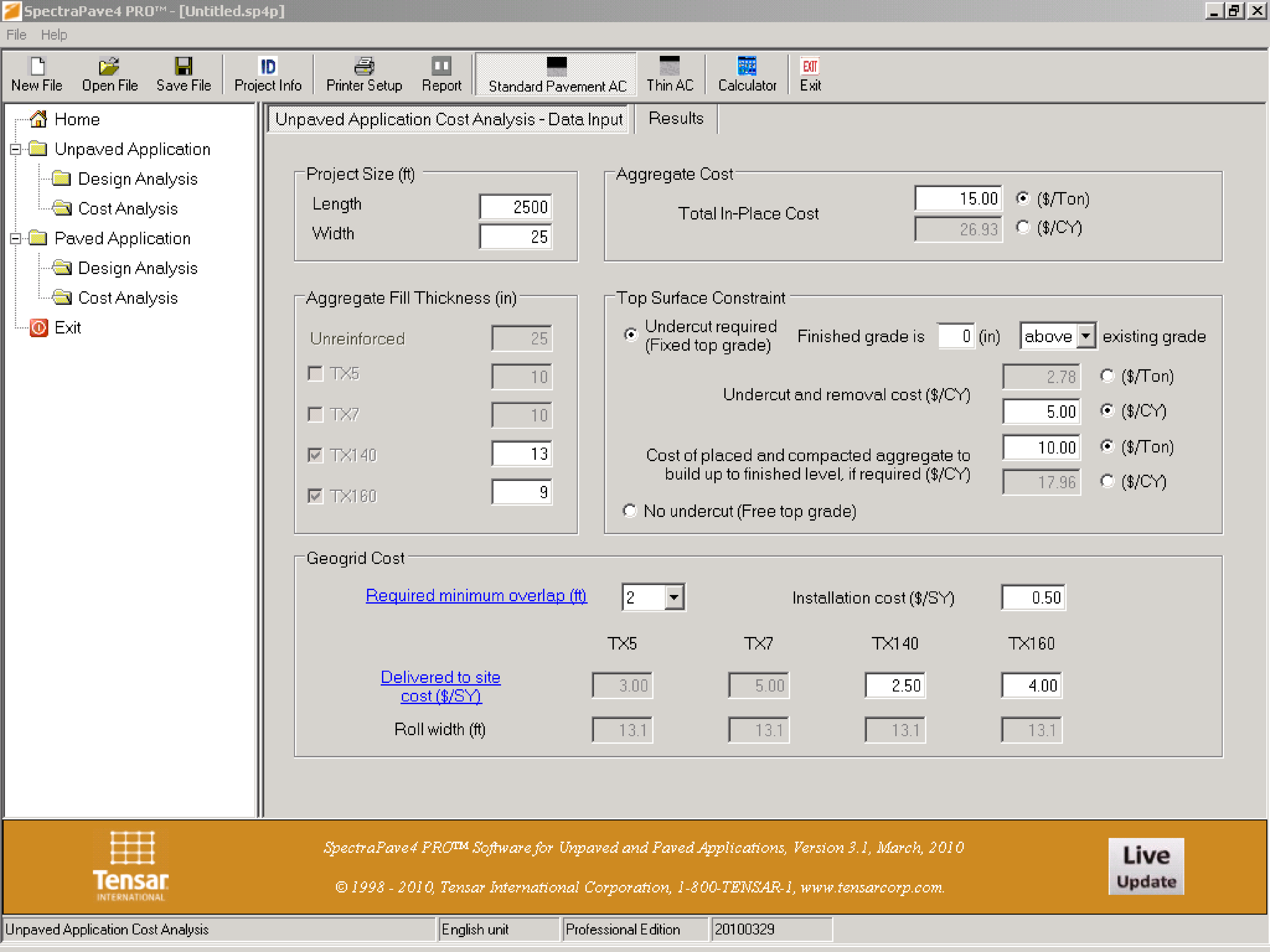
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Cost Analysis
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Cost Analysis
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Unpaved Application Cost Analysis - Data Input
Results
Project Size (ft)
Length
2500
Width
25
Aggregate Cost
Total In-Place Cost
15.00
($/Ton)
26.93
($/CY)
Aggregate Fill Thickness (in)
Unreinforced
25
TX5
10
TX7
10
TX140
13
TX160
9
Top Surface Constraint
Undercut required (Fixed top grade)
Finished grade is
0
(in)
above
existing grade
2.78
($/Ton)
Undercut and removal cost ($/CY)
5.00
($/CY)
10.00
($/Ton)
Cost of placed and compacted aggregate to build up to finished level, if required ($/CY)
17.96
($/CY)
No undercut (Free top grade)
Geogrid Cost
Required minimum overlap (ft)
2
Installation cost ($/SY)
0.50
TX5
TX7
TX140
TX160
Delivered to site cost ($/SY)
3.00
5.00
2.50
4.00
Roll width (ft)
13.1
13.1
13.1
13.1
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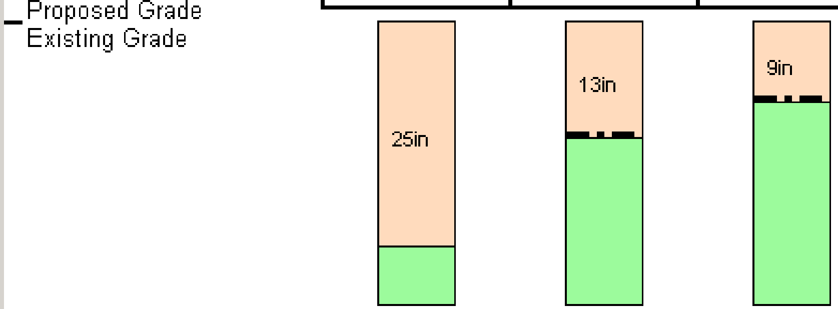
Unpaved Application Cost Analysis - Data Input | Results

Legend

Aggregate fill | Existing subgrade | Additional fill required | Geogrid

Click Here to Modify Design Parameters



	Unreinforced	TX140	TX160
Aggregate costs	$129,871	$67,533	$46,753
Geogrid costs	$0	$24,014	$36,021
Undercut costs	$24,113	$12,539	$8,681
Additional fill costs	$0	$0	$0
Total project costs	$153,983	$89,610	$105,619
Overall project savings	**$0**	**$49,898**	**$62,528**
Percent savings	**0%**	**32%**	**41%**

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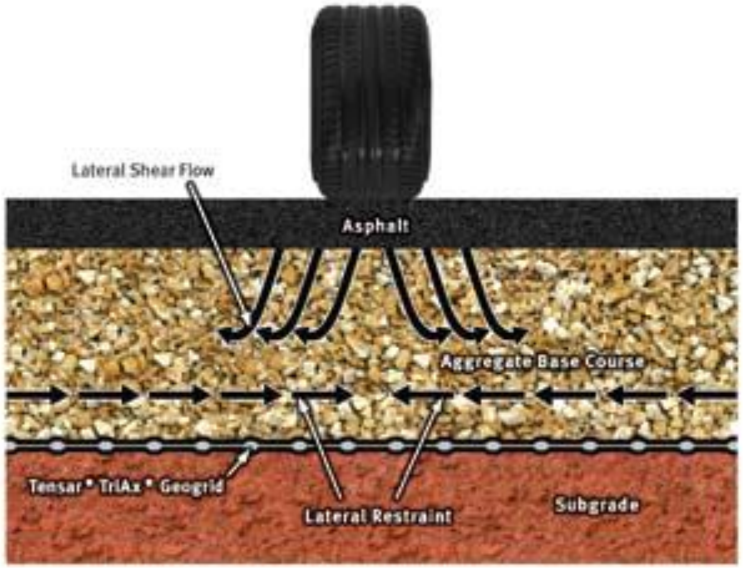
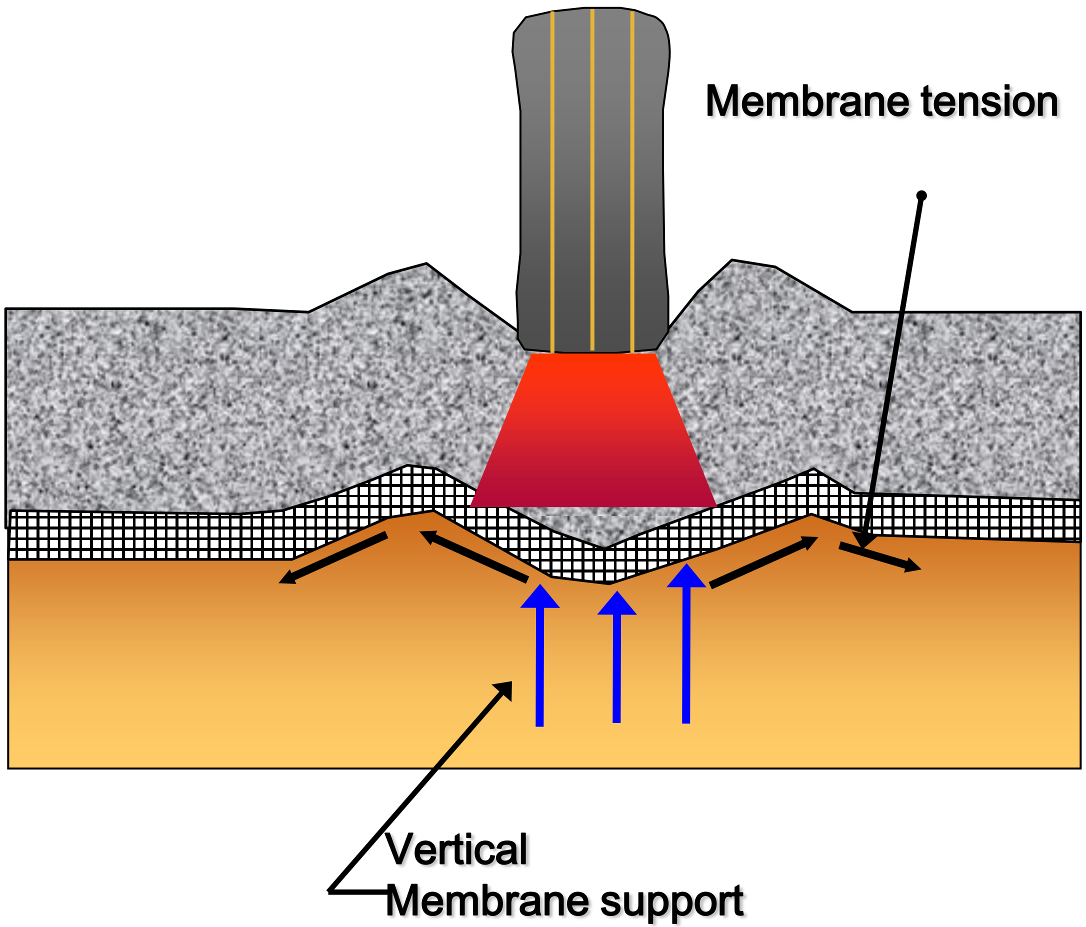
Pavement Design with Geogrid

Pavement Base Reinforcement

- Equal performance for considerably less cost
- Increased performance with lower life cycle costs
- Optimized – Increased performance for the same cost

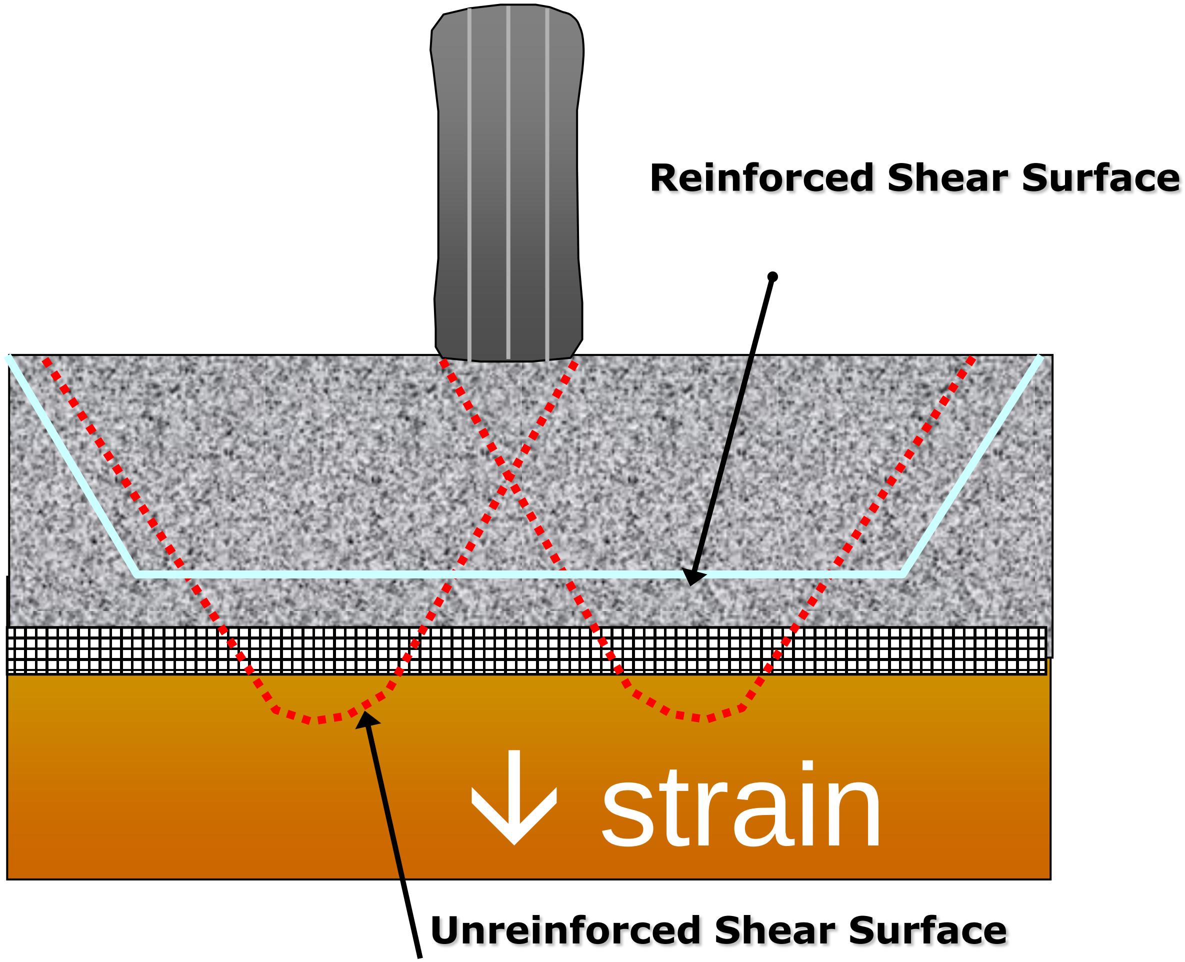


Mechanisms – Tensile Membrane Effect



Source: USACOE ETL 1110-1-189

Mechanisms – Improved Bearing Capacity



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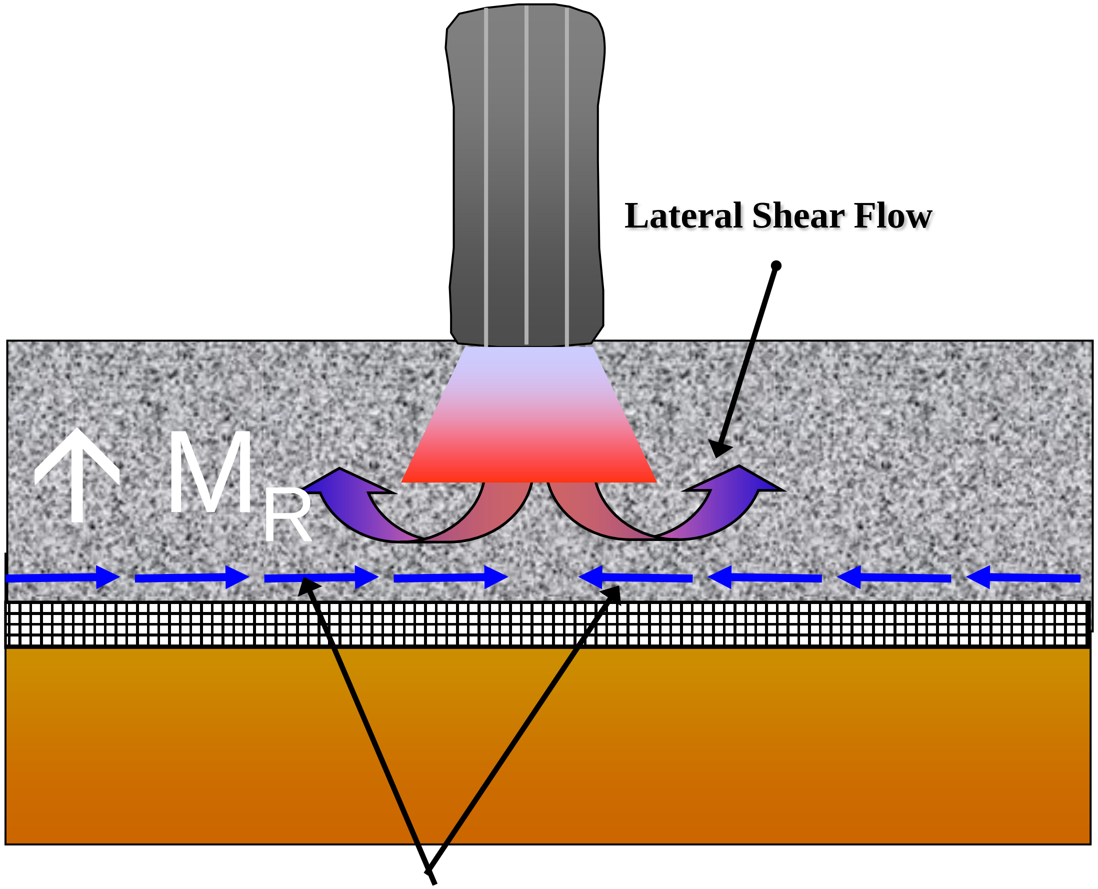
Mechanisms – Lateral Restraint



Lateral Restraint Due to Friction and Aggregate Interlock

Source: USACOE ETL 1110-1-189

AASHTO 1993 Pavement Design Formula

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

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

S_N = 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 = i^{th} layer coefficient

D_i = i^{th} layer thickness (inches)

m_i = i^{th} 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)

Standard Practice for

Geosynthetic Reinforcement of the Aggregate Base Course of Flexible Pavement Structures

AASHTO Designation: R 50-09[1]

1. SCOPE

1.1. This standard practice provides guidance to pavement designers interested in incorporating geosynthetics for the purpose of reinforcing the aggregate base course of flexible pavement structures. Geosynthetic reinforcement is intended to provide structural support of traffic loads over the life of the pavement.

1.1.1. For the purpose of this guide, base reinforcement is the use of a geosynthetic within, or directly beneath, the granular base course.

1.1.2. When referring to geosynthetics, the discussion is limited to geotextiles, geogrids, or geogrid/geotextile composites.

2. REFERENCED DOCUMENTS

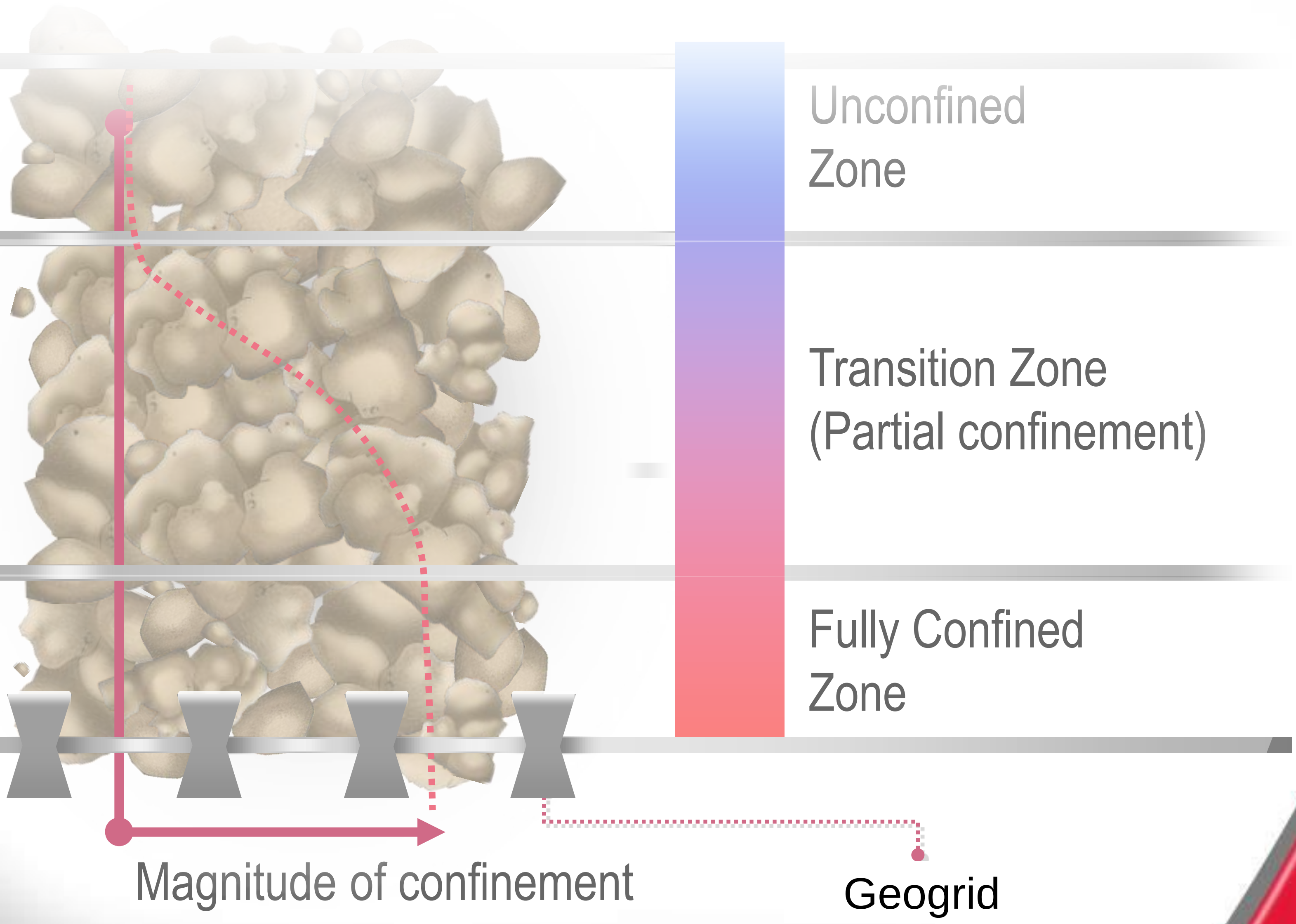
6.1 Geosynthetics are used in the pavement structure for structural support of traffic loads over the design life of the pavement. The geosynthetic is expected to provide one or both of these benefits: 1) *improved or extended service life of the pavement*, or 2) *a reduction in the thickness of the structural section.*

AASHTO Designation: R 50-09[1]

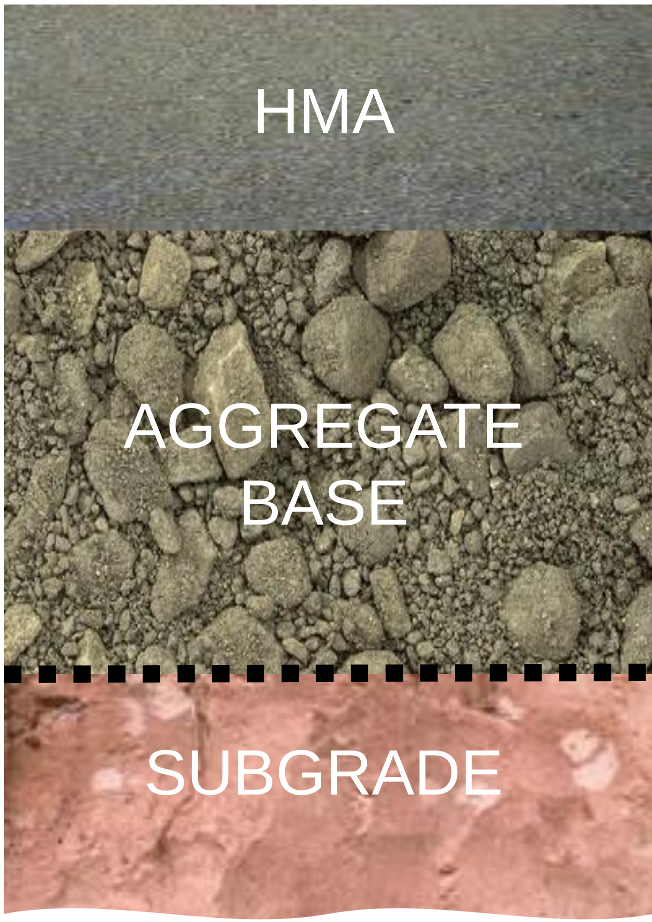
7.1.6.1 The traffic benefit ratio (TBR) is defined as the ratio of the number of load cycles of a reinforced pavement to reach a defined failure state, to the number of loads for the same unreinforced section to reach the same defined failure state.

2. REFERENCED DOCUMENTS

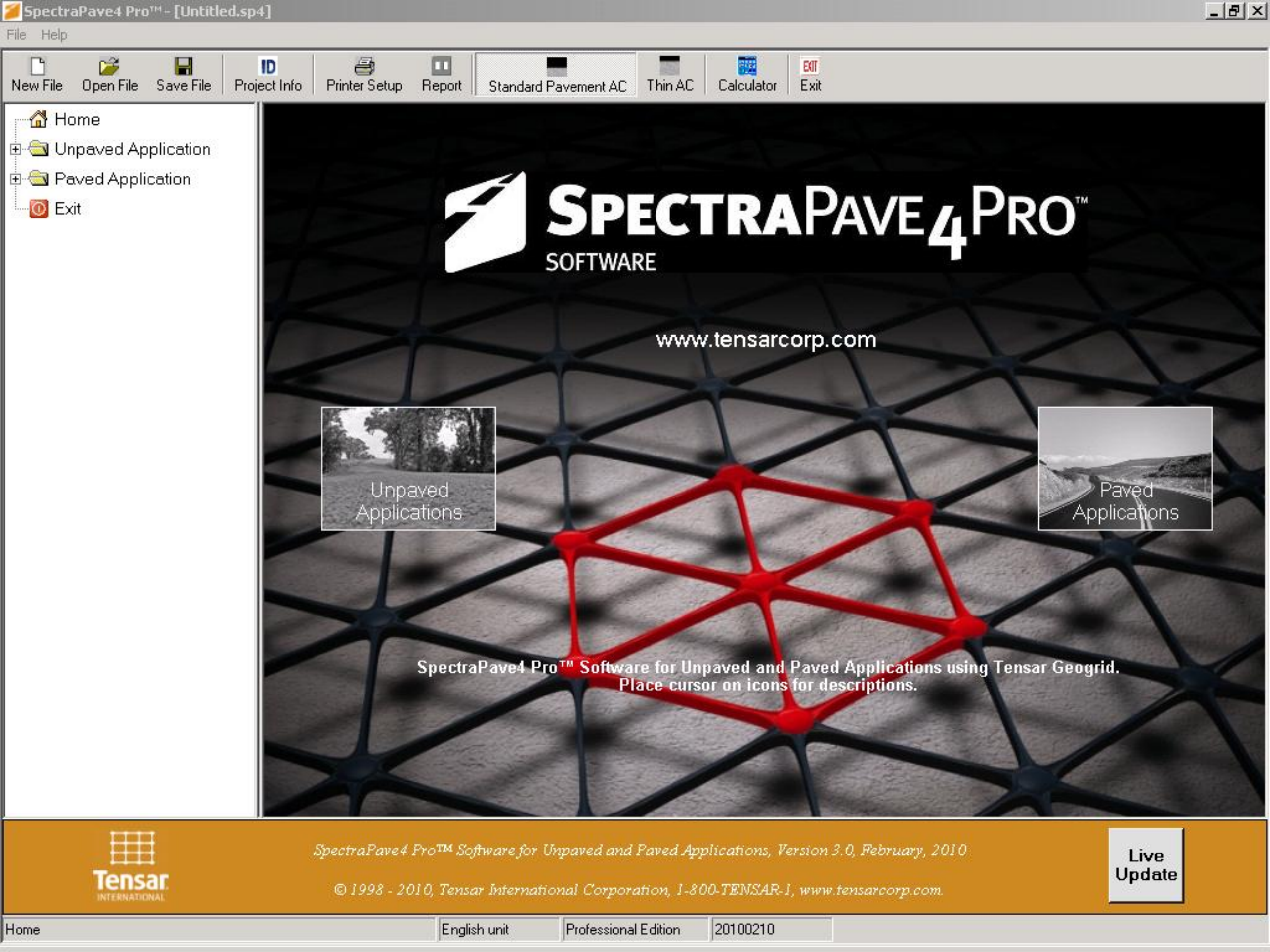
Mechanically Stabilized Layer (MSL)



Typical Pavement Section



ACC: a_i = 0.36 to 0.44	
ABC: a_i = 0.12 to 0.18 ↑ stress = ↑ M_r MSL: a_i up to 0.28	
↓ stress = ↓ strain	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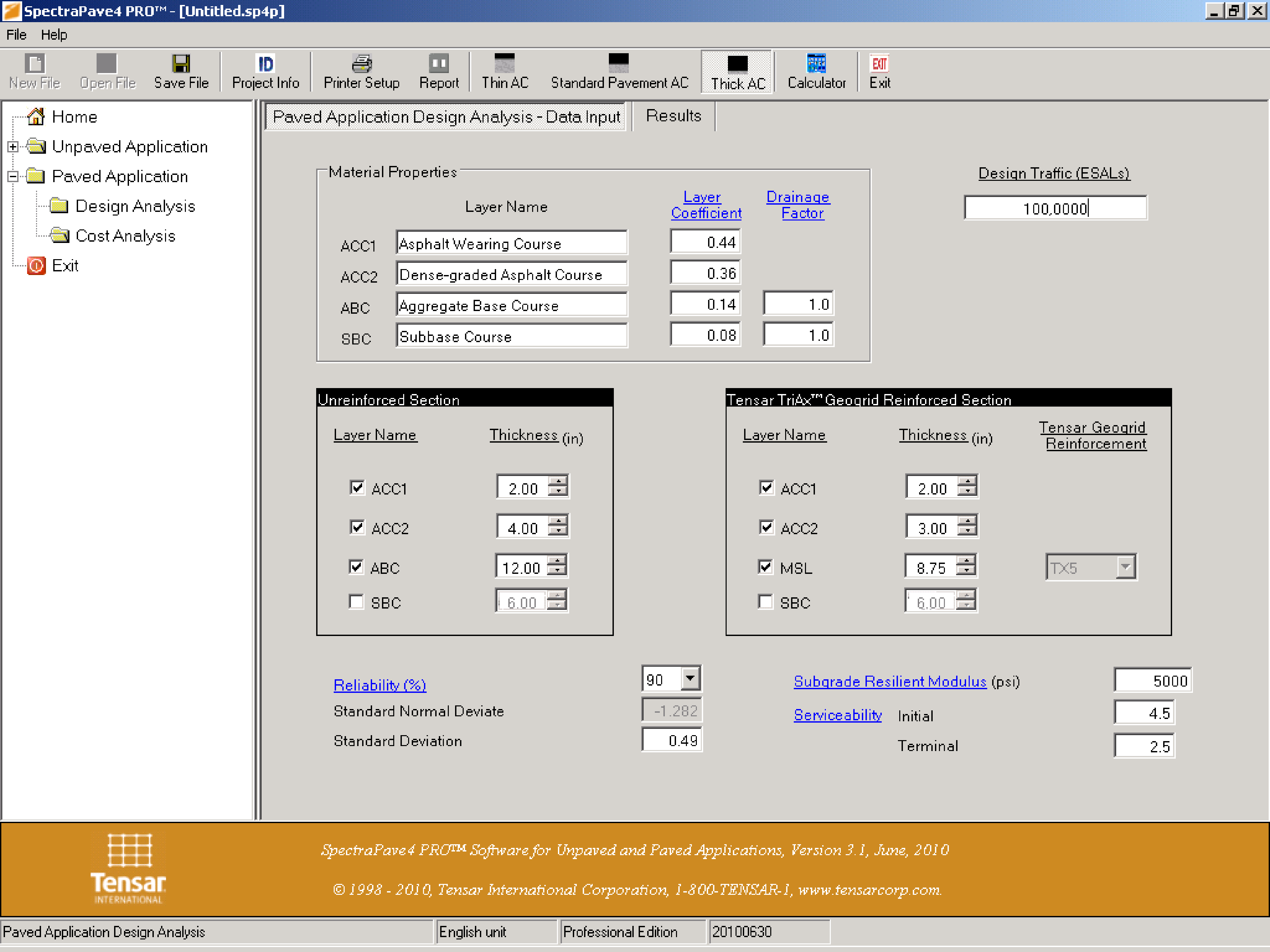
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Results
Material Properties
Layer Name
Layer Coefficient
Drainage Factor
ACC1 Asphalt Wearing Course 0.44
ACC2 Dense-graded Asphalt Course 0.36
ABC Aggregate Base Course 0.14 1.0
SBC Subbase Course 0.08 1.0
Design Traffic (ESALs)
100,0000
Unreinforced Section
Layer Name
Thickness (in)
ACC1 2.00
ACC2 4.00
ABC 12.00
SBC 6.00
Tensar TriAx™ Geogrid Reinforced Section
Layer Name
Thickness (in)
Tensar Geogrid Reinforcement
ACC1 2.00
ACC2 3.00
MSL 8.75
TX5
SBC 6.00
Reliability (%) 90
Standard Normal Deviate -1.282
Standard Deviation 0.49
Subgrade Resilient Modulus (psi) 5000
Serviceability Initial 4.5
Terminal 2.5
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Paved Application Design Analysis - Data Input | Results

Design Traffic (ESALs) = 1,000,000

☑ Round Results

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Unreinforced Section

Layer	Di	ai	mi	SN
ACC1	2.00	0.440	N/A	0.88
ACC2	4.00	0.360	N/A	1.44
ABC	12.00	0.140	1.0	1.68
Overall Structural Number (SN)				4.00

Tensar TriAx™ Geogrid Reinforced Section

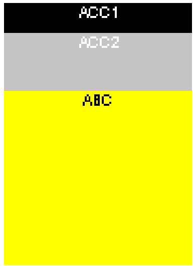
Layer	Di	ai	mi	SN
ACC1	2.00	0.440	N/A	0.88
ACC2	3.00	0.360	N/A	1.08
MSL	8.75	0.234	1.0	2.05
Overall Structural Number (SN)				4.01

Thickness (in)

ACC1: 2.00

ACC2: 4.00

ABC 12.00

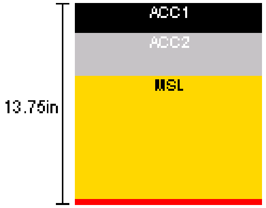


Thickness (in)

ACC1: 2.00

ACC2: 3.00

MSL 8.75



Geogrid Depth

TX5

1,066,000 — Calculated Traffic (ESAL's) — 1,084,000

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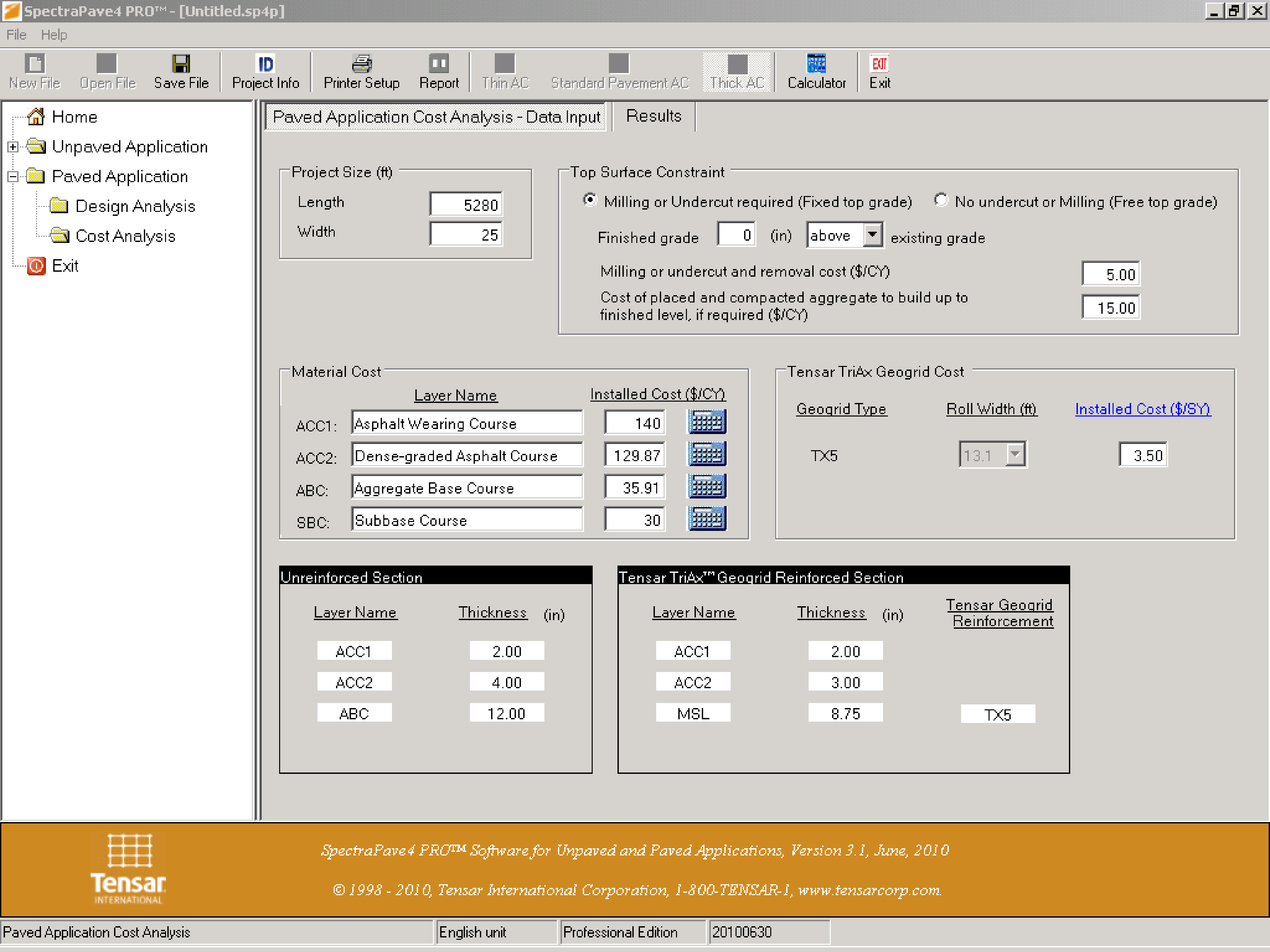

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Results
Project Size (ft)
Length 5280
Width 25
Top Surface Constraint
Milling or Undercut required (Fixed top grade)
No undercut or Milling (Free top grade)
Finished grade 0 (in) above existing grade
Milling or undercut and removal cost ($/CY) 5.00
Cost of placed and compacted aggregate to build up to finished level, if required ($/CY) 15.00
Material Cost
Layer Name
Installed Cost ($/CY)
ACC1: Asphalt Wearing Course 140
ACC2: Dense-graded Asphalt Course 129.87
ABC: Aggregate Base Course 35.91
SBC: Subbase Course 30
Tensar TriAx Geogrid Cost
Geogrid Type
Roll Width (ft)
Installed Cost ($/SY)
TX5 13.1 3.50
Unreinforced Section
Layer Name
Thickness (in)
ACC1 2.00
ACC2 4.00
ABC 12.00
Tensar TriAx™ Geogrid Reinforced Section
Layer Name
Thickness (in)
Tensar Geogrid Reinforcement
ACC1 2.00
ACC2 3.00
MSL 8.75 TX5
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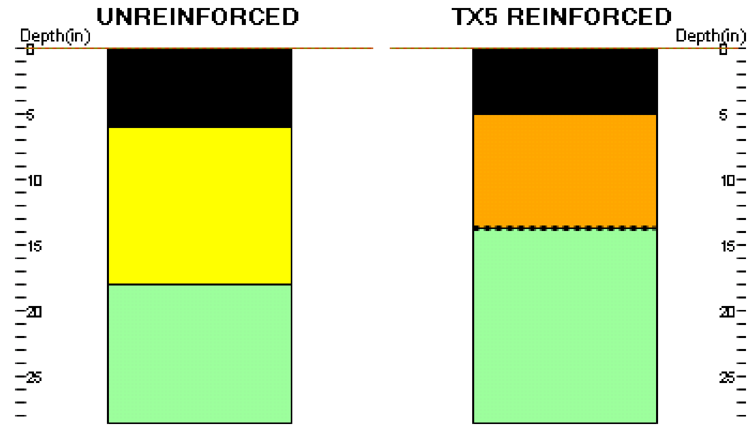
LEGEND

- Existing Grade
- Finished Grade
- Tensar TriAx™ Geogrid
- Asphalt (ACC1+ACC2)
- Base (ABC+SBC)
- Base (MSL+SBC)
- Subgrade
- Additional Fill



	UNREINFORCED	TX5 REINFORCED
Allowable Traffic (ESALs):	1,066,000	1,084,000
Section Unit Cost:	**$36.68/SY**	**$33.01/SY**
% Life Extension:		2%
% Initial Cost Saving:		10%

INITIAL CONSTRUCTION COSTS ☑ **Round Results**

Asphalt (ACC1+ACC2)	$ 325,714	$ 272,804
Aggregate Base (ABC/MSL)	$ 175,560	$ 128,013
Subbase (SBC)	$ 0	$ 0
Milling or Undercut	$ 36,667	$ 28,009
Additional Fill Costs	$ 0	$ 0
Geogrids	$ 0	$ 55,252
Overall Project Cost	**$ 537,941**	**$ 484,078**

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Paved Application Design Analysis - Data Input | Results

Design Traffic (ESALs) = 1,000,000

☑ Round Results

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Unreinforced Section

Layer	Di	ai	mi	SN
ACC1	2.00	0.440	N/A	0.88
ACC2	4.00	0.360	N/A	1.44
ABC	12.00	0.140	1.0	1.68
Overall Structural Number (SN)				4.00

Tensar TriAx™ Geogrid Reinforced Section

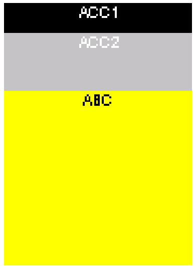
Layer	Di	ai	mi	SN
ACC1	2.00	0.440	N/A	0.88
ACC2	3.00	0.360	N/A	1.08
MSL	12.00	0.215	1.0	2.58
Overall Structural Number (SN)				4.54

Thickness (in)

ACC1: 2.00

ACC2: 4.00

ABC 12.00



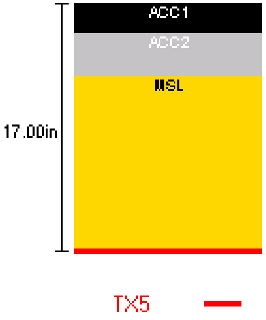
Thickness (in)

ACC1: 2.00

ACC2: 3.00

MSL 12.00

Geogrid Depth



1,066,000 — Calculated Traffic (ESAL's) — 2,549,000

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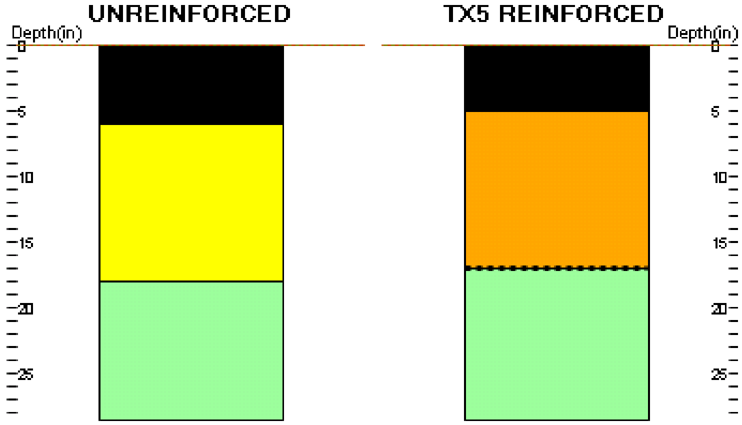
Paved Application Cost Analysis - Data Input | Results

LEGEND

- Existing Grade
- Finished Grade
- Tensar TriAx™ Geogrid
- Asphalt (ACC1+ACC2)
- Base (ABC+SBC)
- Base (MSL+SBC)
- Subgrade
- Additional Fill



	UNREINFORCED	TX5 REINFORCED
Allowable Traffic (ESALs):	1,066,000	2,549,000
Section Unit Cost:	**$36.68/SY**	**$36.70/SY**
% Life Extension:		139%
% Initial Cost Saving:		0%

INITIAL CONSTRUCTION COSTS ☑ Round Results

Asphalt (ACC1+ACC2)	$ 325,714	$ 272,804
Aggregate Base (ABC/MSL)	$ 175,560	$ 175,560
Subbase (SBC)	$ 0	$ 0
Milling or Undercut	$ 36,667	$ 34,630
Additional Fill Costs	$ 0	$ 0
Geogrids	$ 0	$ 55,252
Overall Project Cost	**$ 537,941**	**$ 538,246**

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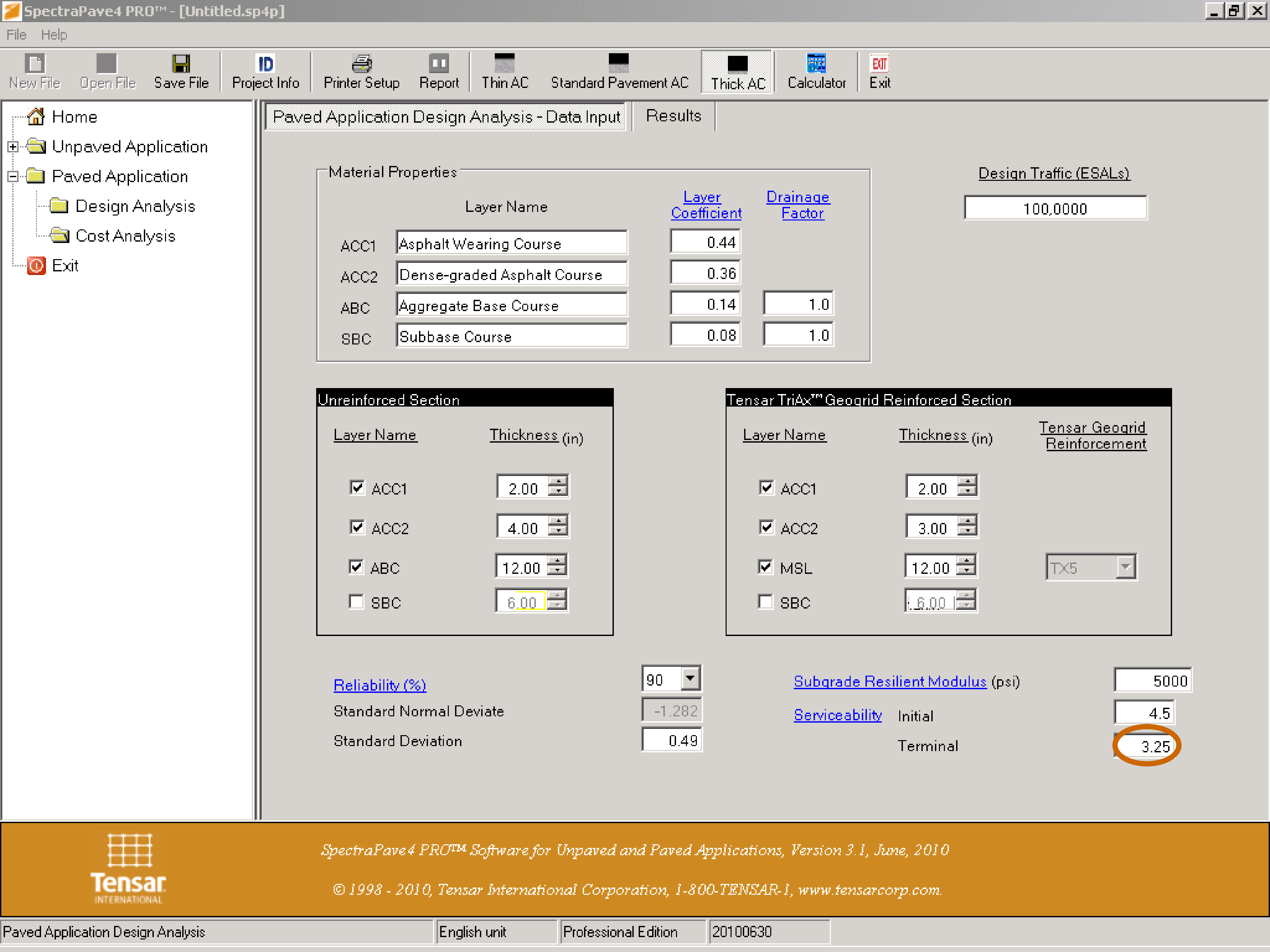
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Cost Analysis
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Paved Application Design Analysis - Data Input
Results
Material Properties
Layer Name
Layer Coefficient
Drainage Factor
ACC1 Asphalt Wearing Course 0.44
ACC2 Dense-graded Asphalt Course 0.36
ABC Aggregate Base Course 0.14 1.0
SBC Subbase Course 0.08 1.0
Design Traffic (ESALs)
100,0000
Unreinforced Section
Layer Name
Thickness (in)
ACC1 2.00
ACC2 4.00
ABC 12.00
SBC 6.00
Tensar TriAx™ Geogrid Reinforced Section
Layer Name
Thickness (in)
Tensar Geogrid Reinforcement
ACC1 2.00
ACC2 3.00
MSL 12.00
TX5
SBC 6.00
Reliability (%)
90
Standard Normal Deviate
-1.282
Standard Deviation
0.49
Subgrade Resilient Modulus (psi)
5000
Serviceability Initial
4.5
Terminal
3.25
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Paved Application Design Analysis - Data Input | Results

Design Traffic (ESALs) = 1,000,000

☑ Round Results

Click Here to Conduct Paved Application Cost Analysis

Unreinforced Section

Layer	Di	ai	mi	SN
ACC1	2.00	0.440	N/A	0.88
ACC2	4.00	0.360	N/A	1.44
ABC	12.00	0.140	1.0	1.68
Overall Structural Number (SN)				4.00

Tensar TriAx™ Geogrid Reinforced Section

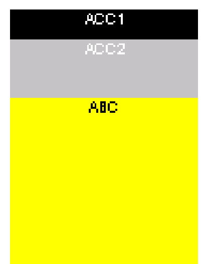
Layer	Di	ai	mi	SN
ACC1	2.00	0.440	N/A	0.88
ACC2	3.00	0.360	N/A	1.08
MSL	12.00	0.215	1.0	2.58
Overall Structural Number (SN)				4.54

Thickness (in)

ACC1: 2.00

ACC2: 4.00

ABC 12.00



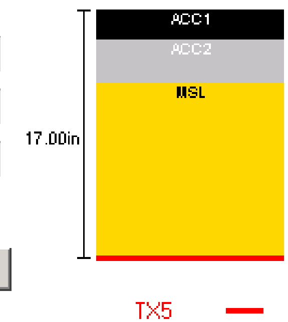
Thickness (in)

ACC1: 2.00

ACC2: 3.00

MSL 12.00

Geogrid Depth



522,000 — Calculated Traffic (ESAL's) — 1,087,000

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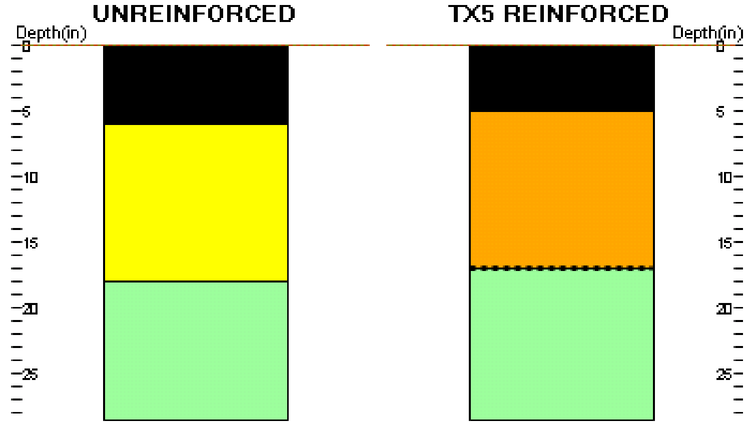
LEGEND

- Existing Grade
- Finished Grade
- Tensar TriAx™ Geogrid
- Asphalt (ACC1+ACC2)
- Base (ABC+SBC)
- Base (MSL+SBC)
- Subgrade
- Additional Fill



	UNREINFORCED	TX5 REINFORCED
Allowable Traffic (ESALs):	522,000	1,087,000
Section Unit Cost:	**$36.68/SY**	**$36.70/SY**
% Life Extension:		108%
% Initial Cost Saving:		0%

INITIAL CONSTRUCTION COSTS ☑ **Round Results**

Asphalt (ACC1+ACC2)	$ 325,714	$ 272,804
Aggregate Base (ABC/MSL)	$ 175,560	$ 175,560
Subbase (SBC)	$ 0	$ 0
Milling or Undercut	$ 36,667	$ 34,630
Additional Fill Costs	$ 0	$ 0
Geogrids	$ 0	$ 55,252
Overall Project Cost	**$ 537,941**	**$ 538,246**

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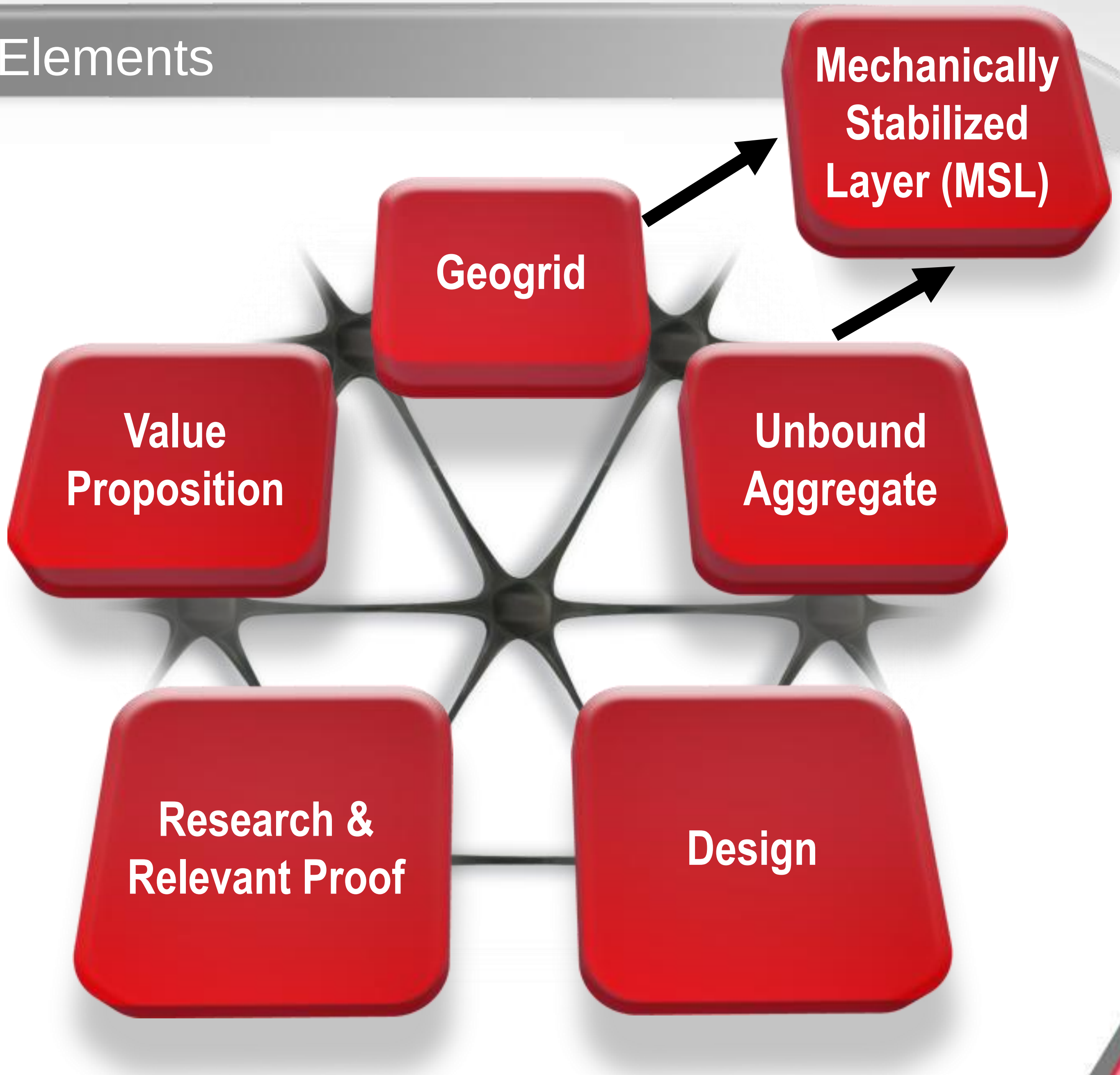
Pavement Design Summary

Pavement	HMA Thickness	Agg Base Thickness	ESALs	+ / -	Svcblty Loss	Cost $/SY	+ / -
Original Design	6"	12"	1,066,000	N.A.	2	$36.68	N.A.
Reinforced for Maximum Cost Savings	5"	8.75"	1,084,000	2%	2	$33.01	-10%
Reinforced for Maximum Performance Cost Neutral	5"	12"	2,549,000	139%	2	$36.70	0%
Reinforced for Optimized Serviceability Cost Neutral	5"	12"	1,087,000	2%	1.25	$36.70	0%

Specifications

Design Elements



2003 - Tingle and Webster (U.S. Army Corps of Engineers)

"Extruded geogrids are formed using a polymer sheet that is punched and drawn in either one or two directions for improvement of engineering properties. Extruded geogrids have shown good performance when compared to other types for pavement reinforcement applications."

Source: U.S. Army Corps of Engineers ETL 1110-1-189 (Tingle and Webster)

2004: Giroud and Han

"In addition to the aperture stability modulus, other properties of geogrids likely affect their ability to interlock with aggregate and efficiently reinforce the base course. Tensile modulus at small strains is one obvious property that is important. Webster (1992) listed rib thickness, rib cross-section shape, junction strength, and aperture size as properties, in addition to aperture stability, that affect performance of geogrid-reinforced bases."

Source: ASCE August 2004 *Journal of Geotechnical and Geoenvironmental Engineering*

AASHTO Designation: R 50-09

3.1. Because the benefits of geosynthetic reinforced pavement structures may not be derived theoretically, test sections are necessary to obtain benefit quantification. Studies have been done that demonstrate the value added by a geosynthetic in a pavement structure. These studies, necessarily limited in scope, remain the basis for design in the field.

AASHTO Designation: R 50-09

5.2 Design procedures use experimentally derived input parameters that are often geosynthetic specific. Thus, *computed engineering designs and economic benefits are not easily translated to other geosynthetics*. Therefore, users of this document are encouraged to affirm their designs with field verification of the reinforced pavement performance, both in engineering design and economic benefits.

Geogrid Specifications

- Material Specification
  - Specify only geogrid properties
  - Difficult to assess performance based on geogrid index properties only
  - Basis of design can be compromised
- System Specification
  - Specify performance of composite geogrid / aggregate system
  - Ensures an acceptable performance level
  - Protects your design
  - Uses results from full-scale testing to predict performance
  - Design methodologies endorsed by FHWA and AASHTO already exist

Material Specification Excerpt

•Properties	•MD Values[1]	•CMD Values[1]	•General[1]
•Aperture Dimensions[2], mm(in)	•25 (1.0)	•33 (1.3)	
•Minimum Rib Thickness[2]	•1.27 (0.05)	•1.27 (0.05)	
•Rib shape			•rectangular
•Aperture shape			•rectangular
•Junction Efficiency[3], %			•93
•Aperture stability[4], m-N/deg			•0.65
•Flexural Stiffness[5], mg-cm			•750,000
•Tensile Strength @ 2% Strain[6], kN/m (lb/ft)	•6.0 (410)	•9.0 (620)	
•Ultimate Tensile Strength[6], kN/m (lb/ft)	•19.2 (1,310)	•28.8 (1,970)	
•Resistance to chemical degradation[7]			•100%
•Resistance to ultra-violet light and weathering[8]			•100%

System Specification Excerpt

1. **PERFORMANCE CRITERIA**

   A. The design of the pavement shall be in accordance with the 1993 American Association of State Highway and Transportation Officials (AASHTO) Guide for Design of Pavement Structures.

   B. The design of the pavement shall be based on the following parameters:

      (1) Subgrade Resilient Modulus XX psi

      (2) Serviceability Loss XX

      (3) Reliability XX %

      (4) Standard Deviation 0.49

      (5) Design traffic = XX Equivalent Single Axle Loads (ESALs)

   C. The Mechanically Stabilized Layer (MSL) within the pavement structure shall have a thickness of XX inches or as shown on the contract plans.

   D. The MSL shall be incorporated into the pavement design by using modified layer coefficients. Modified layer coefficients shall be calibrated and validated with the results of full scale laboratory, field and/or accelerated pavement testing where actual geogrids are tested in-soil and in representative conditions.

Summary

- Mechanically Stabilized Layers consisting of engineered composite sections of geogrid and aggregate are a reliable, value added method to improve soil performance.
- Geogrid reinforcement in flexible pavements can be used to design for maximum initial cost savings or optimized designs that produce increased performance at equal cost
- Proven design methods, endorsed by FHWA and AASHTO, can be employed for subgrade stabilization and pavement design.
- In order to ensure a road performs as intended, a performance specification is recommended

Thank You

See you in the Hallway!