GEOSYNTHETICS IN PAVEMENT SYSTEMS APPLICATIONS

Section One: Geogrids
Section Two: Geotextiles

July 1, 1998
Prepared for AASHTO
by the Geosynthetic Materials Association
(Formerly the IFAI Geotextile Division)

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Introduction

This "white paper" is provided in response to the requests from AASHTO Subcommittee on Materials Technical Section 4E Task Force on Geogrid/Geotextile Specification, to provide background information and specifications for the use of geogrids and geotextiles in pavement system applications. The white paper contains the following items.

- Terminology
- Summary of Installation Damage Studies
- Summary of Base Reinforcement Performance Studies
- Summary of Ongoing Work
- Proposed Application Specifications
- Research Needs

The members of the Geosynthetic Materials Association are extremely appreciative of the opportunity to provide these proposed standard specifications to the AASHTO committee. We believe that the AASHTO committee will recognize the benefit to these specifications, and we look forward to discussing the specifications in more detail with the AASHTO committee and/or answering any questions that might arise.

GEOSYNTHETICS IN PAVEMENT SYSTEMS APPLICATIONS

Section One: Geogrids

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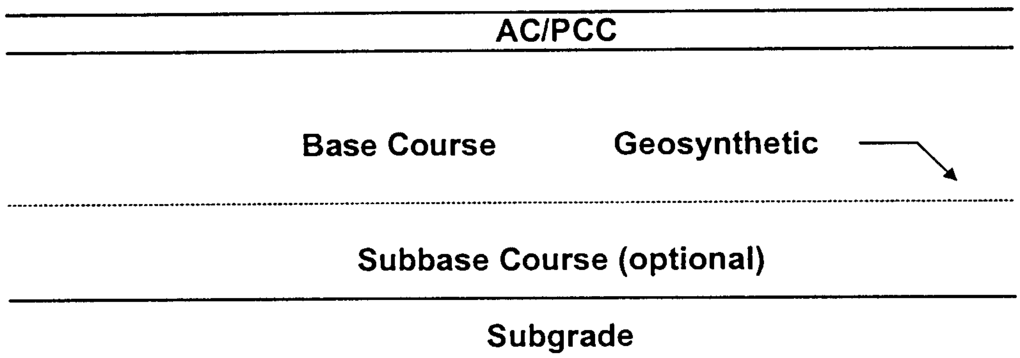
Definitions: Base and Subbase Reinforcement*

Note: After further review of the definitions that GMA has developed below the group would not be adverse to changing the names from Base Reinforcement to Base Confinement and Subbase Reinforcement to Subbase Improvement.

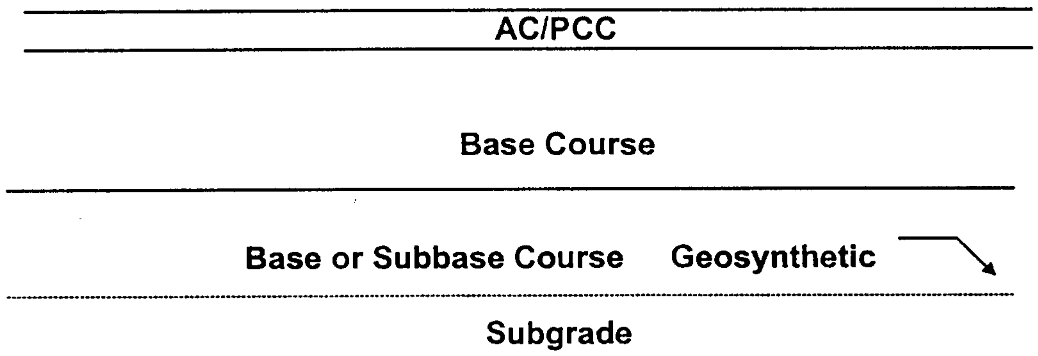
Base Reinforcement, in properly designed paved roads, occurs when a geosynthetic is placed at the bottom or within the base course to:

(1) Improve the service life and/or;
(2) obtain equivalent performance with a reduced structural section.

The mechanisms associated with the incorporation of a geosynthetic include: lateral restraint, increased bearing capacity and/or tension membrane. The cross section for this situation is shown below.



Subbase Reinforcement, in properly designed paved roads, occurs when a geosynthetic is placed at the subgrade/subbase interface to increase the workability for the construction platform over weak subgrade and provide improved support for the roadway structural section. The mechanisms associated with the incorporation of a geosynthetic include: lateral restraint, increased bearing capacity, and/or tension membrane. The cross section for this situation is shown below.



*Note: Base depth to the geosynthetic is approximately $\leq$ 250 mm

Summary of Literature Survey: Installation Survivability of Geogrids and Their Role in Paved Roadways

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G.N. Richardson & Associates

Introduction

Base Reinforcement, in properly designed paved roads, occurs when a geogrid is placed at the subgrade/subbase interface to (1) provide improved subgrade support for the roadway structural section, (2) extend the service life of the flexible pavement, and/or (3) to allow the use of a reduced base section.. The mechanisms associated with the incorporation of a geogrid include: lateral restraint of the base stone, increased bearing capacity of the subgrade, and/or reinforcement resulting from the geogrid acting as a tensioned membrane.

Survivability is defined as resistance to mechanical damage during road construction and initial operation. The ability of a geosynthetic to survive installation and reasonable service loads must be assured if it is to perform as designed. Survivability can be demonstrated using tests that install, exhume, and evaluate samples, or by implication from their successful performance in a given application

This literature review focuses on papers that present geogrid survivability data based on exhumed field samples and/or observed roadway performance (both paved and unpaved), and papers that provide examples of subbase or base reinforcement in paved roadway systems using geogrids. Summaries of individual paper/report reviews are provided in an attached document.

Geogrid Survivability

Geogrids represent the newest 'geo' products for soil reinforcement having emerged commercially only in the early 80's. Fortunately, however, their role as reinforcements in walls and embankments has generated significant interest and research related to their ability to survive installation. The very nature of the roles provided by geogrid however make evaluation of their survivability easier than for geotextile, e.g., the question of the impact of holes vs. retained strength is not of concern.

Guidelines, GG4, for performing survivability tests were developed by the Geosynthetic Research Institute in the early 90's as the result of a comprehensive geotextile field exhumation program, see Koerner and Koerner (1990). Past studies, see Rainey and Barksdale (1993), have indicated that the installation damage to a geogrid is a function of the following:

- Geogrid thickness
- Compactive effort and lift thickness
- Type and weight of construction equipment used for fill spreading
- Grain size distribution of backfill
- Angularity of backfill
- Polymer used in manufacture of geogrid
- Geogrid manufacturing process.

Two methods can be used to evaluate the ability of a geogrid to survive installation damage: 1- successful installations where failure of the geogrid would have resulted in failure of the designed system, and 2 - testing of exhumed specimens recovered after installation. Existing literature and data supporting both of these evaluation techniques are presented herein.

Survivability Data Base - Service Life Demonstration ---- Service life demonstrations can be obtained from both service and test field installations and where performance data is available. Unfortunately, many 'case studies' available in the literature address only the initial installation of the geosynthetic and provide no basis for confirming its successful application. Lists of installations have not been included in Table 1 since the role of the geogrid is not established and since the information supplied by various manufacturers varied widely. Fortunately, a number of excellent service life demonstrations are available as shown on Table 1.

Survivability Data Base - Recover and Testing Demonstrations ---- Installation reduction factors, RF_{ID}, for a range of geogrids are presented on Table 2. It is readily apparent that a significant amount of field scale level trials have been conducted on most geogrids for a wide range of fill soils and aggregate. In general RF_{ID} increases with the D_{50} of the fill, fill angularity, compactive effort, and the flexibility of the grid. Physical properties for the geogrids are presented on Table 3. In general, the prediction of post installation strength of a geogrid does not appear to have the same level of uncertainty as predicting the number of penetrations in a geotextile or even uncertainties related to subgrade strengths.

Summary: The Role of Geogrids in Paved Roadways

Geogrids can provide significant advantage to a paved roadway system both as reinforcement within a working bench beneath the system and as a means of improving the performance of the base stone within the system. This latter role may be unique to geogrids and is commonly referred to as base reinforcement or base confinement. The 'confinement' term was first used by Carroll et al. (1987) in describing their pioneering work related to applications over soft sand subgrades. The benefit of the geogrid is easily seen in even the first 100 ESAL before sufficient displacements occur to mobilize a membrane type reinforcing action. This low-strain performance is important in their application to paved roadway systems.

Need for Separation ---- Penner and Ismeik detail those tests where separation was either no problem, a moderate problem, or a problem as follows:

Separation	Author	Subgrade	Subbase/Base
Problems	Al-Quadi	Silty Sand (SM, A-4) (CBR 2-4)	none/crushed granite <10% fines
	Halliday & Potter	Plastic Clay (CH, A-7-6) (CBR .7-4.2)	none/crushed granite
Moderate Problems	Anderson & Killearavy	Soft Silt and Clay (CBR ?)	none/crushed limestone
	Barksdale	Silty Clay (CL,A-6) (CBR 2.6-3.2)	none/crushed limestone <8% fines
No Problems	Cancelli	Sand (SP, A-3)	
	Collin	Silty Sand (SM,A-2)	May be silty clay!
	Hass	Fine Sand (SP)	
	Miura	Clay	8"sub/crushed limestone
	Webster	Clay (CH,A-7-6) (CBR 3-8)	none/crushed limestone 13% fines, 63%sand

It is clear that the use of a geogrid over a subgrade that contains sufficient fines to have a plasticity index requires either a separator geotextile or the use of a 'choked' subbase aggregate. The use of a geogrid to reinforce aggregate placed over soft sandy subgrades would not require consideration of a separator, see Ref# 53. Such soils are not impacted by seasonal changes such as freeze-thaw, fluctuation ground water levels, etc. that can lead to a seasonal degradation of the subgrade.

Optimal Placement/Properties of Reinforcement ----- The impact of the grid location in the roadway section appears to be influenced by the type of subgrade, the thickness of the base, and the magnitude of the loading. The data summary presented below would indicate that for very heavy loads the reinforcement belongs on the bottom of the base layer, and for typical loading the reinforcement belongs on the bottom when the base section is less than 250 mm thick and in the middle when it is thicker.

Author	Location	Load	Subgrade
Moghaddas	middle	vlight	sand
Barksdale	middle	mod.	silty sand
Haas	botton < 250mm middle > 250mm	heavy	fine sand
Collin	bottom < 255mm	heavy	silty sand
Webster	bottom	vheavy	clay
Barker	none @ middle	vheavy	sandy silt

There appears to be good agreement that to provide the 'reinforcement' the geosynthetic must provide lateral restraint to the base stone. For a geogrid, this requires that the stones be of a size that strike through can occur - with the role of grid rigidity being important factors cited by Webster (1992) and Collin et al. (1995). The geogrid has an intuitive advantage in low-strain lateral restraint of aggregate with the benefit of grid 'rigidity' and strike through being intuitive advantages to provide confinement of the aggregate.

Base Reinforcement Design Procedure ----

Design methods for base reinforcement fall into the following categories:

- Development of modified SN for base layer by using actual ESAL from tests and back-calculating SN_{lab}. The ratio of the calculated SN to the measured SN_{lab} is credited to the reinforcement role of the geosynthetic. Carroll et al. (1987), Penner et al. (see ref # 51) , Montanelli et al. (1997), and Webster (1992) used this method.
- Calculate permanent deformation with each load cycle to predict cumulative rut depth - Davies and Biddie.
- Soil-geotextile-aggregate models that models the GT as a membrane and accounts for lateral restraint - Sellmeijer.
- Empirical load/deflection data used to predict extended service life - Collin et al. (1995), Tensar (1996).

All methods currently are empirical in that there is no demonstrated means of applying the observed service of a given geogrid to the properties of an alternative grid. Thus it would appear that the installation data base developed by a given manufacturer would be of significant value in predicting the success of their product to a given application.

Table 1 Summary of Performance Based Survivability of Geogrids

Reference	Location and Details	Overlying Lift Details	Soil Properties	Compactive Effort	Performance Base Survivability	
				Spec Equipment Number of Passes	**Product Used** Manufacturer Trade Name / Structure(1)	**Comments**
Cancelli, et al. Ref # 63	Italy	12"-20" well graded gravel	Clay w/ CBR 1%, 3% and 8%	compacted for paving - details not provided	Tenax MS220, MS330/PP Tensar SS1, SS2/PP	Significant reduction in rut depths for 18-kip ESAL beyond ESAL 80,000
Webster Ref #10	Vicksburg, MS	6" and 10" crush limestone aggreg 12",14",18"	CBR = 8% CBR = 3%	max 6" lifts comp w/ smooth drum vibratory roller	Tensat SS-1/PP Tensar SS-2/PP Fortrac 30/20-20/P-PVC Miragrid 5T/ P-AL	Significant reduction in rut depths caused by 30-kip wheel loads in geogrid sections vs control sections. Limited improvement in 18" section.
Fannin, et al. Ref # 36	Vancouver, BC	very sandy gravel 0.25-0.50m thick	Organic clayey silt undrained shear strength = 40 kPa	small vibrating plate	high junction strength biaxial/PP (?Tensar SS-2)	unpaved road test, significant reduction in rutting compared to control
Barksdale, et al. Ref # 6	Georgia Tech	6" sand&gravel or 8" crushed limestone	silty clay CBR = 2.5%	not provided	high junction strength biaxial/PP (?Tensar SS-2)	tests w/ paved sections showed that grid in middle of base section reduced rutting. Suggests SN of base should be less than 3 to see benefit
Kinney, et al. SeeRef #39&55	Fairbanks, Alaska	6-18" compacted rock base	soft clayey silt CBR 1.6 - 2.7	not provided density = 130 pcf	Tensar SS-1/PP Tensar SS-2/PP	tests showed extended service life from 2-6 times control. Max benefit with base thickness of 9"

(1) PE - HDPE Uniaxial, PP - PP biaxial, PET - Polyester, P-PVC - PVC coated PET, P-AL - Acrylic coated P

Table 2 Summary of Recovery and Testing Based Survivability of Geogrids

Reference	Location and details	Overlying Lift Details	Subgrade Properties	Compactive Effort Spec Equipment Number of Passes	Geogrid Survivability		
					Product Used Manufacturer Trade Name Structure(1)	Installation Reduction Factor, RF_{ID} MD XD	Comments
Rainy & Barksdale Ref #64	Atlanta, GA	6"-10" Poorly Graded Gravel D50=30mm	4" compacted layer same as lift	smooth drum vibratory roller 4 pass back/forth	Tensar/UX1400SB/PE	1.07-1.42	Tensar sponsored research - all original data sheets provided for this review
					Tensar/UX1500SB/PE	1.14-1.29	
					Tensar/UX1600SB/PE	1.05-1.13	
					Tensar/BX1100/PP	.97-1.38/1.09-1.45	Fill placed with a small front end loader 10" lift compacted with a large Bomag smooth drum vibratory compactor
					Tensar/BX1200/PP	.97-1.17/1.01-1.14	
					Tensar/UX1600HT/PE	1.08-1.21	
					Miragrid 5T/P-AL	1.50-2.02	
					Miragrid 10T/P-AL	1.37-1.33	6" lift compacted with Wacker W55 walk behind smooth drum vibratory
					Conwed 9027/P-PVC	1.26-1.65	
					Fortrac 80/20-30/P-PVC	1.07-1.20	
					Matrix 120/P-PVC	1.30-1.22	
		6"-10" sand (SP) D50=0.80mm	4" compacted layer same as lift		Tensar/UX1400SB/PE	1.04-1.02	
					Tensar/UX1500SB/PE	1.12-1.12	
					Tensar/UX1600SB/PE	0.99-0.99	
					Tensar/BX1100/PP	.93-.94/.98-.99	
					Tensar/BX1200/PP	.94-.95/.98-1.0	
					Tensar/UX1600HT/PE	1.07-1.05	
					Miragrid 5T/P-AL	1.29-1.15	
					Miragrid 10T/P-AL	1.48-1.88	
					Conwed 9027/P-PVC	1.22-1.16	
					Fortrac 80/20-30/P-PVC	1.35-1.85	
					Matrix 120/P-PVC	1.54-1.81	
		6"-10" silty sand (SM) D50 = 6.3mm	4" compacted layer same as lift		Tensar/UX1400SB/PE	1.0-1.03	
					Tensar/UX1500SB/PE	1.03-1.07	
					Tensar/UX1600SB/PE	1.05-1.05	
					Tensar/BX1100/PP	.98-.99/1.01-1.10	
					Tensar/BX1100/PP	.99-1.0/1.02-1.11	
					Tensar/UX1600HT/PE	1.03-1.06	
					Miragrid 5T/P-AL	err-1.06	
					Miragrid 10T/P-AL	1.13-1.15	
					Conwed 9027/P-PVC	1.14-1.14	
					Fortrac 80/20-30/P-PVC	.95-1.02	
					Matrix 120/P-PVC	1.06-1.09	
Al-Quadi, et al. Ref #52	Virginia	100,200,300mm limestone aggregate VDOT-21	sandy silts CBR=3-8	smooth drum roller	Tensar BX 1200/PP	1.0	exhumed after 3 years of service

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Table 2(cont) Summary of Recovery and Testing Based Survivability of Geogrids

Reference	Location and details	Overlying Lift Details	Subgrade Properties	Compactive Effort	Geogrid Survivability		
				Spec Equipment Number of Passes	**Product Used** Manufacturer/ Trade Name/ Structure$^{(1)}$	**Installation Reduction Factor, RF_{ID}** MD XD	Comments
Tensar/Geosyntec	Atlanta, GA	10" 37.5mm crusher run D50 = 17mm			Tensar/UX1400SB/PE	1.18	
					Tensar/UX1500SB/PE	1.13	
					Tensar/UX1600SB/PE	1.17	
					Tensar/UX1500HS/PE	1.16	
					Tensar/UX1600HS/PE	1.23	
		8" sandy angular gravel D50 = 10.44mm			Tensar/UX1100SB/PE	1.19	
					Tensar/UX1400SB/PE	1.09	
					Tensar/UX1600SB/PE	1.11	
					Tensar/UX1700SB/PE	1.08	
					Tensar/UX1100HS/PE	1.18	
					Tensar/UX1400HS/PE	1.32	
					Tensar/UX1600HS/PE	1.22	
					Tensar/UX1700HS/PE	1.22	
					Tensar/UXMESA 2	1.20	
					Tensar/UXMESA 3	1.32	
					Tensar/UXMESA 5	1.22	
					Tensar/UXMESA 6	1.22	
		8" angular gravelly sand D50 = 2.57mm			Tensar/UX1100SB/PE	1.06	
					Tensar/UX1400SB/PE	1.03	
					Tensar/UX1600SB/PE	1.04	
					Tensar/UX1700SB/PE	1.02	
					Tensar/UX1100HS/PE	1.12	
					Tensar/UX1400HS/PE	1.12	
					Tensar/UX1600HS/PE	1.19	
					Tensar/UX1700HS/PE	1.08	
					Tensar/UXMESA 2	1.12	
					Tensar/UXMESA 3	1.12	
					Tensar/UXMESA 5	1.20	
					Tensar/UXMESA 6	1.10	
Illinois Tollway Authority Ref #68	Illinois	10" 37.5mm CA6 coarse aggregate, D50=5.25mm			Tensar/UX1500SB/PE	1.08	Field test at installation site
					Tensar/UX1600SB/PE	1.05	

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Table 2(cont) Summary of Recovery and Testing Based Survivability of Geogrids

Reference	Location and details	Overlying Lift Details	Subgrade Properties	Compactive Effort Spec Equipment Number of Passes	Geogrid Survivability			
					Product Used Manufacturer Trade Name Structure[(1)]	Installation Reduction Factor, RF_{ID} MD	XD	Comments
Watts&Brady Ref #56	Transport Research Lab., England	7" crushed limestone agg. (1.5" max)	crushed limestone aggregate	Bomag 160AD 2 passes	Tensar SR80	1.23		large scale laboratory tests built on 'tilt' to allow ready recovery of samples. Compaction used full scale equipment
					Tenax TT 401-AMP	1.00		
					Fortrac 55/30-20	1.73		
				to refusal "excess effort"	Tensar SR80	1.32		
					Tenax TT 401-AMP	1.03		
					Fortrac 55/30-20	1.50		
Watts&Brady Ref #57	Transport Research Lab., England			Bomag 160AD	HDPE grid (54 Kn/m)	1.08		
				to refusal	HDPE grid	1.15		
Tenax, et al. Ref# 58	Transport Research Lab., England	crushed limestone agg	crushed limestone aggregate	Bomag 160AD?	Tenax/TT201/PE	1.05		Summary of additional work by Watts & Brady and Wright & Greenwood
					Tenax/TT301/PE	1.00-1.07		
					Tenax/TT401/PE	1.00-1.05		
					Tenax/TT701/PE	1.00-1.02		
					Tenax/LBO220Samp	1.00-1.01		
					Tenax/LBO303Samp	1.00-1.06		
					Tenax/MS220	1.02-1.08		
					Tenax/MS1000	1.00-1.02		
					Tensar/SR55/PE	1.39		
					Tensar/SR80/PE	1.30		
					Tensar/SR110/PE	1.06		
					Tensar/SS2/PP	1.10-1.18		
					Tensar/SS1/PP	1.06-1.08		
					Fortrac 35/20-20/P-PVC	1.35-1.96		
					Fortrac 80/30-20/P-PVC	1.10-1.32		
					Fortrac110/30-20/P-PVC	1.13		
					Raugrdi 6-6/15	1.49		
Tenax Trials Ref #57	Not indicated	angular, crushed granite 40-60mm	compacted gravel (175mm) bed	6 pass Simesa 30 ton dual drum vibratory comp.	Tenax/TT201SAMP	1.00	1.07	No publication reference provided
					Tenax/TT220SAMP	1.00	1.00	
					Tenax/TT301SAMP	1.02	1.04	
					Tenax/TT303SAMP	1.01	1.06	
					Tenax/TT401SAMP	1.04	1.06	
					Tenax/MS1000	1.00	1.00	
					Tenax/MS220	1.04	1.12	
					Tenax TT201SAMP	1.11		
					Tenax TT301SAMP	1.08		
					Tenax TT401SAMP	1.06		
					Tenax TT701SAMP	1.00		

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Table 2(cont) Summary of Recovery and Testing Based Survivability of Geogrids

Reference	Location and details	Overlying Lift Details	Subgrade Properties	Compactive Effort Spec Equipment Number of Passes	Geogrid Survivability: Product Used Manufacturer Trade Name Structure(1)	Installation Reduction Factor, RF_{ID} MD	XD	Comments
Tenax Trials Ref #57	Not Indicated	angular, crushed granite 40-60nn	compacted gravel bed	6 pass Simesa 30 ton dual drum vibratory comp.	Tensar /SS-1/PP Tensar /SS-2/PP Tensar /SR80/PE Fortrac 35/20-30/P-PVC Fortrac 80/20-30/P-PVC	1.06 1.02 1.43 1.96 1.32	1.11 1.17	
Strata Ref #62	Minnesota	8" MNDOT Class5 sand 2 @ 8" MNDOT Class5 sand	MNDOT Class5 (sand)	Duomat 2 ton walk behind	Strata/GB-3024/P-PVC Strata/GB-9027/P-PVC Strata/GB-3024/P-PVC Strata/GB-9027/P-PVC	1.11 1.10 1.08 1.04	1.02 1.05 1.02 1.14	Previously sold by Conwed tests peformed with MN-DOT
		8"fine-med sand 2@8"f-md sand 8" #57 stone	8" #57 stone		Strata/GB-9027/P-PVC Strata/GB-9027/P-PVC Strata/GB-9027/P-PVC	1.06 1.02 1.19	1.07 1.08 1.05	
Troost & Ploeg Ref #65	Netherlands	8" sand	compacted sand (95% std)	walk behind vibratory plate	Fortrac 20/13-20/P-PVC Fortrac 35/20-20/P-PVC Fortrac 55/30-20/P-PVC Fortrac 80/30-20/P-PVC Fortrac110/30-20/P-PVC	1.09 1.09 1.02 1.00 1.00		low compactive effort
		8" sandy gravel			Fortrac 35/20-20/P-PVC Fortrac 55/30-20/P-PVC Fortrac 80/30-20/P-PVC	1.15 1.03 1.02		
		8" basalt stone			Fortrac 35/20-20/P-PVC Fortrac 55/30-20/P-PVC Fortrac 80/30-20/P-PVC	1.18 1.22 1.03		
Richardson	Raleigh, NC	10" #78 stone	#78 stone	tracking with D3	Lukenhause 4/2 /P-AL Lukenhause 6/3 /P-AL Tensar UX750SB/PE	1.40 1.25 1.02		work to be published fall, 1998 in GFR
		14" #78 stone			Lukenhause 4/2 /P-AL Lukenhause 6/3 /P-AL Tensar UX750SB/PE	1.07 1.06 1.06		
		10" #57 stone	#57 stone		Lukenhause 4/2 /P-AL Lukenhause 6/3 /P-AL Tensar BX4100/PE	1.62 1.18 100/1.02(2)		
		14" #57 stone			Lukenhause 4/2 /P-AL Lukenhause 6/3 /P-AL Tensar BX4100/PE	1.29 1.18 100/1.03(2)		

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Table 2(cont) Summary of Recovery and Testing Based Survivability of Geogrids

Reference	Location and details	Overlying Lift Details	Subgrade Properties	Compactive Effort Spec Equipment Number of Passes	Geogrid Survivability			
					Product Used Manufacturer Trade Name Structure[(1)]	Installation Reduction Factor, RF_{ID} MD	XD	Comments
Sandri, et al. Ref #61	Venezuela	9" rock fill 3" max	same as overlying lift	sheeps foot or 10 ton static smooth drum roller	Miragrid 7T/P-AL Miragrid 10T/P-AL	1.69-1.18 1.05		test for slope stabilization application
		9" drain aggreg. 1.5" max			Miragrid 5T/P-AL Miragrid 7T/P-AL Miragrid 10T/P-AL	1.17 1.13-1.12 1.11		
		9" drain aggreg. 3" max			Miragrid 7T/P-AL Miragrid 10T/P-AL Miragrid 12T/P-AL	1.11 1.13 1.13		
B.L. Barnes Ref #70	Asheville, NC	2-6" lifts AASHTO ABC grade crushed aggregate	Sandy Silt CBR 1.0 to 1.4	Smooth drum vibratory	AKZO TR-20/AR-NM AKZO TR-30/AR-NM AKZO TR-40/AR-NM	1.12 1.20 1.22	1.24 1.19 1.22	installation performed at ongoing road work by NC-DOT

(1) PE - HDPE Uniaxial, PP - PP biaxial, PET - Polyester, P-PVC - PVC coated PET, P-AL - Acrylic coated P, AR-NW aramid grid in polyester nonwoven

Table 3 Geogrid Properties

Geogrid	Wide-Width Tensile(1), kN/m	Grid Apperture size(1), mm	Structure(2)	Weight, g/m2
	ASTM D-4595			ASTM D-3776
AKZO NOBEL				
TRC-Grid 20	20 x 20	14 x 14	AR-NW	140
TRC-Grid 20	30 x 30	14 x 14	AR-NW	160
TRC-Grid 20	40 x 40	14 x 14	AR-NW	180
Conwed/Strata				
Conwed 9027			P-AL	
Strata GB-3024			P-AL	
Strata GB-9027			P-AL	
Fortrac				
20/13-20	20 x 13	20 x 20	P-PVC	170
35/20-20	35 x 20	20 x 20	P-PVC	250
55/30-20	55 x 30	20 x 20	P-PVC	340
80/30-20	80 x 30	20 x 20	P-PVC	500
80/20-30	80 x 20	20 x 20	P-PVC	450
110/30-20	110 x 30	20 x 20	P-PVC	560
Luckenhaus				
4/2				
6/3				
Raugrid 6-6				
Mirafi				
5T				
7T				
10T				
12T				
Tenax				
TT201	45	13 x 15	PE	450
TT301	65	13 x 15	PE	620
TT401	80	13 x 15	PE	770
TT701	110	13 x 15	PE	1000
LBO220	20 x 20	41 x 31	PP	270
LBO303	30 x 30	40 x 27	PP	420
MS1000	14 x 20	30 x 40	PP	250
MS220	21 x 25	14 x 20	PP	220
Tensar				
UX1100SB	38.9	15.2	PE	
UX1400SB	54	14.5	PE	
UX1500SB	87.6	14.5	PE	
UX1600SB	112	13.7	PE	
UX1700SB	14.0	13.7	PE	
UX1100HS	39.4		PE	
UX1400HS	64.2		PE	
UX1500HS	100.7		PE	
UX1600HS	131.4		PE	
UX1700HS	157.7		PE	

(1) MD x XD

(2) PE - HDPE Uniaxial, PP - PP biaxial, PET - Polyester, P-PVC - PVC coated PET, P-AL - Acrylic coated P, AR-NW aramid grid in polyester nonwoven

Table 3(cont) Geogrid Properties

Geogrid	Wide-Width Tensile(1), kN/m	Grid Apperture size(1), cm	Structure(2)	Weight, g/m2
	ASTM D-4595		ASTM D-1777	ASTM D-3776
Tensar(cont)				
UXMESA 2	39.3		PE	
UXMESA 3	64.1		PE	
UXMESA 5	131.3		PE	
UXMESA 6	157.3		PE	
BX1100	12.4 x 19	25 x 33	PP	
BX1200	17.5 x 28.8	25 x 33	PP	
SS1	12.5 x 20.5*	28 x 40	PP	
SS2	17.5 x 31.5*	28 x 40	PP	
SR55	55*	16	PE	
SR80	80*	16	PE	
	*Netlon QC Method, not ASTM D-4595			

(1) MD x XD

(2) PE - HDPE Uniaxial, PP - PP biaxial, PET - Polyester, P-PVC - PVC coated PET, P-AL - Acrylic coated P, AR-NW aramid grid in polyester nonwoven

Standard Specification
for

Geogrids Used as Reinforcement for Base and Subbase Layers in Pavement Structures

AASHTO Designation: M XXX - Draft 7
June 18, 1998

1. SCOPE

1.1 This is a materials specification covering geogrids for use in base and subbase reinforcement of pavement structures. The function of the reinforcement in this application refers to including a tensile member in the form of a geogrid within or beneath the unbound base or subbase with the intent of increasing the structural support capacity of that component of the pavement structure. The geogrid may also serve to stabilize the subgrade provided that the functions of separation and filtration are achieved.

1.2 Base reinforcement is defined as a Class 1 Geogrid placed directly beneath, Figure A, or within, Figure B, the base course of properly designed paved roads to improve service life, and/or obtain an equivalent performance with a reduced structural section. The potential mechanisms provided by the base reinforcement include lateral restraint or increased bearing capacity. Base course in this specification is defined as the layer or layers of unbound specified or selected material of designed thickness placed on a subbase or a subgrade to support a surface course (AC and/or PCC).

1.3 Subbase reinforcement is defined as a Class 2 Geogrid, see Figure B, placed at the subgrade/subbase interface of properly designed paved roads to increase the workability for the construction platform over weak subgrades and to provide support for the roadway structural section. The potential mechanisms provided by the subbase reinforcement include increased bearing capacity, lateral restraint, and/or tensioned membrane effect. Subbase in this specification is defined as the layer or layers of specified or selected material of designed thickness placed on a subgrade to support a base course.

1.4 This is a material purchasing specification and design review of its use is recommended. This is not a construction or design specification. Reinforcement of the pavement section is a site-specific design issue which should be addressed by the Engineers responsible for the pavement and embankment design. This specification is not appropriate for embankment reinforcement where stress conditions may cause global subgrade foundation or embankment failure.

1.5 This specification is based on the minimum requirements of the geogrid to provide tensile reinforcement and survivability from installation stresses. The physical properties listed in Table 1 are applicable for a minimum backfill thickness of 150 mm. However, in general, the geogrid shall be placed at the proper elevation, location, and orientation as detailed on the plans and specification. The Contractor shall follow the project specification for construction/installation guidelines, or if not provided, the geogrid manufacturers recommended installation guidelines.

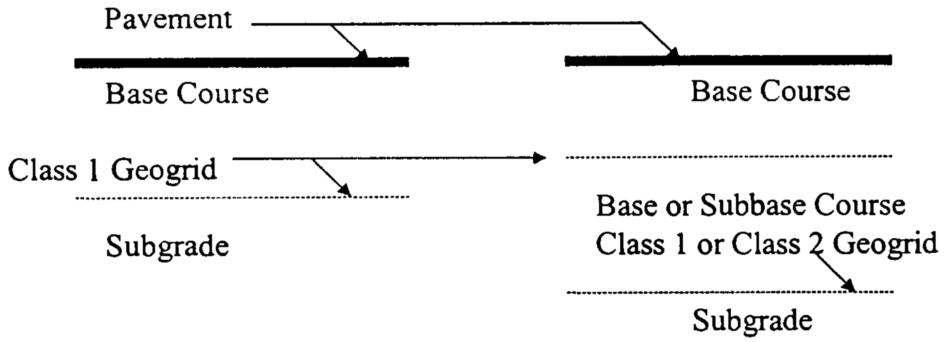

Figure A. - Base Course,
The depth to geosynthetic
is less than or equal to 250 mm

Figure B - Base and Subbase Courses, greater than 250 mm in depth. Use a Class 1 or Class 2 Geogrid.

2. REFERENCED DOCUMENTS

2.1 *ASTM Standards*

D 4354	Practice for Sampling of Geosynthetics for Testing
D 4355	Test Method for Deterioration of Geotextiles from Exposure to Ultraviolet Light and Water (Xenon-Arc Type Apparatus)
D 4439	Terminology for Geosynthetics
D 4595	Test Method for Tensile Properties of Geotextiles by the Wide-Width Strip Method[1]
D 4759	Practice for Determining the Specification Conformance of Geosynthetics
D 4873	Guide for Identification, Storage, and Handling of Geotextiles
COE	Test Method for Determining Percent Open Area of a Geogrids[2]
GRI GG2	Test Method for Junction Strength of Geogrids
GRI GG5	Test Method for Geogrid Pullout

[1] Modified for geogrids such that the gage length is the larger of 2 aperture or 200 mm (8 inches).

[2] Corps of Engineers method as specified in CW 02215 Civil Works Construction Guide, November 1977.

3. PHYSICAL AND CHEMICAL REQUIREMENTS

3.1 Polymers used in the manufacture of geogrids, and the mechanical fasteners or threads used to join adjacent rolls, shall consist of long chain synthetic polymers, composed of at least 95% by weight polyolefins, polyesters, or polyamides. They shall be formed into a stable network such that the ribs, filaments or yarns retain their dimensional stability, including selvages.

3.2 Geogrids used for base and subbase reinforcement shall conform to the physical requirements of Section 7.1.

3.3 All property values in these specifications represent minimum average roll values with the exception of the coefficient of interaction, coefficient of direct shear, and ultraviolet stability.(MARV - Average value minus two standard deviations).

4. CERTIFICATION

4.1 The Contractor shall provide to the Engineer a certificate stating the name of the manufacturer, product name, style number, lot number, chemical composition of the geogrid product and physical properties applicable to this specification.

4.2 The Manufacturer is responsible for establishing and maintaining a quality control program to assure compliance with the requirements of the specification. Documentation describing the quality control program shall be made available upon request.

4.3 The Manufacturer's certificate shall state that the furnished geogrid meets the MARV requirements of the specification as evaluated under the Manufacturer's quality control program. The certificate shall be attested to by the Manufacturer's quality control manager or a registered Professional Engineer.

4.4 Either mislabeling or misrepresentations of materials shall be sufficient reason for rejection of those geogrid products.

5. SAMPLING, TESTING, AND ACCEPTANCE

5.1 Geogrids shall be subject to sampling and testing to verify conformance with this specification. Sampling for testing shall be in accordance with ASTM D 4354. Acceptance shall be based on testing of either conformance samples obtained using Procedure A of ASTM D 4354 or based on manufacturer's certifications and testing of quality assurance samples obtained using Procedure B of ASTM D 4354. A lot size for conformance or quality assurance sampling shall be considered to be the shipment quantity of the given product or a truckload of the given product, whichever is smaller.

5.2 Testing shall be performed in accordance with the methods referenced in this specification for the indicated application. The number of specimens to test per sample is specified by each test method. Geogrid product acceptance shall be based on ASTM D 4759. Product acceptance is determined by comparing the average test results of all specimen within a given sample to the specified MARV.

6. SHIPMENT AND STORAGE

6.1 Geogrid labeling, shipment, and storage shall follow ASTM D 4873. Product labels shall clearly show the manufacturer or supplier name, style number, lot number, and roll number. Each shipping document shall include documentation certifying that the material is in compliance with this specification.

6.2 During storage, geogrid rolls shall be elevated off the ground and adequately protected from the following: site construction damage, excessive precipitation, extended exposure to sunlight, aggressive chemicals, flames or temperatures in excess of 71°C (160°F), and any other environmental condition that may damage the physical property values of the reinforcement.

7. GEOGRID PROPERTY REQUIREMENTS

7.1 The geogrid shall meet the requirements of Table 1. All numeric values in Table 1 represent MARV's with the exception of the coefficient of interaction, coefficient of direct shear, and ultraviolet stability.

7.1.1 The property values in Table 1 represent default values which provide for sufficient geogrid reinforcement and survivability under most construction conditions. The design Engineer may specify properties different from those listed in Table 1 based on engineering design and experience.

8. MEASUREMENT AND PAYMENT

8.1 The geogrid shall be measured by the square meter in place. The measurements used for payment shall not include double measurement for overlaps.

8.2 The accepted quantities shall be paid for at the contract unit price. Payment shall be full compensation for all labor, tools, equipment, and appurtenances necessary to satisfactorily complete the work.

PAY ITEM	UNIT
Geogrid Reinforcement	Square Meter

TABLE 1. Geogrid Reinforcement Property Requirements for Base and Subbase Reinforcement of Pavement Systems[1]

Property	Class 1	Class 2 CBR ≥ 0.5
Ultimate Tensile Strength, UTS[2] (ASTM D4595 modified for geogrids)	12 x 18 (kN/m)	12 x 18 (kN/m)
Tensile Strength at Specified Strain[2] (ASTM D4595 modifed for geogrids)	4 x 6 @ 2% Strain (kN/m)	8 x 13 @ 5% Strain (kN/m)
Geogrid Percent Open Area (COE CW-02215)	50 min. (%)	50 min. (%)
Junction Strength[3] (MD) (GRI GG2 modified to 10%/min.)	35 (N)	35 (N)
Ultraviolet Stability (Retained Strength) (ASTM D 4355)	50 % (500 hrs)	50 % (500 hrs)
Coefficient of Interaction Due to Pullout[4], C_i, (XD)(GRI GG5) Displacement - Normal Load -	C_i ,under development @ 6mm 5 kPa	not applicable
Coefficient of Direct Shear[5], C_{ds}, (XD) (ASTM D 5321) Displacement - Normal Load -	C_{ds} , under development @ geogrid peak 5 kPa	not applicable

Table 1 Notes:

[1] Values listed in Table 1 are MARV's except for UV stability, C_i, and C_{ds}.
(MARV - Average value minus two standard deviations).

[2] Machine Direction (MD) x Cross Machine Direction (XD). Assumes MD is placed parallel to the centerline of the roadway alignment.

[3] Junction strength is required to maintain dimensional stability of the geogrid during deployment. It is not applicable to geogrid/geotextile composite products.

[4] Rate of displacement may be increased to 125 mm/min. A graded angular base material as described in Table 2 below shall be used in laboratory testing to determine C_i. Test sample shall be at least 0.5 meter in length and 0.3 meters in width.

[5] Rate of displacement may be increased to 50 mm/min. A graded angular base material as described in Table 2 below shall be used in laboratory testing to determine C_{ds}. Test sample shall be at least 0.3 meter in length and 0.3 meters in width. NOTE: The calculation of C_{ds} shall be based on the selection of the soil strength at a displacement value that corresponds to the peak shear resistance for the geogrid.

Table 2 - Gradation of Base Material for Determination of Coefficients of Interaction and Direct Sliding

Sieve Size*	Percent Passing
37.5 mm (1 1/2")	100
25 mm (1")	95 – 100
19 mm (3/4")	60 – 100
4.75 mm (#4)	30 – 60
0.425 mm (#40)	10 – 30
0.075 mm (#200)	3 – 10
*Note: LL < 30 and PI <10	

GEOSYNTHETICS IN PAVEMENT SYSTEMS APPLICATIONS

Section Two: Geotextiles

July 1, 1998
Prepared for AASHTO
by the Geosynthetic Materials Association
(Formerly the IFAI Geotextile Division)

Summary of Literature Survey: Installation Survivability of Geotextiles and Their Role in Paved Roadways

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Introduction

Survivability is defined as resistance to mechanical damage during road construction and initial operation. The ability of a geosynthetic to survive installation and reasonable service loads must be assured if it is to perform as designed. Survivability can be demonstrated using tests that install, exhume, and evaluate samples, or by implication from their successful performance in a given application

This literature review focuses on papers that present geotextile survivability data based on exhumed field samples and/or observed roadway performance (both paved and unpaved), and papers that provide examples of subbase or base improvement in paved roadway systems using both geotextiles and geogrids. Summaries of individual paper/report reviews are provided in separate document

Geotextile Survivability

To date, published data on geosynthetic survivability has focused on geotextiles. This summary will review the significant available literature related to geotextile survivability.

Historical Background - Geotextile Survivability Criteria ---- One of the earliest geotextile 'survivability' criteria was developed by Haliburton (1982) as part of an early transportation related training manual. This procedure was refined by Christopher and Holtz (1984) and is presented in Table 1. This procedure has served as the basis for subsequent AASHTO survivability systems. Note that no differentiation is made between woven or nonwoven geotextiles.

In 1982, the subcommittee on Materials of the American Association of State Highway and Transportation Officials (AASHTO), the American Road and Transportation Builders Association (ARTBA), and the Association of General Contractors (AGC) formed Joint Task Force 25 (TF 25) to review tables of suggested geotextile property values for the FHWA Geotextile Manual that was being prepared at the time. Following this review the Task Force continued to develop guide specifications for geotextiles used in paving, subsurface drainage, erosion control, sediment control(silt fences) and separation applications. The Task Force was made up of representatives of the geotextile industry, private contractors, and state and federal transportation agencies.

The material properties included in the original work of TF 25 were based on the experience in the use of these materials at that time. As the use of geotextiles in the United States was relatively new, and there were very few, if any, accepted design methodologies for geotextiles, the task force took a conservative approach to its work.

For subsurface drainage and erosion control applications, geotextile survivability Classes A and B are defined such that Class A is used where installation stresses are more severe than Class B applications, and by aggregate shape, trench depth, and the size and height of drop of armor stone. There were no definitive limits set to the installation stresses as far as differentiating between severe and less severe. For separation applications, survivability Classes H (high) and M (medium) were designated. Selection of a survivability class was based on the CBR at the site, equipment ground contact pressure, and the cover thickness of aggregate.

AASHTO M-288-90 ---- In 1986,Task Force 25 approved the five proposed geotextile specifications which included material property values and notes on construction and installation procedures. Between 1986 and 1990 the five individual specifications were merged into a single material specification that did not include the construction and installation notes that appeared in the individual documents. In 1989 this single document was submitted to an AASHTO Subcommittee on Materials ballot as a revision to the existing AASHTO M-288 Specification for Geotextiles Used for Subsurface Drainage Purposes. As indicated by the title, the then existing specification was for drainage fabrics only. This revision represented an enlargement of the applications covered in the specification. The revisions were approved and the revised specification first appeared in the AASHTO 1990 " Standard Specifications for Transportation Materials and Methods of Sampling and Testing 15th edition," book as AASHTO Specification M-288-90 on Geotextiles. A formal report of Task Force 25's work was also issued in 1990 separate from the 15th edition of the AASHTO specification book.

AASHTO M-288-92 ---- In 1992, with the realization that knowledge on the use of geotextiles had grown at a rapid rate, and the fact that in reality the work of Task Force 25 was nearly ten years old, a proposal was presented to the AASHTO Subcommittee on Materials, Technical Section 4e, that it would be appropriate to start a formal review process of M-288-90. A preliminary review was done with a small task force in early 1993. A formal Joint AASHTO-IFAI Task Force established late in 1993. The Task Force had Federal and State Transportation, academia, and industry(IFAI) representation.

M288-90, as it appeared in the AASHTO Specification Book, did not include the construction and installation guidelines that TF 25 had developed, as it was unclear at the time how to include them. One of the primary objectives of the new task force was to include some form of construction and installation notes in M-288-92. There were no changes made to the recommended material properties however.

AASHTO M-288-96 ---- As experience was gained and design methodologies developed, the need to revisit Specification M-288-92 was realized. A joint AASHTO and Industrial Fabrics Association International (IFAI) Task Force was formed in 1994 to review and revise the specification. The resulting work was adopted by AASHTO in 1996. It is based on accepted design procedures, but also provides default material property values should actual design procedures not be used.

Material Requirements ---- It is emphasized in the Scope of the revised M288-96 that the specification is not a design or construction specification, but is based on geotextile survivability from installation stresses. As such, selection of the geotextile is based on a knowledge of the anticipated installation stresses to which the geotextile will be exposed. The specification covers six applications in which geotextiles are used: subsurface drainage, separation, stabilization, permanent erosion control, temporary silt fences, and paving fabrics. Silt fences and paving fabrics are not discussed in this document since their survivability is not related to soil burial.

In M288-96, the general strength requirements for the subsurface drainage, separation, stabilization, permanent erosion control applications are broken into three classes of geotextiles, with Class 1 being the most robust, and Class 3 the least. Within each survivability class, the strength requirements are established based on elongation at break in the grab strength test. In each class the highest strength requirement are for materials that break at less than fifty percent elongation (typically woven), and the least for those that break at greater than fifty percent elongation (typically nonwoven). The requirements for the silt fence application are based on supported or unsupported fences. The paving fabrics are limited to fabrics with elongation at break greater than fifty percent.

Comparison of Survivability Criteria ---- Tables 2A and 2B compares default M-288-90/92 survivability classes A-B and H-M to the default survivability classes listed in M-288-96. By "Design Class" it is meant that with knowledge of field experience, laboratory tests on exhumed samples, and/or certain site configurations, a lesser class may be used. The use of field experience to modify default survivability classes has been a consistent consideration in all survivability systems.

Table 3 compares the general strength properties for each edition of the specifications for subsurface drainage, separation, stabilization, and permanent erosion control applications. M288-96 made the conversion to SI units while respecting the approximate nature of these numbers. In general, the Class 1 geotextile under M288-96 is slightly stronger than the Class H geotextile under M-288-90/92, and the Class 2 geotextile under M288-96 is intermediate between the Class H and M in M-288-90/92.

Survivability Modification Guidelines ---- The original TF 25 work included notes on construction and installation of the geotextiles in an effort to ensure proper performance of them following installation. This included guidelines for reduction of the default survivability class recommended. Unfortunately, these notes did not get published in M-288-90 or 92. A comparison of the survivability reduction guideline from TF-25 and those in M288-96 is presented on Table 4. Both standards allowed the reduction by the engineer based on the following:

a) The Engineer has found the class of geotextile to have sufficient survivability based on field experience.
b) The Engineer has found the class of the geotextile to have sufficient survivability based on laboratory testing and visual inspection of a geotextile sample removed from a field section constructed under anticipated field conditions

Table 4 indicates that the survivability reduction criteria for subsurface drainage and permanent erosion control was only slightly modified from the original TF-25 recommendations. Conversely, the survivability reduction criteria for separation and stabilization applications has undergone a significant change from TF-25 to M288-96. The stabilization category was created for M288-96 for site subgrades with 1<CBR<3 Weaker sites require consideration of deep failure modes and do not lend themselves to convenient 'standardization.' By limiting the separation category to subgrade having a CBR greater than or equal to 3, lower survivability class geotextiles are acceptable. M288-96 also distinguishes between on-road and off-road vehicles, where TF-25 distinguished between tracked and rubber tired vehicles.

One caution must be expressed in the interpretation of M288 survivability criteria: these installation values are appropriate only when the geotextile in placed on a low CBR soil that does not have aggressive stones. Installation damage factors for those occasions where the geotextile is placed over firm subgrades that contain significant gravel size stones should be based on the installation reduction factors developed by FHWA, Elias et. al (1997), for retaining wall and slope applications. These reduction factors are presented on Table 5 along with additional industry recommended values.

Survivability Data Base - Service Life Demonstrations —— The performance of a roadway system provides a good indicator of the survivability of the geotextile separator used. Table 6 presents a summary of published case studies that provided sufficient performance data that the survivability of the separator geotextile can be implied. This includes both roadway failures such as presented by Sprague et al. (1993) that clearly implied that light woven slit film and needle punched nonwovens should not be used with only 3 inches of base stone. Conversely, the good service of the roadways are the 22 sites exhumed by Metcalfe et al. (1998) clearly demonstrates the ability of woven slit film geotextiles, needle punched, and heat bonded geotextiles to survive installation. In general, it can be seen that the M288-96 criteria would have predicted the survivability and successful separation applications.

Data reported by Bonaparte et al. (1988) is also helpful in identifying installation and service related degradation of the geotextile as mechanical damage and not polymer damage.

Survivability Data Base - Recovery and Testing Demonstrations —— A significant quantity of data on survivability based on field exhumation of previously installed geotextiles exists. Some of this survivability data is presented in Table 7. Note that Table 7 presents test data from both laboratory large scale and field survivability testing. In general the data supports the M288-96 criteria and indicates that the thickness of base over the geotextile should be greater than 6 inches. Much of the recovery examples present 'retained strength' data without commenting on the number of penetrations. It obviously would be helpful if a criteria for minimum retained strength vs. allowable penetrations was clearly known. More importantly, clear criteria relating the number of penetrations and their size to the ability of the geotextile to provide separation would be helpful.

Summary: The Role of Geotextiles in Paved Roadways

M288-96 clearly provides design specifications for geotextiles in subsurface drainage, separation, stabilization, and paving overlay fabrics. Currently M288-96 does not address potential application of geotextile in base reinforcement. A discussion of subsurface drainage and paving fabric applications is outside the scope of this review but is well documented within the literature. However, the role of the remaining functions deserves discussion.

Stabilization ---- The use of a geotextile stabilizer is intended for soils having a CBR value less than 3. The geotextile provides both a separator to protect base stone from contamination by the colloidal fraction of the subgrade and can provide an initial membrane tensile strength to reduce the rate at which subgrade deformation occurs. Frequently, the role of the geotextile is short lived; the consolidation of the underlying weak soils providing the necessary increase in subgrade shear strength to limit future deformation. Obviously the deformations associated with this process exceed acceptable movements for paved roadway systems. Therefore, as applied to paved roadways, the use of a stabilizer geotextile is limited to development of a working platform that allows construction of the design paved roadway system above it. This is typically employed as a alternative to excavation, removal, and backfilling of the soft subgrade.

Separation ---- Under M288-96, this application is limited to soils that either initially or seasonably have a 3<CBR<8. As with stabilization, the current M288-96 specifications provide excellent guidance. In this application the geotextile is a substitute for choked subbase stone commonly used over plastic subgrades. It is important to understand that this function may be required when geogrids are used to provide base reinforcement or confinement, see geogrid white paper.

Base Confinement ---- The use of a geogrid beneath or within the base stone to limit lateral movement of the stone has been the subject of significant research and is discussed in a separate report. The role of a geotextile in this application is not as clear. Early work by Haliburton and Barron (1981) examined the ability of a geotextile to limit lateral spreading of stone on the optimum depth for the geotextile related to the foundation width. While Haliburton's work clearly showed that geotextile may be provide a lateral restraint against stone movement, the geotextile industry has not pursued this research and can not currently provide design guidelines for this application.

Table 1A Survivability Class after Christopher and Holtz (1984)

Subgrade Preparation Conditions	Construction equipment and 15-30 cm of cover material initial lift thickness		
	Low ground-contact pressure equipment (<27 Kpa)	Medium ground-contact pressure equipment (>27 Kpa <55Kpa))	High ground-contact pressure equipment (<>55 Kpa)
Subgrade is smooth and level	Low	Moderate	High
Subgrade has been cleared of large obstacles	Moderate	High	Very High
Minimal site preparation is provided	High	Very High	Not recommended

Table 1B Minimum Fabric Properties

Survivability Class	Grab strength (lbs)	Puncture Strength (lbs)	Burst Strength (psi)	Trap Tear (lb)
Very High	270	110	430	75
High	180	75	290	50
Moderate	130	40	210	40
Low	90	30	145	30

Table 2A - AASHTO Specifications M-288 Applications/Classes

Application	M288 Version	Survivability Class Default	Design Class
Subsurface Drainage	M288-90/92	A	B
Subsurface Drainage	M288-96	2	3
Erosion Control	M288-90/92	A	B
Permanent Erosion Control	M288-96	1(1)	2
Separation(CBR>2)	M288-90/92	M	M
(CBR<1)		H	M
Separation (CBR>3)	M288-96	2	3
Stabilization (1<CBR<3)	M288-96	1	2, 3

(1) Class 2 for woven monofilaments, Class 1 for all others, no slit film

Table 2B Construction Survivability Ratings

Site Soil CBR at Installation	<1		1-2		>2	
Equipment Ground Contact Pressure (PSI)	>50	<50	>50	<50	>50	<50
Cover Thickness(1) (in)(compacted)						
4(2,3)	NR	NR	H	H	M	M
6	NR	NR	H	H	M	M
12	NR	H	H	M	M	M
18	H	M	H	M	M	M

H =High M = Medium NR = Not Recommended

(1) Maximum aggregate size not to exceed one half the compacted cover thickness

(2) For low volume unpaved road (ADT 200 vehicles)

(3) The four inch minimum cover is limited ti existing road bases and not intended for use in new construction.

Table 3 AASHTO M288 Geotextile Survivability Strength Requirements

Property	ASTM Test Method	Units	M288-90/92 Geotextile Survivability				M288-96 Geotextile Survivability Class					
			Separation		Drainage and Erosion Control		Class 1		Class 2		Class 3	
			H	M	A	B	<50%(1)	□50%(1)	<50%(1)	□50%(1)	<50%(1)	□50%(1)
Grab Strength	D 4632	N (lb)	800-1200 (180-270)	500-800 (115-180)	800-1200 (180-270)	356-800 (80-180)	1400 (315)	900 (205)	1100 (250)	700 (160)	800 (180)	600 (115)
Seam Strength	D 4632	N (lb)	N/A	N/A	710-1070 (160-240)	310-710 (70-160)	1260 (280)	810 (185)	990 (220)	630 (140)	720 (165)	450 (100)
Tear Strength	D 4533	N (lb)	350-445 (75-100)	180-310 (40-70)	220-445 (50-100)	110-310 (25-70)	500 (115)	350 (80)	400 (90)	250 (55)	300 (70)	180 (40)
Puncture Strength	D 4833	N (lb)	350-445 (75-100)	180-310 (40-70)	350-445 (78-100)	110-310 (25-70)	500 (115)	350 (80)	400 (90)	250 (55)	300 (70)	180 (40)
Burst Strength	D 3786	kPa (psi)	N/A	N/A	2000-2200 (450-500)	895-965 (200-220)	3500 (510)	1700 (255)	2700 (400)	1300 (200)	2100 (305)	950 (140)

(1) Elongation at break as measured in accordance with ASTM D 4632

Table 4 AASHTO M-288 Construction Guidelines

Application	TF 25 and AASHTO M288-92	AASHTO M288-96
Subsurface Drainage	Class A Drainage applications for fabrics where installation stresses are more sever than Class B applications, i.e., very course sharp angular aggregate is used, a heavy degree of compaction (95 AASHTO T99) is specified or depth of trench is greater that 10 feet.	Class 3 if drain depth is less than 2m, drain aggregate diameter is less than 30 mm and compaction is equal to or less than 95% of AASHTO T-99. (1)
Permanaent Erosion Control	Class A erosion Control fabric applications are used under conditions where installation stresses are more severe than Class B. Stone placement height should be less than 3 ft and stone weights should not exceed 250 lbs. Class B Erosion control applications are those where fabric is used in structures or under conditions where the fabric is protected by a sand cushion or by a "zero drop height' placement of stone.	Class 2 if armor layer stone weights less than 100 kg, stone drop height is less than 1m, and the geotextile is protected by a 150 mm thick aggregate bedding layer designed to be compatible with the armor layer. Class 2 if armor stone weights do not exceed 100 kg and stone is placed with zero drop height. (1)
Separation	See Table 2B	Class 3 if cover thickness over first lift over the geotextile exceeds 300mm and aggregate diameter is less than 50 mm. Class 3 if aggregate cover thickness of the first lift over the geotextile exceeds 150mm, aggregate diameter is less than 30mm, and construction equipment contact pressure is less than 550 Kpa. (1)
Stabilization	See Table 2B	(1)

(1) The Engineer may specify a survivability class lower than the default based on one or more of the following

- **a)** The Engineer has found the class of geotextile to have sufficient survivability based on field experience.
- **b)** The Engineer has found the class of the geotextile to have sufficient survivability based on laboratory testing and visual inspection of a geotextile sample removed from a field section constructed under anticipated field conditions

Table 5 Degradation Reduction Factors for Geosynthetics

Geosynthetic	Degradation Reduction Factors		
	FHWA Recommendation		IFAI Recommendation
	Type 1 Backfill max. size 100 mm D_{50} about 30 mm	Type 2 Backfill max. size 20 mm D_{50} about 0.7 mm	Type 3 Backfill max. size 20 mm 0.1 mm$<D_{50}<$0.5mm
HDPE uniaxial geogrid	1.20-1.45	1.10-1.20	1.05-1.15
PP biaxial geogrid	1.20-1.45	1.10-1.20	1.05-1.15
PVC-coated PET geogrid	1.30-1.85	1.10-1.30	1.05-1.20
Acrylic-coated PET geogrid	1.30-2.05	1.20-1.40	1.15-1.30
Woven geotextiles (PP and PET)	1.40-2.20	1.10-1.40	1.05-1.20
Nonwoven geotextiles (PP and PET)	1.40-2.50	1.10-1.40	1.05-1.20
Slit-film woven PP geotextile	1.60-3.00	1.10-2.00	1.10-1.75

Table 6 Summary of Performance Based Survivability of Geotextiles

Reference	Location and Details	Application/ Function	Overlying Lift Details	Soil Properties	Compactive Effort	Geotextile Properties			M288-96
		Unpaved Road Paved Road Erosion Lab Test Reinforcement Separator Stabilizer		Aggregate/ Subgrade	Spec Equipment Number of Passes	Product Used Manufacturer Trade Name / Structure(1) (gm/m2)	M288-96 Surviv-ability	Observed Performance	Satisfy Criteria?
Sprague Ref #17	Greenville County, SC	P/S	1.5" HAC/ 3" CSB 3"Triple (?)/ 3"CSB	Saprolite - ML? Firm/Dry poorly drained	8 ton roller	/NP(140) /WS(140) /NP(140) /WS(140) /NP(210) NP(210	3 3 3 3 2 2	Rapid deterioration over 2 years - very poor performance	below below below below below below below
Pourkhosrow Ref # 24 Guram et al. Ref # 35	Oklahoma	P/S	chip seal/ 6" aggregate 1.5" HAC add @2 year	silty clay (A-6/7)	Std. Proc	Supac/ WS(180) Supac/ NP(280)	3 2	After 9 years, PSI was still acceptable. An alternative to $$$$ lime amendment	
Fannin et al. Ref #36	British Columbia	U/S,R	sandy gravel 19mm minus .25m to .5m	organic clayey silt (OH)	96% Std Proc	/NP(310) NP(268) NP(204) GG	2 2 3 n/a	Significant improvement in rut depths and improved ESAL	Yes N/A
White Ref # 40	Colorado	U(airfield)/S	10" aggregat	clay (firm)	?	WS (220# grab)	2	2 airfields built and performed well	Yes
Wallace Ref #46	Alaska	U/S	0.6m	clean round stone/silt	smooth drum	Bidim/NP34	2	Excellent ove 99% - had problem when placed over frozen soil	Yes
Metcalfe et al. Ref #48	22 sites in Washington	P/S	varies	range from GM to CL	?	NP(143-270) HB(118-136) WS(136-231)	2-3 3 2-3	provide separation as documented by exhuming	Yes
Reemay	Oerlandet, Norway	P/S	>40cm granite stone	soft clay, silt, silty sand	?	Typar 3507	2	stopped sinking of subbase	Yes
Ref #69	Alvwick, England	P/S P/St	coarse granulr drain	CBR = 1 clay	?	Typar 3407	3	sep fly ash from drain	below
	Indiana, A.B. Brown St.	U/S	rock aggregate	CBR 4-8 clay	?	Typar 3401	3	reduce frost heave damage	below
	Andrews AFB	P/S	13" stone	CBR 5 silty clay	?	Typar 3401	3	reduce excavation depth	below

Table 7 Summary of Recovery and Testing Based Survivability of Geotextiles

Reference	Location and details	Application/ Function	Overlying Lift Details	Soil Properties	Compactive Effort	Geotextile Properties					M288-96
		Unpaved Road Paved Road Erosion Lab Test Reinforcement Separator Stabilizer		Aggregate/ Subgrade	Spec Equipment Number of Passes	Product Used Manufacturer Trade Name / Structure(1)	M288-96 Surviv-ability	Installation Reduction Factor, RF_{ID}		Excess Holes	Satisfy Criteria?
								MD	XD		
DeBernadino, et.al (1994) Ref # 25	Georgia Institute Technology 1.22m sq. test box,	L/S			95% Proctor gas powered 'Wacker'	Exxon/W-PE					
			30cm lift	Clay/Clay		GTF 550T	1	1.11	1.15	no	Exceeds
						GTF 1000T	1+	1.22	1.09	no	Exceeds
						GTF 1500T	1+	1.07	1.09	no	Exceeds
			30cm lift	Sand/Sand		GTF 550T	1	1.34	1.25	no	Exceeds
						GTF 1000T	1+	1.40	1.22	no	Exceeds
						GTF 1500T	1+		1.25	no	Exceeds
			30cm lift	Gravel/Clay		GTF 550T	1	1.36	1.39	no	Exceeds
						GTF 1000T	1+	1.32	1.25	no	Exceeds
						GTF 1500T	1+	1.30	1.13	no	Exceeds
			30cm lift	Gravel/Gravel		GTF 550T	1	1.64	1.64	no	Exceeds
						GTF 1000T	1+	1.51	1.30	no	Exceeds
						GTF 1500T	1+	1.45	1.23	no	Exceeds
Geoservices (1987) Ref # 44	east Texas, field recovery	U/St	9-12 inch lift gravel	Gravel(<2.5")/Clay (CBR 1-2)	in service 11 years	Typar 3401 HB-PP	3	1.23		no	Less Than
	east Texas, field recovery	U/St	9-12 inch lift gravel	Gravel(<2.5")/Clay (CBR 1-2)	in service 11 years	Typar 3401 HB-PP	3	1.10		no	Less Than
	west Washington, field recovery	U/S	40"	Gravel/ Clay (CBR 1)	in service 9 years	Typar 3401 HB-PP	3	1.19		no	Less Than
	west Washington, field recovery	U/St	12 inch lift gravel	Gravel/Sand+ Gravel+Cobbles	in service 8 years	Typar 3401 HB-PP	3	1.32		yes	Less Than
	Illinois, field recovery	U/S	8 inch lift gravel	Gravel/ looseSand	in service 5 years	Typar 3401 HB-PP	3	1.18		no	Less Than
	Illinois, field recovery	U/S	12 inch lift gravel	Gravel/ soft Clay Spoil	in service 5 years	Typar 3601 HB-PP	2	2.00		no	Yes
	Illinois, field recovery	U/S	8-12 inch lift gravel	Gravel 12" max /Clay Spoil	in service 5 years	Typar 3601 HB-PP	2	2.00		yes	Yes

(1) HB-PP heat bonded polypropylene, NW-NP needle punched polypropylene, W-PE woven polyester, W-PP woven polypropylene, WS woven slit film, WM woven mono

Table 7 Summary of Recovery and Testing Based Survivability of Geotextiles

Reference	Location	Application / Function	Overlying Lift Details	Soil Properties	Compactive Effort	Geotextile Properties					M288-96
		Unpaved Road Paved Road Erosion Lab Test Reinforcement Separator Stabilizer		Aggregate/ Subgrade	Spec Equipment Number of Passes	Product Used Manufacturer Trade Name / Structure[(1)]	M288-96 Surviv-ability	Installation Reduction Factor, RF_{ID} MD	XD	Excess Holes	Satisfy Criteria?
Rix, et al (1995) Ref # 27 Rix, et.al. (1995a) Ref # 31	Georgia Institute Technology 1.22 m sq. test box	L/S	S	GAB=1"minus	95% Proctor Gas Wacker	Amoco/W-PP					
			15 cm lift	GAB/Silty Sand	95% Mod.	2016	3	1.10	1.15	no	less than
				CBR=5		2006	3	1.04	1.22	no	less than
						2002	3	1.16	1.59	no	less than
			30 cm lift			2016	3	1.03	1.10	no	less than
						2006	3	1.06	1.14	no	less than
						2002	3	1.00	1.28	no	less than
			15 cm lift	GAB/Silty Sand	95% Std.	2016	3	1.09	1.10	no	less than
				CBR=2		2006	3	1.06	1.28	no	less than
						2002	3	1.12	1.43	no	less than
						2044	1+	1.00	1.06	no	exceed
			30 cm lift			2016	3	1.03	1.11	no	less than
						2006	3	1.11	1.18	no	less than
						2044	1+	1.00	1.02	no	exceed
			15 cm lift	GAB/GAB		2044	1+	1.00	1.15	no	exceed
			30 cm lift			2044	1+	1.00	1.02	no	exceed
			25 mm lift	GP/GP(3"max)	95-100% Mod	2006	3	1.43	1.59	no	less than
						2040	1+	1.07	1.19	no	exceed
	Field Test	U/S	15 cm lift	GAB/GAB		2044	1+	1.00	1.16	no	exceed
			30 cm lift			2044	1+	1.00	1.16	no	exceed
van't Hoog (1994)	Seattle geotextile retaining wall	R/R	20 cm lift	<3/4", angular	95% Proctor	Amoco/W-PP 2044	1+	1.08	1.12	<0.5%	exceed
Valentine (1995)	Commerce City, Colorado	R	15-cm lift	Gravel/Gravel	95% Proctor	Amoco/W-PP 2044	1+	1.00	1.08	2/ 50 ft2	
						Philips 5WS		1.00	1.28	30/ 50 ft2	

(1) HB-PP heat bonded polypropylene, NW-NP needle punched polypropylene, W-PE woven polyester, W-PP woven polypropylene, WS woven slit film, WM woven mono

Table 7 Summary of Recovery and Testing Based Survivability of Geotextiles

Reference	Location	Application / Function	Overlying Lift Details	Soil Properties	Compactive Effort	Geotextile Properties				M288-96
		Unpaved Road Paved Road Erosion Lab Test Reinforcement Separator Stabilizer		Aggregate/ Subgrade	Spec Equipment Number of Passes	Product Used Manufacturer Trade Name / Structure[1]	M288-96 Surviv-ability	Installation Reduction Factor, RF_{ID} MD XD	Exces s Holes	Satisfy Criteria?
Koerner and Koerner (1990) Ref # 42	48 field sites	Varies	Not Provided	Not Provided	Not Provided	/(gm/m2)	Table 1	Average	#/m2	
						WS/(135-215)	low-	1.18	6	less than
						WS/(135-215)	mod(3)	1.22	3.6	Yes
						WM/(220)	low	1.04	0	less than
						WM/(215)	mod(3)	1.12	2	Yes
						WM/(210-215)	high(1)	1.10	1	Yes
						HB(135)	low	1.16	0	less than
						NP(150-240)	low	1.19	0	less than
						NP(150-340)	mod(3)	1.15	1	Yes
						NP(680)	high(1)	1.05	0	Yes
Sprague et al. Ref #17	Greenville County SC	P/S	1.5" HAC/ 3" CSB	/Saprolite (ML)	8 ton roller	/NP(140)		1.00	Yes	less than
				firm/dry		/WS(140)		1.07	Yes	less than
						/NP(140)		1.25	Yes	less than
						/WS(140)		1.30	Yes	less than
			Triple/	poorly drained		/NP(210)		1.30	Yes	less than
			3" CSB			/NP(210)		1.75	Yes	less than
Guram et al. Ref # 35	Oklahoma	P/S	1.5"HAC/ 6" aggregate	/silty clay (A-6/7)	Std. Proc	Supac/NP(280)		1.00	No	Yes
Koener et al. Ref #43	Philadelphia	R	250 mm	gravel/gravel	95-100 Mod. Proctor	/GG(848)		1.41	NA	
						/NP(542)		1.72	.57%	
						/NP(203)		2.7	.99	
						/NP(153)		3.22	2.9	
						/HB(115)		2.70	.84.	
						/WS(237)		3.33	.81	
						/WS(237)		2.27	.79	
				sand/sand		/GG(848)		1.00	0	
						/NP(542)		1.10	0	
						/NP(203)		1.39	0	
						/NP(153)		1.39	0	
						/HB(115)		1.32	0	
						/WS(237)		1.14	0	
						/WS(237)		1.04	0	

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(1) HB-PP heat bonded polypropylene, NW-NP needle punched polypropylene, W-PE woven polyester, W-PP woven polypropylene, WS woven slit film, WM woven mono

Standard Specification
for

Geotextiles Used as Reinforcement for Base and Subbase Layers in Pavement Structures

AASHTO Designation: M XXX - Draft 5
June 24, 1998

1. SCOPE

1.1 This is a materials specification covering geotextiles for use in base and subbase reinforcement of pavement structures. The function of the reinforcement in this application refers to including a tensile member in the form of a geotextile beneath the unbound base or subbase with the intent of increasing the structural support capacity of that component of the pavement structure. The geotextile may also serve to stabilize the subgrade provided the geotextile conforms with the requirements for separation and filtration as defined in AASHTO M288.

1.2 Base reinforcement is defined as a **Class 1 Geotextile** placed directly beneath the base course (See Figure A) of properly designed paved roads to improve service life, and/or obtain an equivalent performance with a reduced structural section. The potential mechanisms provided by the base reinforcement include lateral restraint or increased bearing capacity. Base course in this specification is defined as the layer or layers of specified or selected unbound material of designed thickness placed on a subbase or a subgrade to support a surface course.

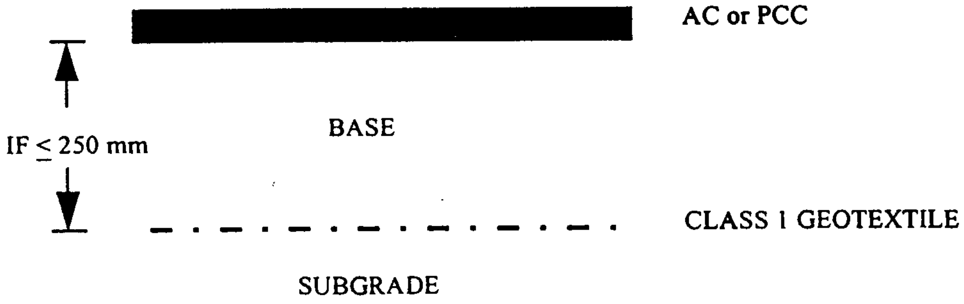

FIGURE A: BASE REINFORCEMENT

1.3 Subbase reinforcement is defined as a **Class 2 Geotextile** placed at the subgrade/subbase interface (See Figure B) of properly designed paved roads to provide support for the roadway structural section. The potential mechanisms provided by the subbase reinforcement include increased bearing capacity, lateral restraint, and/or tensioned membrane effect. Subbase in this specification is defined as the layer or layers of specified or selected material of designed thickness placed on a subgrade to support a base course.

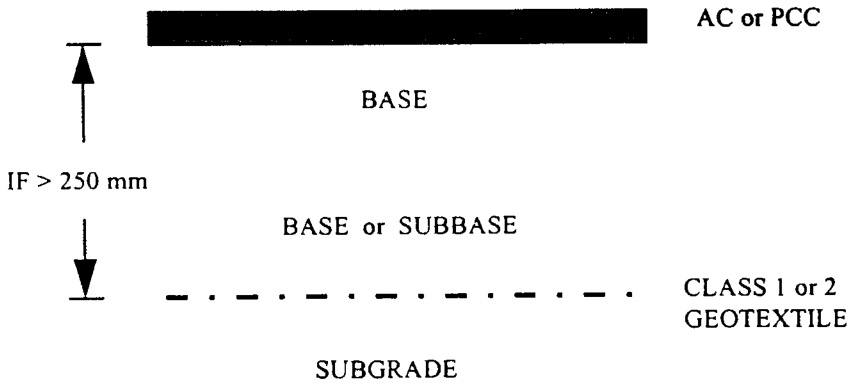

FIGURE B: BASE OR SUBBASE REINFORCEMENT

1.4 This is a material purchasing specification and design review of its use is recommended. Reinforcement of the pavement section is a site-specific design issue which should be addressed by the Engineers responsible for the pavement and embankment design. This specification is not appropriate for embankment reinforcement where stress conditions may cause global subgrade foundation or embankment failure.

1.5 This specification is based on the minimum requirements of the geotextile to provide tensile reinforcement and survivability from installation stresses. The physical properties listed in Table 1 are applicable for a minimum backfill thickness of 150 mm. This is not a construction specification. However, in general, the geotextile shall be placed at the proper elevation, location, and orientation as detailed on the plans and specification. The Contractor shall follow the project specification for geotextile construction/installation guidelines, or if not provided, the geotextile manufacturers recommended installation guidelines.

2. REFERENCED DOCUMENTS

2.1 *AASHTO Standards*

M288-96	Standard Specification for Geotextiles

2.2 *ASTM Standards*

D 4354	Practice for Sampling of Geosynthetics for Testing
D 4355	Test Method for Deterioration of Geotextiles from Exposure to Ultraviolet Light and Water (Xenon-Arc Type Apparatus)
D 4439	Terminology for Geosynthetics
D 4491	Test Methods for Water Permeability of Geotextiles by Permittivity
D 4533	Test Method for Trapezoid Tearing Strength of Geotextiles
D 4595	Test Method for Tensile Properties of Geotextiles by the Wide-Width Strip Method
D 4759	Practice for Determining the Specification Conformance of Geosynthetics
D 4873	Guide for Identification, Storage, and Handling of Geotextiles
D 5321	Test Methods for Determining the Coefficients of Soil and Geosynthetic or Geosynthetic and Geosynthetic Friction by Direct Shear Test
GRI GT 6	Test Method Geotextile Pullout

3. PHYSICAL AND CHEMICAL REQUIREMENTS

3.1 Polymers used in the manufacture of geotextiles, and the mechanical fasteners or threads used to join adjacent rolls, shall consist of long chain synthetic polymers, composed of at least 95% by weight polyolefins, polyesters, or polyamides. They shall be formed into a stable network such that the ribs, filaments or yarns retain their dimensional stability relative to each other, including selvages.

3.2 Geotextiles used for base and subbase reinforcement shall conform to the physical requirements of Section 7.1. Geotextiles used as a filtration, separation, or stabilization material in conjunction with the reinforcement shall also conform to the physical requirements in AASHTO M288-96.

3.3 All property values in these specifications represent minimum average roll values (MARV - Average value minus two standard deviations) with the exception of ultraviolet stability, coefficient of interaction, and coefficient of direct sliding.

4. CERTIFICATION

4.1 The Contractor shall provide to the Engineer a certificate stating the name of the manufacturer, product name, style number, lot number, chemical composition of the geotextile product and physical properties applicable to this specification.

4.2 The Manufacturer is responsible for establishing and maintaining a quality control program to assure compliance with the requirements of the specification. Documentation describing the quality control program shall be made available upon request.

4.3 The Manufacturer's certificate shall state that the furnished geotextile meets the MARV requirements of the specification as evaluated under the Manufacturer's quality control program. The certificate shall be attested to by the Manufacturer's quality control manager or a registered Professional Engineer associated with the manufacturer.

4.4 Either mislabeling or misrepresentations of materials shall be sufficient reason for rejection of those geotextile products.

5. SAMPLING, TESTING, AND ACCEPTANCE

5.1 Geotextiles shall be subject to sampling and testing to verify conformance with this specification. Sampling for testing shall be in accordance with ASTM D 4354. Acceptance shall be based on testing of either conformance samples obtained using Procedure A of ASTM D 4354 or based on manufacturer's certifications and testing of quality assurance samples obtained using Procedure B of ASTM D 4354. A lot size for conformance or quality assurance sampling shall be considered to be the shipment quantity of the given product or a truckload of the given product, whichever is smaller.

5.2 Testing shall be performed in accordance with the methods referenced in this specification for the indicated application. The number of specimens to test per sample is specified by each test method. Geotextile product acceptance shall be based
on ASTM D4759. Product acceptance is determined by comparing the average test results of all specimen within a given sample to the specified MARV.

6. SHIPMENT AND STORAGE

6.1 Geotextile labeling, shipment, and storage shall follow ASTM D 4873. Product labels shall clearly show the manufacturer or supplier name, style number, lot number, and roll number. Each shipping document shall include documentation certifying that the material is in compliance with the reinforcement specification.

6.2 Geotextile rolls shall be protected from damage due to shipment and contaminants with protective wraps. The wrapping shall be maintained during periods of shipment and storage prior to deployment.

6.3 During storage, the geotextile rolls shall be elevated off the ground and adequately protected from the following: site construction damage, excessive precipitation, extended exposure to sunlight, aggressive chemicals, flames or temperatures in excess of 71°C (160°F), and any other environmental condition that may damage the physical property values of the reinforcement.

7. GEOTEXTILE PROPERTY REQUIREMENTS

7.1 The geotextile shall meet the requirements of Table 1. All numeric values in Table 1 represent MARV's with the exception of the ultrviolet stability, coefficient of interaction, and coefficient of direct sliding.

7.1.1 The property values in Table 1 represent default values which provide for sufficient geotextile reinforcement and survivability under most construction conditions. The design Engineer may specify properties different from those listed in Table 1 based on engineering design and experience.

7.1.2 The geotextile is assumed to be placed with the machine direction (MD - roll length) parallel with the centerline of the roadway alignment. If the geotextile is placed with the machine direction transverse to the centerline of the roadway alignment, the machine direction (MD) and cross machine direction (XD) tensile strength requirements listed in Table 1 shall be reversed.

8. MEASUREMENT AND PAYMENT

8.1 The geotextile shall be measured by the square meter in place. The measurements used for payment shall not include double measurement for overlaps.

8.2 The accepted quantities shall be paid for at the contract unit price. Payment shall be full compensation for all labor, tools, equipment, and appurtenances necessary to satisfactorily complete the work.

PAY ITEM	UNIT
Geotextile Reinforcement	Square Meter

TABLE 1

Geotextile Reinforcement Property Requirements for Base and Subbase Reinforcement of Pavement Systems[1]

Property	**Class 1**	**Class 2** (CBR $\geq$ 0.5)
Ultimate Tensile Strength[2] (ASTM D 4595)	35 x 70 (kN/m)	35 x 70 (kN/m)
Tensile Strength at Specified Strain[2] (ASTM D 4595)	4 x 14 @ 2% Strain (kN/m)	8 x 22 @ 5% Strain (kN/m)
Permittivity (ASTM D 4491)	0.05 (sec^{-1})	0.05 (sec^{-1})
Trapezoid Tear Strength (ASTM D 4833)	0.4 (kN)	0.4 (kN)
Ultraviolet Stability (Retained Strength) (ASTM D 4355)	50 % (500 hrs)	50 % (500 hrs)
Coefficient of Interaction Due to Pullout[3], C_i (GRI GT6) @ 6 mm Displacement Normal Load = 5 kPa	**(C_i To Be Determined)**	Not Applicable
Coefficient of Direct Shear[4], C_{ds} (ASTM D 5321) @ Peak Geotextile Shear Strength[5] Normal Load = 5 kPa	**(C_{ds} To Be Determined)**	Not Applicable

Table 1 Notes:

[1] Values listed in Table 1 except for Ultraviolet Stability, C_i, and C_{ds} values are MARV's (MARV - Average value minus two standard deviations).

[2] Machine Direction (MD) x Cross Machine Direction (XD). Assumes MD is placed parallel to the centerline of the roadway alignment.

[3] **Rate of displacement may be increased to 125 mm/min. A graded angular base material as described in Table 2 shall be used in laboratory testing to determine C_i. Test sample shall be at least 0.5 meter in length and 0.3 meters in width.**

[4] **Rate of displacement may be increased to 50 mm/min. A graded angular base material as described in Table 2 shall be used in laboratory testing to determine C_{ds}. Test sample shall be at least 0.3 meter in length and 0.3 meters in width.**

[5] **The coefficient of direct shear shall be determined using the peak geotextile shear strength with the shear strength of the graded angular base measured at the same displacement as the peak geotextile shear strength.**

TABLE 2

Gradation of Base Material for Determining the Coefficients of Interaction and Direct Sliding

Sieve Size*	Percent Passing
37.5 mm (1 1/2")	100
25 mm (1")	95 - 100
19 mm (3/4")	60 - 100
4.75 mm (#4)	30 - 60
0.425 mm (#40)	10 - 30
0.075 mm (#200)	3 - 10

* Note: LL< 30 and PI < 10

PROPOSED RESEARCH NEEDS STATEMENT
AASHTO White Paper for Subbase/Base Reinforcement Specification

Reinforcement

The laboratory investigation and the sensitivity analyses indicate that further research is needed in the following specific areas of base reinforcement: (1) Prerutting: Prerutting a non reinforced aggregate base appears to have the best overall potential of the methods studied for improving pavement performance. Prerutting in the large-scale experiments was found to be both effective and is also inexpensive. (2) Low quality aggregate: The geosynthetic reinforcement of an unstabilized, low quality aggregate base appears to offer promise as one method for reducing permanent pavement deformation of pavements having this asphalt surfacings. (3) Weak Subgrade: Geosynthetics reinforcement of light pavement sections constructed on weak subgrades shows promise for reducing permanent deformations needs to be further studied in the field.

The recommendation is therefore made that an additional experimental investigation should be conducted to further evaluate these three techniques for potentially improving pavement performance. This investigation should consist of carefully instrumented, full-scale field test sections. Geogrid reinforcement was found to perform better than a much stiffer woven geotextile. Therefore geogrid reinforcement is recommended as the primary reinforcement for use in this study. A description of a proposed experimental plan for the study is given in Appendix H.

Separation and Filtration

Important areas involving separation and filtration deserving further research are:

1. *Geosynthetic Durability.* A very important need presently exists for conducting long-term durability tests on selected geosynthetics known to have good reinforcing properties. Such a study would be applicable to mechanically stabilized earth reinforcement applications in general. The geosynthetics used should be subjected to varying levels of stress and buried in several different carefully selected soil environments. Tests should run at least 5 years and preferably 10 years. Soil environments to include in the experiment should be selected considering the degradation susceptibility of the polymers used in the study to specific environments. Properties to be evaluated as a function of time should include changes in geosynthetic strength, stiffness, ductility, and chemical composition.

   Each geosynthetics product has a different susceptibility to environmental degradation, and a considerable amount of valuable information could be obtained from a long-term durability study of this type.

2. *Filtration*. A formal study should be undertaken to evaluate the filtration characteristics of a range of geotextiles when subjected to dynamic load and flowing water conditions likely to be encountered both beneath a pavement and also at lateral edge drains. The tests should be performed in a triaxial cell by applying cyclic loads as water is passed through the sample. At least 10^6 load repetitions should be applied during the test to simulate long-term conditions.[1]

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[1] Barksdale, R. D., Brown, S. F. and Chan F., (1989) Potential Benefits of Geosynthetics in Flexible Pavement Systems, National Cooperative Highway Research Program Report, 315, Transportation Research Board, Washington, D.C., pp. 52-53