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Photo 1. To simulate service-type loads, this loaded dump truck made 100 passes over the geosynthetic reinforcement being tested for survivability.

Field evaluation of geosynthetic survivability in aggregate road base

Test results demonstrate the reliability of established installation-damage reduction factors.

By Gregory N. Richardson

TRANSPORTATION- AND REINFORCEMENT-design procedures increasingly have emphasized empirical survivability factors to account for geosynthetics damage that occurs during installation. Exhumation testing historically has shown that geosynthetics are damaged to a much greater extent by the impact of installation practices than by subsequent service loads. This paper includes a brief history of the development of survivability criteria for geosynthetics and presents data from a field test conducted to evaluate geosynthetics survivability in an extreme stone-above/stone-below environment—one typical of retaining-wall and roadway base-reinforcement applications.

This survivability test was "piggy-backed" onto a geomembrane-cushion test sponsored by the stone industry and performed by the author last winter. Geosynthetic manufacturers—including TNS Advanced Technologies, Greer, S.C.; Lückenhaus North America Inc., Spartanburg, S.C.; and Tensar Earth Technologies, Atlanta—provided additional financial, testing and labor support. While originally intended to support the industry move to American Association of State Highway and Transportation Officials (AASHTO) M288-96 standards, the testing actually provides excellent support for the installation-reduction factors (RF_{ID}) recently proposed by the U.S. Federal Highway Administration (FHWA) for reinforcement applications (Elias et al. 1997). This paper also discusses the difference between these two survivability criteria.

Geotextile-survivability criteria

Geotextile-survivability criteria traditionally have applied to placement of the material over a low CBR (< 8) clayey subgrade for roadway-separation or stabilization applications. One of the earliest geotextile-stone/subgrade survivability criteria was developed by Haliburton as part of a transportation-related training manual (1982). This procedure, refined by Christopher and Holtz, has served as the basis for the subsequent AASHTO survivability criteria (1984). Care must be taken to differentiate such stone/subgrade criteria from the stone/stone criteria developed by FHWA for retaining-wall applications (Elias et al. 1997).

In 1982, the Committee on Materials of AASHTO, the American Road and Transportation Builders Association, and the Association of General Contractors formed Joint Task Force 25 (TF 25). The new group's mission was to review tables of suggested geotextile-property values for the *FHWA Geotextile Manual* that was being prepared at the time. In 1986, Task Force 25 approved five proposed geotextile specifications that 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. However, the construction and installation notes appeared in a separate section.

In 1989, this document was submitted to an AASHTO Subcommittee on Materials ballot as a revision to the existing M-288 Specification for Geotextiles Used for Subsurface Drainage Purposes. As indicated by the title, the existing specification was for drainage fabrics only, while the revision represented an enlargement of the applications that were covered. The modifications were approved, and the revised specification first appeared in the AASHTO *1990 Standard Specifications for Transportation Materials and Methods of Sampling and Testing* (15th ed.) as Specification M-288-90 on Geotextiles.

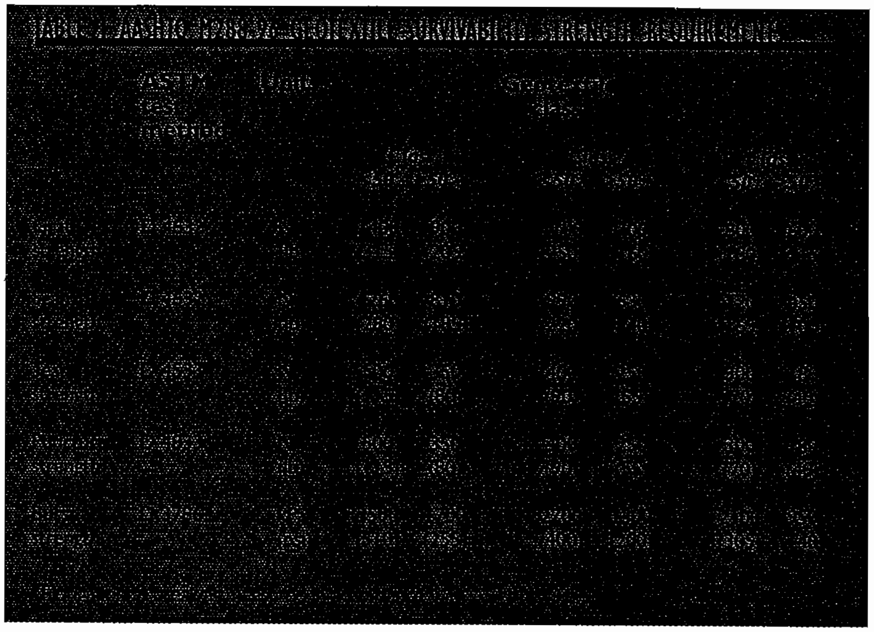
AASHTO M288-92

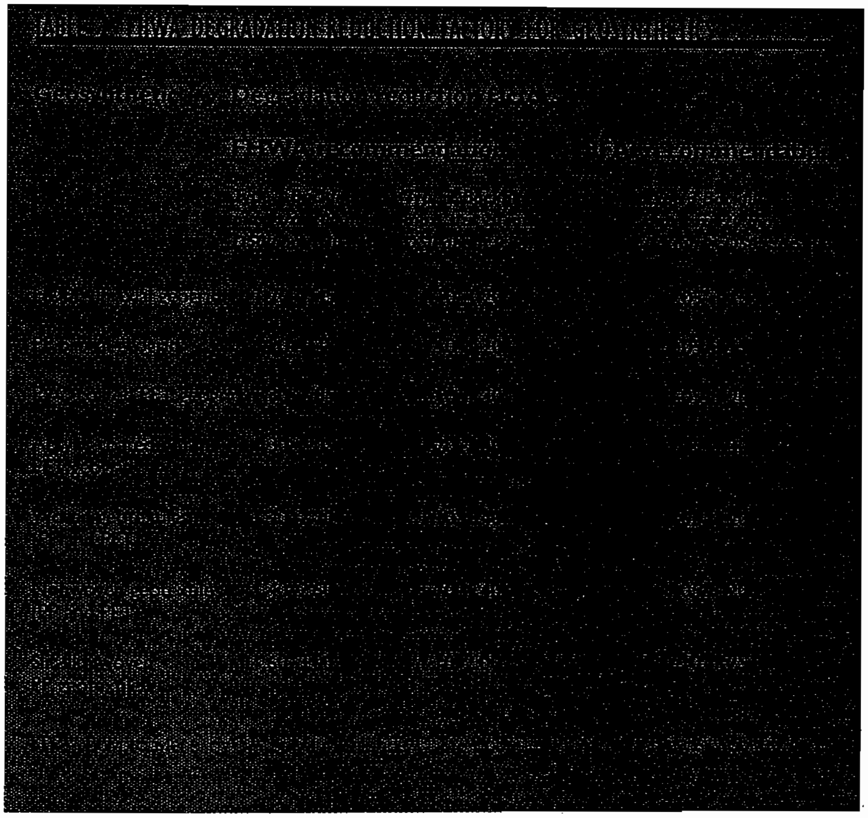
In 1992, a proposal to start a formal review process of M288-90 was presented to the AASHTO Subcommittee on Materials, Technical Section 4e. M288-90, as it appeared in the AASHTO specifications book, did not include the construction and installation guidelines that TF 25 had developed. One of the primary changes in M-288-92 was the inclusion of construction and installation guidelines. However, no changes were made to the recommended material properties.

AASHTO M288-96

A joint AASHTO and Industrial Fabrics Association International (IFAI) Task Force formed in 1994 to revise Specification M-288-92. The resulting work, which was approved by AASHTO in 1996 and published in January 1998, is based on state-of-practice techniques and provides default material-property values.

AASHTO M288-96 guidelines provide three different survivability classes of standard geotextiles based on standard strength parameters. **Table 1** presents the mechanical properties that distinguish these three survivability classes (Suits and Richardson 1998). Within M288, a default survivability class is suggested for most typical transportation applications, with the understanding that the designer can increase the survivability requirement as needed. M288-96 relates to stone/subgrade conditions common to roadway applications.





FHWA/AASHTO soil-reinforcement criteria

Recent work by FHWA has led to development of installation-damage reduction factors to reduce the allowable tensile strength of geosynthetic reinforcement used in retaining-wall and slope-stabilization applications. **Table 2** gives current FHWA presumptive installation-damage reduction factors for a variety of geosynthetics. Recommended values from IFAI's Geotextile Division (now the Geosynthetic Materials Association [GMA]) also are shown. These installation-damage reduction factors reflect potential stone/stone applications.

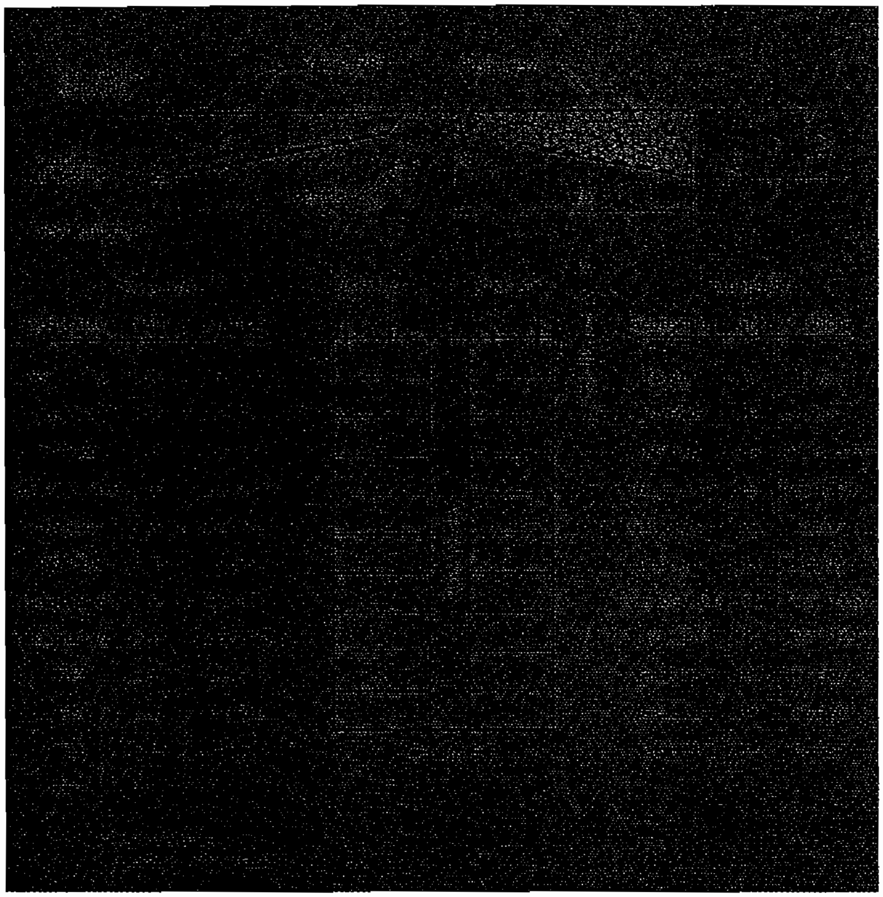


Figure 1. Survivability- and cushion-test layout

Traditional geogrid-survivability criteria

Geogrids represent the newest "geo" products for soil reinforcement, having emerged commercially only in the early '80s. Fortunately, their role as reinforcement in walls and embankments has generated significant interest and research related to their installation survivability. The geometry and function of geogrids make evaluating their survivability easier than that of geotextiles—i.e., the question of the impact of holes on retained strength is not a concern.

The GRI-GG4 guidelines for determining long-term design strength of geogrids, developed by the Geosynthetic Research Institute, include performing survivability tests. These guidelines resulted from a comprehensive geotextile field-exhumation program in the early '90s (Koerner and Koerner 1990). Studies have indicated that 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 manufacturing geogrid
- geogrid-manufacturing process (Rainey and Barksdale 1993).

GMA has compiled a significant body of geogrid installation-damage test data for AASHTO. This data shows excellent agreement with the FHWA installation-damage criteria presented in **Table 2.**

Field-survivability test

The ability of geosynthetics to survive a stone/stone installation represents the most aggressive survivability test. Such an environment would be unusual for most transportation applications but common in reinforcement applications that require granular backfill. A test-pad layout, shown on **Figure 1,** was developed to allow a range of burial depths and traffic loading on the geosynthetics. The geomembrane/cushion component of the test will be addressed in a subsequent paper.

Field variables that affect the level of installation damage include:

- gradation and angularity of backfill
- type and properties of the geosynthetic
- lift thickness
- type of compactive effort used
- service loads, if any.

Gradation and angularity of backfill

Two distinct crushed-stone gradations were used in the test: a North Carolina Department of Transportation (NCDOT) #78M stone with a maximum particle size of 0.75 in., and a NCDOT #57 stone with a maximum particle size of 1.5 in. The stone is angular and granitic, with no fines present. The #57 stone represents a Type 1 backfill, as shown on Table 2. The #78 stone is approximately a Type 2 backfill.

Type and properties of the geosynthetics

Table 3 presents a summary of the geosynthetic materials analyzed in the survivability test. The geosynthetics ranged from typical nonwovens and geogrids to extremely high-strength geotextiles. This last would be a Class 1++ survivability geosynthetic under M288-96. All geotextiles used meet Class 1 survivability under M288-96.

Lift thickness

The slope of the underlying geomembrane allowed the lift thickness to range from approximately 1+ in. up to 24 in. The tapered stone layer was constructed as a single full section using a Cat D7 dozer to allow the influence of lift thickness to be evaluated. During this placement, the dozer avoided significant turns while on the geosynthetic reinforcement.

Type of compactive effort used

The stone was compacted using a minimum of 20 passes of the same D-7 dozer used to place the stone.

Service loads

Service-type loads were achieved by using 100 passes of a loaded tandem-axle dump truck (18-kip axle load and 90 psi tire pressure), as shown in **Photo 1.** The traffic lanes are plotted on Figure 1. This resulted in tire contact of approximately 0–24 in. over the

TABLE 3 PHYSICAL PROPERTIES OF GEOSYNTHETICS TESTED

Manufacturer(1)/ product	*Weight, g/m² ASTM D 3776*	*Grab strength, N ASTM D 4632*	*Tear strength, N ASTM D 4533*	*Puncture strength, kPa ASTM D 4833*	*Burst strength, N ASTM D 3786*	*M288-96 Survivability class*
Woven slit film (5)	240	890 x 930	575	530	5,170	3
Nonwoven (5)	N/A	800	330	445	2,275	2
TNS/RO60	N/A	712	289	401	2,170	2
TNS/RO70	N/A	801	334	467	2,411	2
TNS/RO80	N/A	912	378	579	2,750	1
TET/WPV175	475	24.0 x 23.0(2)	3000	N/A	N/A	1+
TET/WPV630	855	70.2(2)	N/A	N/A	N/A	1+
TET/WPV700	1080	78.6(2)	10,900	N/A	N/A	1+
TET/KPV2000	N/A	41.7(2)	N/A	N/A	N/A	1+

Manufacturer(1)/ product	*Weight, g/m² ASTM D 3776*	*Wide-width Tensile, kN/m ASTM D 4595*	*Grid aperature Size, mm*	*Thickness, mm ASTM D 1777*
LH/ 4/2	350	41.8 x 13	15 x 15	N/A
LH/ 6/3	470	55.5 x 14	15 x 15	N/A
TET/ UX750SB	N/A	32.1	15.24	.46/1.83(3)
TET/ BX4100	N/A	12.5/12.5(4)	35.6/35.6(4)	.76/2.79(3)

(1) TNS - TNS Advanced Technologies, LK - Lückenhaus, TET - Tensar Earth Technologies

(2) Wide-Width Tensile, kN/m, ASTM D 4595

(3) Ribs/Junction

(4) MD/XMD

(5) Manufacturer's name withheld

geosynthetic reinforcement. The traffic was considered a good simulation of the tight roadways commonly experienced during placement of fill behind a segmental-faced retaining wall.

After loading was completed, the survivability samples were recovered. To avoid damage, the stone within -4 in. of the survivability samples was excavated with a small backhoe, as shown on **Photo 2.** (p.38) The remaining stone was removed by hand shoveling.

Full-width geosynthetic samples were recovered in such a manner as to include the wheel-load tracks that had been applied. A sufficient length was obtained in this manner to enable four wide-width tensile tests (ASTM D-4595) to be performed on each geosynthetic-sample depth.

Measured installation/ service damage

The exhumed geosynthetic samples were examined for visual damage. They then were marked, boxed and shipped to Texas Research Institute Inc. (TRI), Austin, Texas, for wide-width testing. Sufficient samples were sent to allow five tests to be performed for each geosynthetic/load condition.

The results of the wide-width testing, which are shown in **Table 4**, indicate the following trends:

- Damage decreases with increasing lift thickness.
- Damage did not decrease significantly with decreasing stone size.
- M288-96 survivability criteria are not good indicators for stone/stone installations common to retaining walls that use granular backfill.
- FHWA reduction factors (RF_{ID}) appear to be reasonable for gravel/gravel installations with lift thickness greater than 4 in.
- With the exception of the Lückenhaus woven geogrid and the Tensar high-strength geotextiles, all of the geosynthetics suffered significant visual damage with 4-in. lifts.

It should be noted that the number of wide-width tests performed was less than GRI-GG4 guidelines recommend.

Summary

The measured-strength reductions of the tested geosynthetics agree well with FHWA survivability-reduction factors when the base course above the geosynthetic is greater than 4 in. thick. The tests clearly show that industry guidelines are accurate predictors of geosynthetic survivability. In fact, the author believes that designers now can predict the installed strength of a geosynthetic with greater reliability than that typically attributed to the engineering properties of the subgrade.

Photo 2. A small backhoe was used to carefully remove most of the stone without damaging the underlying geosynthetic.

The tests also clearly show that installation damage to a geosynthetic can be minimized by observing the following guidelines:

- Use a minimum 6-in. initial lift over the geosynthetic (I prefer 8 in.).
- Use a minimum M288-96 survivability Class 2 geotextile in stone/stone applications (I prefer Class 1).
- Limit turning of equipment over the initial lift—trafficking of dozers and trucks has minimal effect.
- Limit the maximum stone size in the initial lift to less than ¼ of the lift thickness.

By following these minimum guidelines, the user can achieve the FHWA recommended installation-reduction factors. The inability of M288-96 to provide a good survivability indicator is not surprising, since the stone/subgrade interface they reflect is less damaging. Conversely, the reasonableness of the FHWA reduction factors reflects their application to reinforced structures where the gravel/gravel environment tested here is typical.

TABLE 4. WIDE-WIDTH STRENGTH RETAINED FROM FIELD SURVIVABILITY TESTS

Manufacturer/ Product	Polymer/ Structure	M288-96 Class	Stone	FHWA % Retain 100/RDF	4" stone depth/ % retain	10" stone depth / % retain	14" stone depth / % retain	22" stone depth / % retain
Woven slit film	PP/W	3	78	71–91	36.4	45.5	71.1	err.
Nonwoven	PP/NP	2	78	71–91	62.3	63.6	75.3	81.6
TNS RO60	PP/NP	2	78	71–91	45.6	66.4	90.9	100+
TNS RO70	PP/NP	2+	78	71–91	49.9	88.2	100+	100+
TNS RO80	PP/NP	1	78	71–91	71.6	75.2	75.9	79.6
Lückenhaus 4/2	PET/W	N/A	78	77–91	71.1	71.4	92.9	88.4
Lückenhaus 6/3	PET/W	N/A	78	77–91	84.3	79.8	93.7	93.1
Tensar UX750SB	PE/D	N/A	78	83–91	n/t	98	94	94
Tensar WPV175	PET/W	1++	78	45–71	45.6	41.6	81.7	81.3
Tensar WPV630	PET/W	1++	78	45–71	47.2	57.7	62	n/t
Tensar WPV700	PET/W	1++	78	45–71	54.3	70.2	66.4	n/t
TNS RO60	PP/NP	2	57	45–71	38.8	66.9	92.4	94.0
TNS RO70	PP/NP	2+	57	45–71	43.6	71.8	100+	100+
TNS RO80	PP/NP	1	57	45–71	74.7	74.5	80.1	89.2
Lückenhaus 4/2	PET/W	N/A	57	49–77	42.9	61.8	77.5	82.0
Lückenhaus 6/3	PET/W	N/A	57	49–77	45.4	85.7	85.0	88.2
Tensar BX4100	PE/D	N/A	57	69–83	n/t	100/98(4)	100/97(4)	100/97(4)
Tensar WPV175	PET/W	1++	57	45–71	46.9	59.4	73.8	78.6
Tensar WPV630	PET/W	1++	57	45–71	54.0	53.9	57.7	n/t
Tensar KPV2000	PET/K	1++	57	45–71	54.0	57.8	65	n/t

[1] Polymer: PP = polypropylene, PET = polyester, PE = polyester; Structure: W = woven, K = knit
NP = needlepunched nonwoven, D = drawn sheet
n/t = not tested

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