

## COMMITTEE ON MATERIALS AND PAVEMENTS

Meeting ( <i>Annual or Mid-Year</i> )	Annual – Baltimore, MD
Date	Wednesday, August 7, 2019
Scheduled Time	2:00 PM – 3:00 PM EDT
Technical Subcommittee & Name	4e – Joints, Bearings, and Geosynthetics
Chair Name and (State)	Timothy Ramirez (Pennsylvania)
Vice Chair Name and (State)	Michael Benson (Arkansas)
Research Liaison Name and (State)	Timothy Ramirez (Pennsylvania)

### I. Introduction and Housekeeping

### II. Call to Order and Opening Remarks

#### A. Brief Summary of Activities

*(Briefly explain the goals of today's meeting and what you hope to accomplish. Get everyone up to speed and on the same page.)*

### III. Roll Call of Voting Members

Present	Member Name	State	Present	Member Name	State
<input type="checkbox"/>	Michael Benson	AR	<input type="checkbox"/>	F. Heiser	NY
<input type="checkbox"/>	Robert Lauzon	CT	<input type="checkbox"/>	Chris Peoples	NC
<input type="checkbox"/>	Richard Douds	GA	<input type="checkbox"/>	Kenny Seward	OK
<input type="checkbox"/>	Daniel Tobias	IL	<input type="checkbox"/>	Timothy Ramirez	PA
<input type="checkbox"/>	Richard Barezinsky	KS	<input type="checkbox"/>	Danny Lane	TN
<input type="checkbox"/>	Jason Davis	LA	<input type="checkbox"/>	John Schuler	VA
<input type="checkbox"/>	Clement Funk	MA	<input type="checkbox"/>	Kurt Williams	WA
<input type="checkbox"/>	James Williams, III	MS	<input type="checkbox"/>	Becca Lane	ON
<input type="checkbox"/>	Brett Trautman	MO	<input type="checkbox"/>		
<input type="checkbox"/>	Ross (Oak) Metcalfe	MT	<input type="checkbox"/>		

*Quorum Rules Met?*

Annual Meeting: Simple majority of voting members (☐y/ ☐n) | Mid-Year Meeting: Voting members present (☐y/ ☐n)

#### A. Review of Membership (*New members, exiting members, etc.*)

### IV. Approval of Technical Subcommittee Minutes

TS 4e 2019 Mid-Year Webinar Meeting Minutes (January 7, 2019) – **Attachment A (Pages 6-10)**.

### V. Old Business

#### A. Review of COMP Ballot 18-03 (Rolling Ballot Group 2 – 11/1/2018 to 11/28/2018)

COMP Ballot #	Standard	Results ( <i>neg/affirm</i> )	Comments/Negatives	Action
18-03 (Item 14)	T 367 ( <i>Accelerated Aging of Hot-Poured Asphalt Crack Sealant Using a Vacuum Oven</i> )	0/44	Comments from Kentucky and Tennessee.  Comments from both states related to the vacuum requirements.	Published as R 95.  Did not address comments from Kentucky and Tennessee.  Still working with University of Illinois at Urbana-Champaign to address comments from Kentucky and Tennessee (Future TS Ballot).

## B. Technical Subcommittee Ballots

TS Ballot #	Standard	Results (neg/affirm)	Comments/Negatives	Action
N/A	N/A	N/A	N/A	N/A

## C. Review of TS 4e Ballot 18-01 Reconfirmation Ballot

Reconf. Ballot #	Standard	Results (neg/affirm)	Comments/Negatives	Action
TS 4e 18-01 (item 1)	M 213 [ <i>Preformed Expansion Joint Fillers for Concrete Paving and Structural Construction (Nonextruding and Resilient Bituminous Types)</i> ]	0/16	None.	Reconfirmed
TS 4e 18-01 (item 2)	M 297 ( <i>Preformed Polychloroprene Elastomeric Joint Seals for Bridges</i> )	0/16	None.	Reconfirmed
TS 4e 18-01 (item 3)	R 69 ( <i>Determination of Long-Term Strength for Geosynthetic Reinforcement</i> )	0/16	None.	Reconfirmed
TS 4e 18-01 (item 4)	MP 25 ( <i>Performance-Graded Hot-Poured Asphalt Crack Sealant</i> )	0/16	None.	Extended for 2 Years
TS 4e 18-01 (item 5)	MP 26 ( <i>Cotton Dock Fabric Bridge Bearings</i> )	0/16	None.	Extended for 2 Years
TS 4e 18-01 (item 6)	PP 85 ( <i>Grading or Verifying the Sealant Grade (SG) of a Hot-Poured Asphalt Crack Sealant</i> )	0/16	None.	Extended for 2 Years
TS 4e 18-01 (item 7)	TP 126 [ <i>Evaluation of the Tracking Resistance of Hot-Poured Asphalt Crack Sealant by Dynamic Shear</i> ]	0/16	None.	Extended for 2 Years

### C. Review of TS 4e Ballot 18-01 Reconfirmation Ballot

Reconf. Ballot #	Standard	Results (neg/affirm)	Comments/Negatives	Action
	<i>Rheometer (DSR)</i>			

### D. Task Force Reports

Task Force #	Title	Members	Status/Update
4e-2006-01	M 251 alignment with AASHTO NTPEP Elastomeric Bridge Bearing (EBB) Technical Committee Workplan.	Michael Benson, Chair (Arkansas), James Williams (Mississippi), Representative from Bridge Bearing Manufacturers Association, and Representatives from AASHTO NTPEP EBB Technical Committee	
4e-2015-01	M 288 revisions to include geogrid for base reinforcement, address comments from ASTM D35 committee received from Jim Goddard, include geotextile for wrapping pipe, and other revisions.	Danny Lane, Chair (Tennessee), Tim Ramirez, (Pennsylvania), James Williams (Mississippi), Tom Burnett (New York), Chris Peoples and Scott Hidden (North Carolina), Tony Allen (Washington State), Jonathan Curry (GMA), Daniel Selander (Thrace-LINK and Chair GMA Geotextile Focus Group), Mike Clements (Huesker, Inc.), Jim Goddard (Consultant), and AASHTO NTPEP Technical Committee on Geosynthetics (GTX & REGEO) Representatives: John Schuler (Virginia) and Rodrigo Herrera (Florida).	

## VI. New Business

- A. AASHTO re:source/CCRL/NTPEP (*Observations from assessments, as applicable.*)
  1. No known observations.
- B. Presentation by Industry/Academia
  1. No presentations by Industry scheduled.
- C. Revisions/Work on Standards for Coming Year
- D. Review of Stewardship List  
TS 4e Status of Standards – **Attachment B (Pages 11-12)**
- E. Proposed New Standards

- 1.
- F. NCHRP Issues
  1. Update from NCHRP?
- G. Correspondence, Calls, Meetings
  1. Email from Dan Tobias (Illinois) regarding M 251 proposed revisions being drafted by AASHTO NTPEP Auditor, Robert Sarcinella, and potential task force involving COMP TS 4e, AASHTO NTPEP Elastomeric Bridge Bearings Technical Committee, and the AASHTO Committee on Bridges and Structures, Technical Committee T-2, Bearings and Expansion Devices – **Attachment C (Pages 13-17)**.
- H. Proposed New Task Forces *(Include list of volunteers to lead and/or join TF.)*
- I. New TS Ballots
  1. R 69, Determination of Long-Term Strength for Geosynthetic Reinforcement
    - a. Revisions received from Scott Hidden (NC). Revisions proposed from Tony Allen (Wash DOT), Sam Allen (TRI) and the NTPEP Geosynthetics Committee, In general, the revisions were made to address updates to non-aggressive environments to be consistent with the AASHTO Bridge Design Specifications and 2019 MSE wall agenda items (CBS T-15 Technical Committee) as well as address revisions for geostrips which are now being submitted to NTPEP for the REGEO program and are more completely covered with the 2019 MSE wall agenda items.
    - b. Proposed revisions – **Attachment D (Pages 18-66)**
  2. M 288, Geosynthetic Specification for Highway Applications
    - a. Revisions received from Scott Hidden (NC). Revisions to add subgrade stabilization to M 288.
      - i. Renamed the stabilization in Section 5.4 to “Soil Stabilization” and added the definition from ASTM D653 for it.
      - ii. Moved the enhancement in Section 5.5 to a new Section 12 for “Subgrade Stabilization” and removed the term “enhancement”.
      - iii. Combined the Class 1A geotextile with the geogrids from the GMA consensus spec into a new Table 12 with Classes 4B through 4D for the geogrids and relabeled the 1A as 4A.
      - iv. Removed the Class 1A from Table 1 since it is not needed there anymore.
    - b. Proposed revisions – **Attachment E (Pages 67-96)**.

## VII. Open Discussion

- A.
- B.

## VIII. Adjourn

## TS Meeting Summary

Meeting Summary		
Items Approved by the TS for Ballot <i>(Include reconfirmations.)</i>		
Standard Designation	Summary of Changes Proposed	Ballot Type
		<input type="checkbox"/> TS <input type="checkbox"/> COMP <input type="checkbox"/> CONCURRENT
		<input type="checkbox"/> TS <input type="checkbox"/> COMP <input type="checkbox"/> CONCURRENT
		<input type="checkbox"/> TS <input type="checkbox"/> COMP <input type="checkbox"/> CONCURRENT
		<input type="checkbox"/> TS <input type="checkbox"/> COMP <input type="checkbox"/> CONCURRENT
		<input type="checkbox"/> TS <input type="checkbox"/> COMP <input type="checkbox"/> CONCURRENT

<b>Meeting Summary</b>		
		<input type="checkbox"/> TS <input type="checkbox"/> COMP <input type="checkbox"/> CONCURRENT
		<input type="checkbox"/> TS <input type="checkbox"/> COMP <input type="checkbox"/> CONCURRENT
		<input type="checkbox"/> TS <input type="checkbox"/> COMP <input type="checkbox"/> CONCURRENT
		<input type="checkbox"/> TS <input type="checkbox"/> COMP <input type="checkbox"/> CONCURRENT
		<input type="checkbox"/> TS <input type="checkbox"/> COMP <input type="checkbox"/> CONCURRENT
		<input type="checkbox"/> TS <input type="checkbox"/> COMP <input type="checkbox"/> CONCURRENT
<b>New Task Forces Formed</b>		
<b>Task Force Name</b>	<b>Summary of Task</b>	<b>TF Member Names and (States)</b>
<b>Research Proposals <i>(Include number/title/states interested.)</i></b>		
<b>Other Action Items</b>		

## COMMITTEE ON MATERIALS & PAVEMENTS

**2019 Mid-Year Meeting (Webinar)**

**Monday, January 7, 2019**

**12:00 – 2:00 PM EST**

### TECHNICAL SUBCOMMITTEE 4e Joints, Bearings and Geosynthetics Minutes

#### I. Introduction and Housekeeping (AASHTO Liaison)

The subcommittee was reminded that a 2/3 majority was no longer required for any votes taken, only a simple majority was required.

#### II. Call to Order and Opening Remarks

A. Brief summary of activities (Please briefly explain the goals of today's meeting and what you hope to accomplish. Get everyone up to speed and on the same page.) The Chair indicated the meeting would follow the agenda.

#### III. Roll Call

TS-4e Vice Chair took roll call of the voting members only. Other Mid-Year Meeting attendees were asked to send an email to Casey Soniera to indicate their attendance to the Mid-Year Meeting.

Voting Members as of 1/4/2019:

Name	Agency	Email	Present
Ramirez, Timothy (Chair)	PA	<a href="mailto:tramirez@pa.gov">tramirez@pa.gov</a>	x
Benson, Michael (Vice Chair)	AR	<a href="mailto:michael.benson@ardot.gov">michael.benson@ardot.gov</a>	x
Lauzon, Robert G.	CT	<a href="mailto:robert.lauzon@ct.gov">robert.lauzon@ct.gov</a>	x
Douds, Richard	GA	<a href="mailto:rdouds@dot.ga.gov">rdouds@dot.ga.gov</a>	
Tobias, Daniel H.	IL	<a href="mailto:daniel.tobias@illinois.gov">daniel.tobias@illinois.gov</a>	x
Barezinsky, Richard A.	KS	<a href="mailto:rick.barezinsky@ks.gov">rick.barezinsky@ks.gov</a>	x
Davis, Jason	LA	<a href="mailto:jason.davis@la.gov">jason.davis@la.gov</a>	
Hood, Woody (deceased)	MD		
Fung, Clement	MA	<a href="mailto:clement.fung@state.ma.us">clement.fung@state.ma.us</a>	x
Williams, III, James A.	MS	<a href="mailto:jwilliams@mdot.state.ms.us">jwilliams@mdot.state.ms.us</a>	
Trautman, Brett S.	MO	<a href="mailto:brett.trautman@modot.mo.gov">brett.trautman@modot.mo.gov</a>	x
Metcalfe, Ross Oak	MT	<a href="mailto:rmetcalfe@mt.gov">rmetcalfe@mt.gov</a>	
Heiser, F. Steven	NY	<a href="mailto:steve.heiser@dot.ny.gov">steve.heiser@dot.ny.gov</a>	x
Peoples, Chris A.	NC	<a href="mailto:cpeoples@ncdot.gov">cpeoples@ncdot.gov</a>	
Seward, Kenny R.	OK	<a href="mailto:kseward@odot.org">kseward@odot.org</a>	
Lane, Danny L.	TN	<a href="mailto:danny.lane@tn.gov">danny.lane@tn.gov</a>	x
Williams, Kurt	WA	<a href="mailto:willikr@wsdot.wa.gov">willikr@wsdot.wa.gov</a>	
Lane, Becca	ON	<a href="mailto:Becca.Lane@ontario.ca">Becca.Lane@ontario.ca</a>	x

Non-Voting Members (Associate Members, Ex Officio Members, Liaisons, Friends, Members, or Other) as of 1/7/2019:

Name/Friends/Guests	Affiliation	Email Address	Present
Fragapane, Ryan	AASHTO	<a href="mailto:rfragapane@ashto.org">rfragapane@ashto.org</a>	
Malusky, Katheryn	AASHTO	<a href="mailto:kmalusky@ashto.org">kmalusky@ashto.org</a>	
Lacinak, Henry	AASHTO	<a href="mailto:hlacinak@ashto.org">hlacinak@ashto.org</a>	x
Lenker, Steven	AASHTO re:source	<a href="mailto:slenker@ashtoresource.org">slenker@ashtoresource.org</a>	



Name/Friends/Guests	Affiliation	Email Address	Present
Knake, Maria	AASHTO re:source	<a href="mailto:mknake@ashtoreource.org">mknake@ashtoreource.org</a>	
Voth, Michael D.	FHWA	<a href="mailto:michael.voth@dot.gov">michael.voth@dot.gov</a>	x
Curry, Jonathan	Industrial Fabrics Assoc. International	<a href="mailto:jicurry@ifai.com">jicurry@ifai.com</a>	x
Boardman, Jonathan T.	CT	<a href="mailto:jonathan.boardman@ct.gov">jonathan.boardman@ct.gov</a>	
Allen, Tony M	WA	<a href="mailto:allent@wsdot.wa.gov">allent@wsdot.wa.gov</a>	x
Holt, Anne	ON	<a href="mailto:anne.holt@ontario.ca">anne.holt@ontario.ca</a>	
Schell, Hanna	ON	<a href="mailto:Hannah.Schell@ontario.ca">Hannah.Schell@ontario.ca</a>	
Watson, Ronald	RJ Watson, Inc.	<a href="mailto:rwatson@rjwatson.com">rwatson@rjwatson.com</a>	
Geary, Georgene	GGfGA Engineering, LLC	<a href="mailto:ggeary@ggfga.com">ggeary@ggfga.com</a>	
Carlson, Paul J.	Road Infrastructure, Inc.	<a href="mailto:PCarlson@roadinfrastructureinc.com">PCarlson@roadinfrastructureinc.com</a>	

Others known to have attended the Mid-Year Meeting included: Casey Soneira (AASHTO), Scott A. Hidden (NCDOT) and Fred Chuck (Huesker, Inc.),

#### IV. Approval of Technical Subcommittee Minutes

Approval of COMP TS-4e 2018 Annual Meeting Minutes, August 7, 2018, Cincinnati, OH.

Motion: CT

Second: TN

Discussion: None

Result: Technical Subcommittee 4e meeting minutes from 2018 Annual Meeting passes.

#### V. Old Business

A. COMP Ballot Items (Including any ASTM Changes/equivalencies)

- Item 14, REVISE T 367, *Accelerated Aging of Hot-Poured Asphalt Crack Sealant Using a Vacuum Oven*. COMP Ballot Item.

Affirmative: 44 of 52

Negative: 0 of 52

No Vote: 8 of 52

Comments from Kentucky and Tennessee.

Received 2/3 Affirmative Vote in COMP; therefore, revision adopted.

Revised T 367 from T to an R standard because there is no "result."

The Kentucky comment can be made editorially from cm Hg to mm Hg.

The first comment from TN is an equipment requirement rather than a requirement to maintain the vacuum. For the other TN comments, there is clarification needed in Section 10.2 for those who are using the standard at higher elevations. Chair will work with University of Illinois for revision needed to clarify the minimum vacuum requirements at elevations above sea level.

Agency (Individual Name)	Comments	Resolution
Kentucky Department of Transportation (Allen H. Myers)	In Section 4.1, Section 6.1, Note 2, Section 10.2, and Section X1.2, why is the unit "cm Hg" utilized rather than the more common unit "mm Hg"?	Chair will consider this revision editorially. This may editorially affect other areas of the standard where "cmHg" is indicated.

Agency (Individual Name)	Comments	Resolution
Tennessee Department of Transportation (Brian K. Egan)	<p>Comment: Section 6.1 states "the oven must be capable of maintaining a vacuum of 75.9 ± 2 cmHg"(73.9-77.9), but section 10.2 states "Start timing once the vacuum has reached 73.3 cmHg. Maintain a vacuum better than 73.7 cmHg". These are inconsistent; one should be revised. What if you are at an elevation that cannot maintain a vacuum of 73.9 or 73.7 cmHg?</p>	<p>The Section 6.1 75.9 ± 2 cmHg value is the maximum vacuum attainable at sea level, so this is just a requirement of the oven itself to be able to hold the maximum vacuum at sea level.</p> <p>The Section 10.2 and the 73.3 cmHg value is considered an adequate minimum vacuum to start the timing for the required 16 h aging. This minimum value could be further clarified if operating at different elevations.</p> <p>The Section 10.2 and the requirement to maintain a vacuum better than 73.7 cmHg could be further clarified if operating at different elevations.</p>

2. Outstanding items from Annual Meeting? **None.**
- B. TS Ballots – **None.**
- C. Reconfirmation Ballots
1. TS-4e 18-01
    - a. Item 1, M 213, Preformed Expansion Joint Fillers for Concrete Paving and Structural Construction (Nonextruding and Resilient Bituminous Types).  
Affirmative:16 of 18, Negative: 0 of 18, No Vote: 2 of 18, Comments: None.  
Received 2/3 Affirmative Vote in TS; therefore, reconfirmed.
    - b. Item 2, M 297, Preformed Polychloroprene Elastomeric Joint Seals for Bridges.  
Affirmative:16 of 18, Negative: 0 of 18, No Vote: 2 of 18, Comments: None.  
Received 2/3 Affirmative Vote in TS; therefore, reconfirmed.
    - c. Item 3, R 69, Determination of Long-Term Strength for Geosynthetic Reinforcement.  
Affirmative:16 of 18, Negative: 0 of 18, No Vote: 2 of 18, Comments: None.  
Received 2/3 Affirmative Vote in TS; therefore, reconfirmed.
    - d. Item 4, MP 25, Performance-Graded Hot-Poured Asphalt Crack Sealant.  
Affirmative:16 of 18, Negative: 0 of 18, No Vote: 2 of 18, Comments: None.  
Received 2/3 Affirmative Vote in TS; therefore, reconfirmed.
    - e. Item 5, MP 26, Cotton Dock Fabric Bridge Bearings.  
Affirmative:16 of 18, Negative: 0 of 18, No Vote: 2 of 18, Comments: None.  
Received 2/3 Affirmative Vote in TS; therefore, reconfirmed.
    - f. Item 6, PP 85, Grading or Verifying the Sealant Grade (SG) of a Hot-Poured Asphalt Crack Sealant.  
Affirmative:16 of 18, Negative: 0 of 18, No Vote: 2 of 18, Comments: None.  
Received 2/3 Affirmative Vote in TS; therefore, reconfirmed.
    - g. Item 7, TP 126, Evaluation of the Tracking Resistance of Hot-Poured Asphalt Crack Sealant by Dynamic Shear Rheometer (DSR).  
Affirmative:16 of 18, Negative: 0 of 18, No Vote: 2 of 18, Comments: None.  
Received 2/3 Affirmative Vote in TS; therefore, reconfirmed.
- Reconfirmed standards will all be submitted to AASHTO publications for moving forward with publication in 2019.**



D. Task Force Reports

1. 2006-01 M 251

- a. Task Force to update the standard to ensure the AASHTO standard aligns with the AASHTO NTPEP EBB work plan.
- b. Task Force Members: Michael Benson, Chair (Arkansas), James Williams (Mississippi), Representative from Bridge Bearing Manufacturers Association, and Representatives from AASHTO NTPEP EBB Technical Committee.

**Action: TN will pass along the TS-4e need for any updates from AASHTO NTPEP EBB Technical Committee to Ryan Fragapane.**

2. 2015-01 M 288

- a. Task Force to update the standard to include geogrid for base reinforcement, address comments from the ASTM D35 committee received from Jim Goddard, include geotextile for wrapping pipe, and other revisions.
- b. Task Force Members: Danny Lane, Chair (Tennessee), Tim Ramirez, (Pennsylvania), James Williams (Mississippi), Tom Burnett (New York), Chris Peoples and Scott Hidden (North Carolina), Tony Allen (Washington State), Jonathan Curry (GMA), Ken Bedenbaugh\* (Willacoochie Industrial Fabrics), Mike Clements (Huesker, Inc.), and Jim Goddard (Consultant). AASHTO NTPEP Technical Committee on Geosynthetics (GTX & REGEO) Representatives: John Schuler (Virginia) and Rodrigo Herrera (Florida).

There is a desire for other technical experts to get involved with this TF. What has already been submitted for changes? There should be a TF call to get this group backup to speed, followed by more regular (monthly) calls to develop revisions to M 288.

**Action: Chair will organize a Doodle poll to get some dates in place for moving forward with TF conference calls.**

*\*Post Mid-Year Meeting: Chair received email from Jonathon Curry indicating Daniel Selander of Thrace-LINK and chair of GMA's Geotextile Focus Group will be replacing Ken Bedenbaugh on the TF 2015-01 M 288.*

**VI. New Business**

- A. Research Proposals None
- B. AASHTO Re:source/CCRL - Observations from Assessments? None
- C. NCHRP Issues None
- D. Correspondence, calls, meetings IL DOT question from a Ministry in Canada regarding testing of PTFE adhesion to metal plate for high rotation bearings. Chair provided a general response to IL, but also reached out to NY for any experience. Chair will forward information received from NY to IL.
- E. Presentation by Industry/Academia None
- F. Revisions/Work on Standards for Coming Year – Status of TS-4e Standards (**Attachment 1 & Attachment 2**)

Attachment 1 is the Chair's status of the TS-4e Standards. A yellow highlighted "2019" in the "Reconfirm Required" column are those standards requiring reconfirmation in 2019.

Attachment 2 is AASHTO's status of the TS-4e Standards. A yellow highlighted "Begin Review" in the "Planning Needed" column indicates those standards requiring reconfirmation in 2019. Other Standards with "Begin Review" in the "Planning Needed" column (without yellow highlighting) require reconfirmation in 2020. On Attachment 2, Chair yellow highlighted and added red text corrections for some of the Standards.

The Chair and AASHTO encourage the TS members to volunteer to be stewards of standards for preparing or revising standards for balloting (reconfirmation, TS, or COMP ballots) and specially to volunteer for those standards coming up for reconfirmation in 2019. Casey Soneira reviewed the responsibilities of stewards and what's expected.

- 1. Reconfirmations:
  - a. M 33
  - b. M 153

- c. M 168
  - d. M 230
  - e. M 251
  - 2. TS Ballot(s)
    - a. M 33 – ASTM Equivalency
    - b. M 288 – Task Force Revisions
    - c. R 69 – Revisions from AASHTO NTPEP Geosynthetics Technical Subcommittee.
  - G. Proposed New Standards  
If there are ever new standards proposed, AASHTO publications needs to have the original drawing/picture with a permission form to use it.
  - H. Proposed New Task Forces  
(Include list of volunteers to lead and/or join TF)
  - I. New TS Ballots?  
There may be need for a TS ballot. Any TS ballots should be out by April to ensure enough time to vote and review the ballot item comments before the 2019 Annual Meeting in August.
  - J. Technical Subcommittee membership  
If you would like to be a friend or know of any states interested in membership on TS-4e, contact the Chair or AASHTO Liaison.
- VII. Open Discussion**  
None
- VIII. Adjourn**  
KS motion; TN second to adjourn 12:52 pm

COMP TS-4e Status of Standards (2019)						
TS 4e AASHTO Standard (Published 2018)	1st Published Date of Provisional	Reconfirm Required	Referenced ASTM Standard	Current ASTM Standard	Standard Title	Assigned To:
M 33-99 (2016)		2019	D994-98 (2010)	D994/D994M-11 (2016)	Preformed Expansion Joint Filler for Concrete (Bituminous Type)	MT
M 153-06 (2016)		2019	D1752-04a (2013)	D1752-18	Preformed Sponge Rubber and Cork Expansion Joint Fillers for Concrete Paving and Structural Construction	AR
M 168-07 (2016)		2019			Wood Products	MT
M 213-01 (2019)		2022	D1751-04 (2013)	D1751-18	Preformed Expansion Joint Fillers for Concrete Paving and Structural Construction (Nonextruding and Resilient Bituminous Types)	MO
M 230-07 (2016)		2019			Expanded and Extruded Foam Board (Polystyrene)	NY
M 251-06 (2016)		2019			Plain and Laminated Elastomeric Bridge Bearings	NY
M 288-17		2020			Geotextile Specification for Highway Applications	NY
M 297-10 (2019)		2022	D3542-08 (2013)		Preformed Polychloroprene Elastomeric Joint Seals for Bridges	PA
R 50-09 (2018)		2021			Geosynthetic Reinforcement of the Aggregate Base Course of Flexible Pavement Structures	NY
R 69-15 (2019)		2022			Determination of Long-Term Strength for Geosynthetic Reinforcement	WA
R 95-19 (formerly T 367)		2022			Accelerated Aging of Hot-Poured Asphalt Crack Sealant Using a Vacuum Oven	PA/AR
T 42-10 (2015) <i>Discontinued</i>			D545-08	D545-14	Preformed Expansion Joint Filler for Concrete Construction	PA
T 366-18		2021			Apparent Viscosity of Hot-Poured Asphalt Crack Sealant Using Rotational Viscometer	PA/AR
T 368-17		2020			Measuring Low-Temperature Flexural Creep Stiffness of Hot-Poured Asphalt Crack Sealant by Bending Beam Rheometer (BBR)	PA/AR
T 369-17		2020			Evaluation of the Low-Temperature Tensile Property of Hot-Poured Asphalt Crack Sealant by Direct Tension Test	PA/AR
T 370-18		2021			Measuring Adhesion of Hot-Poured Asphalt Crack Sealant Using Direct Adhesion Tester	PA/AR
T 371-17		2020			Measuring Interfacial Fracture Energy of Hot-Poured Asphalt Crack Sealant Using a Blister Test	PA/AR
MP 25-18 (2019)	2015	2020			Performance-Graded Hot-Poured Asphalt Crack Sealant	PA/AR
MP 26-15 (2019)	2015	2020			Cotton Duck Fabric Bridge Bearings	AR

COMP TS-4e Status of Standards (2019)						
TS 4e AASHTO Standard (Published 2018)	1st Published Date of Provisional	Reconfirm Required	Referenced ASTM Standard	Current ASTM Standard	Standard Title	Assigned To:
PP 85-18 (2019)	2017	2020			Grading or Verifying the Sealant Grade (SG) of Hot-Poured Asphalt Crack Sealant	PA/AR
TP 126-18 (2019)	2017	2020			Evaluation of the Tracking Resistance of Hot-Poured Asphalt Crack Sealant by Dynamic Shear Rheometer (DSR)	PA/AR

**Ramirez, Timothy**

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**From:** Tobias, Daniel H <Daniel.Tobias@illinois.gov>  
**Sent:** Wednesday, June 26, 2019 11:15 AM  
**To:** Ramirez, Timothy  
**Cc:** Bonk, Aaron M - DOT; joseph.r.stilwell@maine.gov; rfragapane@ashto.org; sarc.engineering@yahoo.com; Puzey, Carl; Riechers, Kevin L; Pfeifer, Brian A  
**Subject:** FW: [External] Re: AASHTO Bridge T-2, AASHTO Materials TS 4e, and NTPEP Tech Committee on Elastomeric Bridge Bearings

Mr. Ramirez:

Please see the thread below (especially the initial e-mail to Carl Puzey, Chair of the CoBS T-2 Subcommittee on Bearing and Joints).

At this point, we are not completely sure if you “commissioned” Mr. Sarcinella for a markup/comments on M251. If you did, that is great, and if not that is perfectly fine as well.

Basically it looks like there will be some substantial and viable suggestions coming from Mr. Sarcinella that probably should be considered by TS 4e (I do happen to be a voting member of TS 4e and the NTPEP Elastomeric Bridge Bearing Pads committees, and many years ago was on the staff of the Chair of T-2).

In corresponding and talking with Mr. Puzey and his staff yesterday and today, they have indicated to me that they also have several comments from other states concerning M251.

So, I am using this note as an FYI and to suggest that at some point in the near future (probably after AASHTO COMP in Baltimore) that AASHTO COMP TS 4e, AASHTO CoBS T-2, and the AASHTO NTPEP Tech Committee on Elastomeric Bridge Bearing Pads form a Joint Task Force in order to resolve the issues that are now coming before us.

As I noted to the NTPEP Committee in early June in Montana, the AASHTO Materials, Bridge, and Construction specifications for Elastomeric Bridge Bearings are fairly intimately intertwined or “married” such that revising or changing one likely impacts one or more of the others.

Many years ago (10 to 12, maybe more), a similar Joint Task Force was formed between T-2 And TS 4e when Illinois and Arkansas were the chairs. The Task Force was very successful and produced a lot of good work.

So, just let me (but more importantly Mr. Puzey, T-2 Chair and Mr. Bonk, NTPEP Chair) know what you think and if you would like to move forward.

Best Regards,

Dan.....

*Daniel H. Tobias Ph.D., P.E., S.E.  
 Central Bureau of Materials  
 Illinois Department of Transportation  
 126 East Ash Street  
 Springfield, IL 67204-4766*

*Ph.: 217-782-2912  
 Daniel.Tobias@illinois.gov*

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**From:** Robert Sarcinella <sarc.engineering@yahoo.com>

**Sent:** Tuesday, June 25, 2019 3:51 PM

**To:** Stilwell, Joseph R <Joseph.R.Stilwell@maine.gov>; Bonk, Aaron M - DOT <aaron.bonk@dot.wi.gov>; Tobias, Daniel H <Daniel.Tobias@illinois.gov>

**Cc:** Fragapane Ryan <rfragapane@ashto.org>

**Subject:** [External] Re: AASHTO Bridge T-2, AASHTO Materials TS 4e, and NTPEP Tech Committee on Elastomeric Bridge Bearings

Folks,

I will have the draft available in a few days. Just want to tidy up some of the comments and include some justification. This will still be the "First" draft in its raw form. We will continue to refine as we go.

**Sarc.**

Robert L. Sarcinella, P.E.

*Sarc. Engineering & Consulting Services*

Representing: **AASHTO's National Transportation Product Evaluation Program (NTPEP)**

(512) 791-5591

[sarc.engineering@yahoo.com](mailto:sarc.engineering@yahoo.com)

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**From:** Bonk, Aaron M - DOT <[Aaron.Bonk@dot.wi.gov](mailto:Aaron.Bonk@dot.wi.gov)>

**Sent:** Tuesday, June 25, 2019 2:05 PM

**To:** Tobias, Daniel H <[Daniel.Tobias@illinois.gov](mailto:Daniel.Tobias@illinois.gov)>

**Cc:** [joseph.r.stilwell@maine.gov](mailto:joseph.r.stilwell@maine.gov); Fragapane Ryan <[rfragapane@ashto.org](mailto:rfragapane@ashto.org)>; [sarc.engineering@yahoo.com](mailto:sarc.engineering@yahoo.com)

**Subject:** [External] RE: AASHTO Bridge T-2, AASHTO Materials TS 4e, and NTPEP Tech Committee on Elastomeric Bridge Bearings

Dan,

Thanks for working to pull in others from IDOT that have extensive knowledge of these bridge elements as well as the materials spec involved. Ryan can likely speak better on the topic of getting the chair of TS 4e involved, but my understanding is that the request for NTPEP to review M251 came directly from him or that committee. That being the case, I'd imagine that person will be happy to be a part of getting all parties on the same page related to this spec. Thanks again and don't hesitate to let me know if there is something else that I can assist with on this.

**Aaron M. Bonk, P.E. | Structures Design Supervisor**

Office: (608) 261-0261| Mobile: (608) 516-3453

[aaron.bonk@dot.wi.gov](mailto:aaron.bonk@dot.wi.gov)|[BOS Website](#)



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**From:** Puzey, Carl

**Sent:** Tuesday, June 25, 2019 11:13 AM

**To:** Tobias, Daniel H <[Daniel.Tobias@illinois.gov](mailto:Daniel.Tobias@illinois.gov)>

**Cc:** Pfeifer, Brian A <[Brian.Pfeifer@illinois.gov](mailto:Brian.Pfeifer@illinois.gov)>

**Subject:** RE: AASHTO Bridge T-2, AASHTO Materials TS 4e, and NTPEP Tech Committee on Elastomeric Bridge Bearings

Dan, thanks for the update. I am at AASHTO CoBS this week. Yes, I think it would be a good idea for us to meet sometime in late July. I am aware of a couple issues that need addressed in M251 and I recently received questions from WSDOT that Kevin and I haven't even digested yet, but may also be something for us to discuss. Thanks.

Carl Puzey

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**From:** Tobias, Daniel H

**Sent:** Tuesday, June 25, 2019 10:53 AM

**To:** Puzey, Carl <[Carl.Puzey@illinois.gov](mailto:Carl.Puzey@illinois.gov)>

**Cc:** Pfeifer, Brian A <[Brian.Pfeifer@illinois.gov](mailto:Brian.Pfeifer@illinois.gov)>

**Subject:** AASHTO Bridge T-2, AASHTO Materials TS 4e, and NTPEP Tech Committee on Elastomeric Bridge Bearings

Carl:

Looks like you are out of the office through next week, but I thought I'd at least touch base to suggest that we may want to have a short meeting sometime this summer concerning T-2, Materials TS 4e, and NTPEP. It is probably a good idea if Kevin Riechers is there too. He knows the history of national bearing specifications as well as or better than I do.

I just recently got back from the annual NTPEP meeting (I am member of NTPEP's committee on Elastomeric Bridge Bearing Pads and am also a member of AASHTO Materials Subcommittee 4e which among other things encompasses elastomeric bridge bearings.) IDOT does now require bearing manufacturers be "NTPEP Compliant" in our Specs (which Tobi is along with one or two others).

Basically, a NTPEP auditor with many years of experience (former Texas DOT) presented an extensive markup of M251 (the testing standard for elastomeric bearings) that he intends to use as suggestions for revisions to TS 4e. In general, he wants TS 4e to revise M251 such that it reflects the realities of what bearing manufacturers across the US actually do. (We or IDOT do like his ideas). He wants to get rid of or de-emphasize some tests and highlight or re-emphasize other tests. The “get rid of or de-emphasize” stuff is basically the work that Prof. Yura did many years ago, and the “re-emphasize” is basically the stuff that Ralph, Kevin, and I along with the TS 4e chair from Arkansas put back in M251 many years ago. This is a big reason why IDOT likes this.

Turns out though, that there is a long and complex history about why the AASHTO LRFD Bridge Design Code is written the way it is and how it is intimately tied to M251 and the AASHTO Bridge Construction Specifications that the NTPEP auditor was not fully aware of.

Suffice it to say that if certain changes are made to M251, they have a very good chance (about 100%) of also impacting AASHTO LRFD Design and Construction.

I offered to serve as a bridge between the Bridge and Materials folks in this matter. This is why I am reaching out to you first, but I did not realize until today that you are the chair of T-2 (at least you are listed as such on the AASHTO website) which actually makes things much easier.

The NTPEP auditor is still working on finalizing his markup's/suggestions for M251 at this time is my understanding. I only saw what he presented at the NTPEP meeting, but what he did show is what I would call “major surgery”. I'll ask him to provide me with his current draft so that we have some substance to look at.

At any rate, just let me know what you think about meeting sometime in July. I think the AASHTO Materials meeting is either late July or Early August. I try to go to the national meetings every other year and this year is not my year to attend.

Dan.....

*Daniel H. Tobias Ph.D., P.E., S.E.*

*Central Bureau of Materials*

*Illinois Department of Transportation*

*126 East Ash Street*

*Springfield, IL 67204-4766*



Ph.: 217-782-2912

[Daniel.Tobias@illinois.gov](mailto:Daniel.Tobias@illinois.gov)

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**Standard Practice for**

**Determination of Long-Term  
Strength for Geosynthetic  
Reinforcement**

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AASHTO Designation: R 69-~~15~~(2019)20<sup>1</sup>

Technical Subcommittee: 4e, Joints, Bearings,  
and Geosynthetics

Release: Group 2 (June)

American Association of State Highway and Transportation Officials  
444 North Capitol Street N.W., Suite 249  
Washington, D.C. 20001

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Standard Practice for

## Determination of Long-Term Strength for Geosynthetic Reinforcement

AASHTO Designation: R 69-~~45~~(2019)20<sup>1</sup>

Technical Subcommittee: 4e, Joints, Bearings,  
and Geosynthetics

Release: Group 2 (June)

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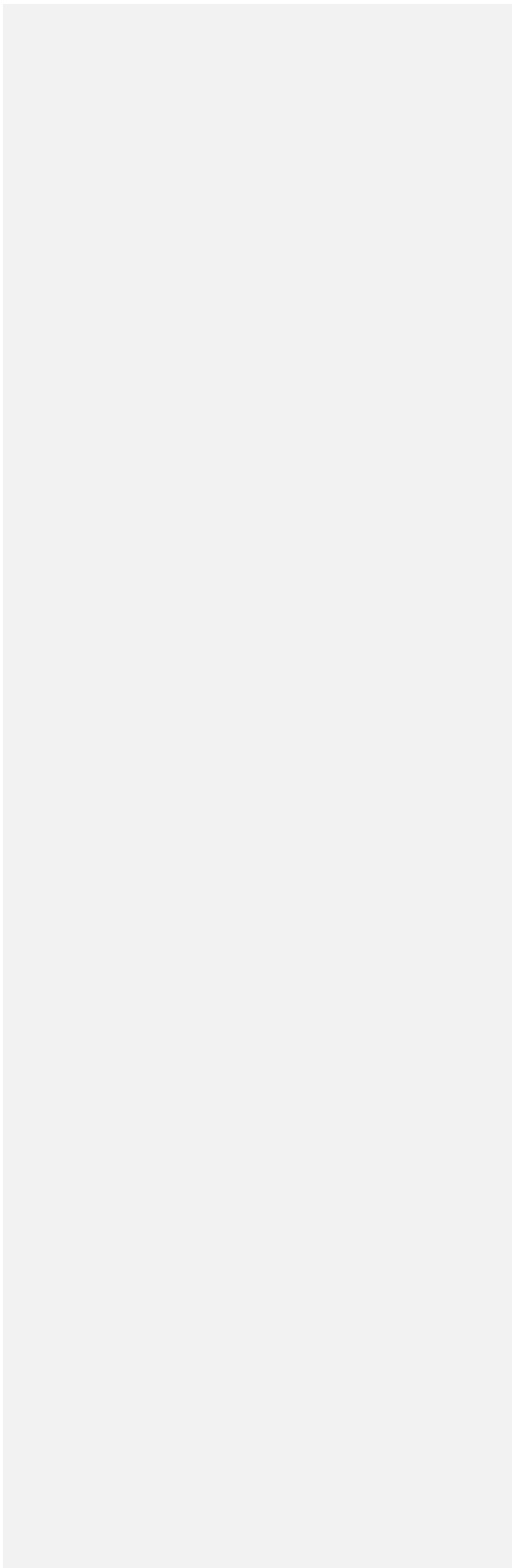
### INTRODUCTION

Through this protocol, the long-term strength and stiffness of geosynthetic reinforcements can be determined. This protocol contains test and evaluation procedures to determine reduction factors for installation damage, creep, and chemical/biological durability, as well as the method to combine these factors to determine the long-term strength. The long-term strength and stiffness values determined from this protocol can be used as input values for geosynthetic structure designs conducted in accordance with *AASHTO LRFD Bridge Design Specifications* and related Federal Highway Administration (FHWA) design guidelines. The long-term strength and stiffness values determined from this protocol can also be compared to the required design strength and stiffness values provided in the contract for the geosynthetic structure(s) in question to determine whether the selected product meets the contract requirements. This protocol can be used for product qualification or acceptance (e.g., for inclusion in a Qualified Products List), or for verification to facilitate periodic review of products for which the long-term strength has been previously determined using this standard practice.

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### 1. SCOPE

- 1.1. This protocol has been developed to address polypropylene (PP), polyethylene (PE or HDPE), and polyester (PET) geosynthetics ~~(i.e., geotextiles and geogrids)~~. See Section 3.1 for definitions of geosynthetic reinforcement and types of geosynthetics addressed in this standard practice. For other geosynthetic polymers [(e.g., polyamide (PA) or polyvinyl alcohol (PVA)], the installation damage and creep protocols provided herein are directly applicable. While the chemical and biological durability procedures and criteria provided herein may also be applicable to other polymers (for example, hydrolysis testing as described in Annex C is likely applicable to PA and PVA geosynthetics), additional investigation will be required to establish a detailed protocol and acceptance criteria for these other polymers. These other polymers may be considered for evaluation using this protocol once modifications to the chemical/biological durability aspects of this protocol have been developed and are agreed on by the approval authority.
- 1.2. The values stated in SI units are to be regarded as the standard.
- 1.3. *This standard may involve hazardous materials, operations, and equipment. This standard does not propose to address all safety problems associated with its usage. It is the duty and responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*



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TS-4e R 69-2 AASHTO

## 2. REFERENCED DOCUMENTS

### 2.1. *AASHTO Standards and Specifications:*

- T 96, Resistance to Degradation of Small-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine
- *AASHTO LRFD Bridge Design Specifications*

### 2.2. *ASTM Standards:*

- D1248, Standard Specification for Polyethylene Plastics Extrusion Materials for Wire and Cable
- D2488, Standard Practice for Description and Identification of Soils (Visual-Manual Procedure)
- D2837, Standard Test Method for Obtaining Hydrostatic Design Basis for Thermoplastic Pipe Materials or Pressure Design Basis for Thermoplastic Pipe Products
- D3045, Standard Practice for Heat Aging of Plastics Without Load
- D3083, Specification for Flexible Poly (Vinyl Chloride) Plastic Sheeting for Pond, Canal, and Reservoir Lining (withdrawn 1998)
- D4101, Standard Classification System and Basis for Specification for Polypropylene Injection and Extrusion Materials
- D4355/D4355M, Standard Test Method for Deterioration of Geotextiles by Exposure to Light, Moisture and Heat in a Xenon Arc Type Apparatus
- D4595, Standard Test Method for Tensile Properties of Geotextiles by the Wide-Width Strip Method
- D4603, Standard Test Method for Determining Inherent Viscosity of Poly(Ethylene Terephthalate) (PET) by Glass Capillary Viscometer
- D5261, Standard Test Method for Measuring Mass per Unit Area of Geotextiles
- D5262, Standard Test Method for Evaluating the Unconfined Tension Creep and Creep Rupture Behavior of Geosynthetics
- D5322, Standard Practice for Laboratory Immersion Procedures for Evaluating the Chemical Resistance of Geosynthetics to Liquids
- D5818, Standard Practice for Exposure and Retrieval of Samples to Evaluate Installation Damage of Geosynthetics
- D6637/D6637M, Standard Test Method for Determining Tensile Properties of Geogrids by the Single or Multi-Rib Tensile Method
- D6992, Standard Test Method for Accelerated Tensile Creep and Creep-Rupture of Geosynthetic Materials Based on Time-Temperature Superposition Using the Stepped Isothermal Method
- D7409, Standard Test Method for Carboxyl End Group Content of Polyethylene Terephthalate (PET) Yarns

### 2.3. *Other Standards:*

- ISO 13438:2004(en), Geotextiles and geotextile-related products—Screening test method for determining the resistance to oxidation
- GRI-GG8, Determination of the Number Average Molecular Weight of PET Yarns Based on a Relative Viscosity Value
- ISO 10319:2008, Geosynthetics—Wide-width tensile test
- ISO/DIS 10722:2007, Geosynthetics—Index test procedure for the evaluation of mechanical damage under repeated loading. Part 1: Installation in granular materials

- ISO/FDIS 9080:2012, Plastic piping and ducting systems—Determination of long-term hydrostatic strength of thermoplastics materials in pipe form by extrapolation

### 3. TERMINOLOGY

#### 3.1. Definitions:

- 3.1.1. *apertures*—the open spaces formed between the interconnected network of longitudinal and transverse ribs of a geogrid.
- 3.1.2. *d<sub>50</sub>*—the grain size at 50 percent passing by weight for the backfill.
- 3.1.3. *effective design temperature*—the temperature that is halfway between the average yearly air temperature and the normal daily air temperature for the warmest month at the geosynthetic structure site.
- 3.1.4. *geogrid*—geosynthetic formed by a regular network of integrally connected elements with apertures greater than 1/4 inch to allow interlocking with surrounding soil, rock, earth, and other surrounding materials to function primarily as reinforcement.
- 3.1.5. *geostrip*—polymeric material in the form of a strip (also sometimes called a polymer strap) of width not more than 8 inches, used in contact with soil or other materials in geotechnical and civil engineering applications, or both.
- 3.1.6. *geosynthetic reinforcement*—geogrids, geostrips, and geotextiles that reinforce soil or aggregate for retaining walls, soil slopes and embankments.
- 3.1.7. *geotextile*—permeable geosynthetic comprised solely of textiles.
- 3.4.4.3.1.8. *HDPE*—high-density polyethylene.
- 3.4.5.3.1.9. *hydrolysis*—the reaction of water molecules with the polymer material, resulting in polymer chain scission, reduced molecular weight, and strength loss.
- 3.4.6.3.1.10. *in-isolation testing*—geosynthetic testing in which the specimen is surrounded by air or a fluid (not soil).
- 3.4.7.3.1.11. *installation damage*—damage to the geosynthetic, such as cuts, holes (geotextiles only), abrasion, fraying, etc., created during installation of the geosynthetic in the backfill soil.
- 3.4.8.3.1.12. *load level*—for creep or creep-rupture testing, the load applied to the test specimen divided by  $T_{lot}$ , the short-term ultimate strength of the lot or roll/coil of material used to form the creep testing.
- 3.4.9.3.1.13. *MARV*—the minimum average roll value for the geosynthetic, defined as two standard deviations below the mean for the product (i.e., 97.5 percent of all test results will meet or exceed the MARV). For practical purposes, from the user's viewpoint, the average for a sample taken from any roll/coil in the lot shipped to the job site should meet or exceed the MARV.
- 3.4.10.3.1.14. *minimum value*—the lowest sample value from documented manufacturing quality control test results for a defined population from one test method associated with one specific property.
- 3.4.11.3.1.15. *MSE*—mechanically stabilized earth.

**Commented [RT1]:** Added definitions are same as in ASTM D4439 and 2019 ballot item for Section 11.2 of the AASHTO LRFD Bridge Design Specifications.

**Commented [RT2]:** Geostrip rolls are called "coils" so this has been changed throughout where appropriate.

~~3.1.12. nonaggressive environment—for geosynthetic walls and slopes, soils that have a  $d_{50}$  of 4.75 mm or less, a maximum particle size of 31.5 mm or less, a pH of 4.5 to 9, and an effective design temperature of 30°C (85°F) or less.~~

**Commented [RT3]:** Expanded and clarified in Section 5 so not necessary here anymore.

~~3.1.13.3.1.16.~~ *oxidation*—the reaction of oxygen with the polymer material, initiated by heat, UV radiation, and possibly other agents, resulting in chain scission and strength loss.

~~3.1.14.3.1.17.~~ *PET*—polyester.

~~3.1.15.3.1.18.~~ *postconsumer recycled material*—polymer products sold to consumers that have been returned by the consumer after use of the products for the purpose of recycling.

~~3.1.16.3.1.19.~~ *PP*—polypropylene.

~~3.1.17.3.1.20.~~ *primary and secondary products*—for product line characterization purposes, the primary product is the product in which the full suite of index and performance level tests are conducted to characterize the product line, whereas the secondary products are those used to characterize the consistency of the properties throughout the range of products included in the line (or to facilitate the interpolation of those properties to products in the line not specifically tested) using a limited suite of index and performance level tests.

~~3.1.18.3.1.21.~~ *product line*—a series of products manufactured using the same polymer (including stabilizers) in which the polymer for all products in the line comes from the same source and/or is purchased or manufactured by the geosynthetic manufacturer using the same property and material specifications for the base polymer plus additives, the manufacturing process is the same for all products in the line, and the only difference is in the product weight/unit area or number of fibers contained in each reinforcement element.

~~3.1.19.3.1.22.~~ *product qualification testing*—testing used to establish the acceptability of the product or product line by an agency prior to shipment or use of the product in a specific project (e.g., as the basis for adding the product to the agency's qualified or approved products list).

~~3.1.20.3.1.23.~~ *product verification testing*—testing used to verify that the product or product line has not changed since being tested for product qualification (e.g., as the basis for allowing the product or product line to remain on the agency's qualified or approved products list).

~~3.1.21.3.1.24.~~ *QPL*—qualified products list.

~~3.1.22.3.1.25.~~ *RF*—combined reduction factor to account for long-term degradation due to installation damage, creep, and chemical/biological aging.

~~3.1.23.3.1.26.~~ *RF<sub>CR</sub>*—strength reduction factor to prevent long-term creep rupture of the reinforcement.

~~3.1.24.3.1.27.~~ *RF<sub>D</sub>*—strength reduction factor to prevent rupture of the reinforcement due to long-term chemical and biological degradation.

~~3.1.25.3.1.28.~~ *RF<sub>ID</sub>*—strength reduction factor to account for installation damage to the reinforcement.

~~3.1.26.3.1.29.~~ *sample*—a portion of material that is taken for testing or for record keeping purposes, from which a group of specimens can be obtained to provide information that can be used for making statistical inferences about the population(s) from which the specimens are drawn.

~~3.1.27.3.1.30.~~ *specimen*—a specific portion of a material or laboratory sample on which a test is performed or that is taken for that purpose.

~~3.1.28-3.1.31.~~ *survivability*—the ability of a geosynthetic to survive a given set of installation conditions with an acceptable level of damage.

~~3.1.29-3.1.32.~~  $T_{al}$ —the long-term tensile strength that will not result in rupture of the reinforcement during the required design life, ~~calculated on a load per unit of reinforcement width basis.~~

~~3.1.30-3.1.33.~~  $T_{ult}$ —the ultimate tensile strength of the reinforcement determined from wide-width tensile tests.

~~3.1.31-3.1.34.~~ *UV*—ultraviolet light.

**Commented [RT4]:** Tal and Tult applies to geostrips too but are calculated on a different basis than for sheet type geosynthetic reinforcement. This has been clarified in 6.4.1.

#### 4. SIGNIFICANCE AND USE

4.1. This recommended practice provides a protocol to assess the reduction in tensile strength and stiffness of geosynthetic ~~(i.e., geotextiles and geogrids)~~ reinforcement that occurs due to the installation of the material in or immediately beneath soil backfill and due to time exposure to the ambient environment (e.g., temperature, pH, oxygen, water, or other materials or chemicals in the surrounding environment) during the design life for the structure. This recommended practice is applicable to the assessment of these long-term properties for individual geosynthetic reinforcement products as well as for geosynthetic reinforcement product lines. This reduced strength can be used as a design value in the design of geosynthetic reinforced structures such as retaining walls, reinforced slopes, or embankment base reinforcement, or can be used for material acceptance and verification purposes for the construction of such structures.

4.2. Due to the length of time required to obtain the test data required, this recommended practice is generally not practical to be carried out on a suite of products for a specific project. Its primary use is to establish values that can be used at a program level by an agency or the geosynthetic manufacturer, using data developed for a range of site conditions likely to be encountered, which can then be adapted to the site-specific conditions encountered in specific construction projects as needed.

4.3. This practice has not been developed to establish strength and stiffness properties directly applicable to dynamic loading situations, such as in pavement base course reinforcement. The strength and stiffness properties obtained using this practice have been shown to be applicable to seismic loading situations, though the values obtained are likely to be conservative in that case, at least with regard to creep.

#### 5. EVALUATION OF SOIL ENVIRONMENT AGGRESSIVENESS EFFECTS ON LONG-TERM STRENGTH DETERMINATION

5.1. The assessment of geosynthetic long-term strength depends on the aggressiveness of the environment to which it will be subjected. The protocols provided generally address what are defined as non-aggressive environments, except where noted. The aggressiveness of the environment with regards to geosynthetic long-term strength determination shall be based on soil gradation and particle characteristics of the backfill soil, chemical properties of the backfill soil and adjacent environment, and site temperature. Soil gradation and particle characteristics primarily affect potential  $RF_D$  values, chemical properties affect the potential for high  $RF_D$  values, and temperature affects potential for high  $RF_D$  and high  $RF_{CR}$  values. In general, the more angular the soil, the more uniform its gradation, the greater the maximum particle size; and the more durable the particles, the more aggressive the soil is with regard to potential for installation damage. While installation damage can be evaluated for a wide range of soil gradation and characteristics, it is generally undesirable to use soils and associated installation conditions that result in an  $RF_D$  value that is greater than approximately 1.7 due to the likelihood of excessive variability in the results. The decision regarding what gradation characteristics are to be considered too aggressive shall be made by the approval authority.



- 5.2. Regarding gradation of the reinforced backfill, the maximum particle size shall be less than or equal to 0.75 in. to be considered nonaggressive. Soils with a larger maximum particle size may be considered nonaggressive if full scale installation damage tests are conducted in accordance with this standard and  $RFID$  is less than or equal to 1.7.
- 5-2-5.3. Regarding chemical properties of the environment surrounding the geosynthetic in the wall or slope, the pH shall be between 4.5 and 9 to be considered nonaggressive. This applies both in the reinforced backfill and at the back of the face of walls or other surficial treatments. See Elias et al. (2009) for a detailed discussion of soil conditions that can contribute to a chemically aggressive environment. In addition, the soil organic content of the reinforced backfill shall be less than or equal to 1% to be considered nonaggressive.
- 5-3-5.4. Regarding temperature, the effective design temperature at the wall or slope site shall be less than 30°C (85°F) for the environment to be considered nonaggressive. In all but the most southerly tier of states in the United States, all geosynthetic structure sites are anticipated to have an effective design temperature that is below 30°C (85°F). Unless otherwise indicated in the contract specifications for a given project, the design temperature used to determine  $RF$  and  $T_{al}$  from product-specific data shall be assumed to be 20°C (68°F).

## 6. PRODUCT TESTING AND EVALUATION

### 6.1. *Product Testing Approach:*

- 6.1.1. The focus of the product testing shall be to characterize the long-term strength and stiffness properties for the entire product line, selecting samples from specific products within the product line to represent the entire product line. As a first step, it shall be verified which geosynthetic products should be included as a single product line, unless only a single product is to be evaluated. If a single product is to be evaluated, the product shall be subjected to the full suite of product qualification tests as described herein.

**Note 1**—The product line concept provides the ability to conduct performance testing to assess strength reduction factors and stiffness values on selected representative products in the product line. The test results from these representative products are then used to interpolate the reduction factors and stiffness values for the products in the product line not performance tested. This interpolation, or in some cases extrapolation, is performed using a parameter for which a clear relationship with the value of the strength reduction factor or stiffness for the product line exists (e.g., unit weight or tensile strength). Alternatively, a lower bound value could be applied to the rest of the product line based on the test results from the weakest or lightest weight product in the product line, provided the lower bound value can be selected with confidence. The ability to test only representative products from the product line can significantly reduce testing costs. However, it must be recognized that there is some risk associated with the use of this product line concept with regard to the determination of the properties of the intermediate products not specifically tested. The product line concept relies on the ability of the testing/evaluating organization to verify that the polymer source and fibers used to make the products in the line not tested are, in fact, the same as those used in the products that are specifically tested. In addition, for coated geogrids and geostrips, the consistency of the coating type, process, and thickness/weight across all the products in the product line must also be verified. To reduce this risk to an acceptable level, a manufacturing plant auditing process should be used, and a limited testing program focused on evaluating the consistency among all products in the product line should be conducted on products in the product line not selected and subjected to performance tests as product line representatives. See Section 6.3 for details.

### 6.2. *Sampling:*

- 6.2.1. All materials or products, or both, to be tested will be furnished by the manufacturer/supplier at no cost to the review/approval authority. Samples will be selected for testing by agency or owner personnel or designated parties.
- 6.2.2. Sampling shall be conducted in accordance with the requirements in the specific AASHTO, ASTM, GRI, or ISO test standard for the specific tests conducted as part of this standard practice. For products selected as representative of the product line, an entire roll/coil should be taken, but no less than the sum of the sample sizes required for all tests to be conducted on each product. For the remaining geotextile and geogrid products in the product line, a sample with the dimensions of the product roll width by 20 ft should be taken. For the remaining geostrip products in the product line, another entire coil should be taken. As a minimum, the following shall be obtained:
- A geosynthetic product sample of sufficient size to accommodate all of the specified testing;
  - Information showing the manufacturer's name and description of product (style, brand name, etc.);
  - Product roll/coil and lot number; and
  - A sample of the polymer component(s) used to manufacture the product or product line in sufficient quantity to conduct the specified polymer tests. Typically, a minimum 500-g sample of the component material(s) will be sufficient.
- 6.2.3. All samples for the specified product qualification testing shall be from the same roll/coil of material for each product tested. Regarding the polymer components, they should be obtained from the production line used to produce the geosynthetic products being evaluated.
- 6.2.4. A sampling report should be developed and, as a minimum, should include the following information:
- Date of sampling;
  - A brief description of the manufacturing facility/production line;
  - The facility location;
  - Any prearrangements made with the manufacturer to sample, especially considering any advance warning of the sampling event provided to the manufacturer;
  - The information for each sample required in Section 6.2.2;
  - Where the sample was taken within the facility; and
  - How the sample was prepared for shipping and supervised by the sampler.
- 6.3. *Evaluation of Product Lines (Determination and Testing Strategy):*
- 6.3.1. *Assessment to Define Product Line*—Data must be obtained for each product to facilitate the determination of which products should be considered as included in the product line. The assessment of whether or not all products identified as a product line by the geosynthetic manufacturer qualify as such should be based, as a minimum, on the following information for each product in the product line:
- Geosynthetic type, structure, and weaving process used to construct yarns or ribs;
  - For geogrids, spacing and dimensions of geogrid elements, including photographs or small samples for visual examination. The receiving laboratory should verify these dimensions on receipt of the sample(s) using hand measurement techniques. This is especially critical for geogrid strength determination based on a single or a limited number of ribs in the specimens tested.
  - For geostrips, dimensions and shape of each geostrip, including photographs or small samples for visual examination. The receiving laboratory should verify these dimensions on receipt of the sample(s) using hand measurement techniques;
  - Polymer(s) used for fibers, ribs, etc.;

- Polymer(s) used for coating, if present;
- Polymer source(s) used for product;
- For HDPE and PP, primary resin ASTM type, class, grade, category (for HDPE use ASTM D1248, and for PP use ASTM D4101), and any other material and property specifications used to purchase the raw materials or as manufacturing targets;
- For PET, minimum production number average molecular weight (ASTM D4603 and GRI-GG8) and maximum carboxyl end group content (ASTM D7409), with supporting test data. Information regarding the laboratory where the testing was conducted and date of testing shall also be provided, and any other material and property specifications used to purchase the raw materials or as manufacturing targets;
- Percent of postconsumer recycled material, by weight;
- Minimum weight per unit area for product (ASTM D5261); and
- Minimum average roll value (MARV) or minimum value for ultimate **wide-width** tensile strength (ASTM D4595 or ASTM D6637/D6637M), with supporting test data used by the product manufacturer to establish the MARV or minimum values. Information regarding the laboratory where the testing was conducted, and date of testing, shall also be provided.

6.3.2. Once an initial assessment of the product line has been made based on the product description and index property data described above, performance and additional index property testing for installation damage, creep, and durability shall be conducted for the products identified as a product line (see Section 6.4 and Annexes A, B, and C for detailed testing and evaluation requirements). The full suite of performance tests for installation damage, creep, and durability shall be obtained for at least one product in the product line to qualify the product line. This product shall be designated as the “primary product” for product line characterization purposes. For certain tests, such as UV resistance and oven aging, it is permissible to test only the lightest weight product in the product line, provided it is obvious that doing so will be a conservative characterization of the entire product line for those specific properties. Additional product-specific test results for installation damage, creep, and durability as described herein shall be obtained for a minimum of two other products in the product line (designated as “secondary products”) to verify consistency of the other products in the line with the primary product and the ability to interpolate installation damage, creep, and durability behavior to estimate strength reduction factors for the entire product line. For larger product lines (i.e., greater than 10 products in the line), a minimum of one secondary product per each additional 5 products in the product line shall be tested to characterize the creep behavior of the product line. In addition, a limited manufacturing plant audit shall be conducted at the time the samples for testing are obtained. See Sections 6.3.2.1 through 6.3.2.4 and Note 1 for additional guidance on the assessment of each product in the product line.

6.3.2.1. Product-specific installation damage data obtained in accordance with Annex A should be obtained for each product in the line. However, it is permissible to obtain installation damage data for only some of the products in the product line if interpolation of the installation damage reduction factor between products is feasible, or if an upper bound value of  $RF_{ID}$  can be determined for the entire product line. Testing and interpretation requirements to determine  $RF_{ID}$  for each product in the product line provided in Annex A, Section A1.1.1.6.4 shall be followed. For the products in the product line not tested in accordance with Annex A as primary or secondary products for product line characterization, a limited testing program should be conducted that allows direct comparison to the installation damage test results obtained for the products (primary and secondary per Section 6.3.2) used to characterize the product line. One of the following two options should be used to accomplish this:

1. Conduct bench-scale installation damage tests (ISO/DIS 10722:2007) on all products in the product line; or
2. Conduct a full-scale field installation damage test per Annex A and ASTM D5818, but using only the soil with a  $d_{50}$  size that is equal to or larger than 4.75 mm, or other  $d_{50}$  size as determined by the approval authority, and the aggregate shall have a maximum LA Abrasion (T 96) percent loss of 35 percent.

This limited testing program should be used to verify that the installation damage test results for products not tested as primary or secondary products per Section 6.3.2 for product line characterization are consistent with the installation damage data for the primary and secondary products. Consistency between the primary and secondary product test results and the limited test results for the remaining products in the product line should be judged as described in Section A1.1.1.6.4.

The comparison between the primary/secondary product installation damage test results and the test results for the remaining products shall be conducted for the same type of installation damage test (i.e., ISO tests for all products in the product line, or full-scale installation damage tests for one soil for all products in the product line).

- 6.3.2.2. For extension of the creep data obtained on the product identified as the primary product for the product line to the entire product line as defined herein, a limited creep testing program shall be conducted on at least two additional products (i.e., secondary products per Section 6.3.2) in the product line. If the results are not consistent with the primary product creep-rupture envelope in accordance with Section B1.7 in Annex B, all products in the product line shall be creep tested, or the product line should be divided into groups of products that are consistent and that meet the definition of a product line.
- 6.3.2.3. For determination of the durability reduction factor,  $RF_D$ , for the product line, the weakest or lightest product in the range of products in the product line should be tested. For molecular weight/viscosity and carboxyl end group testing of polyester geosynthetics, it is acceptable to perform the tests on the yarn sampled at the geosynthetic manufacturing facility provided that it can be demonstrated that the yarn sampled is used to manufacture the geosynthetic products that are included in the product line being evaluated, in accordance with Section 6.3.2.4. If this cannot be verified, then yarn/fibers obtained from each product in the product line shall be tested.
- 6.3.2.4. The focus of the geosynthetic reinforcement manufacturing plant limited audit is to verify traceability of materials used for each product in the product line, and to verify consistency in the manufacturing process used for all products in the product line. The audit of the geosynthetic reinforcement manufacturing facility, as a minimum, shall include the following:
- Verification that the same base polymer and yarn is used in all products included in the product line;
  - Verification of polymer source(s) used and consistency of the polymer property standards for the sources used;
  - Verification of the consistency of the manufacturing process used with regard to the base polymeric yarn, filament, or rib, including heating/quenching history, weaving, rib junction construction, etc.; and
  - For coated geogrids and geostrips, verification of the coating material used and its consistency for all products in the line, including thickness and/or weight per unit area, temperature history, and other processing variables.

The audit should be conducted in conjunction with the sampling conducted. A report of the audit findings shall be developed by the auditor and included with the sampling report.

#### 6.4. *Determination of Strength Reduction Factors and Long-Term Geosynthetic Strength:*

- 6.4.1. The long-term geosynthetic strength shall be determined by applying strength reduction factors to the ultimate tensile strength of the geosynthetic, as shown in Equations 1 and 2, derived from the test results obtained through this standard practice.

$$T_{al} = \frac{T_{ult}}{RF} \quad (1)$$

where:

$$RF = RF_{ID} \times RF_{CR} \times RF_D \quad (2)$$

where:

$T_{al}$  = the long-term tensile strength that will not result in rupture of the reinforcement during the required design life; for geogrids (calculated on a load per unit of reinforcement width basis) and geostrips (calculated on a load per strip basis);

$T_{ult}$  = the minimum ultimate tensile strength (MARV) of the reinforcement determined in accordance with ASTM D4595 for geotextiles and ASTM D6637/D6637M for geogrids (calculated on a load per unit of reinforcement width basis) and geostrips (calculated on a load per strip basis);

$RF$  = a combined reduction factor to account for potential long-term degradation due to installation damage, creep, and chemical/biological aging;

$RF_{ID}$  = a strength reduction factor to account for installation damage to the reinforcement;

$RF_{CR}$  = a strength reduction factor to prevent long-term creep rupture of the reinforcement; and

$RF_D$  = a strength reduction factor to prevent rupture of the reinforcement due to chemical and biological degradation.

#### 6.4.1.1.

The value selected for  $T_{ult}$  is the MARV for the product to account for statistical variance in the material strength. For geogrids and geostrips, a statistically based minimum value may be used in lieu of the MARV. Other sources of uncertainty and variability in the long-term strength include installation damage (Annex A), creep strength and stiffness (Annex B), and chemical durability (Annex C). The observed variability in the creep-rupture envelope should be assumed to be 100 percent correlated with the short-term tensile strength,  $T_{ult}$ , as the creep strength is typically directly proportional to the short-term tensile strength within a product line (Bathurst et al., 2012) (see Annex B and Note B7 in Annex B if this is not the case). Therefore, the MARV of  $T_{ult}$  adequately takes into account that source of variability. For additional discussion of this issue, see Note 2.

**Note 2**—The product strength variability is not taken into account by using the creep limited strength,  $T_i$ , directly or in normalizing  $T_i$  by  $T_{baseline}$  (see Annex B).  $T_i$  only accounts for extrapolation uncertainty. Furthermore,  $T_{baseline}$  is specific to the lot of material used for the creep testing. Normalizing by  $T_{baseline}$  makes the creep reduction factor  $RF_{CR}$  applicable to the rest of the product line, as creep strength is typically directly proportional to the ultimate tensile strength, within a product line. As shown below, it is not correct to normalize the creep strength  $T_i$  using  $T_{ult}$ , the MARV of the tensile strength for the product, nor is it correct to use  $T_i$  directly in the numerator to calculate  $T_{al}$ .

$$RF_{CR} = \frac{T_{baseline}}{T_i} \neq \frac{T_{ult}}{T_i} \quad \text{and} \quad T_{al} \neq \frac{T_i}{RF_{ID} \times RF_D}$$

In the former case, the creep strength is not indexed to the actual tensile strength of the material used in the creep testing, and because there is a 50 percent chance that  $T_{baseline}$  will be less than or equal to  $T_{ult}$ , using  $T_{ult}$  in this case would result in an unconservative determination of  $RF_{CR}$ . In the latter case, where  $T_i$  is used directly as a creep-reduced strength, the product strength variability is not taken into account, because  $T_i$  is really a mean creep strength. Hence,  $RF_{CR}$  must be determined as shown in Equation B1.5 in Section B1.6.1, and the MARV or minimum value must be used for  $T_{ult}$  when determining  $T_{al}$ . Note that the use of the MARV for  $T_{ult}$  may not fully take into account the additional variability caused by installation damage. For the typical degree of installation damage observed in practice, this additional variability is minor and can be easily handled through the overall safety factor used in design of reinforced structures. For specific procedures regarding how to account for this additional variability, see Bathurst et al. (2011). For durability ( $RF_D$ ), additional variability does not come into play if a default reduction factor is used. If a more refined durability analysis is performed, additional variability resulting from chemical degradation may need to be considered.

- 6.4.1.2. The  $RF_{ID}$  and  $RF_{CR}$  shall be determined from product-specific data for all geosynthetic reinforcement products or product lines. The product-specific data for these reduction factors shall be interpreted/extrapolated in accordance with Annexes A and B.  $RF_D$  shall be determined from long-term product-specific data interpreted/extrapolated in accordance with Annex C, or a default value may be used as described below. A default reduction factor for  $RF_D$  may be used if the environment is nonaggressive and if the product meets the minimum polymer and physical property requirements provided in Table 1. In this case, a default value for  $RF_D$  of 1.3 may be used for PET, HDPE, and PP geosynthetics. This default value for  $RF_D$  presumes that the geosynthetic is not excessively damaged during installation (i.e.,  $RF_{ID} > 1.7$ ). This is especially important for coated polyester geogrids and geostrips, as there is reliance on the coating to protect the underlying polyester fibers from exposure to moisture that could cause hydrolysis. Other default values for  $RF_D$  may be used based on the more detailed guidance provided in Berg, et al. (2009) if the soil environment is nonaggressive.
- Note 3**—The default value for  $RF_D$  of 1.3, which can be used for products that meet the minimum property requirements in Table 1, was determined for effective design temperatures that are less than or equal to 20°C (68°F). A higher default value of 1.5 for products that meet the property requirements in Table 1 may be desirable for more temperate climates that still meet the requirements for a nonaggressive environment, especially to address polyolefin oxidative degradation, as the potential for this type of degradation, even for products that meet the property requirements in Table 1, becomes more uncertain at higher temperatures due to the lack of protocols that can accurately identify the amount or effectiveness of end use antioxidants present.
- 6.4.1.3. If the environment is identified as aggressive due to the chemical regime or due to temperature, or if the geosynthetic product does not meet the requirements in Table 1, default reduction factors should not be used for  $RF_D$ . For chemically aggressive or elevated temperature environments,  $RF_D$  must be determined based on long-term product-specific data for an environment that is as or more aggressive than the project specific environment in question. Once the appropriate reduction factors are established, the long-term geosynthetic strength is determined using Equations 1 and 2, or as determined in Note B7 of Annex B.
- 6.4.1.4. If a default reduction factor for  $RF_D$  is to be used, geosynthetic products likely to have good resistance to installation stresses and to long-term chemical degradation are required to minimize the risk of significant long-term degradation. Polymer materials not meeting the requirements in Table 1 could be used if detailed product-specific data, extrapolated to the design life intended for the geosynthetic structure (see Annex C), is provided.
- 6.4.1.5. The test data obtained through this protocol and the determination of the strength reduction factors shall be consistent with the design life requirements for their intended use. Unless otherwise specified by the agency or owner, a minimum design life of 75 years for permanent structures shall be used for this purpose in accordance with the *AASHTO LRFD Bridge Design Specifications*.

**Table 1**—Minimum Requirements for Geosynthetic Products to Allow Use of Default Reduction Factor for Long-Term Degradation

Polymer Type	Property	Test Method	Criteria to Allow Use of Default $RF$
PP and HDPE	UV oxidation resistance	ASTM D4355/D4355M	Min. 70% strength retained after 500 h in weatherometer
PET	UV oxidation resistance	ASTM D4355/D4355M	Min. 50% strength retained after 500 h in weatherometer if geosynthetic will be buried within 1 week, 70% if left exposed for more than 1 week.
PP and HDPE	Thermo-oxidation resistance	ISO 13438:2004, Method A (PP) or B (HDPE)	Min. 50% strength retained after 28 days (PP) or 56 days (HDPE)
PET	Hydrolysis resistance	Inherent viscosity method (ASTM D4603 and GRI-GG8), or determine	Min. number average molecular weight of 25,000

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PET	Hydrolysis resistance	directly using gel permeation chromatography	
All Polymers	% postconsumer recycled material by weight	ASTM D7409 Certification of materials used	Max. carboxyl end group content of 30 Maximum of 0%

**Note 4**—The requirements provided in Table 1 utilize currently available index tests and are consistent with current *AASHTO LRFD Bridge Design Specifications*. These index tests can provide an approximate measure of relative resistance to long-term chemical degradation of geosynthetics. Values selected as minimum criteria to allow use without additional long-term testing are based on values for such properties determined from long-term research reported in the literature. These values are considered indicative of good long-term performance or represent a readily available current standard within the industry that signifies that a product has been enhanced for long-term environmental exposure. There is little long-term history or even laboratory data regarding the durability of geosynthetics containing a significant percentage of recycled material. Therefore, their potential long-term performance is unknown, and long-term data should be obtained for products with significant recycled material to verify their performance before using them.

6.5. *Report:*

6.5.1. *The following information shall be included in the product or product line evaluation report:*

6.5.1.1. *Basis for Determination of Product Line Members:*

- 6.5.1.1.1. Geosynthetic type, structure, and weaving process used to construct yarns or ribs.
- 6.5.1.1.2. Spacing and dimensions of geogrid elements or width of geostrips, including photographs or small samples for visual examination. The receiving laboratory should verify these dimensions on receipt of the sample(s) using hand measurement techniques.
- 6.5.1.1.3. Polymer(s) used for fibers, ribs, etc.
- 6.5.1.1.4. Polymer(s) used for coating, if present.
- 6.5.1.1.5. Whether or not all polymer materials and property specifications for each polymer material used by the manufacturer to obtain or manufacture the products was consistent throughout the product line, as described in the audit report for the manufacture obtained in accordance with this standard practice.
- 6.5.1.1.6. For HDPE and PP, primary resin ASTM type, class, grade, category (for HDPE use ASTM D1248, and for PP use ASTM D4101).
- 6.5.1.1.7. For PET, minimum production number average molecular weight (ASTM D4603 and GRI-GG8) and maximum carboxyl end group content (ASTM D7409), with supporting test data. Information regarding the laboratory where the testing was conducted, and date of testing, shall also be provided.
- 6.5.1.1.8. Percent of postconsumer recycled material by weight.
- 6.5.1.1.9. Minimum weight per unit area for product (ASTM D5261).
- 6.5.1.1.10. MARV or minimum value for ultimate wide-width tensile strength (ASTM D4595 or D6637/D6637M), with supporting test data used by the product manufacturer to establish the

MARV or minimum value. Information regarding the laboratory where the testing was conducted, and date of testing, shall also be provided.

- 6.5.1.2. *Installation Damage Data Requirements ( $RF_{ID}$ )*—Installation damage testing and interpretation shall be conducted in accordance with Annex A. As a minimum, for each product tested, the following information should be obtained and provided in the report:
- 6.5.1.2.1. Date tests were conducted.
  - 6.5.1.2.2. Name(s), location(s), and telephone number(s) of laboratory(ies) conducting the testing and evaluation.
  - 6.5.1.2.3. Whether installation damage testing was conducted as a site-specific evaluation for an actual construction project or was conducted as a non-site-specific evaluation.
  - 6.5.1.2.4. Any deviations in the installation and exhumation procedures used relative to this standard practice.
  - 6.5.1.2.5. Photographs illustrating procedures used and the conditions at the time of the testing, if available.
  - 6.5.1.2.6. Measured mass/unit area per ASTM D5261 for the sample tested for installation damage and for the sample used to establish the undamaged strength. Also obtain product manufacturer quality control (QC) data on the uncoated product (i.e., greige-good) for the lot used for installation damage testing, if available.
  - 6.5.1.2.7. Tensile test results for the product before exposure to installation conditions (i.e., virgin material,  $T_{baseline}$ ), and whether both virgin and damaged samples were taken from the same roll/coil of material, or just from rolls/coils within the same lot of material.
  - 6.5.1.2.8. Tensile test results for specimens taken from the damaged material after installation.
  - 6.5.1.2.9. Tensile test results for both virgin and damaged specimens should include individual test results for each specimen, typical individual load–strain curves that are representative of the specimens tested, including associated calibration data as necessary to interpret the curves (curves in which strain and load/unit width are already calculated are preferred), the average value for each sample, the coefficient of variation for each sample, and a description of any deviations from the standard tensile test procedures required by Annex A.
  - 6.5.1.2.10. Gradation curves for backfill material located above and below the installation damage geosynthetic samples, including the  $d_{50}$  size, maximum particle size, and a description of the angularity of the soil particles per ASTM D2488, including photographs illustrating the soil particle angularity, if available. Also include LA Abrasion (T 96) test results for the backfill material used.
  - 6.5.1.2.11. Photographs or a description, or both, of the type and extent of damage visually evident in the exhumed samples and specimens.
  - 6.5.1.2.12. The  $RF_{ID}$  values for the range of soil gradations tested, and the data interpretation approach used to determine them.
- 6.5.1.3. *Creep Data Requirements ( $RF_{CR}$  and Creep Stiffness  $J$ )*—As a minimum, for each product tested, the following information should be obtained and provided in the test report:
- 6.5.1.3.1. Date tests were conducted.



- 6.5.1.3.2. Name(s), location(s), and telephone number(s) of laboratory(ies) conducting the testing and evaluation.
- 6.5.1.3.3. Photographs illustrating the creep testing equipment and procedures used, as available.
- 6.5.1.3.4. Tensile test results for the product before creep testing (i.e., virgin material), and whether both virgin and creep tested samples were taken from the same roll/coil of material or just from rolls/coils within the same lot of material.
- 6.5.1.3.5. Tensile test results should include individual test results for each specimen, typical load–strain curves that are representative of the specimens tested, including associated calibration data as necessary to interpret the curves (curves in which strain and load/unit width are already calculated are preferred), the average value for each sample, the coefficient of variation for each sample, and a description of any deviations from the standard tensile test procedures required by Annex B.
- 6.5.1.3.6. Creep test standard used and any deviations from the procedures required in Annex B.
- 6.5.1.3.7. Load and time to rupture for each specimen as a minimum; however, strain data as a function of time are desirable if available.
- 6.5.1.3.8. If elevated temperature testing is conducted, creep data before and after time/load shifting, including shift factors used and a description of how the shift factors were derived.
- 6.5.1.3.9. Data illustrating the variability of the creep test environment, including temperature and humidity, during the creep test time period, or some assurance that the creep test environment was maintained within the variation of temperature prescribed herein.
- 6.5.1.3.10. Description of statistical extrapolation procedures used in accordance with Annex B, if statistical extrapolation is performed.
- 6.5.1.3.11.  $RF_{CR}$ , and a description of how  $RF_{CR}$  was determined for each product.
- 6.5.1.3.12. In addition, regardless of which approach is used to determine  $RF_{CR}$ , creep strain data at a load level that results in a strain of 2 percent at approximately 1000 h, including the ramp and hold test results used to establish the load level needed to obtain 2 percent strain at 1000 h.
- 6.5.1.3.13. For both creep rupture and low strain creep stiffness testing, if single-rib, yarn, or narrow-width specimens are used, 1000-h creep data in accordance with Annex B that demonstrate the single-rib, yarn, or narrow-width test results are consistent with the results from multi-rib/wide-width testing procedure.
- 6.5.1.4. *Long-Term Durability Data Requirements to Establish Default Value of  $RF_D$* —If a default value for  $RF_D$  is to be used, the following information and test results shall be provided in the report:
  - 6.5.1.4.1. Ultraviolet resistance at 500 h in weatherometer (ASTM D4355/D4355M). Information regarding the laboratory where the testing was conducted, and date of testing, shall also be provided.
  - 6.5.1.4.2. Oven-aging tests conducted in accordance with ISO 13438:2004, Method A (PP) or B (HDPE), for polyolefin geosynthetics. Information regarding the laboratory where the testing was conducted, and date of testing, shall also be provided.
  - 6.5.1.4.3. Inherent viscosity/molecular weight (ASTM D4603 and GRI-GG8) and carboxyl end group (CEG) content (ASTM D7409) for polyester geosynthetics conducted on the base yarn used for the manufacture of the geosynthetic. Information regarding the laboratory where the testing was conducted, and date of testing, shall also be provided.

## 7. VERIFICATION REQUIREMENTS FOR GEOSYNTHETIC PRODUCTS THAT HAVE BEEN THROUGH PRODUCT LINE PERFORMANCE TESTING

### 7.1. *Verification Purpose and Testing Approach:*

7.1.1. Verification testing, when conducted, shall be used to verify that product or product line properties have not changed significantly relative to the most recent full product or product line performance testing conducted in accordance with Section 6. As a minimum, verification testing shall consist of index property and limited performance-level testing conducted on at least one product in the product line to verify that the properties have remained consistent with the product test results conducted in accordance with Section 6, as specified in the subsections that follow.

7.1.1.1. Retesting in accordance with Section 6 shall be done if there is any change in the product relative to those test results, as defined in this section. If it is determined that one or more products in the product line has changed since the last full product or product line performance testing program was conducted, a complete assessment of the product or product line in accordance with Section 6 instead of just a verification evaluation may be required by the approval authority, depending on the nature and magnitude of the change(s). Examples of changes that could necessitate that a new full product or product line performance testing program be conducted include changes in the processing technique or variables used for the product line, changes in the polymer properties or additives used that could affect the product's(s') mechanical/chemical durability or creep resistance, changes in the shape or surface area of the ribs or yarns, changes in the way ribs and cross-ribs are connected together, changes in the coating properties or thickness, changes in tensile strength, etc. The potential impact of such changes on the long-term strength of the reinforcement product(s) should be assessed by the approval authority. Some types of product changes may only affect certain aspects of the product's(s') long-term strength, necessitating that only a portion of the product qualification testing program be conducted (e.g., changes in yarn or rib geometry may only affect installation damage resistance). Therefore, the approval authority may need to make a determination of what portions of the full product or product line performance testing program should be conducted, if it is determined that additional testing is needed.

### 7.2. *Data Verification Requirements:*

7.2.1. *The following information about each product shall be obtained for verification purposes:*

7.2.1.1. Geosynthetic type and structure, and weaving process used to construct yarns or ribs.

7.2.1.2. *Spacing and dimensions of geogrid elements or width of geostrips*—The receiving laboratory should verify these dimensions on receipt of the sample(s) using hand measurement techniques. This is especially critical for geogrid strength determination based on a single or limited number of ribs in the specimens tested.

7.2.1.3. Polymer(s) used for fibers, ribs, etc.

7.2.1.4. Polymer(s) used for coating, if present.

7.2.1.5. Polymer source(s) used for product, and any other material and property specifications used to purchase the raw materials or as manufacturing targets.

7.2.1.6. For HDPE and PP, primary resin ASTM type, class, grade, and category (for HDPE, use ASTM D1248, and for PP use ASTM D4101).

7.2.1.7. Percent postconsumer recycled material by weight.

- 7.2.1.8. Minimum weight per unit area for product (ASTM D5261).
- 7.2.1.9. MARV for ultimate **wide-width** tensile strength (ASTM D4595 or D6637/D6637M).
- 7.3. *Verification Sampling:*
- 7.3.1. Samples will be selected for testing by agency or owner personnel or designated parties. Sampling shall be conducted in accordance with the requirements in the specific AASHTO, ASTM, GRI, or ISO test standard for the specific tests conducted as part of this standard practice. For products selected as representative of the product line, an entire roll/**coil** should be taken, but no less than the sum of the sample sizes required for all tests to be conducted on each product. As a minimum, the following shall be obtained:
- A geosynthetic product sample of sufficient size to accommodate all of the specified testing;
  - Information showing the manufacturer's name and description of product (style, brand name, etc.);
  - Product roll/**coil** and lot number; and
  - A sample of the polymer component(s) used to manufacture the product or product line in sufficient quantity to conduct the specified polymer tests.
- 7.3.2. All samples for the specified verification testing shall be from the same roll/**coil** of material for each product tested. Regarding the polymer components, they should be obtained from the production line used to produce the geosynthetic products being evaluated.
- 7.4. *Verification Testing:*
- 7.4.1. Short-term tensile strength shall be determined in accordance with ASTM D4595 for geotextiles and ASTM D6637/D6637M for geogrids **and geostrips**. As a minimum, these tensile tests shall be conducted on the products selected for installation damage and creep testing. Verification testing required to verify that the values of  $RF_{ID}$ ,  $RF_{CR}$ , and  $RF_D$  determined from the full product line testing are applicable to the current product (i.e., the verification test results are statistically consistent with the full product line test results obtained in accordance with Section 6) is as follows:
- 7.4.1.1. *Installation Damage Testing:*
- 7.4.1.1.1. For installation damage evaluation, a field-exposure trial conducted in accordance with Annex A shall be conducted for the product in the product line with the highest  $RF_{ID}$  from the product testing conducted in accordance with Section 6 using soil with a  $d_{50}$  size that is equal to or larger than 4.75 mm, or other  $d_{50}$  size as determined by the approval authority, and the aggregate shall have a maximum LA Abrasion (T 96) percent loss of 35 percent. The  $d_{50}$  size, angularity, and durability of the selected backfill should be consistent with the  $d_{50}$  size used for testing conducted in accordance with Section 6 (the same material should be used for both the Section 6 testing and the verification testing, if possible). Alternatively, reduced-scale laboratory installation damage tests conducted in accordance with ISO/DIS 10722:2007 may be used. In this case, these laboratory installation damage tests must also be conducted as part of the Section 6 testing to establish a baseline value. The ultimate tensile strength of the lot or roll/**coil** of material used in the installation damage testing obtained in accordance with ASTM D4595 or ASTM D6637/D6637M using the multi-rib **wide-width** procedure (or ISO 10319:2008 if ISO/DIS 10722:2007 is used) shall be obtained to normalize the installation damage test results in accordance with Annex A. If it was determined during the Section 6 testing for coated geogrids **and geostrips** that the installation damage factor was not correlated to product weight or tensile strength, the coating weight should also be evaluated. In this case, the mass/unit area of the sample tested shall be determined in accordance with ASTM D5261. The coating weight can then be established using the lot-specific mass/unit area of the uncoated product from product manufacturer QC data.

#### 7.4.1.2. *Creep Testing:*

7.4.1.2.1. The product used for the primary product in the testing conducted as specified in Section 6 for the product line shall be selected for the verification testing and evaluation. For creep-rupture evaluation, a minimum of three creep-rupture points shall be obtained using the Stepped Isothermal Method (i.e., SIM) per ASTM D6992 or ASTM D5262 tests (for which elevated test temperatures may be employed to accelerate creep; see Annex B) at a load level that corresponds to a minimum rupture time of 100,000 h at the reference temperature using the rupture envelope established as part of the testing required in Section 6. If elevated temperature block shifting creep testing using ASTM D5262 is performed, the shift factors obtained from the block shifting creep testing conducted as specified in Section 6 shall be used to extrapolate the verification creep test data to the reference temperature. A fourth SIM test (or conventional ASTM D5262 test conducted at the reference temperature) shall be performed at a load level established from the rupture envelope obtained from the testing conducted in accordance with Section 6 that corresponds to a minimum rupture time of 500 h at the reference temperature.

7.4.1.2.2. For creep stiffness evaluation, if the testing conducted in accordance with Section 6 indicates that the creep is log linear at the low strain levels tested, short-term (1000-s) ramp and hold (R+H) tests as described in ASTM D6992 may be used and extrapolated to 1000 h in lieu of 1000-h creep tests. A minimum of two R+H tests shall be conducted for one product in the product line at the load level in which 2 percent strain at 1000 h was achieved in the product qualification testing. The product used as the primary product for the testing conducted as specified in Section 6 shall be used for this QA testing. If the testing conducted as specified in Section 6 indicates that the creep is not log linear at the low strain level tested, then a minimum of two full 1000-h creep tests must be conducted at that load level. These tests shall be conducted on the same width specimens as used for the creep stiffness testing conducted as specified in Section 6.

7.4.1.2.3. If SIM is used for this verification creep-rupture testing, it shall have been demonstrated for the testing conducted as specified in Section 6 that the reduced specimen width typically used for SIM testing does not have a significant effect on the creep-rupture results, and demonstrated that SIM meets the requirements in Annex B, Section B1.4.2, for use in characterizing the creep-rupture behavior of the product line.

7.4.1.2.4. The ultimate tensile strength of the lot or roll/coil of material used in the creep testing obtained in accordance with ASTM D4595 or D6637/D6637M shall be obtained to normalize the creep-rupture loads in accordance with Annex B.

**Note 5**—If ASTM D5262 creep testing is performed for verification purposes, it is assumed that the product has not changed relative to what was tested for the testing conducted as specified in Section 6, thereby allowing the assumption to be made that the shift factors obtained through the Section 6 product testing are valid to be applied to the verification testing. Requiring new block shifting creep test shift factors to be established would result in the need to fully repeat the test program conducted in accordance with Section 6, which would not be practical for verification purposes. Regarding the fourth creep test data point, the requirement to use only data obtained at the reference temperature if block shifting creep testing is performed provides a second check that eliminates the need for this shift factor assumption and any inaccuracies associated with that assumption.

#### 7.4.1.3. *Durability Testing:*

7.4.1.3.1. If only index durability testing was conducted to allow use of a default value for  $RF_D$  for testing conducted as specified in Section 6, only index durability testing should be conducted for verification purposes. In this case, the product tested for verification purposes shall be the same product tested for the Section 6 durability testing and shall consist of the determination of molecular weight based on ASTM D4603 and GRI-GG8 and carboxyl end group content based on ASTM D7409 for polyesters, UV resistance based on ASTM D4355/D4355M for polyolefins and

PETs, and an oven-aging exposure test per ISO 13438:2004 for polyolefin geosynthetics. Regarding the oven-aging test, control and postexposure specimens shall be tested for tensile properties (ASTM D4595 or D6637/D6637M). The results of this oven-aging testing should be used only to compare a product with itself and to meet the minimum requirements in Table 1. If more than one product was tested in the testing program conducted as specified in Section 6, the lightest weight product tested shall be evaluated as part of this verification program.

7.5. *Verification Analysis and Reporting:*

7.5.1. Verification of the product or product line testing conducted as specified in Section 6 shall be based on the statistical significance, or lack thereof, of the difference between the verification test results and the test results obtained as specified in Section 6. The criteria and methods for determining the statistical significance between the verification and Section 6 test results shall be as follows:

7.5.1.1. *Short-Term Index Tensile Testing:*

7.5.1.1.1. For **wide-widthultimate** tensile strength, the mean of the test results for the sample for each product tested shall be greater than or equal to the MARV or minimum value reported for the product. Report both the MARV or minimum value and the verification tensile test results.

7.5.1.2. *Installation Damage Testing:*

7.5.1.2.1. If the mean strength of the verification sample after damage as a percent of the undamaged strength is less than the mean value obtained for the same product and condition during the testing conducted as specified in Section 6, the maximum difference between the two means shall be no greater than what is defined as statistically insignificant based on a one-sided Student's  $t$ -distribution at a level of significance of 0.05. In this case,  $t$  is determined as follows:

$$t_{\alpha/2, n_1 + n_2 - 2} = \frac{(\bar{P}_1 - \bar{P}_2) - \delta}{\sqrt{(n_1 - 1)s_1^2 + (n_2 - 1)s_2^2}} \sqrt{\frac{n_1 n_2 (n_1 + n_2 - 2)}{(n_1 + n_2)}} \quad (3)$$

where:

$t_{\alpha/2, n_1 + n_2 - 2}$  = value of the  $t$ -distribution for the installation damage samples;

$\bar{P}_1$  = the mean of the strength retained after installation damage (i.e.,  $T_{\text{dam}}/T_{\text{lot}}$ ) obtained as specified in Section 6;

$\bar{P}_2$  = the mean of the strength retained after installation damage (i.e.,  $T_{\text{dam}}/T_{\text{lot}}$ ) obtained for verification testing;

$\delta$  = the difference in the means for the populations corresponding to the sample means  $\bar{P}_1$  and  $\bar{P}_2$  (assumed equal to zero for this test);

$s_1$  = the standard deviation corresponding to  $\bar{P}_1$ ;

$s_2$  = the standard deviation corresponding to  $\bar{P}_2$ ;

$n_1$  = the number of data points corresponding to  $\bar{P}_1$ ; and

$n_2$  = the number of data points corresponding to  $\bar{P}_2$ .

7.5.1.2.2. The  $t_{\alpha/2, n_1 + n_2 - 2}$  calculated using Equation 3 shall be no greater than  $t$  determined from the applicable Student's  $t$ -table (or from the Microsoft Excel function  $\text{TINV}(\alpha, n-2)$ ) at  $\alpha = 0.05$  and  $n_1 + n_2 - 2$  degrees of freedom. If this is not true, the difference between  $\bar{P}_1$  and  $\bar{P}_2$  is determined to

be statistically significant and  $\bar{P}_1 > \bar{P}_2$ , two additional samples from the same installation condition shall be tested and  $\bar{P}_2$  shall be recalculated and statistically compared to  $\bar{P}_1$ . If the QA test results are still too low, a full installation damage study conducted as specified in Section 6 must be completed in accordance with Annex A, and new values of  $RF_{ID}$  established.

7.5.1.2.3. Report the results of the statistical analysis, as well as the mean values for the Section 6 testing and the verification testing.

7.5.1.3. *Creep-Rupture Testing for Prediction of Creep Limit:*

7.5.1.3.1. For creep evaluation, the four creep-rupture points—one at a load level that results in an approximate rupture time, after time shifting, of 500 h, and three at a load level that results in an approximate rupture time, after time shifting, of 100,000 h—on the rupture envelope obtained in accordance with Section 6 shall be compared to the creep data obtained as specified in Section 6. The log of the rupture time for each of these four rupture points shall be equal to or greater than the 95 percent lower prediction limit of the variable, log time, established by Student's  $t$ -test of the original Section 6 data set.

7.5.1.3.2. The prediction limit for the regression performed in accordance with Section 6 is given by (Wadsworth, 1998):

$$\log t_L = \log t_{\text{reg}} - \left[ t_{\alpha/2, n-2} \sqrt{1 + \frac{1}{n} + \frac{(P - \bar{P})^2}{\sum (P_i - \bar{P})^2}} \right] \times \sigma \quad (4)$$

and

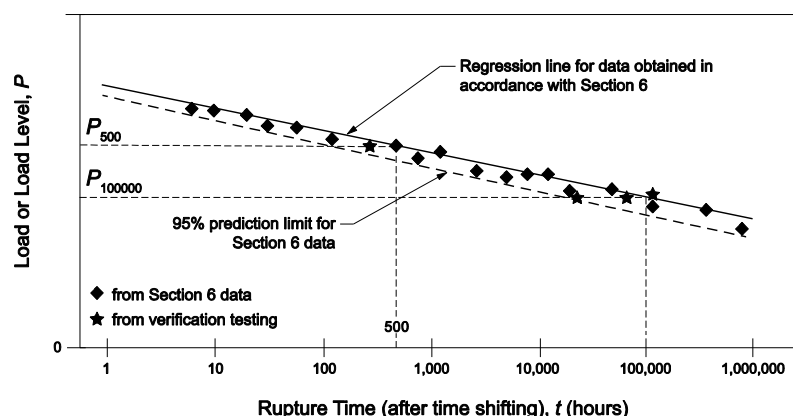
$$\sigma = \sqrt{\frac{\sum [\log t_i - \log \bar{t}]^2 - \frac{[\sum [(P_i - \bar{P})(\log t_i - \log \bar{t})]]^2}{\sum (P_i - \bar{P})^2}}{n - 2}} \quad (5)$$

where:

- $\log t_L$  = lower bound prediction limit;
- $t_{\text{reg}}$  = time corresponding to the load level from the Section 6 creep-rupture envelope at which verification creep tests were performed (e.g., at 500 and 100,000 h after time shifting);
- $t_{\alpha/2, n-2}$  = value of the Student's  $t$ -distribution determined from applicable Student's  $t$ -table (or from the Microsoft Excel function TINV( $\alpha, n-2$ )) at  $\alpha/2 = 0.05$  and  $n - 2$  degrees of freedom (this corresponds to the 95 percent one-sided prediction limit);
- $n$  = the number of rupture or allowable run-out points in the original test sample (i.e., obtained as specified in Section 6);
- $P$  = load level obtained at  $t_{\text{reg}}$  from the regression line developed from the initial Section 6 testing;
- $\bar{P}$  = the mean rupture load level for the original test sample (i.e., all rupture or run-out points used in the regression to establish the rupture envelope for Section 6 testing);
- $P_i$  = the rupture load level of the  $i$ th point for the rupture points used in the regression for establishing the rupture envelope obtained in the Section 6 testing;

- $\log \bar{t}$  = the mean of the log of the rupture time for the original test sample (i.e., all rupture or run-out points used in the regression to establish the rupture envelope for the Section 6 testing);
- $t_i$  = the rupture time of the  $i$ th point for the rupture points used in the regression for establishing the rupture envelope for the Section 6 testing.

- 7.5.1.3.3. The comparison between the verification test results and the Section 6 test results is illustrated conceptually in Figure 1. Once  $\log t_L$  has been determined at each specified load level, compare this value to the log rupture time (i.e.,  $\log t_{QA}$ ) obtained for each verification creep-rupture test at the specified load level (e.g., 500 and 100,000 h). If  $\log t_{QA} < \log t_L$  for any of the verification creep-rupture test results, perform two additional tests at the load level  $P$  for the specified  $t_{reg}$  where this verification criterion was not met and compare those results to  $\log t_L$ . If, for these two additional tests, this criterion is not met, perform adequate additional creep-rupture testing to establish a new rupture envelope for the product in accordance with Section 6 requirements (see also Annex B). This new rupture envelope will form the baseline for any future verification testing.

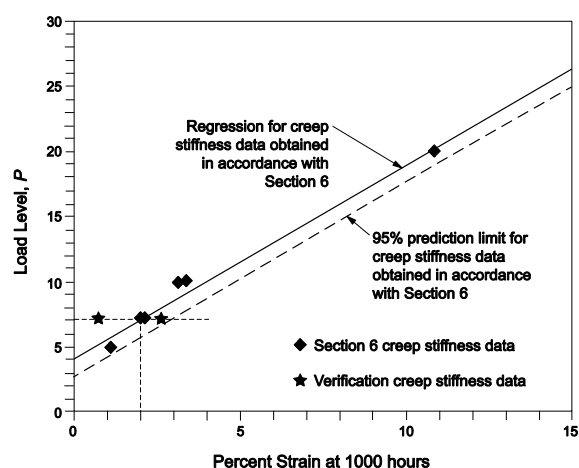


**Figure 1**—Conceptual Illustration of the Comparison of Verification Creep-Rupture Test Results to Creep-Rupture Test Results Obtained as Specified in Section 6

- 7.5.1.3.4. Report a plot of the verification data in comparison to the Section 6 test results as shown in Figure 1, and the verification creep-rupture load levels and time to rupture in comparison to the 95 percent prediction limit calculated at the load levels used to obtain the verification creep-rupture data.
- 7.5.1.4. *Assessment of Creep Stiffness at Low Strain:*
- 7.5.1.4.1. The comparison between the creep data obtained for the testing conducted as specified in Section 6 and the verification creep data obtained in accordance with Section 7.4.1.2.2 shall be performed at a specified time, in this case 1000 h unless otherwise specified by the agency or owner. Determine the strain at 1000 h for each ramp and hold test or 1000-h test. Plot the load level as a function of the percent strain for the ramp and hold data extrapolated to 1000 h and/or the 1000-h creep test data obtained as specified in Section 6, and perform a regression for this data set to determine the 95 percent prediction limit for the regression (i.e., Equations 4 and 5). The percent strains determined at 1000 h for the verification creep data shall be compared to the Section 6 creep data as illustrated in Figure 2. The estimated strain at 1000 h for each of the two

verification creep data points shall be equal to or greater than the 95 percent lower prediction limit of the variable percent strain, established by the Student's *t*-test of the original Section 6 data set, using Equations 4 and 5.

- 7.5.1.4.2. If the percent strain at 1000 h for any of the verification creep strain test results is greater than the 95 percent lower prediction limit strain at the same load level, perform two additional tests at the same load level *P* and determine the percent strain at 1000 h and compare those results to the 95 percent lower prediction limit strain at the same load level. If, for these two additional tests, this criterion is not met, perform adequate additional creep testing to establish a new low strain creep stiffness value for the product in accordance with Section 6 requirements (see also Annex B). This new low strain creep stiffness value will be included in the baseline for any future verification testing.



**Figure 2**—Conceptual Illustration of the Comparison of Creep-Stiffness Test Results to Creep-Stiffness Test Results Obtained as Specified in Section 6

7.5.1.5. *Durability Testing:*

- 7.5.1.5.1. For UV resistance (all polymers), molecular weight and CEG (PET only), and oven aging (PP and HDPE), the verification test results shall meet the minimum requirements provided in Table 1. For the oven-aging tests (polyolefins only), if the mean strength of the sample after exposure as a percent of the ultimate strength is less than the mean value obtained for the same product during the testing conducted as specified in Section 6, the maximum difference between the two means shall be no greater than what is defined as statistically insignificant based on a one-sided Student's *t*-distribution at a level of significance of 0.05, as determined using Equation 3. In this case,  $\bar{P}_1$  and  $\bar{P}_2$  are defined as the strength retained after oven aging.

- 7.5.1.5.2. The  $t_{\alpha/2, n_1+n_2-2}$  calculated using Equation 3 for the oven-aging tests shall be no greater than *t* determined from the applicable Student's *t*-table (or from the Microsoft Excel function TINV( $\alpha, n-2$ )) at  $\alpha/2 = 0.05$  and  $n-2$  and  $n_1 + n_2 - 2$  degrees of freedom. If this is not true, the difference between  $\bar{P}_1$  and  $\bar{P}_2$  is determined to be statistically significant and  $\bar{P}_1 > \bar{P}_2$ , two additional samples from the same roll/coil of material shall be tested in accordance with



ISO 13438:2004(en) and  $\bar{P}_2$  recalculated and statistically compared to  $\bar{P}_1$ . If the verification test results are still unacceptable, or if the product loses more than 50 percent of its tensile strength during the verification test, a more complete investigation shall be performed in accordance with Annex C. Report  $\bar{P}_1$  and  $\bar{P}_2$  for the Section 6 testing and the verification testing.

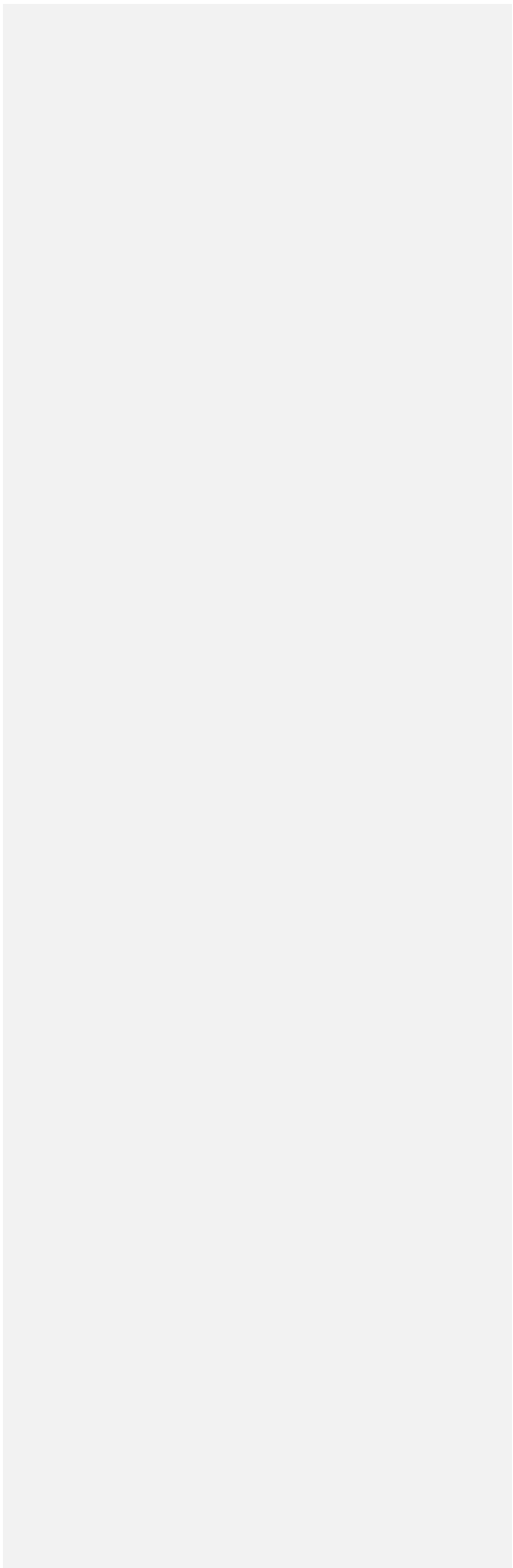
## 8. KEYWORDS

- 8.1. Creep; durability; geogrid; **geostrip**; geosynthetic; quality assurance; stiffness; strength.

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## ANNEX A—INSTALLATION DAMAGE TESTING

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(Mandatory Information)

### A1. PRODUCT-SPECIFIC TESTING AND DATA INTERPRETATION REQUIREMENTS TO DETERMINE $RF_{ID}$ FOR GEOSYNTHETIC REINFORCEMENTS

#### A1.1. General:

A1.1.1. The effect of installation damage on geosynthetic reinforcement strength and deformation shall be determined from the results of full-scale installation damage tests in accordance with ASTM D5818, except as modified herein.

A1.1.1.1. Place and compact 150 mm (6 in.) or more of soil (same soil as used to cover the geosynthetic) on a flat, level, relatively incompressible subgrade. The compacted layer shall simulate the roughness and compressibility of the backfill conditions in which the geosynthetic layer is likely to be placed in full-scale structures.

A1.1.1.2. Place the geosynthetic on top of the compacted soil pad. The geosynthetic shall be pulled taut with no wrinkles or folds. It may be necessary to pin the corners of the geosynthetic to maintain its position as soil is placed over it.

**Note A1**—In addition to the removal requirements described in ASTM D5818, a lifting plate may be placed below the compacted soil pad below the geosynthetic layer as described in Sprague and Allen (2003) to facilitate easy removal of the soil above the geosynthetic. The lift thickness between the lifting plate and the geosynthetic layer should be large enough to prevent undue influence of the very stiff lifting plate on the compliance of the gravel pad surface immediately below the geosynthetic layer.

A1.1.1.3. If the installation damage test is conducted for a specific project, the actual backfill material planned for use in the geosynthetic structure should be used for the test. If the purpose of the installation damage testing is to generate  $RF_{ID}$  values for general use for future projects (i.e., the testing is not intended to be project specific), a range of soil backfill gradations/types shall be used in the testing. The range of backfill materials selected should permit interpolation as needed to match to a project-specific soil used as reinforced soil backfill. In general, the backfill materials tested should range from soil classified as a sand to coarse gravel (e.g.,  $d_{50}$  sizes ranging from 0.5 to 25 mm). The backfill materials selected should be angular to subangular and shall be durable. The coarse sand and gravel portions of the backfill material should have a Los Angeles Wear (LA Abrasion) percent loss after 500 revolutions (T 96) of no more than 35 percent. Additional installation damage tests may be conducted with a less durable backfill material, at the discretion of the manufacturer and the approval authority. If tests are conducted using a backfill material that does not meet the LA Abrasion requirement stated above, the condition of the backfill shall be evaluated for changes in angularity and gradation after each use. If changes in these two parameters are observed, the aggregate shall be immediately replaced with fresh material. This gradation/angularity evaluation should be conducted periodically even for more durable backfill material. Note that if the backfill materials available in the region for which the approval authority has jurisdiction consistently cannot meet the maximum LA Abrasion requirement of 35 percent loss, a less durable aggregate may be used for all the backfill materials tested, at the discretion of the approval authority.

A1.1.1.4. The first nine prenumbered specimens identified on the exhumed sample shall be selected for testing. If any of these specimens were damaged due to the exhumation process, that specimen(s) shall be skipped, and the next consecutively numbered specimen(s) shall be selected for testing. If the coefficient of variation for the tensile test results of these first nine prenumbered specimens is

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greater than 5 percent, the required number of specimens shall be recomputed using the one-sided Student's *t*-distribution as required by ASTM D4595 or D6637/D6637M. The additional specimens shall be selected from the next consecutively numbered specimens.

**Note A2**—An alternative predetermined numbering scheme may be used to ensure that the sample locations are not biased within the sample with regard to damage patterns, provided that bias due to the visual appearance of specimen damage is eliminated.

A1.1.1.5. *Geosynthetic Testing*—Samples subjected to installation damage shall be tested for tensile strength and deformation characteristics in accordance with ASTM D4595 (geotextiles) or ASTM D6637/D6637M (geogrids and geostrips). The number of specimens tested should be in accordance with ASTM D4595 or D6637/D6637M. Single-rib tests shall not be used for installation damage evaluation, as it is difficult to assess the effect of severed ribs on the strength and stiffness of damaged materials. Test results from damaged specimens shall be compared to tensile test results obtained from undamaged (i.e., not exposed to installation conditions) control specimens.

A1.1.1.6. *Data Analysis and Report:*

A1.1.1.6.1 The installation damage reduction factor  $RF_{ID}$  is determined as follows:

$$P = \frac{T_{\text{dam}}}{T_{\text{baseline}}} \quad (A1.1)$$

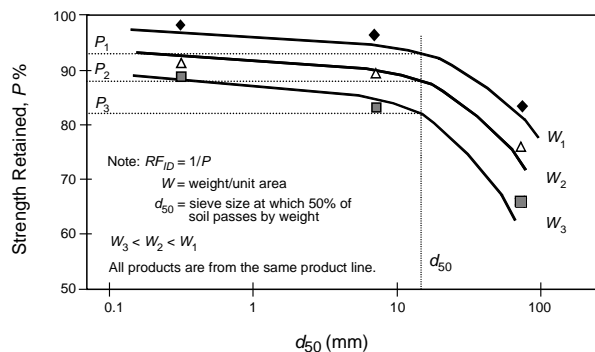
where:

$T_{\text{dam}}$  = the average roll/coil specific tensile strength after installation. In no case should  $RF_{ID}$  be less than 1.05; and

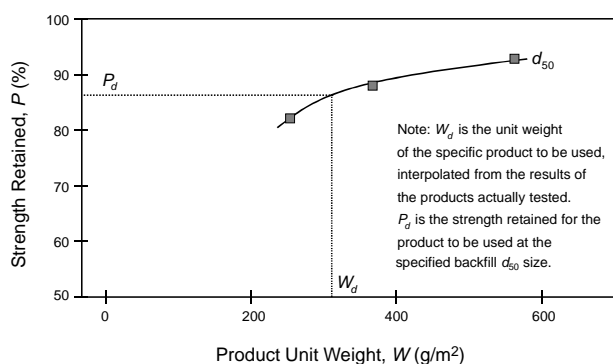
$T_{\text{baseline}}$  = the average roll/coil specific tensile strength before exposure to installation (baseline tensile strength for the installation damage test).

A1.1.1.6.2 To select an appropriate reduction factor for design, the project site installation conditions must be related to the installation test conditions. To relate the installation damage test conditions to the actual site conditions, primary consideration shall be given to the backfill characteristics ( $d_{50}$  particle size, potential for oversize material, particle angularity, and overall gradation) and, to a lesser degree, the method of spreading the backfill over the geosynthetic, the type of compaction equipment, and initial backfill lift thickness over the geosynthetic, provided that the initial lift thickness is 150 mm (6 in.) or more. The actual installation conditions used in the test must be clearly stated in the test report, specifically identifying any deviations from typical geosynthetic reinforcement installation practices in full-scale structures, and the impact those deviations have on the values of  $RF_{ID}$  determined.

A1.1.1.6.3 A repeatable interpolation procedure to estimate  $RF_{ID}$  for soils that fall between the soil gradations tested and for the products in the product line not tested (if not all the products in the product line are tested for installation damage resistance) shall be developed. Values of  $RF_{ID}$  may be estimated for a specified soil gradation using interpolation as illustrated in Figure A1.1. The  $d_{50}$  size of the soil has commonly been used for interpolating between soil backfills for determination of  $RF_{ID}$ . Other combinations of soil particle size and factors that account for soil angularity and durability may be considered for this correlation and interpolation procedure per mutual agreement between the geosynthetic manufacturer and the approval authority. The range of backfill gradations, angularity, and durability will affect the range of applicability of the  $RF_{ID}$  values obtained from the testing.  $RF_{ID}$  values should not be extrapolated beyond the coarsest backfill soil tested.

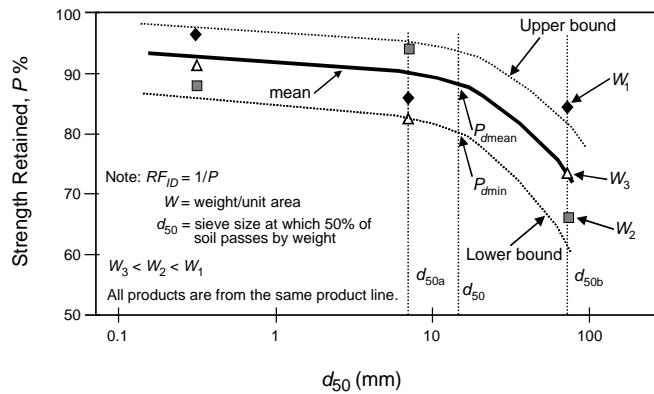


**Figure A1.1**—Example of Installation Damage Data as a Function of Backfill  $d_{50}$  Size for Several Products That Represent a Product Line When a Strong Relationship between a Product Index Property (e.g., Weight/Unit Area,  $W$ ) and Strength Retained Is Observed

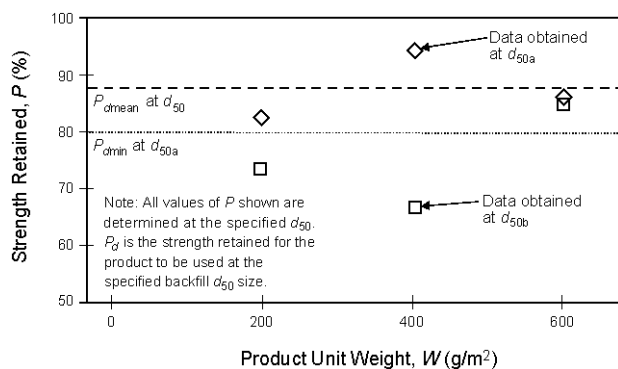


**Figure A1.2**—Example of Installation Damage Data Presentation That Can Be Used to Interpolate Values of Strength Retained for Products Not Installation Damage Tested When a Strong Relationship between a Product Index Property and Strength Retained Is Observed

**A1.1.1.6.4** If not all the products within a product line are tested for installation damage, interpolation between products to estimate  $RF_{ID}$  is required. The interpolation procedures used depend on whether or not there is strong relationship between a product property (e.g., weight/unit area, tensile strength) and the product's ability to resist damage. If the installation damage resistance of each product in the product line can be correlated to a product property, the interpolation procedure provided in Figures A1.1 and A1.2 may be used. The additional testing specified in Section 6.3.2.1 on the products in the line not subjected to the full suite of full-scale installation damage testing should be used to verify the adequacy of the correlation between the strength retained and the product property. In this case, the installation damage test results for the remaining products in the product line shall be greater than or equal to the 95 percent prediction limit for the regression of the primary and secondary product installation damage data (see Section 7.5.1.3.2 for procedures to be used to conduct this analysis).



**Figure A1.3**—Example of Installation Damage Data as a Function of Backfill  $d_{50}$  Size for Several Products That Represent a Product Line When a Weak Relationship between a Product Index Property and Strength Retained Is Observed



**Figure A1.4**—Example of Installation Damage Data Presentation That Can Be Used to Interpolate Values of Strength Retained for Products Not Installation Damage Tested When a Weak Relationship (or No Relationship) between a Product Index Property and Strength Retained Is Observed

If the installation damage resistance of each product in the product line cannot be strongly correlated to a product property, the interpolation/ $RF_{ID}$  product line assessment procedures for backfill gradation and product characteristics in Figures A1.3 and A1.4 may be used. From these two figures, a minimum strength retained value can be determined and applied to the entire product line. The additional installation damage testing specified in Section 6.3.2.1 on the products in the line not subjected to the full suite of full-scale installation damage testing should be used to verify the minimum value of strength retained to be used to establish  $RF_{ID}$ .

For coated polyester geogrids and geostrips, typical properties such as weight/unit area or tensile strength usually do not correlate well to installation damage and the magnitude of  $RF_{ID}$ . In that case, the coating thickness or coating mass per unit area relative to the mass per unit area of the

product should be considered for the purpose of correlating  $RF_{ID}$  between products rather than product unit weight or tensile strength alone.

**Note A3**—For coated geogrids and geostrips, the weight of coating placed on the fibers or yarns may influence the amount of installation damage obtained (Sprague et al., 1999). It is acceptable to obtain the coating mass/unit area through the use of manufacturer QC data on the lot specific mass/unit area of the uncoated material (i.e., the weight of the greige-good), subtracting that mass/unit area from the total mass/unit area of the finished product, if such data are available from the manufacturer. The total mass per unit area of the sample used in the installation damage testing should be obtained in accordance with ASTM D5261.

A1.2. *References:*

A1.2.1. Sprague, C. J., and S. A. Allen. "Testing Installation Damage of Geosynthetic Reinforcement," *Geotechnical Fabrics Report*, Vol. 21, No. 6, 2003, pp. 24–27.

## ANNEX B—CREEP STRENGTH AND STIFFNESS TESTING

(Mandatory Information)

### B1. CREEP TESTING AND EXTRAPOLATION PROCEDURES TO DETERMINE $RF_{CR}$ FOR GEOSYNTHETIC REINFORCEMENTS

B1.1. *General:*

B1.1.1. The effect of long-term load/stress on geosynthetic reinforcement strength and deformation characteristics shall be determined from the results of product-specific, long-term laboratory creep tests conducted for a range of load levels and durations, adequate for extrapolation purposes to the desired design life, carried out to rupture of the geosynthetic.

B1.2. *Creep Testing Requirements:*

B1.2.1. Creep testing, unless otherwise specified herein, shall be conducted in accordance with ASTM D5262 or D6992.

B1.2.1.1. Creep testing in accordance with ASTM D5262, carried out to rupture, and at elevated temperatures for the purpose of creep extrapolation using time–temperature superposition principles, is identified herein as the "block shifting method." ASTM D6992 (Stepped Isothermal Method, or SIM) is also identified herein as an alternative accelerated creep-testing method.

B1.2.1.2. For both test methods, unless otherwise specified or mutually agreed on by the geosynthetic supplier, the testing laboratory, and the owner, a baseline testing temperature of 68 °F (20 °C) shall be used for this testing. Higher test temperatures shall be considered as elevated temperatures to be used for the purpose of time extrapolation, unless a higher baseline temperature is needed to match the effective design temperature for a specific site.

B1.2.1.3. ASTM D5262 requires that the testing temperature be maintained at  $\pm 3.6^\circ\text{F}$  ( $2^\circ\text{C}$ ). For some polymers, this degree of variance could significantly affect the accuracy of the shift factors and extrapolations determined in accordance with this annex. For polymers that are relatively sensitive to temperature variations, this issue should be considered when extrapolating creep data using time–temperature superposition techniques; or minimized by using a tighter temperature tolerance.

B1.2.1.4. Specimens shall be tested in the direction in which the load will be applied in use.

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- B1.2.1.5. Single ribs for geogrids, or yarns or narrow width specimens for woven geotextiles, may be used for creep testing for the determination of  $RF_{CR}$  provided that it can be shown through a limited creep-testing program conducted as described in Section B1.7 that the rupture behavior and envelope for the single-rib, yarns, or narrow width specimens are the same as that for the full-width product as defined in ASTM D5262. This comparison must demonstrate that there is no statistical difference between the full-width product creep-rupture regression line and the single-rib, yarn, or narrow width specimen regression line at a time of 1000 h using Student's  $t$ -distribution at a confidence level of 0.10 (see Equation B1.3).
- B1.3. *Overview of Creep Extrapolation Approach:*
- B1.3.1. Test results shall be extrapolated to the required structure design life. Based on the extrapolated test results, for ultimate limit state design, determine the highest load, designated  $T_l$ , that precludes both ductile and brittle creep rupture within the required lifetime.  $T_l$  should be determined at the design site temperature. Creep test results may also need to be extrapolated (not necessarily to the structure design life) to estimate the long-term stiffness of the geosynthetic as specified in Section B2.
- B1.3.2. If elevated temperature is used to obtain accelerated creep data, minimum increments of 10°C should be used to select temperatures for elevated temperature creep testing. The highest temperature tested, however, should be below any transitions for the polymer in question. Using test temperatures below 70 to 75°C for PP, HDPE, and PET geosynthetics should allow significant polymer transitions to be avoided. If higher temperatures must be used, the effect of any transitions on the creep behavior should be carefully evaluated.
- Note B1**—At high temperatures, significant chemical interactions with the surrounding environment are possible, necessitating that somewhat lower temperatures or appropriate environmental controls be used. These chemical interactions are likely to cause the creep test results to be conservative. Therefore, from the user's point of view, potential for chemical interactions is not detrimental to the validity of the data for predicting creep limits. However, exposure to temperatures near the upper end of these ranges could affect the stress-strain behavior of the material due to loss of molecular orientation, or possibly other effects that are not the result of chemical degradation. Therefore, care needs to be exercised when interpreting results from tests performed at temperatures near or above the maximum test temperatures indicated above. In general, if the stiffness of the material after exposure to the environment is significantly different from that of the virgin material, the stress-strain properties, and possibly the strength, of the material may have been affected by the exposure temperature in addition to the chemical environment. If the stiffness has been affected, the cause of the stiffness change should be thoroughly investigated to determine whether or not the change in stiffness is partially or fully due to the effect of temperature, or alternatively not use the data obtained at and above the temperature where the stiffness was affected. The SIM does use temperatures above 75°C, and, at least for PET geosynthetics, test temperatures above this level have not adversely affected the accuracy of the SIM extrapolations.
- B1.4. *Extrapolation of Stress (Creep) Rupture Data:*
- B1.4.1. *Block Shifting Method:*
- B1.4.1.1. Obtain creep rupture data at a constant temperature for a range of load levels such that rupture times are evenly distributed through each log cycle of time at each temperature level. As a minimum, rupture envelopes should be established in this manner at the baseline temperature (i.e., real time creep data) and at two elevated temperatures (i.e., to facilitate extrapolation using time-temperature superposition principles). A minimum of 12 to 18 data points (i.e., combined from all temperature levels tested to produce the envelope for a given product, with a minimum of four data points to develop an envelope at each temperature) are required to establish a rupture envelope. Rupture points with a time to rupture of less than 5 h, in general, should not be used,



unless it can be shown that these shorter duration points are consistent with the rest of the envelope (i.e., they do not contribute to nonlinearity of the envelope).

**Note B2**—It is recognized that it is difficult to determine up front what load levels to use to achieve a given time to rupture, as time is the dependent variable in this case. The recommendations that follow in this note are simply target times to rupture to use to select a range of load levels to use. Therefore, as a guide, three of the test results should have rupture times (not shifted by temperature acceleration) of 10 to 100 h, four of the test results should have rupture times between 100 and 1000 h, and four of the test results should have rupture times of 1000 to 10,000 h, with at least one additional test result having a rupture time of approximately 10,000 h (1.14 years) or more. It is recommended that creep strain be measured as well as time to rupture, because the creep strain data may assist with time–temperature shifting and in identifying any change in behavior that could invalidate extrapolation of the results.

**B1.4.1.2.** Perform linear regressions of the rupture data obtained at each temperature to facilitate time–temperature superposition and statistical extrapolation of the creep–rupture data for each product tested, using load or load level as the independent variable and time as the dependent variable. To obtain a linear envelope, the data will usually need to be regressed as a function of the logarithm of time to rupture (i.e., semilog). This is usually sufficient to produce a good fit of the rupture data for PET reinforcements. If the rupture envelope is still not linear, then conducting the regression using the logarithm of load or load level and the logarithm of time should be used (i.e., log–log; this has been shown to apply to HDPE and PP reinforcements). Figure B1.1 illustrates regression of the data at each temperature as a function of the logarithm of time to rupture (i.e., a semilog plot). The regression technique that provides the best and most consistent fit of the data should be used.

**B1.4.1.3.** Extrapolate the creep–rupture data. Elevated temperature creep–rupture data can be used to extrapolate the rupture envelope at the design temperature through the use of a time shift factor,  $a_T$ . Use of a single time shift factor to shift all the creep–rupture data at a given temperature, termed “block shifting,” assumes that the shift factor  $a_T$  is not significantly stress level dependent and that the envelopes at all temperatures are approximately parallel, allowing an average value of  $a_T$  to be used for all of the rupture points at a given temperature.

The time to rupture for the elevated temperature rupture data is shifted in accordance with the following equation:

$$t_{\text{amb}} = (t_{\text{elev}})(a_T) \quad (B1.1)$$

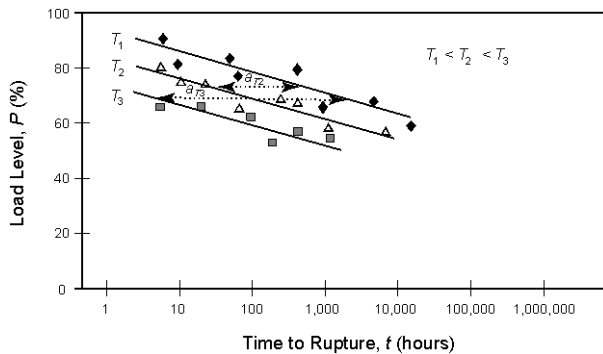
where:

$t_{\text{amb}}$  = the predicted time at the ambient or temperature to reach rupture under the specified load;  
 $t_{\text{elev}}$  = the measured time at elevated temperature to reach a rupture under the specified load; and  
 $a_T$  = the time shift factor.

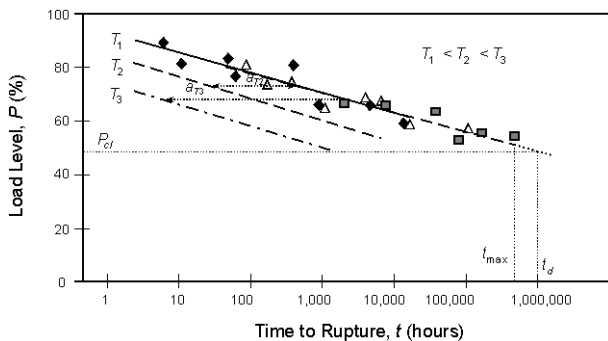
This single-shift factor and how it is used to extrapolate the rupture envelope is illustrated in Figures B1.1 and B1.2. A computer spreadsheet optimization program to select the best shift factors for each constant temperature block of data to produce the highest  $R^2$  value for the combined creep–rupture envelope to produce the result in Figure B1.2 should be used.

**Note B3**—Incomplete tests (i.e., creep tests in which rupture had not yet been achieved) may be included, with the test duration replacing the time to rupture, but should be listed as such in the reported results, provided that the test duration, after time shifting, is 10,000 h or more. The rule for incomplete tests is as follows: The regression should be performed with and without the incomplete tests included. If the incomplete test results in an increase in the creep limit, keep the incomplete tests in the regression, but if not, do not include them in the regression. Record the

duration of the longest test that has ended in rupture, or the duration of the longest incomplete test, the duration of which exceeds its predicted time to failure: this duration is denoted as  $t_{\max}$ .



**Figure B1.1**—Typical Stress Rupture Data for Geosynthetics, and the Determination of Shift Factors for Time-Temperature Superposition



**Figure B1.2**—Extrapolation of Stress Rupture Data and the Determination of the Creep Limit Load

**B1.4.1.4.** It is preferred that creep-rupture data not be extrapolated statistically beyond the elevated temperature time-shifted data. However, if statistical extrapolation is necessary, it shall be accomplished using regression analysis (i.e., curve fitting) up to a maximum of one log cycle of time for all geosynthetic polymers (greater extrapolation using only statistical methods is feasible, but uncertainty in the result increases substantially and must be taken into account). Therefore, adequate elevated temperature data should be obtained to limit the amount of statistical extrapolation required.

**Note B4**—There may be situations in which extrapolation to create a creep-rupture envelope at a lower temperature than was tested is necessary. Situations in which this may occur include the need to elevate the ambient temperature to have greater control regarding the temperature variations during the creep testing (i.e., ambient laboratory temperature may vary too much), or for sites where the effective design temperature is significantly lower than the “standard” reference temperature used for creep testing (e.g., northern or high-elevation climates). In such cases, it is feasible to use lower bound shift factors based on previous creep testing experience to allow the creep-rupture envelope to be shifted to the lower temperature, as shift factors for the materials

typically used for geosynthetic reinforcement are reasonably consistent. Based on previous creep testing experience and data reported in the literature (Chow and Van Laeken, 1991; Thornton et al. 1998; Thornton et al., 1998a; Lothspeich and Thornton, 2000; Takemura, 1959; Bush, 1990; Popelar et al., 1990; Wrigley et al., 1999; Takaku, 1981; Thornton and Baker, 2002), shift factors for HDPE and PP geosynthetics are typically in the range of 0.05 to 0.18 decades (i.e., log cycles of time) per 1°C increase in temperature (i.e., a 10°C increase would result in a time shift factor of 12 to 15) and 0.05 to 0.12 decades per 1°C increase in temperature for PET geosynthetics. It is recommended that if shifting the creep-rupture envelope to temperatures below the available data is necessary, a shift factor of 0.05 decades per 1°C increase in temperature for PP, HDPE, and PET be used. This default shift factor should not be used to shift the creep-rupture data more than 10°C.

#### B1.4.1.5.

Once the creep data have been extrapolated, determine the design, roll/*coil* specific, creep limit load by taking the load level at the desired design life directly from the extrapolated stress rupture envelope as shown in Figure B1.2. If statistical extrapolation beyond the time-shifted stress rupture envelopes (PP or HDPE), or beyond the actual data if temperature accelerated creep data are not available, is necessary to reach the specified design life, the calculated creep limit load  $T_l$  should be reduced by an extrapolation uncertainty factor as follows:

$$T_l = \frac{P_{cl} T_{baseline}}{1.2^{x-1}} \quad (B1.2)$$

where:

- $T_l$  = the creep limit load,
- $P_{cl}$  = the creep limit load level taken directly from the extrapolated stress rupture envelope,
- $T_{baseline}$  = the average roll/*coil* specific ultimate tensile strength (ASTM D4595 or ASTM D6637/D6637M) for the roll/*coil* of material used for the creep testing, and
- $x$  = the number of log cycles of time the rupture envelope must be extrapolated beyond the actual or time-shifted data and is equal to  $\log t_d - \log t_{max}$  as illustrated in Figure B1.2.

The factor  $1.2^{x-1}$  is the extrapolation uncertainty factor. If extrapolating beyond the actual or time-shifted data less than one log cycle, set “ $x-1$ ” equal to “0.” This extrapolation uncertainty factor applies only to statistical extrapolation beyond the actual or time-shifted data using regression analysis and assumes that a “knee” in the rupture envelope beyond the actual or time-shifted data does not occur.

**Note B5**—A condition on the extrapolation is that there is no evidence or reason to believe that the rupture behavior will change over the desired design life. It should be checked at long durations and at elevated temperatures, if used, that:

- There is no apparent change in the gradient of the creep-rupture curve.
- There is no evidence of disproportionately lower strains to failure.
- There is no significant change in the appearance of the fracture surface.

Any evidence of such changes, particularly in accelerated tests, should lead to the exclusion of any reading in which either the gradient, strain at failure, or appearance of the failure is different from those in the test with the longest failure duration. Particular attention is drawn to the behavior of unoriented thermoplastics under sustained load, where a transition in behavior is observed in long-term creep-rupture testing (i.e., the so-called “ductile to brittle transition”—Popelar et al., 1991). The effect of this transition is that the gradient of the creep-rupture curve becomes steeper at the so-called “knee” such that long-term failures occur at much shorter lifetimes than would otherwise be predicted. The strain at failure is greatly reduced and the appearance of the fracture surface changes from ductile to semibrittle. If this is observed, any extrapolation should assume that

the “knee” will occur. For the method of extrapolation, reference should be made to ISO/FDIS 9080:2012, ASTM D2837, and Popelar et al. (1991).

- B1.4.1.6. The extrapolation uncertainty factor also assumes that the data quality is good, data scatter is reasonable, and that approximately 12 to 18 well-distributed data points define the stress rupture envelope for the product. If these assumptions are not true for the data in question, this uncertainty factor should be increased. This extrapolation uncertainty factor should be increased to as much as 1.4x if there is the potential for a “knee” in the stress rupture envelope to occur beyond the actual or time-shifted data, or if the data quality, scatter, or amount is inadequate. Furthermore, if the data quantity or distribution over the time scale is inadequate, it may be necessary to begin applying the extrapolation uncertainty factor before the end of the time-shifted data.

**Note B6**—Based on experience, the  $R^2$  value for the composite (i.e., time-shifted) creep-rupture envelope should be approximately 0.8 to 0.9 or higher to be confident that Equation B1.2 will adequately address the extrapolation uncertainty. If the  $R^2$  value is less than approximately 0.6 to 0.7, extrapolation uncertainty is likely to be unacceptably high and additional testing and investigation should be performed. In general, such low  $R^2$  values are typically the result of data that is too bunched up, unusually high specimen-to-specimen variability, or, possibly, poor testing technique.

- B1.4.2. *Stepped Isothermal Method (SIM):*

- B1.4.2.1. The testing and analysis shall be conducted in accordance with ASTM D6992. SIM may be used to generate and extrapolate geosynthetic creep and creep-rupture data, provided this method is shown to produce results that are consistent with the block shifting extrapolation techniques recommended in Section B1.4.1. To verify consistency, creep-rupture testing shall be conducted using ASTM D5262 tests and SIM tests (ASTM D6992). At least six SIM rupture tests and six ASTM D5262 rupture tests shall be conducted on one of the products in the product line being evaluated. Typically, the product tested is the one defined as the primary product in Section 6.3.2.

**Note B7**—It is recognized that it is difficult to determine up front what load levels to use to achieve a given time to rupture, as time is the dependent variable in this case. The recommendations that follow in this note are simply target times to rupture to use to select a range of load levels to use. Therefore, as a guide, of the six SIM rupture tests, one should have a rupture time (shifted as appropriate) of less than 100 h; one should have a rupture time of greater than 100 h and less than 2000 h; two should have rupture times of greater than 2000 h and less than 100,000 h; and two should have rupture times of greater than 100,000 h. For the ASTM D5262 creep tests, the rupture points should be as evenly distributed as possible between rupture times of 5 and 10,000 h. All of the real-time creep rupture points shall be obtained at the reference temperature (i.e., not temperature shifted). For the real-time creep-rupture tests, the test with the longest rupture time should have a rupture time that is approximately 10,000 h.

- B1.4.2.2. Creep-rupture plots shall be constructed, regression lines computed, and the rupture envelopes compared at a load level that corresponds to 500 h and 100,000 h on the ASTM D5262 creep-rupture envelope for the two data sets. The log time to rupture for the SIM regression at this load level shall be within the upper and lower 90 percent confidence limits of the mean ASTM D5262 creep regressed rupture time at the same load level using Student’s  $t$ -test.

- B1.4.2.3. The confidence limit for the regression performed for the ASTM D5262 creep-rupture data is given by (Wadsworth, 1998):

$$\log t_L = \log t_{\text{reg}} \pm \left[ t_{\alpha, n-2} \sqrt{\frac{1}{n} + \frac{(P - \bar{P})^2}{\sum (P_i - \bar{P})^2}} \right] \times \sigma \quad (B1.3)$$

and

$$\sigma = \sqrt{\frac{\sum [\log t_i - \log \bar{t}]^2 - \frac{\left\{ \sum [(P_i - \bar{P})(\log t_i - \log \bar{t})] \right\}^2}{\sum (P_i - \bar{P})^2}}{n - 2}} \quad (B1.4)$$

where:

- $\log t_L$  = lower and upper bound confidence limit (the + or – term in Equation B1.3 results in the lower and upper bound confidence limits, respectively);
- $t_{reg}$  = time corresponding to the load level from the ASTM D5262 creep-rupture envelope at which the comparison between the two envelopes will be made (e.g., at 500 and 100,000 h after time shifting);
- $t_{\alpha, n-2}$  = value of the Student's  $t$ -distribution determined from applicable Student's  $t$ -table (or from the Microsoft Excel function  $TINV(\alpha, n-2)$ ) at  $\alpha = 0.10$  and  $n-2$  degrees of freedom (this corresponds to the 90 percent two-sided prediction limit);
- $n$  = the number of rupture or allowable run-out points in the original test sample (i.e., the ASTM D5262 creep-rupture data);
- $P$  = load level obtained at  $t_{reg}$  from the regression line developed from the ASTM D5262 creep-rupture testing;
- $\bar{P}$  = the mean rupture load level for the original test sample (i.e., all rupture or run-out points used in the regression to establish the ASTM D5262 creep-rupture envelope);
- $P_i$  = the rupture load level of the  $i$ th point for the rupture points used in the regression for establishing the conventional creep-rupture envelope;
- $\log \bar{t}$  = the mean of the log of rupture time for the original test sample (i.e., all rupture or run-out points used in the regression to establish the conventional creep-rupture envelope); and
- $t_i$  = the rupture time of the  $i$ th point for the rupture points used in the regression for establishing the conventional creep-rupture envelope.

Once  $\log t_L$ , both upper and lower bound, has been determined at the specified load level, compare these values to the log rupture time (i.e.,  $\log t_{SIM}$ ) obtained for the SIM creep-rupture envelope test at the specified load level (e.g., 500 and 100,000 h). The value of  $\log t_{SIM}$  at the two specified load levels must be between the upper and lower bound confidence limits ( $\log t_L$ ). If this requirement is not met, perform two additional SIM tests at each load level  $P$  for the specified  $t_{reg}$  where this comparison was made, and develop a new SIM creep-rupture envelope using all of the SIM data. If, for the revised SIM regression envelope resulting from these additional tests, this criterion is still not met, perform adequate additional creep-rupture testing using the block shifting method to establish the complete rupture envelope for the product in accordance with this Annex.

- B1.4.2.4. If the criterion provided above is met, the SIM testing shall be considered to be consistent with the ASTM D5262 data, and SIM may be used in combination with the ASTM D5262 data to meet the requirements of Section B1.4 regarding the number of rupture points and their distribution in time and maximum duration. Therefore, the combined data can be used to create the creep-rupture envelope as shown in Figure B1.2. In that figure, the SIM data shall be considered to already be time shifted. Equation B1.2 is then used to determine  $T_L$ . If, for a given product or product line, SIM has been previously demonstrated to be consistent with the conventional creep data, and it is known that the product or product line has not changed significantly with regard to the polymer and the product processing, SIM data may continue to be used without performing a new comparison between the SIM and ASTM D5262 data. In this case, a minimum of 12 rupture points that are well distributed over the full range of time to be evaluated shall be obtained.

**Note B8**—As a guide, the distribution of rupture points after time–temperature shifting (or real time for those data points that are obtained at the reference temperature, i.e., not accelerated by elevated temperature) for the SIM, or SIM and real-time creep-rupture tests in combination, should be as follows: three points at rupture times of less than 100 h, four points at rupture times of greater than 100 h and less than 2000 h, four points at rupture times of greater than 2000 h and less than 100,000 h, and two points at rupture times of greater than 100,000 h.

**B1.5.** *Extrapolation of Creep Strain Data:*

- B1.5.1.** While it is possible to use creep strain data to estimate  $T_i$ , it generally provides no practical advantage over taking creep test specimens to rupture to develop a creep-rupture envelope. Therefore, detailed procedures to use creep strain data for this purpose are not provided in this standard practice. See WSDOT T 925 (WSDOT 2005) for additional information and discussion on use of creep strain data for this purpose, as well as other related information and guidance on handling creep strain data.

**B1.6.** *Determination of  $RF_{CR}$ :*

- B1.6.1.** The creep reduction factor,  $RF_{CR}$ , is determined by comparing the long-term creep strength,  $T_i$ , to the ultimate tensile strength (ASTM D4595 or ASTM D6637/D6637M) of the sample tested for creep ( $T_{baseline}$ ). The sample tested for ultimate tensile strength should be taken from the same roll/coil of material used for the creep testing. The strength reduction factor to prevent long-term creep rupture is determined as follows:

$$RF_{CR} = \frac{T_{baseline}}{T_i} \quad (B1.5)$$

where:

$T_{baseline}$  = the average roll/coil specific ultimate tensile strength (ASTM D4595 or ASTM D6637/D6637M) for the roll/coil of material used for the creep testing.

- B1.6.2.** This creep reduction factor takes extrapolation uncertainty into account, but does not take into account variability in the strength of the material. Material strength variability shall be taken into account when  $RF_{CR}$  is applied to  $T_{ult}$  to determine the long-term strength, using the minimum average roll value or minimum value for  $T_{ult}$ .

**B1.7.** *Evaluation of Product Lines with Regard to Creep Data:*

- B1.7.1.** For creep evaluation of a new product not part of the original product line, but, based on the definition of a product line in Sections 3.18 and 6.3, considered as part of the original product line, this limited testing program should include creep tests taken to at least 1000 to 2000 h in duration before time shifting if using the block shifting creep testing approach, with adequate elevated temperature data to permit extrapolation to 100,000 h or more. If it has been verified that the use of SIM is acceptable for the product line in accordance with Section B1.4.2.2, durations after time shifting due to elevated temperature up to a minimum of approximately 100,000 h are required. A minimum of four data points per temperature level tested should be obtained to determine time-shift factors and to establish the envelope for the new product. The data points, after time shifting, should be as evenly distributed along the time axis as possible. This comparison between the creep-rupture data obtained for the original product line and the creep data for the new product shall demonstrate that there is no statistical difference between the regression lines for the existing product line and the new product at a time of 500 h (not temperature accelerated) and 100,000 h (after time shifting) using Student's  $t$ -distribution at a confidence level of 0.10 (see Section B1.4.2.3, specifically Equation B1.4). If no statistical difference is observed, the results from the full testing program for the original product line could be applied to the new product. If this is not the case, then a full testing and evaluation program for the new product should be conducted (i.e., treat it as a primary product as defined in Section 6.3.2).

B1.7.2. For extension of the creep data obtained on one product in the product line (i.e., the primary product tested, which is typically a product in the middle of the range of products in the product line) to the entire product line as defined herein, a limited creep testing program shall be conducted on at least two additional products in the product line in accordance with Section 6.3.1. The combination of the three or more products should span the full range of the product line in terms of weight and/or strength. The limited test program described in Section B1.7.1 shall be applied to these additional products. The loads obtained for the data in each envelope should then be normalized by the roll/coil specific ultimate tensile strength,  $T_{\text{baseline}}$ . All three envelopes should plot on top of one another, once normalized in this manner, and the two additional product envelopes should be located within the confidence limits for the product with the more fully developed creep-rupture envelope (i.e., the “primary” product) as described in Section B1.7.1. If this is the case, then the creep reduction factor for the product line shall be the lesser of: (1) the reduction factor obtained for the product with the fully developed rupture envelope, and (2) the envelope of all three products combined. Normalization using the ultimate tensile strength shall be considered acceptably accurate if this is the case. If this is not the case, then the creep-rupture envelopes for the two products, plus enough other products within the product line, shall be determined, to establish the trend in  $RF_{CR}$  as a function of product weight or ultimate tensile strength, so that the  $RF_{CR}$  for the other products within the product line can be accurately interpolated. Furthermore,  $T_{al}$  must be determined in accordance with Note B9.

**Note B9**—Note that normalization using the ultimate lot specific tensile strength may not be completely accurate for some geosynthetic products regarding characterization of creep-rupture behavior, and other normalization techniques may be needed (Wrigley et al., 1999). In such cases, individual creep reduction factors for each product in the product line may need to be established through fully developed creep-rupture envelopes for representative products obtained at the low-, middle-, and high-strength end of the product series. Once the creep limited strength,  $T_i$ , and the creep reduction factors are established for each product, in this case, product variability must still be taken into account. In such cases,  $T_{al}$  must be the lesser of the determination from Equation 1 and the following determination:

$$T_{al} = \frac{P_{95}}{RF_{ID} \times RF_D} \quad (B1.6)$$

where:

$P_{95}$  = the tensile strength determined from the 95 percent lower bound prediction limit for the creep-rupture envelope at the specified design life (see Equations 4 and 5 in Section 7.5.1.3.2).

## B2. ESTIMATION OF CREEP STIFFNESS

B2.1. *General:*

B2.1.1. Unless otherwise specified per agreement of the parties involved, the creep stiffness should be determined at a strain level of 2 percent. The stiffness value to be used for geosynthetic structure design should be determined at the end of construction ( $J_{EOC}$ ) or at the end of the structure design life ( $J_{DL}$ ). Either ASTM D5262 creep testing may be used, or SIM may be used to estimate the stiffness if SIM is determined to be consistent with the ASTM D5262 creep strain, especially at low strain levels. If comparison between SIM creep strain data and ASTM D5262 creep strain data at low strain levels has not been conducted, then comparison testing between the two approaches will be needed if it is desired to use SIM for the products tested at low strain levels.  $J_{EOC}$  should be determined at 1000 h from creep data, unless another time period is specified by the parties involved to match the actual or anticipated time required to construct the geosynthetic structure for which the stiffness values are to be used.

**Note B10**—The primary purpose of this stiffness calculation is to provide input data for working stress methods such as the K-Stiffness method (Allen et al., 2003; WSDOT, 2013), or for more sophisticated analyses such as finite element or finite difference numerical simulations. The time

period on which the stiffness value  $J_{EOC}$  is to be based is typically 1000 h, or the time required to construct the geosynthetic structure. See Walters et al. (2002) and Allen and Bathurst (2002) for a detailed explanation regarding the time period that should be used to determine  $J_{EOC}$ .

**B2.2.** *Creep Stiffness Testing and Analysis Requirements:*

**B2.2.1.** The load application rate during creep load ramp up should be consistent with the application rate used in the governing tensile test method (e.g., ASTM D4595 or D6637/D6637M). If it is not possible to accurately apply the load at a specified rate (e.g., if dead weight is applied through the use of a jack), the actual application rate should be measured and recorded.

**B2.2.2.** The slack tension,  $T_o$ , applied to the specimen based on the governing tensile test (e.g., ASTM D4595 or D6637/D6637M) will likely be too large for creep stiffness testing due to the very low loads that are likely for this type of testing. A maximum slack tension of approximately 10 percent of the anticipated load at 2 percent strain or 9 N (2 lbf), whichever is less, should be used for single-rib or narrow width specimens. For full-width specimens (i.e., per ASTM D5262), a maximum slack tension of approximately 10 percent of the anticipated load at 2 percent strain or 70 N (15 lbf), whichever is less, should be used. Because these maximum slack tension values differ from what is specified in ASTM D4595 and ASTM D6637/D6637M, a special set of tensile tests may need to be conducted for use with the low strain creep stiffness testing program. ASTM D4595 and D6637/D6637M allow both the slack tension and the slack displacement,  $d_o$ , to be set to zero for calculation purposes. For low strain creep stiffness testing, the slack displacement should be set to zero, but the slack tension should be left at its full value for stiffness calculation purposes.

**B2.2.3.** If it has been shown that single-rib/narrow width specimens can be used in lieu of full-width specimens for creep testing at high load levels (see Section B1.2.1.5), single-rib/narrow width specimens may also be used for low strain creep stiffness testing if respective short-term tensile tests also indicate no significant specimen width effects. The maximum difference between the mean values of the load at 2 percent strain in the single-rib/narrow width tensile tests and the full-width tensile tests must be no greater than what is considered statistically insignificant based on a one-sided Student's  $t$ -distribution at a level of significance of 0.05, as determined using Equation 3 in Section 7.5.1.2.1.

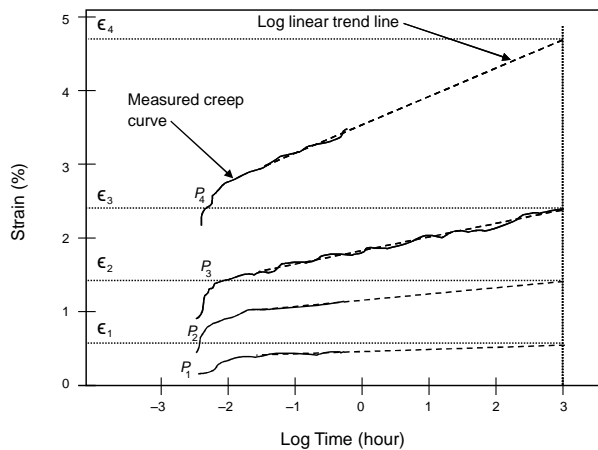
**B2.2.4.** Obtain creep strain data for at least one load level low enough to produce a strain level at the end of structure construction (assume to be 1000 h unless otherwise specified by the approval authority). Per agreement between the approval authority and the reinforcement manufacturer, load levels to produce additional 1000-h strain levels may be tested. A minimum of two specimens per product at each load level shall be tested.

**B2.2.5.** To establish the load levels needed to produce the desired 1000-h strains for each product, conduct a series of 1000-s R+H tests. An initial estimate of the load levels needed for the R+H tests may be obtained from the tensile tests used to establish  $T_{baseline}$  for each product tested. Test a load level that is likely to produce a strain of approximately 2 percent at 1000 h, and then two other load levels to bracket the 2 percent load level (e.g., at load levels that would yield approximately 1 percent strain and 3 to 4 percent strain at 1000 h). Do three replicate R+H tests at each of those load levels, plotting the load level as a function of the estimated strain at 1000 h, assuming a log linear extrapolation is valid for the R+H test results. The creep data extrapolation and analysis process is illustrated in Figures B2.1 and B2.2. Perform a regression analysis of that data to obtain a more accurate estimation of the load level required to produce a strain of 2 percent at 1000 h, and run three replicate R+H tests at that load level. If one of the load levels used for the R+H tests does not produce an estimated strain of 2 percent at 1000 h, a fourth set of three replicate R+H tests may be needed, estimating the load level based on a regression of the R+H tests for the first three load levels. Then conduct two full 1000-h creep tests at the R+H load level that results in the closest estimate to 2 percent strain at 1000 h.

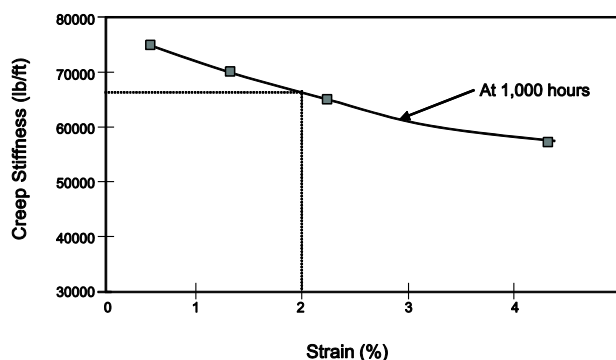


**Note B11**—It is desirable to conduct the full 1000-h creep tests at the R+H load levels tested so that a direct comparison can be made between the 1000-h creep tests and the R+H tests. If the creep observed in the 1000-h creep tests is, in fact, log linear, the R+H tests can then be used for quality assurance testing in the future.

**B2.2.6.** If log linear extrapolation of the short-term creep data is not feasible, create creep stiffness curves at the desired constant strain level (typically 2 percent) as shown in Figures B2.1 and B2.2, but without using R+H tests to establish the creep stiffness as a function of strain at the desired time (i.e., all creep curves must instead be taken to at least 1000 h without log linear extrapolation). Elevated temperature extrapolation should not be necessary if the “conventional” approach is used. Be sure that the creep stiffness curve is developed at the desired effective design temperature.



**Figure B2.1**—Strain versus Time for Short-Term, Low Strain Creep Tests Used to Estimate Secant Stiffness



**Figure B2.2**—Creep Stiffness Determined from the Creep Curves at the Specified Time (see Figure B2.3) as a Function of Strain

B2.2.7. Obtain the creep stiffness at the desired time from the creep stiffness curve as shown in Figure B2.2. The creep stiffness from each creep test at the specified time is calculated as follows:

$$J = \frac{P \times T_{\text{baseline}}}{\epsilon} \quad (B2.1)$$

where:

- $J$  = the secant creep stiffness determined at the specified strain level and time;
- $P$  = the load level expressed as a percent of  $T_{\text{baseline}}$ ;
- $T_{\text{baseline}}$  = the roll/coil specific tensile strength of the sample used for the creep testing; and
- $\epsilon$  = the strain in percent.

These  $J$  values are then used to generate the plot shown in Figure B2.2.

B2.2.8. To extend the creep stiffness values obtained from the testing to the rest of the product line, a minimum of three products in the product line spanning the range of products in the line (i.e., the primary product, and the low and high end of the line in terms of strength) shall be tested as described in Section B1.7.2. To interpolate to other products between the products tested, determine  $T_{\text{baseline}}$  for each product tested, plotting the creep stiffness values obtained in Section B2.2.5 as a function of  $T_{\text{baseline}}$ , as illustrated in Figure B2.3. Creep stiffness values for other products in the product line not tested may be interpolated based on their baseline tensile strengths, if the relationship illustrated in Figure B2.3 is observed for the product line. If not, product-specific testing should be conducted for all products in the product line.

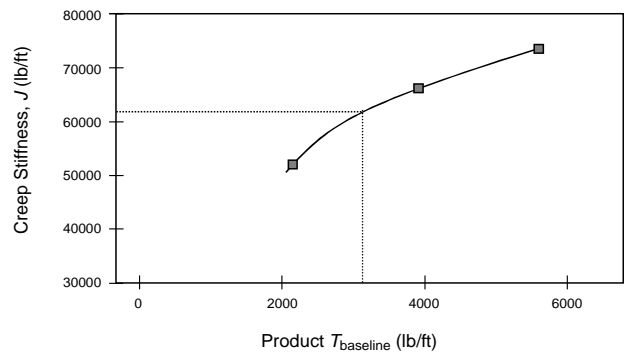


Figure B2.3—Example of Creep Stiffness,  $J$ , as a Function of  $T_{baseline}$

B2.2.9. Once the values for the creep stiffness are determined for each product in the product line, the stiffness values need to be adjusted to reflect the MARV or minimum value for the geosynthetic, so that a minimum stiffness that accounts for uncertainty in the strength of the material is determined, similar to what is done for the determination of  $T_{ul}$ . Calculate the design stiffness value as follows:

$$J_{design} = \frac{J \times T_{ult}}{T_{baseline}} \tag{B2.2}$$

where:

- $J_{design}$  = the low strain design stiffness value at the specified time (e.g.,  $J_{EOC}$ , etc.); and
- $T_{ult}$  = the minimum ultimate tensile strength (MARV) of the reinforcement determined in accordance with ASTM D4595 for geotextiles and ASTM D6637/D6637M for geogrids and geostrips.
- $J_{design}$  = accounts for the variability in the product tensile strength through the use of  $T_{ult}$ .

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## ANNEX C—CHEMICAL DURABILITY TESTING

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(Mandatory Information)

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### C1. PRODUCT-SPECIFIC TESTING AND DATA INTERPRETATION REQUIREMENTS TO DETERMINE $RF_D$ FOR GEOSYNTHETIC REINFORCEMENTS

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#### C1.1. *General:*

C1.1.1. This annex provides guidance regarding the performance of long-term product-specific durability testing that may be conducted in lieu of the durability index testing as described in Section 6.4.1.5. The procedures that follow are required if it is desired to use a value of  $RF_D$  less than the default minimum of 1.3, or to determine  $RF_D$  for environments that are defined as aggressive.

C1.1.2. This annex has been developed to address PP, PE, HDPE, and PET geosynthetics. While the chemical and biological durability procedures and criteria provided herein may also be applicable to other polymers (e.g., hydrolysis testing as described herein is likely applicable to PA and PVA geosynthetics), additional investigation will be required to establish a detailed protocol and acceptance criteria for these other polymers. These other polymers may be considered for evaluation using this protocol once modifications to the chemical/biological durability aspects of this protocol have been developed and are agreed on by the approval authority.

#### C1.2. *Durability Testing Requirements:*

C1.2.1. The product-specific durability studies for the determination of  $RF_D$  should be conducted in or, if necessary, extrapolated to, the chemical/biological environment anticipated in the reinforced backfill. The anticipated temperature of the environment is also a key variable in assessing the durability of a given product, as temperature can have an exponential effect on the rate of product property change. Higher design temperatures may need to be considered for structures with southern exposures. The effective design temperature will be assumed to be 20°C (68°F). Therefore, determine  $RF_D$  at a temperature of 20°C (68°F) unless otherwise specified and agreed on by the parties involved.

C1.2.2. Standards are currently not available for determining the effect of chemical/biological activity on long-term geosynthetic reinforcement strength. However, long-term product-specific durability testing can be conducted in a manner that is likely to produce safe results.

C1.2.3. Geosynthetic durability may be evaluated using either retrieval and testing of geosynthetics in actual installations or through long-term accelerated laboratory testing. Use of field retrieval data from actual installations requires that the baseline, in terms of tensile strength before and immediately after installation, and possibly other properties, be known with certainty, and that the observation period be of sufficient length to permit extrapolation to the desired design life.

**Note C1**—The field retrieval approach, in general, is fraught with practical and technical difficulties (see Allen and Elias, 1996; Elias, 2000; and Elias, 2001). Furthermore, long periods of time may be needed for polyolefins to establish trends that can be extrapolated due to the presence of antioxidants, as no loss in strength will be observed until the antioxidants are used up. Elias (2001) suggests that 30 years of in-service time may be required to obtain adequate observational data for polyolefins, and even PET products may require 20 years of in-service observations or more to accomplish this. Because of the very long observation periods required, long-term laboratory durability testing is the more practical approach to dealing with the durability issue. An overview of an appropriate laboratory testing approach for each geosynthetic polymer type is provided herein.

- C1.2.4. For polyolefin products in which the fibers/ribs do not exhibit microcracks or crazes as manufactured, long-term chemical durability testing may consist of elevated temperature oven-aging tests to evaluate potential for oxidation effects (FHWA, 1997; Elias et al., 1997; Salman et al., 1998; Elias et al., 1999). A magnification of  $\times 2000$  to  $\times 3000$  may be needed to observe whether or not microcracks or crazes are present (Salman et al., 1997). If microcracks or crazes are present, elevated temperatures may significantly affect the molecular structure of polyolefins in the vicinity of the microcracks/crazes, making extrapolation of elevated temperature oxidation behavior to the behavior of the as-manufactured product at ambient temperatures very difficult (Salman et al., 1998). For polyolefins in which the fibers/ribs exhibit microcracks or crazes, a means other than elevated temperature should be considered to accelerate oxidation behavior.
- C1.2.5. *Oven Aging for Thermo-Oxidation Potential for Polyolefin Geosynthetics:*
- C1.2.5.1. If oven-aging tests are conducted, a forced-air oven is strongly recommended to keep the environment inside the oven as uniform as possible during the entire test duration and to keep oxidation products from building up inside the oven, considering the long durations that are likely to be required. Temperature uniformity inside the oven should be maintained at  $\pm 1$  percent. An oven with horizontal air flow is recommended. Specimens should be placed in the oven parallel to the air flow and spaced no closer together than 13 mm (0.5 in.) apart.
- C1.2.5.2. The specimens should not be framed to prevent shrinkage as doing this will create load in the specimen, making the resulting data difficult to interpret.
- C1.2.5.3. Oxidation testing using forced-air ovens will produce conservative estimates of long-term product strength due to the rapid air circulation and the relatively high oxygen content in the oven relative to the oxygen content in the ground.
- C1.2.6. *Hydrolysis Testing for Polyester Geosynthetics:*
- C1.2.6.1. For polyesters, long-term chemical durability testing should consist of elevated temperature immersion tests to evaluate potential for hydrolysis effects. A reactor similar to that illustrated in Elias et al. (1999) is recommended for incubating the geosynthetic specimens. A description of the test protocol is provided by Elias et al. (1999). The reactor should be capable of maintaining temperature uniformity ( $\pm 1$  percent) and stability during long-term use. A minimum solid-to-liquid ratio of 1:40 should be used to size the reactor and to determine the maximum number of specimens that can be placed in the reactor.
- C1.2.6.2. Measures should be taken to minimize possibilities for oxidation and reaction with carbon dioxide during the long-term incubation (e.g., replace any air inside the reactor with nitrogen, use de-aired water, keep system well sealed, etc.).
- C1.2.6.3. Specimens should be suspended in the solution on a hanger made of a material that will not react with or contaminate the immersion fluid and specimens (e.g., Teflon, stainless steel, etc.). The specimens should not be framed to prevent shrinkage so that an unknown amount of tension is not placed on the specimens. Specimens should each be separated by a distance of at least 13 mm (0.5 in.).
- C1.2.6.4. The solution should be intensively stirred to ensure solution uniformity.
- C1.2.6.5. For coated polyester ~~products~~ **geogrid and geostrip**, the immersion tests should be conducted without the coating or the coated specimen ends should not be recoated (i.e., the ends of the core polymer should be left exposed to the immersion liquid).
- C1.2.6.6. Elevated temperatures should be used to accelerate the degradation process, which allows the data to be extrapolated to the desired design life.

- C1.2.6.7. Hydrolysis data should be submitted for the product at a pH of approximately 7 (i.e., neutral conditions—distilled water), at a pH of 9 or more, and at a pH of 4 or less to facilitate the determination of  $RF_D$ .  $RF_D$  should be determined at a pH of 7 and at an alkaline pH (i.e., a pH of 9) as a minimum. If very acidic soils are anticipated (i.e., a pH near the bottom limit of pH = 4 for conditions defined as nonaggressive),  $RF_D$  should be determined at a pH of 4 as well.

**Note C2**—EPA 9090 testing or the ASTM equivalent (ASTM D5322) is not considered adequate for a laboratory testing program to provide an estimate of  $RF_D$ . However, EPA 9090 or ASTM D5322 testing can be used as a first cut screening tool. That is, if any significant degradation of the strength of the product in question is observed for the chemical environment tested, the product would be disqualified for use in that chemical environment unless longer-term testing conducted in accordance with this annex is performed. EPA 9090 testing (or ASTM D5322) could also be used to verify the effects of certain environmental variables that are known, based on the literature, to not significantly affect the given material. For example, based on the literature, low or high pH is known to have little effect on polyolefins. This type of testing could be used to verify that the low or high pH does not affect the tensile strength of a polyolefin product, to allow that product to be used in environments that have a pH outside the range defined as a nonaggressive environment.

- C1.3. *Requirements for Durability Laboratory Test Parameters and Data Interpretation:*

- C1.3.1. Incubation temperatures for the testing should be high enough to adequately accelerate the degradation process, but below any major transitions in polymer behavior (e.g., glass transition, melting). Maximum recommended test temperatures to avoid major transitions are on the order of 70 to 75°C for PP, HDPE, and polyester, except as discussed above for polyolefin products that have microcracks or crazes as manufactured. However, exposure to temperatures near the upper end of these ranges could affect the stress-strain behavior of the material due to loss of molecular orientation, or possibly other effects that are not the result of chemical degradation. Therefore, care needs to be exercised when interpreting results from strength testing after exposure to temperatures near the maximum test temperatures indicated above.

- C1.3.2. In general, if the stiffness of the material after exposure to the environment is significantly different from that of the virgin material, the stress-strain properties, and possibly the strength, of the material may have been affected by the exposure temperature in addition to the chemical environment. If the stiffness has been affected, the cause of the stiffness change should be thoroughly investigated to determine whether or not the change in stiffness is partially or fully due to the effect of temperature or, alternatively, not use the data obtained at and above the temperature where the stiffness was affected. It is additionally recommended that the Arrhenius plot of the data be checked for linearity (see the discussion of Arrhenius modeling in Sections C1.3.8 and C1.3.9). As a minimum, two to three data points above and below the suspected transition should be obtained and the plot checked for linearity through the entire range of temperatures, if it is desired to validate the use of data above the suspected transition for Arrhenius modeling and extrapolation purposes.

- C1.3.3. A minimum of four test temperatures is recommended, typically spaced monotonically at 10°C increments (e.g., see ASTM D3045), except as discussed above for some polyolefin products.

**Note C3**—At the lowest test temperature (e.g., 30 to 50°C), incubation times of 2 to 4 years should be anticipated to get data adequate for long-term extrapolation.

- C1.3.4. Enough retrievals (e.g., a minimum of four retrievals) should be made at a given test condition to adequately define the property loss as a function of incubation time.

- C1.3.5. As a minimum, degradation should be tracked using the tensile strength of the specimens retrieved from the incubation chambers. Full **wide**-width (ASTM D4595 or D6637/D6637M) specimens are preferred; however, single-rib or yarn specimens may be used.

- C1.3.6. It is recommended that degradation be tracked by chemical means, if possible, as well as through the use of scanning electron microscope (SEM) micrographs to verify the significance of the mechanical property degradation observed.
- C1.3.7. The statistical variation of the measured properties after degradation is likely to be greater than what would be observed for the virgin material. This may require that the number of specimens per retrieval be greater than what the property variation for the virgin material would indicate.
- C1.3.8. Extrapolation of chemical durability data for polymers typically utilizes an Arrhenius approach, though there is evidence which suggests that the Arrhenius model does not always work well for geosynthetics. Assuming Arrhenius modeling is appropriate, the slope of the strength degradation versus time plots (transformed mathematically to be linear through zero-, first-, or second-order Arrhenius equations) may be used to characterize the degradation behavior as a function of temperature, allowing the slope at the desired design temperature to be estimated through the Arrhenius extrapolation. The equation order that best fits the data should be used (see Salman et al., 1998, for details). The strength retained at a given time at the design temperature can be calculated directly from the linear equation with the extrapolated slope. Note that Arrhenius modeling may also be conducted as a function of reactant (oxygen) concentration and pressure instead of temperature (Shelton and Bright, 1993; Salman et al., 1998). The extrapolation concept would be similar to that used for temperature. See Shelton and Bright (1993); Salman et al. (1997, 1998); Elias et al. (1999); and Elias (2000) for guidance on Arrhenius modeling techniques as applied to geosynthetics. Also note that because the extrapolation is being conducted over several log cycles of time, uncertainty in the data should be considered when determining the retained strength at the design life and design environment.
- C1.3.9. For polyolefin oxidation, Arrhenius modeling will likely need to be conducted in two steps, as there are two main phases in the oxidation process for polyolefins: (1) the induction phase, in which antioxidant consumption is the primary activity and little, if any, product strength loss occurs; and (2) the main polymer oxidation phase, in which oxidative degradation of the polyolefin occurs, resulting in strength loss, and can generally be described by the kinetics of a Basic Auto-Oxidation Scheme (Salman et al., 1997; Elias et al., 1999). An Arrhenius model for the first phase should be developed so that the induction period,  $t_{ind}$ , at the design temperature or reactant (i.e., oxygen) concentration can be estimated. A second Arrhenius model should then be developed using only the data after the induction period, and time in this case would begin at the end of the induction period at each temperature or reactant concentration tested. This second Arrhenius model is then extrapolated to the design temperature or reactant concentration to estimate the strength loss anticipated at the desired design life minus the induction period. Analysis of the remaining antioxidant content provides an additional method of measuring the duration of the phase I oxidation process, particularly at lower temperatures and long durations, because changes in the antioxidant content take place ahead of the reduction in strength. Note that if the estimated induction period at the design environment is greater than the desired design life, this second phase Arrhenius modeling is unnecessary.
- C1.3.10. Once the tensile strength at a given design life and design temperature has been estimated from the test data, determine  $RF_D$  as follows:

$$RF_D = \frac{T_{baseline}}{T_D} \quad (C1.1)$$

where:

- $T_{baseline}$  = the average roll/coil specific ultimate tensile strength for the roll/coil of material used for  
 — the durability testing; and
- $T_D$  = the extrapolated (i.e., to the required design life) lot specific tensile strength after degradation based on the laboratory aging tests.



In no case should  $RF_D$  be less than 1.1.

**Note C4**—Biological degradation has not proved to be a serious factor in the service life of geosynthetics. This is because the high molecular weight PE, polyester, polypropylene, and PA used are not easily broken down by bacteria and fungi. The high tensile strength of soil reinforcements prevents them from damage by roots or burrowing animals such as rabbits. For this reason, in general, it is not necessary to consider biological degradation in defining  $RF_D$ . However, the possibility of biological degradation should be reviewed if new polymers other than those described are used. Biological durability, if specifically requested by the approval authority, should be evaluated based on ASTM D3083, except the test should be modified to use ASTM D4595 or D6637/D6637M as the tensile test method. If any significant tensile strength loss is observed, as determined using ASTM D4595 or D6637/D6637M, additional longer-term testing should be performed before the product is further considered for use in reinforcement applications (see Bright, 1993).

C1.4. *Evaluation of Product Lines with Regard to Durability Data:*

C1.4.1. For evaluation of a new product that was not part of the original product line, but, based on the definition of a product line in Sections 3.18 and 6.3.1, should be considered as part of the original product line, this limited testing program should include laboratory aging tests with a 1000- to 2000-h incubation period in the same environment used for the full testing program conducted previously, conducted at a temperature near but slightly below any major property transitions. These limited durability test results must show that the durability performance of the product is equal to or better than the performance of the product(s) previously tested. If so, the results from the full testing program used to characterize the product line could be used for the new product. If not, then a full testing and evaluation program for the new product should be conducted.

C1.4.2. For extension of the laboratory aging data obtained on one product in the product line (i.e., the primary product tested, which is typically a product in the middle of the range of products in the product line) to the entire product line as defined herein, a limited laboratory aging program shall be conducted on at least two additional products in the product line. The combination of the three or more products should span the full range of the product line in terms of weight and/or strength. Alternatively, if the primary product tested is the weakest/lightest weight product in the product line, only one secondary product need be tested to characterize the product line. The limited test program described in Section C1.4.1 shall be applied to these additional (secondary) products.

## C2. REFERENCES

- C2.1. AASHTO. *Standard Specifications for Highway Bridges*, Seventeenth Edition. American Association of State Highway and Transportation Officials, Washington, DC, 2002.
- C2.2. Allen, T. M. and V. Elias. *Durability of Geosynthetics for Highway Applications—Interim Report*, FHWA-RD-95-016. Federal Highway Administration, U.S. Department of Transportation, Washington, DC, 1996.
- C2.3. ASTM. *Annual Book of Standards*, Vols. 4.08 and 4.09, *Soil and Rock*. American Society for Testing and Materials, Philadelphia, PA, 1994.
- C2.4. ASTM. *Annual Book of Standards*, Vol. 8.04, *Elastic Pipe and Building Materials*. American Society for Testing and Materials, West Conshohocken, PA, 1994.
- C2.5. Bright, D. G. "The Environmental Stress Cracking of Polymers Used in Geosynthetic Products." *Geosynthetics '93 Conference*, Vancouver, B.C., 1993, pp. 925–934.

- C2.6. Elias, V. *Corrosion/Degradation of Soil Reinforcements for Mechanically Stabilized Earth Walls and Reinforced Soil Slopes*, FHWA-NHI-00-044. Federal Highway Administration, U.S. Department of Transportation, Washington, DC, 2000.
- C2.7. Elias, V. *Durability/Corrosion of Soil Reinforced Structures*, FHWA/RD-89/186. Federal Highway Administration, U. S. Department of Transportation, Washington, DC, 1990.
- C2.8. Elias, V. *Long-Term Durability of Geosynthetics Based on Exhumed Samples from Construction Projects*, FHWA RD-00-157. Federal Highway Administration, U.S. Department of Transportation, Washington, DC, 2001.
- C2.9. Elias, V., J. DiMaggio, and A. DiMillio. "FHWA Technical Note on the Degradation-Reduction Factors for Geosynthetics." In *Geotechnical Fabrics Report*, Vol. 15, No. 6, 1997, pp. 24–26.
- C2.10. Elias, V., A. Salman, I. Juran, E. Pearce, and S. Lu. *Testing Protocols for Oxidation and Hydrolysis of Geosynthetics*, FHWA RD-97-144. Federal Highway Administration, U.S. Department of Transportation, Washington, DC, 1999.
- C2.11. FHWA. *Degradation Reduction Factors for Geosynthetics*, Federal Highway Administration Geotechnology Technical Note. Federal Highway Administration, U.S. Department of Transportation, Washington, DC, 1997.
- C2.12. Salman, A., V. Elias, and A. DiMillio. "The Effect of Oxygen Pressure, Temperature, and Manufacturing Processes on Laboratory Degradation of Polyolefin Based Geosynthetics." *Sixth International Conference on Geotextiles, Geomembranes, and Related Products*, Atlanta, GA, 1998.
- C2.13. Salman, A., V. Elias, I. Juran, S. Lu, and E. Pearce. "Durability of Geosynthetics Based on Accelerated Laboratory Testing." *Geosynthetics '97 Conference*, IFAI, San Diego, CA. Industrial Fabrics Association International, St. Paul, MN, 1997, pp. 217–234.
- C2.14. Shelton, W. S. and D. G. Bright. "Using the Arrhenius Equation and Rate Expressions, to Predict the Long-Term Behavior of Geosynthetic Polymers." *Geosynthetics '93 Conference*, Vol. 2, Vancouver, BC, 1993, pp. 789–802.

<sup>1</sup> Formerly AASHTO Provisional Standard PP 66. First published as a full standard in 2015.

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**Standard Specification for**

**Geosynthetic Specification**

**for Highway Applications**

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AASHTO Designation: M 288-~~17~~20

Technical Subcommittee: 4e, Joints, Bearings,  
and Geosynthetics

Release: Group 2 (June)

American Association of State Highway and Transportation Officials  
444 North Capitol Street N.W., Suite 249  
Washington, D.C. 20001

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### 1. SCOPE

- 1.1. This is a materials specification covering geosynthetics for use in subsurface drainage, separation, stabilization, erosion control, temporary silt fence, paving, and soil (walls and slopes). This is a material purchasing specification and design review of use is recommended.
- 1.2. This specification sets forth a set of physical, mechanical, and endurance properties that must be met or exceeded by the geosynthetic being manufactured.
- 1.3. In the context of quality systems and management, this specification represents a manufacturing quality control (MQC) document. However, its general use is essentially as a recommended design document.
- 1.4. This specification is intended to assure both good quality and performance of geosynthetics used as listed in Section 1.1, but is possibly not adequate for the complete specification in a specific situation, especially in reinforcement applications. Additional tests, more restrictive values for the tests indicated, or values based on project specific design may be necessary under conditions of a particular application.
- 1.5. Minimum strength values provided in this specification are based on geosynthetic survivability from installation stresses. Designers should be aware that the classes and/or property requirements in this specification reflect this basic premise. Refer to Appendix X1 for most geosynthetic construction guidelines.

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### 2. REFERENCED DOCUMENTS

- 2.1. *AASHTO Standards:*
  - R 69, Determination of Long-Term Strength for Geosynthetic Reinforcement
  - T 88, Particle Size Analysis of Soils
  - T 90, Determining the Plastic Limit and Plasticity Index of Soils
  - T 99, Moisture–Density Relations of Soils Using a 2.5-kg (5.5-lb) Rammer and a 305-mm (12-in.) Drop
  - T 289, Determining pH of Soil for Use in Corrosion Testing

## 2.2.

*ASTM Standards:*<sup>1</sup>

- D123, Standard Terminology Relating to Textiles
- D276, Standard Test Methods for Identification of Fibers in Textiles
- D4354, Standard Practice for Sampling of Geosynthetics and Rolled Erosion Control Products (RECPs) for Testing
- D4355/D4355M, Standard Test Method for Deterioration of Geotextiles by Exposure to Light, Moisture and Heat in a Xenon Arc Type Apparatus
- D4439, Standard Terminology for Geosynthetics
- D4491, Standard Test Methods for Water Permeability of Geotextiles by Permittivity
- D4533/D4533M, Standard Test Method for Trapezoid Tearing Strength of Geotextiles
- D4595, Standard Test Method for Tensile Properties of Geotextiles by the Wide-Width Strip Method
- D4603, Standard Test Method for Determining Inherent Viscosity of Poly(Ethylene Terephthalate) (PET) by Glass Capillary Viscometer
- D4632/D4632M, Standard Test Method for Grab Breaking Load and Elongation of Geotextiles
- D4751, Standard Test Methods for Determining Apparent Opening Size of a Geotextile
- D4759, Standard Practice for Determining the Specification Conformance of Geosynthetics
- D4873/D4873M, Standard Guide for Identification, Storage, and Handling of Geosynthetic Rolls and Samples
- D4884/D4884M, Standard Test Method for Strength of Sewn or Bonded Seams of Geotextiles
- D5035, Standard Test Method for Breaking Force and Elongation of Textile Fabrics (Strip Method)
- D5141, Standard Test Method for Determining Filtering Efficiency and Flow Rate of the Filtration Component of a Sediment Retention Device
- D5261, Standard Test Method for Measuring Mass per Unit Area of Geotextiles
- D6140, Standard Test Method to Determine Asphalt Retention of Paving Fabrics Used in Asphalt Paving for Full-Width Applications
- D6241, Standard Test Method for Static Puncture Strength of Geotextiles and Geotextile-Related Products Using a 50-mm Probe
- D6637/D6637M, Standard Test Method for Determining Tensile Properties of Geogrids by the Single or Multi-Rib Tensile Method
- D7409, Standard Test Method for Carboxyl End Group Content of Polyethylene Terephthalate (PET) Yarns

## 2.3.

*U.S. Environmental Protection Agency:*

- EPA/600/R-93/182, Quality Assurance and Quality Control for Waste Containment Facilities

## 2.4.

*Other Standards:*

- ISO 13438:2004(en), Geotextiles and geotextile-related products—Screening test method for determining the resistance to oxidation
- GRI-GG8, Determination of the Number Average Molecular Weight of PET Yarns Based on a Relative Viscosity Value

### 3. TERMINOLOGY

- 3.1. *effective design temperature*—The temperature that is halfway between the average yearly air temperature and the normal daily air temperature for the warmest month at the reinforced soil structure site.
- 3.2. *enhancement*—The use of a geotextile in wet, saturated conditions to provide the coincident functions of separation, filtration, and stabilization (i.e., enhancement).
- 3.3.3.2. *formulation*—The mixture of a unique combination of ingredients identified by type, properties, and quantity. For geosynthetics, a formulation is defined as the exact percentages and types of resin(s), additives, and/or carbon black.
- 3.3. *geogrid (uniaxial or biaxial)*—A geosynthetic formed by a regular network of integrally connected elements with apertures greater than 1/4 inch to allow interlocking with surrounding soil, rock, earth, and other surrounding materials to function primarily as reinforcement. A uniaxial geogrid is defined as ? and a biaxial geogrid is defined as ?.
- 3.4. *geosynthetic*—A class of products consisting of manufactured planar materials used in geotechnical applications, and is inclusive of both geotextiles and geogrids.
- 3.5. *geotextile (woven or nonwoven)*—A permeable geosynthetic comprised solely of textiles.
- 3.5.3.6. *Manufacturing Quality Control (MQC)*—A planned system of inspections that is used to directly monitor and control the manufacture of a material that is factory originated. MQC is normally performed by the manufacturer of geosynthetic materials and is necessary to ensure minimum (or maximum) specified values in the manufactured product. MQC refers to measures taken by the manufacturer to determine compliance with the requirements for materials and workmanship as stated in certification documents and contract specifications [ref. EPA/600/R-93/182].
- 3.6.3.7. *Minimum Average Roll Value (MARV)*—For geosynthetics, a MQC tool used to allow manufacturers to establish published values such that the user/purchaser will have a 97.7 percent confidence that the property in question, when tested, will meet published values. For normally distributed data, MARV is calculated as the average value minus two standard deviations from documented quality control test results for a defined population from one specific test method associated with one specific property.
- 3.7.3.8. *minimum value*—The lowest sample value from documented MQC test results for a defined population from one test method associated with one specific property.
- 3.8.3.9. *maximum value*—The highest sample value from documented MQC test results for a defined population from one test method associated with one specific property.
- Note 1**—Other terminology related to textiles (e.g., nonwoven) and geosynthetics (e.g., apparent opening size) may be used in this specification. Definitions for this terminology may be found in ASTM D123 or D4439.

**Commented [SH1]:** "enhancement" definition is not needed anymore. See later comment about removing 8.5.

**Commented [SH2]:** From ASTM D4439

**Commented [SH3]:** Uniaxial and biaxial not defined or mentioned in ASTM D123 or D4439. Therefore, define here but what definition to use? Need to develop one?

**Commented [SH4]:** Woven and nonwoven terms defined/mentioned in ASTM D123

**Commented [SH5]:** From ASTM D4439

### 4. PHYSICAL REQUIREMENTS

- 4.1. Fibers, yarns, straps, and sheets used in the manufacture of geotextiles and geogrids used in a reinforcement application, and the threads used in joining geotextiles by sewing, shall consist of long-chain synthetic polymers, composed of at least 95 percent, by weight, polyolefins or polyesters. They shall be formed into a stable network such that the filaments, yarns, or ribs retain their dimensional stability relative to each other, including selvages. Fibers used in the manufacture of geotextiles for paving fabrics requiring low ultimate elongation, and the threads

used in joining these geotextiles by sewing, shall consist of combinations of glass fibers or fiberglass and long-chain synthetic polymers, with the combination composed of at least 95 percent, by weight, of fiberglass, polyesters, or polyolefins.

- 4.2. Geotextiles used for subsurface drainage, separation, [soil](#) stabilization, and permanent erosion control applications shall conform to the physical requirements of Section 8. Geotextiles used for temporary silt fence shall conform to the physical requirements of Section 9, and geotextiles used as paving fabrics shall conform to the physical requirements of Section 10. Geotextiles and geogrids used for reinforced soil applications shall conform to the physical requirements of Section 11. [Geotextiles and geogrids used for subgrade stabilization shall conform to the physical requirements of Section 12.](#)
- 4.3. All property values, with the exceptions of apparent opening size (AOS) and property values in Table [940](#) and Table [104](#), in these specifications represent MARV in the weakest principal direction (i.e., average test results of any roll in a lot sampled for conformance or quality assurance testing shall meet or exceed the minimum values provided herein). Values for AOS represent maximum average roll values. Values for properties in Table [940](#) and Table [104](#) are as indicated in those tables.

## 5. CERTIFICATION

- 5.1. The contractor shall provide to the engineer a manufacturer certificate stating the name of the manufacturer; product name; style number; chemical composition of the filaments, yarns, straps, or sheets; and other pertinent information to fully describe the geosynthetic. For soil reinforcement, independent [third-party](#) test data used to identify values for creep, durability, and installation damage must be included with the product certification.
- 5.2. 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 on request. The manufacturer shall have a quality control program that includes an on-site laboratory accredited by the Geosynthetic Accreditation Institute, Laboratory Accreditation Program (GAI-LAP) to perform the required test methods.
- 5.3. The manufacturer's certificate shall state that the furnished geosynthetic meets MARV requirements, except as otherwise specified, of the specification as evaluated under the manufacturer's quality control program. A person having legal authority to bind the manufacturer shall attest to the certificate.
- 5.4. Products without proper identification or labeling, mislabeling, or misrepresentation of materials shall be reason to reject those geosynthetic products.

**Commented [SH6]:** Don't "independent" and "third party" mean the same thing? Same comment below in 6.1.

## 6. SAMPLING, TESTING, AND ACCEPTANCE

- 6.1. All geosynthetics shall be subject to sampling and testing to verify conformance with this specification. Sampling shall be in accordance with the most current ASTM D4354, using the section titled "Procedure for Sampling for Purchaser's Specification Conformance Testing." In the absence of purchaser's testing, verification may be based on manufacturer's certifications as a result of testing by the manufacturer or by an independent [third-party](#) laboratory accredited by GAI-LAP to perform the required test methods, of quality assurance samples obtained using the procedure for sampling for manufacturer's quality assurance (MQA) testing. A lot size shall be considered to be the shipment quantity of the given product or a truckload of the given product, whichever is smaller.

- 6.2. 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. Geosynthetic product acceptance shall be based on ASTM D4759. Product acceptance is determined by comparing the average test results of all specimens within a given sample to the specification MARV except as otherwise specified. Refer to ASTM D4759 for more details regarding geosynthetic acceptance procedures.

**Note 2**—The purchasing agency may specify and require the geosynthetic manufacturer to participate in the applicable AASHTO National Transportation Product Evaluation Program's (NTPEP's) Audit Program for Geosynthetics (GTX, ~~& REGeo~~ and ~~SSGeo~~) depending on the product application. Along with this NTPEP program participation requirement, purchasing agencies may require the manufacturer to have public status data in NTPEP's DataMine, current publically released NTPEP Reports on Laboratory Results of Evaluations, or product or product lines submitted for evaluation under the applicable product application program. The purchasing agency may require the public status data or NTPEP Reports on Laboratory Results of Evaluations to show the physical properties of the geosynthetic product or product line is in compliance with either M 288 or the required project design requirements for reinforced soil applications (geosynthetic reinforcement).

**Commented [SH7]:** SSGEO is new NTPEP Geosynthetic Work Plan that will cover subgrade stabilization geosynthetics.

## 7. IDENTIFICATION, SHIPMENT, AND STORAGE

- 7.1. The identification, shipment, and storage of geosynthetics shall follow ASTM D4873/D4873M. Product labels shall clearly show the manufacturer or supplier name, style name, and roll number. Each shipping document shall include a notation certifying that the material is in accordance with the manufacturer's certificate.

**Note 3**—If the purchasing agency specifies and requires the manufacturer to participate in the AASHTO NTPEP's Audit Program for Geosynthetics (GTX, ~~& REGeo~~ and ~~SSGeo~~), each unique product will require additional product marking and labeling to be in compliance with the AASHTO NTPEP Geosynthetic GTX, ~~REGeo or SSGEO Work Plans or REGeo Work Plan~~, as applicable.

- 7.2. Each geotextile roll and, if required, each geogrid roll shall be wrapped with a material that will protect the geosynthetic, including the ends of the roll, from damage due to shipment, water, sunlight, and contaminants. The protective wrapping shall be maintained during periods of shipment and storage. Each geotextile roll and, if required, each geogrid roll shall include an inner core made from different material that shall protect, ensure ease of handling, and prevent damage from forklifts or other equipment used to transfer or move the geosynthetic roll.

**Note 4**—Polypropylene (PP) and high density polyethylene (HDPE) geogrids may not require an outer wrapping material or an inner core material. PP and HDPE geogrids should be covered for long-term outside storage.

- 7.3. During storage, geosynthetic rolls shall be elevated off the ground and adequately covered to protect them from the following: site construction damage; precipitation; extended ultraviolet radiation, including sunlight; chemicals that are strong acids or strong bases; flames, including welding sparks; temperatures in excess of 71°C (160°F); and any other environmental condition that may damage the physical property values of the geosynthetic.

## 8. GEOTEXTILE PROPERTY REQUIREMENTS FOR SUBSURFACE DRAINAGE, SEPARATION, SOIL STABILIZATION, ~~ENHANCEMENT,~~ AND PERMANENT EROSION CONTROL

- 8.1. *General Requirements:*



- 8.1.1. Table 1 provides strength properties for ~~four~~ **three** geotextile classes. The geotextile shall conform to the properties of Table 1 based on the geotextile class required in Table 2, 3, 4, 5, ~~6~~, or ~~67~~ for the indicated application.
- 8.1.2. All numeric values in Table 1 represent MARV in the weaker principal direction. The geotextile properties required for each class are dependent on geotextile elongation. When sewn seams are required, the seam strength, as measured in accordance with ASTM D4632/D4632M, shall be equal to or greater than 90 percent of the specified grab strength.

**Commented [SH8]:** Missed this change in version sent to Tim.

## 8.2. Subsurface Drainage Requirements:

8.2.1. *Description*—This specification is applicable to placing a geotextile against a soil to allow for long-term passage of water into a subsurface drain system retaining the *in situ* soil. The primary function of the geotextile in subsurface drainage applications is filtration. Geotextile filtration properties are a function of the *in situ* soil gradation, plasticity, and hydraulic conditions.

8.2.2. *Geotextile Requirements*—The geotextile shall meet the requirements of Table 2. Woven slit film geotextiles (i.e., geotextiles made from yarns of a flat, tape-like character) will not be allowed. All numeric values in Table 2, except AOS, represent MARV in the weaker principal direction. Values of AOS represent maximum average roll values.

**Table 1**—Geotextile (Classes 1-3) Strength Property Requirements

	Test Methods	Unit	Geotextile Class <sup>a,b</sup>						
			Class 1A	Class 1		Class 2		Class 3	
			Elongation <sup>c</sup> <50%	Elongation <sup>c</sup> <50%	Elongation <sup>c</sup> ≥50%	Elongation <sup>c</sup> <50%	Elongation <sup>c</sup> ≥50%	Elongation <sup>c</sup> <50%	Elongation <sup>c</sup> ≥50%
Grab strength	ASTM D4632/ D4632M	N	— <sup>d</sup>	1400	900	1100	700	800	500
Sewn seam strength <sup>d</sup>	ASTM D4632/ D4632M	N	— <sup>d</sup>	1260	810	990	630	720	450
Tear strength	ASTM D4533/ D4533M	N	— <sup>d</sup>	500	350	400 <sup>d</sup>	250	300	180
Puncture strength	ASTM D6241	N	— <sup>d</sup>	2750	1925	2200	1375	1650	990
Permittivity	ASTM D4491	sec <sup>-1</sup>	Refer to Table 6.	Minimum property values for permittivity, AOS, and UV stability are based on geotextile application. Refer to Table 2 for subsurface drainage, Table 3 and Table 4 for separation, Table 5 for soil stabilization, and Table 6 <sup>7</sup> for permanent erosion control.					
Apparent opening size	ASTM D4751	mm	Refer to Table 6.						
Ultraviolet stability (retained strength)	ASTM D4355/ D4355M	%	Refer to Table 6.						

<sup>a</sup> Required geotextile class is designated in Table 2, 3, 4, 5, 6, or 6<sup>7</sup> for the indicated application. The severity of installation conditions for the application generally dictates the required geotextile class. Class 1A and Class 1 are specified for more severe or harsh installation conditions where there is a greater potential for geotextile damage, and Classes 2 and 3 are specified for less severe conditions.

<sup>b</sup> All numeric values represent MARV in the weaker principal direction. (See Section 8.1.2.)

<sup>c</sup> As measured in accordance with ASTM D4632/D4632M.

<sup>d</sup> When sewn seams are required. Refer to Appendix X1 for overlap seam requirements.

<sup>e</sup> Property requirement not applicable to Class 1A. Refer to Table 6 for enhancement for wide width tensile property requirement.

<sup>f</sup> The required MARV tear strength for woven monofilament geotextiles is 250 N.

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**Table 2—Subsurface Drainage Geotextile Requirements**

Test Methods	Units	Requirements, Percent <i>in situ</i> Soil Passing 0.075 mm <sup>a</sup>		
		<15	15 to 50	>50
Geotextile class		Class 2 from Table 1 <sup>b</sup>		
Permittivity <sup>c,d</sup>	ASTM D4491 sec <sup>-1</sup>	0.5	0.2	0.1
Apparent opening size <sup>c,d</sup>	ASTM D4751 mm	0.43 max avg roll value	0.25 max avg roll value	0.22 <sup>e</sup> max avg roll value
Ultraviolet stability (retained strength)	ASTM D4355/D4355M	50% after 500 h of exposure		

<sup>a</sup> Based on grain size analysis of *in situ* soil in accordance with T 88.

<sup>b</sup> Default geotextile selection. The engineer may specify a Class 3 geotextile from Table 1 for trench drain applications based on one or more of the following:

1. The engineer has found Class 3 geotextiles to have sufficient survivability based on field experience.
2. The engineer has found Class 3 geotextiles to have sufficient survivability based on laboratory testing and visual inspection of a geotextile sample removed from a field test section constructed under anticipated field conditions.
3. Subsurface drain depth is less than 2 m; drain aggregate diameter is less than 30 mm; and compaction requirement is less than 95 percent of T 99.

<sup>c</sup> These default filtration property values are based on the predominant particle sizes of *in situ* soil. In addition to the default permittivity value, the engineer may require geotextile permeability and/or performance testing based on engineering design for drainage systems in problematic soil environments.

<sup>d</sup> Site-specific geotextile design should be performed especially if one or more of the following problematic soil environments are encountered: unstable or highly erodible soils such as noncohesive silts; gap-graded soils; alternating sand/silt laminated soils; dispersive clays; and/or rock flour.

<sup>e</sup> For cohesive soils with a plasticity index in accordance with T 90 greater than seven, geotextile maximum average roll value for apparent opening size is 0.30 mm.

8.2.3. The property values in Table 2 represent default values that provide sufficient geotextile survivability under most construction conditions. Note *b* of Table 2 provides for a reduction in the minimum property requirements when sufficient survivability information is available. The engineer may also specify properties different from those listed in Table 2 based on engineering design experience.

### 8.3. Separation Requirements:

8.3.1. *Description*—This specification is applicable to the use of a geotextile to prevent mixing of a subgrade soil and an aggregate cover material (subbase, base, select embankment, etc.). This specification may also apply to situations other than beneath pavements where separation of two dissimilar materials is required, but where water seepage through the geotextile is not a critical function.

8.3.2. The separation application is appropriate for pavement structures constructed over soils with a California Bearing Ratio equal to or greater than 3 ( $\text{CBR} \geq 3$ ) (shear strength greater than approximately 90 kPa). It is appropriate for unsaturated subgrade soils. The primary function of a geotextile in this application is separation.

8.3.3. *Geotextile Requirements*—The geotextile shall meet the requirements of Table 3. All numeric values in Table 3 except AOS represent MARV in the weakest principal direction. Values for AOS represent maximum average roll values.

**Table 3—Separation Geotextile Property Requirements**

	Test Methods	Units	Requirements
Geotextile class			See Table 4
Permittivity	ASTM D4491	sec <sup>-1</sup>	0.05 <sup>a</sup>
Apparent opening size	ASTM D4751	mm	0.60 max avg roll value
Ultraviolet stability (retained strength)	ASTM D4355/D4355M	%	50% after 500 h of exposure

<sup>a</sup> Default value. Permittivity of the geotextile should be greater than that of the soil ( $\Psi_g > \Psi_s$ ). The engineer may also require the permeability of the geotextile to be greater than that of the soil ( $k_g > k_s$ ).

**Table 4—Required Degree of Survivability as a Function of Subgrade Conditions, Construction Equipment, and Lift Thickness (Class 1, 2, and 3 properties are given in Table 1. Class 4+A properties are given in Table 126)<sup>a</sup>**

	Low Ground-Pressure Equipment ≤25 kPa (3.6 psi)	Medium Ground-Pressure Equipment >25 to ≤50 kPa (>3.6 to ≤7.3 psi)	High Ground-Pressure Equipment >50 kPa (>7.3 psi)
Subgrade has been cleared of all obstacles except grass, weeds, leaves, and fine wood debris. Surface is smooth and level so that any shallow depressions and humps do not exceed 450 mm (18 in.) in depth or height. All larger depressions are filled. Alternatively, a smooth working table may be placed.	Low (Class 3)	Moderate (Class 2)	High (Class 1)
Subgrade has been cleared of obstacles larger than small to moderate-sized tree limbs and rocks. Tree trunks and stumps should be removed or covered with a partial working table. Depressions and humps should not exceed 450 mm (18 in.) in depth or height. Larger depressions should be filled.	Moderate (Class 2)	High (Class 1)	Very High (Class 4+A)
Minimal site preparation is required. Trees may be felled, delimbed, and left in place. Stumps should be cut to project not more than ±150 mm (±6 in.) above subgrade. Geotextile may be draped directly over the tree trunks, stumps, large depressions and humps, holes, stream channels, and large boulders. Items should be removed only if placing the geotextile and cover material over them will distort the finished road surface.	High (Class 1)	Very High (Class 4+A <sup>b</sup> )	Very High (Class 4+A)

<sup>a</sup> Recommendations are for 150 to 300 mm (6 to 12 in.) initial lift thickness. For other initial lift thicknesses:

1. 300 to 450 mm (12 to 18 in.): reduce survivability requirement one level;
2. 450 to 600 mm (18 to 24 in.): reduce survivability requirement two levels;
3. >600 mm (24 in.): reduce survivability requirement three levels.

For special construction techniques such as prerutting, increase the geotextile survivability requirement one level. Placement of excessive initial cover material thickness may cause bearing failure of the soft subgrade.

<sup>b</sup> Default geotextile selection. The engineer may specify a Class 1 geotextile from Table 1 based on one or more of the following:

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

8.3.4. The property values in Table 3 represent default values that provide for sufficient geotextile survivability under most construction conditions. The engineer may also specify properties different from those listed in Table 3 based on engineering design and experience.

#### 8.4. *Soil Stabilization Requirements:*

8.4.1. *Description*—This specification is applicable to the use of a geotextile in wet, saturated conditions to provide the ~~coincident~~ *primary* functions of separation and filtration. In some installations, the geotextile can also provide the function of reinforcement. *Soil stabilization is defined as chemical or mechanical treatment designed to increase or maintain the stability of a mass of soil or otherwise to improve its engineering properties.* Geotextiles for soil stabilization are considered mechanical treatment in this specification. Soil stabilization is applicable to fill materials and pavement structures constructed over soils with a California Bearing Ratio between one and three (1 < CBR < 3) (shear strength between approximately 30 kPa and 90 kPa).

**Commented [SH12]:** From ASTM D653

- 8.4.2. The soil stabilization application is appropriate for subgrade soils that are saturated due to a high groundwater table or due to prolonged periods of wet weather. This specification is not appropriate for embankment reinforcement where stress conditions may cause global subgrade foundation or stability failure. Reinforcement of the pavement section is a site-specific design issue.
- 8.4.3. *Geotextile Requirements*—The geotextile shall meet the requirements of Table 5. All numeric values in Table 5 except AOS represent MARV in the weakest principal direction. Values for AOS represent maximum average roll values.

**Table 5—Soil Stabilization Geotextile Property Requirements**

	Test Methods	Units	Requirements
Geotextile class			Class 1 from Table 1 <sup>a</sup>
Permittivity	ASTM D4491	sec <sup>-1</sup>	0.05 <sup>b</sup>
Apparent opening size	ASTM D4751	mm	0.43 max avg roll value
Ultraviolet stability (retained strength)	ASTM D4355/D4355M	%	50% after 500 h of exposure

<sup>a</sup> Default geotextile selection. The engineer may specify a Class 2 or 3 geotextile from Table 1 based on one or more of the following:

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

<sup>b</sup> Default value. Permittivity of the geotextile should be greater than that of the soil ( $\Psi_s > \Psi_s$ ). The engineer may also require the permeability of the geotextile to be greater than that of the soil ( $k_s > k_s$ ).

- 8.4.4. The property values in Table 5 represent default values that provide for sufficient geotextile survivability under most construction conditions. Footnote *a* of Table 5 provides for a reduction in the minimum property requirements when sufficient survivability information is available. The engineer may also specify properties different from those listed in Table 5 based on engineering design and experience.

#### 8.5. Enhancement Requirements:

- 8.5.1. *Description*—This specification is applicable to the use of a geotextile in wet, saturated conditions to provide the coincident functions of separation, filtration, and enhancement. Enhancement is applicable to pavement structures constructed over soils with a California Bearing Ratio less than or equal to one ( $\text{CBR} \leq 1$ ) (shear strength less than or equal to approximately 30 kPa).

- 8.5.2. The enhancement application is appropriate for subgrade soils that are saturated due to a high groundwater table or due to prolonged periods of wet weather. This specification may be used as enhancement where instability is of concern.

- 8.5.3. *Geotextile Requirements*—The geotextile shall meet the requirements of Table 6. All numeric values in Table 6 except AOS represent MARV in the weakest principal direction. Values for AOS represent maximum average roll values.

- 8.5.4. The property values in Table 6 represent default values that provide for sufficient geotextile survivability under the most extreme of construction conditions. The engineer may also specify properties different from that listed in Table 6 based on engineering design and experience.

- 8.5.5. Section 8.5 is limited in application to geotextiles. Section 8.5 does not apply to use of other geosynthetics, such as geogrids.

**Commented [SH13]:** Incorporated into new Section 12 as subgrade stabilization.

**Table 6—Enhancement Geotextile Property Requirements**

	Test Methods	Units	Requirements
Geotextile class			Class 1A from Table 1*
Wide width tensile	ASTM D4595	kN/m	70
Sewn seam strength	ASTM D4884/D4884M	kN/m	42
Permittivity	ASTM D4491	sec <sup>-1</sup>	0.2*
Apparent opening size	ASTM D4751	mm	0.60 max avg roll value
Ultraviolet stability (retained strength)	ASTM D4355/D4355M	%	70% after 500 h of exposure

\*—Default value. Permittivity of the geotextile should be greater than that of the soil ( $\Psi_g > \Psi_s$ ). The engineer may also require the permeability of the geotextile to be greater than that of the soil ( $k_g > k_s$ ).

**Commented [SH14]:** Relabeled Class 4A and incorporated into new Table 12

#### 8.6.8.5. Permanent Erosion Control:

**8.6.1.8.5.1. Description**—This specification is applicable to the use of a geotextile between energy absorbing armor systems and the *in situ* soil to prevent soil loss resulting in excessive scour and to prevent hydraulic uplift pressures causing instability of the permanent erosion control system. This specification does not apply to other types of geosynthetic soil erosion control materials, such as turf reinforcement mats.

**8.6.2.8.5.2.** The primary function the geotextile serves in permanent erosion control applications is filtration. Geotextile filtration properties are a function of hydraulic conditions and *in situ* soil gradation, density, and plasticity.

**8.6.3.8.5.3. Geotextile Requirements**—The geotextile shall meet the requirements of Table 67. Woven slit film geotextiles (i.e., geotextiles made from yarns of a flat, tape-like character) will not be allowed. All numeric values in Table 67 except AOS represent MARV in the weaker principal direction. Values for AOS represent maximum average roll values.

**8.6.4.8.5.4.** The property values in Table 67 represent default values that provide for sufficient geotextile survivability under conditions similar to or less severe than those described under Note b of Table 67. Note c of Table 67 provides for a reduction in the minimum property requirements when sufficient survivability information is available or when the potential for construction damage is reduced. The engineer may also specify properties different from those listed in Table 67 based on engineering design and experience.

**Table 76—Permanent Erosion Control Geotextile Requirements**

		Requirements, Percent <i>in Situ</i> Soil Passing 0.075 mm <sup>a</sup>			
Test Methods	Units	<15	15 to 50	>50	
Geotextile class:					
Woven monofilament geotextiles		Class 2 from Table 1 <sup>b</sup>			
All other geotextiles		Class 1 from Table 1 <sup>b,c</sup>			
Permittivity <sup>a,d</sup>	ASTM D4491	sec <sup>-1</sup>	0.7	0.2	0.1
Apparent opening size <sup>c,d,e</sup>	ASTM D4751	mm	0.43 max avg roll value	0.25 max avg roll value	0.22 <sup>e</sup> max avg roll value
Ultraviolet stability (retained strength)	ASTM D4355/D4355M	%	50% after 500 h of exposure		

<sup>a</sup> Based on grain size analysis of *in situ* soil in accordance with T 88.

<sup>b</sup> As a general guideline, the default geotextile selection is appropriate for conditions of equal or less severity than either of the following:

1. Armor layer stone weights do not exceed 100 kg, stone drop height is less than 1 m, and no aggregate bedding layer is required.
2. Armor layer stone weighs more than 100 kg, stone drop height is less than 1 m, and the geotextile is protected by a 150-mm thick aggregate bedding layer designed to be compatible with the armor layer. More severe applications require an assessment of geotextile survivability based on a field trial section and may require a geotextile with strength properties.

<sup>c</sup> The engineer may specify a Class 2 geotextile from Table 1 based on one or more of the following:

1. The engineer has found Class 2 geotextiles to have sufficient survivability based on field experience.
2. The engineer has found Class 2 geotextiles to have sufficient survivability based on laboratory testing and visual inspection of a geotextile sample removed from a field test section constructed under anticipated field conditions.
3. Armor layer stone weighs less than 100 kg, stone drop height is less than 1 m, and the geotextile is protected by a 150-mm thick aggregate bedding layer designed to be compatible with the armor layer.
4. Armor layer stone weights do not exceed 100 kg, and stone is placed with a zero drop height.

<sup>d</sup> These default filtration property values are based on the predominant particle sizes of *in situ* soil. In addition to the default permittivity value, the engineer may require geotextile permeability and/or performance testing based on engineering design for drainage systems in problematic soil environments.

<sup>e</sup> See the following:

1. Site-specific geotextile design should be performed especially if one or more of the following problematic soil environments are encountered: unstable or highly erodible soils such as noncohesive silts; gap-graded soils; alternating sand/silt laminated soils; and/or rock flour.
2. For cohesive soils with a plasticity index greater than seven, geotextile maximum average roll value for apparent opening size is 0.30 mm.

## 9. TEMPORARY SILT FENCE REQUIREMENTS

- 9.1. **Description**—This specification is applicable to the use of a geotextile as a vertical, permeable interceptor designed to remove suspended soil from overland water flow. The function of a temporary silt fence is to filter and allow settlement of soil particles from sediment-laden water. The purpose is to prevent the eroded soil from being transported off the construction site by water runoff.
- 9.2. **Geotextile Requirements**—The geotextile used for temporary silt fence may or may not be supported between posts with wire or polymeric mesh. The temporary silt fence geotextile shall meet the requirements of Table 78. All numeric values in Table 78 except AOS represent MARV. Values for AOS represent maximum average roll values.
- 9.3. Field monitoring shall be performed to verify that the silt fence placement, using posts or support fence, does not damage the geotextile. The minimum height above ground for all silt fences shall be 750 mm. Minimum embedment depth of geotextile shall be 150 mm. Refer to Appendix X1 for more detailed installation requirements.

**Table 87**—Temporary Silt Fence Property Requirements

Test Methods	Units	Supported Silt Fence <sup>a</sup>	Requirements, Unsupported Silt Fence	
			Geotextile Elongation $\geq 50\%$ <sup>b</sup>	Geotextile Elongation $< 50\%$ <sup>b</sup>
Maximum post spacing		1.2 m	1.2 m	2 m
Grab strength	ASTM D4632/D4632M	N		
Machine direction		400	550	550
X-Machine direction		400	450	450
Permittivity <sup>c</sup>	ASTM D4491	sec <sup>-1</sup>	0.05	0.05
Apparent opening size	ASTM D4751	mm	0.60 max avg roll value	0.60 max avg roll value
Ultraviolet stability (retained strength)	ASTM D4355/D4355M	%	70% after 500 h of exposure	70% after 500 h of exposure

<sup>a</sup> Silt fence support shall consist of 14-gauge steel wire with a mesh spacing of 150 mm by 150 mm or prefabricated polymeric mesh of equivalent strength.

<sup>b</sup> As measured in accordance with ASTM D4632/D4632M.

<sup>c</sup> These default filtration property values are based on empirical evidence with a variety of sediments. For environmentally sensitive areas, a review of previous experience and/or site or regionally specific geotextile tests, such as ASTM D5141, should be performed by the agency to confirm suitability of these requirements.

## 10. PAVING FABRIC REQUIREMENTS

10.1. *Description*—This specification is applicable to the use of a paving fabric, saturated with asphalt cement, between pavement layers. The function of the paving fabric is to act as a waterproofing and stress relieving membrane within the pavement structure. This specification is not intended to describe fabric membrane systems specifically designed for pavement joints and localized (spot) repairs.

10.2. *Paving Fabric Requirements*—The paving fabric shall meet the requirements of Table 89. All numeric values in Table 89 represent MARV in the weaker principal direction. Type I paving fabrics are fabrics designed with low ultimate elongation and may be manufactured with a combination of glass fibers or fiberglass and synthetic polymers according to Section 4.1. Type II paving fabrics are fabrics designed with higher ultimate elongation and are manufactured with synthetic polymers according to Section 4.1.

**Table 98**—Paving Fabric Property Requirements<sup>a</sup>

Test Methods	Units	Type I Requirements	Type II Requirements
Grab strength	ASTM D4632/D4632M	N	450
Tensile strength	ASTM D5035, Type 2C-E	N	200
Ultimate elongation	ASTM D4632/D4632M	%	$\geq 50$
	ASTM D5035, Type 2C-E	%	$\leq 5$
Mass per unit area	ASTM D5261	gm/m <sup>2</sup>	125
Asphalt retention	ASTM D6140	1/m <sup>2</sup>	140
Melting point	ASTM D276	°C	205
			150

<sup>a</sup> All numeric values represent MARV in the weaker principal direction. (Refer to Section 10.2.)

<sup>b</sup> Asphalt required to saturate paving fabric only. Asphalt retention must be provided in manufacturer certification. (Refer to Section 5.) Value does not indicate the asphalt application rate required for construction. Refer to Appendix X1 for discussion of asphalt application rate.

<sup>c</sup> Product asphalt retention property must meet the MARV value provided by the manufacturer certification. (Refer to Section 5.)



## 11. GEOTEXTILE AND GEOGRID PROPERTY REQUIREMENTS FOR REINFORCED SOIL APPLICATIONS

- 11.1. *Description*—This specification is applicable to placing a geotextile or geogrid between layers of compacted fill for reinforced soil structures such as retaining walls or reinforced slopes. The primary function of the geotextile or geogrid layer is to add tensile strength and stiffness to the soil mass to improve its stability. The minimum tensile strength and stiffness required is generally site and structure specific, depending on the strength of the subsurface soils, the shear strength and gradational properties of the fill to be reinforced, the height of the structure, the steepness of the slope, and surcharge loads placed above the structure.
- 11.2. *Geosynthetic Requirements*—The geosynthetic shall meet the requirements of Table 940. The minimum strength required to resist installation conditions with minimal damage shall apply to the MARV in the weakest principle direction for geotextiles and biaxial geogrids. For uniaxial geogrids, the minimum strength required to resist installation conditions with minimal damage shall apply to the MARV in the machine direction. Tensile strength in the soil reinforcement application is required to resist both the installation conditions and the reinforced soil structure design requirements. For geogrids, where wide width tensile strength per ASTM D6637/D6637M, and for geotextiles where wide width tensile strength per ASTM D4595, is specified for both resistance to installation conditions and to meet tensile strength structure design requirements, the largest of the two values shall be considered the minimum tensile strength required.

**Table 940—Geosynthetic Reinforcement Property Requirements**

	Geosynthetic Type	Test Methods	Units	Requirements
Minimum Strength to Resist Installation Damage <sup>a</sup>	Geogrid	ASTM D6637/D6637M	kN/m	10 <sup>d</sup>
	Geotextile			Class 1 from Table 1 <sup>d</sup>
Ultimate Tensile Strength based on Structure Specific Design	Geogrid	ASTM D6637/D6637M	kN/m	Site and Structure Specific Value of $T_{max} \times FS \times RF^b$
	Geotextile	ASTM D4595	kN/m	Site and Structure Specific Value of $T_{max} \times FS \times RF^b$
$RF_{ID}$	All	R 69		Value from R 69 for Site Specific Backfill Gradation and Specific Product, but Not Less Than 1.1
$RF_{CR}$	All	R69		Value from R 69 for Specific Product
$RF_D$	All	R 69		1.3 <sup>c</sup>
Secant Stiffness at 1,000 hrs and 2% Strain <sup>e</sup>	All	R 69	kN/m	Site and Structure Specific Value

<sup>a</sup> The minimum strengths required here are to limit damage to the geosynthetic during installation to a tolerable and predictable level. All values are minimum values unless otherwise specified.

<sup>b</sup>  $T_{max}$  is determined from internal stability analysis of the wall or reinforced slope under consideration in accordance with the AASHTO LRFD Bridge Design Specifications, Article 11.10.6.4.3b. FS is the safety factor, or for Load and Resistance Factor Design (LRFD), the combination of load factor divided by the resistance factor.  $RF = RF_{ID} \times RF_{CR} \times RF_D$ .

<sup>c</sup> The default value of 1.3 shall be used only if the geosynthetic meets the minimum requirements in Table 940 and the backfill soil chemical properties meet the requirements in Table 104. If the effective design temperature is greater than 20°C but less than 30°C, a default value for  $RF_D$  of 1.5 should be used. If  $RF_{ID}$  is greater than 1.7, consideration should be given to either using a finer backfill material with a smaller top size to reduce installation damage, or conducting long-term chemical durability tests on damaged material to justify the use of a default reduction factor of  $RF_D$ .

<sup>d</sup> Minimum strength requirements are based on the results of numerous exhumations of geosynthetics, in which it was determined that installation damage was minimal for products with a minimum weight of 270 g/m<sup>2</sup> (8 oz/yd<sup>2</sup>) (Koerner and Koerner, 1990; Allen, 1991). This roughly corresponds to a Class 1 geotextile as specified in Table 1. A lighter weight geotextile class may be used if site specific installation damage testing is conducted in accordance with R 69, and  $RF_{ID}$  is determined to be 1.7 or less.

<sup>e</sup> Property requirement is optional as specified by the purchasing agency.

**Table 4410**—Minimum Polymer Durability Requirements to Justify Use of Default Value for  $RF_D$ 

Property	Polymer Type	Test Methods	Units	Criteria to Allow Use of Default $RF^a$
UV Oxidation Resistance	PP and HDPE	ASTM D4355/D4355M		Min. 70% strength retained after 500 hrs in weatherometer <sup>b, c</sup>
	PET	ASTM D4355/D4355M		Min. 50% strength retained after 500 hrs in weatherometer if geosynthetic will be buried within one week, 70% if left exposed for more than one week. <sup>b</sup>
Thermo-Oxidation Resistance	PP and HDPE	ISO 13438:2004(en), Method A (PP), or Method B (HDPE)	kN/m	Min. 50% strength retained after 28 days (PP) or 56 days (HDPE)
Hydrolysis Resistance	PET	ASTM D4603 and GRI GG8 (Inherent Viscosity Method) or Determine Directly Using Gel Permeation Chromatography		Min. Number Average Molecular Weight of 25,000
	PET	ASTM D7409		Max. Carboxyl End Group Content of 30
% Post-Consumer Recycled Material by Weight, Max	All	Certification of Materials Used	%	0

<sup>a</sup> Polymers not meeting these requirements may be used if product specific test results obtained and analyzed in accordance with R 69, Annexes A, B, C, and D are provided.

<sup>b</sup> The minimum values specified are to minimize UV degradation during the temporary exposure to sunlight during construction of the geosynthetic structure.

<sup>c</sup> For PP and HDPE, the higher percent strength retained is needed to help ensure that some degree of stabilization for oxidation is provided in the polymer for both UV and thermal oxidation.

**Table 4211**—Environment Aggressiveness to Justify Use of Default Value for  $RF_D$ 

	Test Methods	Units	Requirements <sup>a</sup>
Effective Design Temperature, Max		°C	30
Backfill pH	T 289		4.5 to 9

<sup>a</sup> See R 69 for other environment aggressiveness considerations.

## 12. GEOTEXTILE AND GEOGRID PROPERTY REQUIREMENTS FOR SUBGRADE STABILIZATION

**12.1.** *Description*—This specification is applicable to the use of a geotextile or geogrid in wet, saturated conditions for subgrade stabilization. The primary function of the geotextile or geogrid is reinforcement which provides lateral confinement, subgrade restraint, and increased effective bearing capacity to improve stability of subgrade soils. A stabilization geotextile will also provide coincident functions of separation and filtration. In some geogrid installations, the addition of a geotextile may be considered to similarly provide the coincident functions of separation and filtration. Subgrade stabilization is applicable to fill materials and pavement structures constructed over soft soils and especially in situations when minimal site preparation or high ground pressure construction equipment is used.

**12.2.** This subgrade stabilization application is appropriate for soils that are saturated due to a high groundwater table or **due to** prolonged periods of wet weather. This specification may be used to stabilize subgrades where instability is a concern.

**12.3.** *Geosynthetic Requirements*—The geosynthetic shall meet the requirements of Table 12. All numeric values in Table 12 except AOS, Percent Open Area, and Geogrid Wide Width Tensile Strength represent MARV in the weakest principal direction. Values for AOS represent maximum average roll values and values for Percent Open Area represent typical values. Values for Geogrid Wide Width Tensile Strength are the sum of the values for the wide width tensile strengths in the machine and cross machine directions.

- 12.4. The geotextile property values in Table 12 represent default values that provide for sufficient geotextile survivability under the most extreme construction conditions. The geogrid property values in Table 12 are applicable for common non-proprietary roadway geogrids and are based on geogrid survivability considerations. Other geosynthetics, such as those possessing unique features, may be specified according to their descriptive index and performance properties and evaluated and considered for allowance as alternatives to the products meeting the classes listed in Table 12. Allowance as an alternative should be based on documented field experience or an independent laboratory evaluation that reasonably simulates anticipated field conditions. The engineer may also specify geosynthetic properties and types different from those listed in Table 12 based on engineering design and experience.

**Table 642—Subgrade Stabilization (Class 4) Geosynthetic Property Requirements**

	Test Methods	Units	Geosynthetic Class <sup>a, b</sup> and Type			
			Class 4A <sup>a</sup> Geotextile	Class 4B <sup>b</sup> Geogrid	Class 4C <sup>b</sup> Geogrid	Class 4D <sup>b</sup> Geogrid
Geotextile Wide Width Tensile Strength	ASTM D4595	kN/m	70	—	—	—
Permittivity	ASTM D4491	sec <sup>-1</sup>	0.2 <sup>c</sup>	—	—	—
Apparent opening size	ASTM D4751	mm	0.60 max avg roll value	—	—	—
Geogrid Wide Width Tensile Strength	ASTM D6637/6637M	kN/m	—	51.1	36.5	21.9
Tensile Strength at 2% Strain	Method B		—	8.0	5.8	3.6
Junction Strength	ASTM D7737 Method A	N	—	200	156	111
Percent Open Area	Direct Measure	%	—		70	
Ultraviolet stability (retained strength)	ASTM D4355/4355M	%		70% after 500 h of exposure		

<sup>a</sup> Required geotextile class is designated in Table 4 for the required degree of survivability. The severity of installation conditions for the application generally dictates the required geotextile class. Class 4A geotextile is specified for more severe or harsh installation conditions where there is a greater potential for geotextile damage.

<sup>b</sup> Class 4B geogrid may be used for all survivability conditions but is the default geogrid selection for severe survivability conditions. Class 4C geogrid is the default geogrid selection for moderate survivability conditions. The engineer may specify a Class 4D geogrid for light survivability conditions, based on one or more of the following:

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

<sup>c</sup> Default value. Permittivity of the geotextile should be greater than that of the soil ( $\Psi_g > \Psi_s$ ). The engineer may also require the permeability of the geotextile to be greater than that of the soil ( $k_g > k_s$ ).

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## 12.13. KEYWORDS

12.13.1. Erosion control; fabric; geosynthetic; geotextile; geogrid; stabilization; silt.

## APPENDIX

(Nonmandatory Information)

### X1. CONSTRUCTION/INSTALLATION GUIDELINES

X1.1. General:

X1.1.1. This Appendix is intended for use in conjunction with M 288 for geosynthetics. The specification details materials properties for geosynthetics used in drainage, erosion control, separation, stabilization, silt fences, pavement overlay, and soil reinforcement (walls and slopes) applications.

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M 288-16

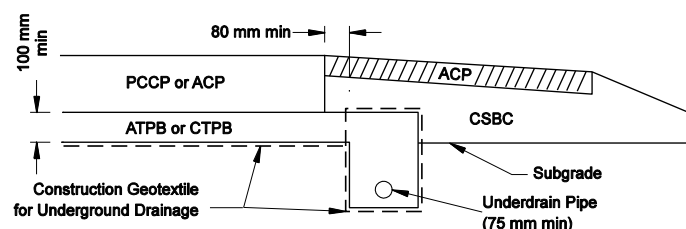
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The material properties are only one factor in a successful installation involving geosynthetics. Proper material handling, construction, and installation techniques are essential in order to ensure that the intended function of the geosynthetic is fulfilled.

- X1.1.2. *Geosynthetic Identification, Packaging, and Storage:*
- X1.1.2.1. Refer to ASTM D4873.
- X1.1.2.2. Ensure the geosynthetic is accompanied with proper certification and is properly identified, packaged for shipment, and stored according to Section 7.1.
- X1.1.3. *Geosynthetic Exposure Following Placement:*
- X1.1.3.1. Atmospheric exposure of geosynthetics to the elements following lay down shall be a maximum of 14 days to minimize damage potential.
- X1.1.4. *Seaming or Joining:*
- X1.1.4.1. If a sewn seam is to be used for the seaming of the geotextile, the thread used shall consist of high-strength polypropylene, or polyester. Nylon thread shall not be used. For erosion control applications, the thread shall also be resistant to ultraviolet radiation. The thread shall be of contrasting color to that of the geotextile itself.
- X1.1.4.2. For seams that are sewn in the field, the contractor shall provide at least a 2-m length of sewn seam for sampling by the engineer before the geotextile is installed. For seams that are sewn in the factory, the engineer shall obtain samples of the factory seams at random from any roll of geotextile that is used on the project.
- X1.1.4.3. For seams that are field sewn, the seams sewn for sampling shall be sewn using the same equipment and procedures as will be used for the production seams. If seams are sewn in both the machine and cross machine direction, samples of seams from both directions shall be provided.
- X1.1.4.4. The contractor shall submit the seam assembly description along with the sample of the seam. The description shall include the seam type, stitch type, sewing thread, and stitch density.
- X1.1.4.5. If geogrid is to be joined in the field, the joining shall consist of hog ties, zip ties, etc. The contractor shall submit the joining assembly description along with the sample of the joining. The description shall include the joining material and joining procedure.
- X1.1.4.6. For geogrid that is joined in the field, the contractor shall provide at least a 2-m length of joined geogrid for sampling by the engineer before the geogrid is installed. For geogrid rolls joined in the factory, the engineer shall obtain samples of the factory joints at random from any roll of geogrid that is used on the project.
- X1.2. *Drainage Geotextiles<sup>2</sup> (See Sections 8.1 and 8.2.):*
- X1.2.1. *Construction:*
- X1.2.1.1. Trench excavation shall be done in accordance with details of the project plans. In all instances, excavation shall be done in such a way so as to prevent large voids from occurring in the sides and bottom of the trench. The graded surface shall be smooth and free of debris.
- X1.2.1.2. In the placement of the geotextile for drainage applications, the geotextile shall be placed loosely with no wrinkles or folds, and with no void spaces between the geotextile and the ground surface.

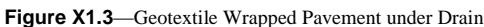
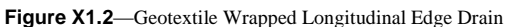
Successive sheets of geotextiles shall be overlapped a minimum of 300 mm, with the upstream sheet overlapping the downstream sheet.

- X1.2.1.3. In trenches equal to or greater than 300 mm in width, after placing the drainage aggregate, the geotextile shall be folded over the top of the backfill material in a manner to produce a minimum overlap of 300 mm. In trenches less than 300 mm but greater than 100 mm wide, the overlap shall be equal to the width of the trench. Where the trench is less than 100 mm, the geotextile overlap shall be sewn or otherwise bonded. All seams shall be subject to the approval of the engineer.
- X1.2.1.4. Should the geotextile be damaged during installation or drainage aggregate placement, a geotextile patch shall be placed over the damaged area, extending beyond the damaged area a distance of 300 mm, or the specified seam overlap, whichever is greater.
- X1.2.1.5. Placement of drainage aggregate should proceed immediately following placement of the geotextile. The geotextile should be covered with a minimum of 300 mm of loosely placed aggregate prior to compaction. If a perforated collector pipe is to be installed in the trench, a bedding layer of drainage aggregate should be placed below the pipe, with the remainder of the aggregate placed to the minimum required construction depth.
- X1.2.1.6. The aggregate should be compacted with vibratory equipment to a minimum of 95 percent standard AASHTO density unless the trench is required for structural support. If higher compactive effort is required, a Class 1 geotextile as per Table 1 of M 288 is needed.
- X1.2.1.7. Figures X1.1 through X1.3 illustrate various geotextile drainage application details.



Note: ACP = Asphalt Concrete Pavement  
 ATPB = Asphalt Treated Permeable Base  
 CSBC = Crushed Stone Base Course  
 CTPB = Cement Treated Permeable Base  
 PCCP = Portland Cement Concrete Pavement

**Figure X1.1—Geotextile Drain Requirements for Permeable Bases**

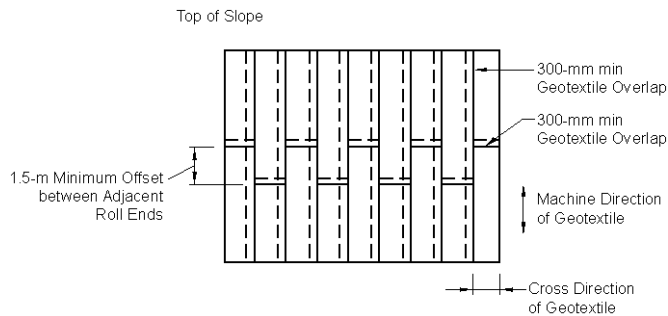


- X1.3. *Separation/Stabilization/Enhancement Geosynthetic Textiles* (See Sections 8.1, 8.3, 8.54, and 12.08.5.):
- X1.3.1. *Construction:*
- X1.3.1.1. The installation site shall be prepared by clearing, grubbing, and excavating or filling the area to the design grade. This includes removal of topsoil and vegetation.
- Note X1**—Soft spots and unsuitable areas will be identified during site preparation or subsequent proof rolling. These areas shall be excavated and backfilled with select material and compacted using normal procedures.
- X1.3.1.2. The geotextile shall be laid smooth without wrinkles or folds on the prepared subgrade in the direction of construction traffic. Adjacent geotextile rolls shall be overlapped, sewn, or joined as required in the plans. Overlaps shall be in the direction as shown on the plans. See Table X1.1 for overlap requirements.

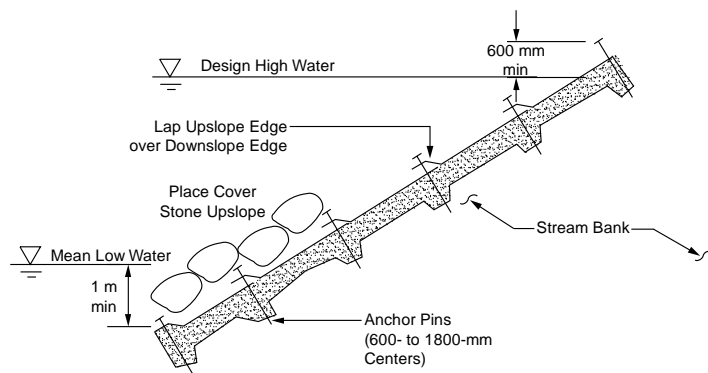
**Table X1.1—Overlap Requirements**

Soil CBR	Minimum Overlap
>3	300–450 mm
1–3	0.6–1 m
0.5–1	1 m or sewn
<0.5	sewn
All roll ends	1 m or sewn

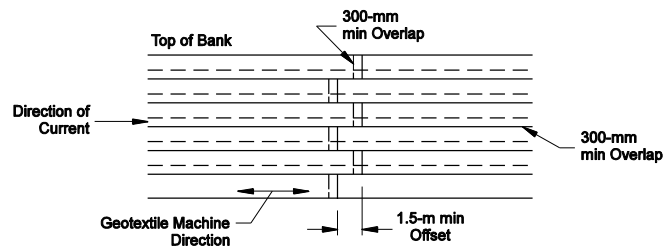
- X1.3.1.3. On curves, the geotextile may be folded or cut to conform to the curves. The fold or overlap shall be in the direction of construction and held in place by pins, staples, or piles of fill or rock.
- X1.3.1.4. Prior to covering, the geotextile shall be inspected to ensure that it has not been damaged (i.e., holes, tears, rips) during installation. The inspection shall be done by the engineer or the engineer's designated representative. It is recommended that the designated representative be a certified inspector.  
Damaged geotextiles, as identified by the engineer, shall be repaired immediately. Cover the damaged area with a geotextile patch that extends an amount equal to the required overlap beyond the damaged area.
- X1.3.1.5. The subbase shall be placed by end dumping onto the geotextile from the edge of the geotextile, or over previously placed subbase aggregate. Construction vehicles shall not be allowed directly on the geotextile. The subbase shall be placed such that at least the minimum specified lift thickness shall be between the geotextile and equipment tires or tracks at all times. Turning of vehicles shall not be permitted on the first lift above the geotextile.  
**Note X2**—On subgrades having a CBR value of less than one, the subbase aggregate should be spread in its full thickness as soon as possible after dumping to minimize the potential of localized subgrade failure due to overloading of the subgrade.
- X1.3.1.6. Any ruts occurring during construction shall be filled with additional subbase material and compacted to the specified density.
- X1.3.1.7. If placement of the backfill material causes damage to the geotextile, the damaged area shall be repaired as previously described in Section X1.3.1.4. The placement procedures shall then be modified to eliminate further damage from taking place (i.e., increase initial lift thickness, decrease equipment loads, etc.).  
**Note X3**—In stabilization applications, the use of vibratory compaction equipment is not recommended with the initial lift of subbase material, as it may cause damage to the geotextile.
- X1.4. *Erosion Control Geotextiles* (See Section 8.5.):
- X1.4.1. *Construction:*
- X1.4.1.1. The geotextile shall be placed in intimate contact with the soils without wrinkles or folds and anchored on a smooth graded surface approved by the engineer. The geotextile shall be placed in such a manner that placement of the overlying materials will not excessively stretch so as to tear the geotextile. Anchoring of the terminal ends of the geotextile shall be accomplished through the use of key trenches or aprons at the crest and toe of slope. Refer to Figures X1.4 through X1.7 for construction details.  
**Note X4**—In certain applications to expedite construction, 450-mm anchoring pins placed on 600- to 1800-mm centers, depending on the slope of the covered area, have been used successfully.



**Figure X1.4**—Method of Placing Geotextile for Protection of Cut and Fill Slopes

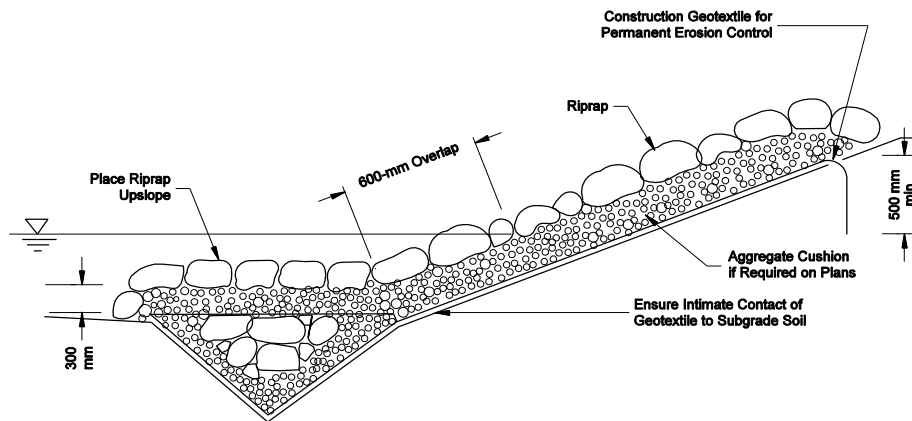


**Figure X1.5**—Cross Section of Slopes with Riprap



**Figure X1.6**—Geotextile Placement Scheme for Streambank Protection





**Figure X1.7**—Key Detail at Top and Toe of Slope for Geotextiles Used for Permanent Erosion Control

- X1.4.1.2. The geotextile shall be placed with the machine direction parallel to the direction of water flow, which is normally parallel to the slope for erosion control runoff and wave action (Figure X1.4), and parallel to the stream or channel in the case of streambank and channel protection (Figure X1.6). Adjacent geotextile sheets shall be joined by either sewing or overlapping. Overlapped seams of roll ends shall be a minimum of 300 mm except where placed under water. In such instances the overlap shall be a minimum of 1 m. Overlaps of adjacent rolls shall be a minimum of 300 mm in all instances.
- Note X5**—When overlapping, successive sheets of the geotextile shall be overlapped upstream over downstream, and/or upslope over downslope. In cases where wave action or multidirectional flow is anticipated, all seams perpendicular to the direction of flow shall be sewn.
- X1.4.1.3. Care shall be taken during installation so as to avoid damage occurring to the geotextile as a result of the installation process. Should the geotextile be damaged during installation, a geotextile patch shall be placed over the damaged area extending 1 m beyond the perimeter of the damage.
- X1.4.1.4. The armor system placement shall begin at the toe and proceed up the slope. Placement shall take place so as to avoid stretching and subsequent tearing of the geotextile. Riprap and heavy stone filling shall not be dropped from a height of more than 300 mm. Stone with a mass of more than 100 kg shall not be allowed to roll down the slope.
- X1.4.1.5. Slope protection and smaller sizes of stone filling shall not be dropped from a height exceeding 1 m, or a demonstration provided showing that the placement procedures will not damage the geotextile. In underwater applications, the geotextile and backfill material shall be placed the same day. All void spaces in the armor stone shall be backfilled with small stone to ensure full coverage.
- X1.4.1.6. Following placement of the armor stone, grading of the slope shall not be permitted if the grading results in movement of the stone directly above the geotextile.
- X1.4.1.7. Field monitoring shall be performed to verify that the armor system placement does not damage the geotextile.

X1.4.1.8. Any geotextile damaged during backfill placement shall be replaced as directed by the engineer at the contractor's expense.

X1.5. *Silt Fence Geotextiles* (See Section 9.):

X1.5.1. *Related Material Requirements:*

X1.5.1.1. Wood, steel, or synthetic support posts having a minimum length of 1 m plus the burial depth may be used. They shall be of sufficient strength to resist damage during installation and to support the applied loads due to material buildup behind the silt fence.

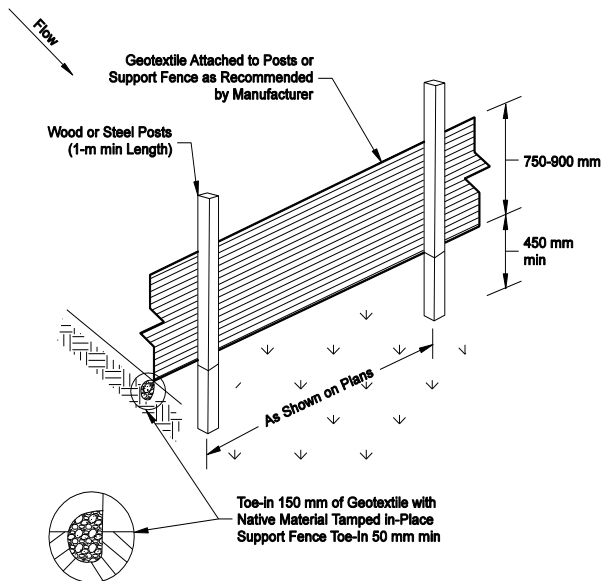
**Note X6**—It has been found that hardwood posts having dimensions of at least 30 mm by 30 mm, No. 2 Southern Pine at least 65 mm by 65 mm, or steel posts of U, T, L, or C shape weighing 600 g per 300 mm have performed satisfactorily.

X1.5.1.2. Wire or polymer support fences shall be at least 750 mm high and strong enough to support applied loads. Polymer support fences shall meet the same ultraviolet degradation requirements as the geotextile.

**Note X7**—Wire support fences having at least six horizontal wires and being at least 14-gauge wire have performed satisfactorily. Vertical wires should be a maximum of 150 mm apart.

X1.5.2. *Construction:*

- X1.5.2.1. The geotextile at the bottom of the fence shall be buried in a “J” configuration to a minimum depth of 150 mm in a trench so that no flow can pass under the silt fence. The trench shall be backfilled and the soil compacted over the geotextile.
- X1.5.2.2. The geotextile shall be spliced together with a sewn seam only at a support post, or two sections of fence may be overlapped instead.
- X1.5.2.3. The contractor must demonstrate to the satisfaction of the engineer that the geotextile can withstand the anticipated sediment loading.
- X1.5.2.4. See Figure X1.8 for details.



**Figure X1.8**—Typical Silt Fence Detail

- X1.5.2.5. The posts shall be placed at spacing as shown on the project plans. Posts should be driven or placed a minimum of 500 mm into the ground. Depth shall be increased to 600 mm if the fence is placed on a slope of 3:1 or greater.  
**Note X8**—Where 500-mm depth is impossible to attain, the posts should be adequately secured to prevent overturning of the fence due to sediment loading.
- X1.5.2.6. The support fence shall be fastened securely to the upslope side of the fence post. The support fence shall extend from the ground surface to the top of the geotextile.
- X1.5.2.7. When a self-supported fence is used, the geotextile shall be securely fastened to fence posts.

- X1.5.2.8. Silt fences should be continuous and transverse to the flow. The silt fence should follow the contours of the site as closely as possible. The fence shall also be placed such that the water cannot run off around the end of the fence.
- X1.5.2.9. The silt fence should be limited to handle an area equivalent to 90 m<sup>2</sup> per 3 m of fence. Caution should be used where the site slope is greater than 1:1 and water flow rates exceed 3 L per second per 3 m of fence.
- X1.5.3. *Maintenance:*
- X1.5.3.1. The contractor shall inspect all temporary silt fences immediately after each rainfall and at least daily during prolonged rainfall. The contractor shall immediately correct any deficiencies.
- X1.5.3.2. The contractor shall also make a daily review of the location of silt fences in areas where construction activities have altered the natural contour and drainage runoff to ensure that the silt fences are properly located for effectiveness. Where deficiencies exist as determined by the engineer, additional silt fence shall be installed as directed by the engineer.
- X1.5.3.3. Damaged or otherwise ineffective silt fences shall be repaired or replaced promptly.
- X1.5.3.4. Either sediment deposits shall be removed when the deposit reaches half the height of the fence or a second silt fence shall be installed as directed by the engineer.
- X1.5.3.5. The silt fence shall remain in place until the engineer directs that it be removed. Upon removal, the contractor shall remove and dispose of any excess sediment accumulations, dress the area to give it a pleasing appearance, and cover with vegetation all bare areas in accordance with contract requirements.
- X1.5.3.6. Removed silt fence may be used at other locations provided the geotextile and other material requirements continue to be met to the satisfaction of the engineer.
- X1.6. *Paving Fabrics* (See Section 10.):
- X1.6.1. *Materials:*
- X1.6.1.1. The sealant material used to impregnate and seal the paving fabric, as well as bond it to both the base pavement and overlay, shall be a paving grade asphalt recommended by the paving fabric manufacturer and approved by the engineer.
- X1.6.1.2. Uncut asphalt cements are the preferred sealant; however, cationic and anionic emulsions may be used provided the precautions outlined in Section X1.6.3.3 are followed. Cutbacks and emulsions that contain solvents shall not be used.
- X1.6.1.3. The grade of asphalt cement specified for hot mix design in each geographic location is generally the most acceptable material.
- X1.6.1.4. Washed concrete sand may be spread over asphalt saturated paving fabric to facilitate movement of equipment during construction or to prevent tearing or delamination of the paving fabric. Hot mix broadcast in front of construction vehicle tires may also be used to serve this purpose. If sand is applied, excess quantities shall be removed from the paving fabric prior to placing the surface course.
- X1.6.1.5. Sand is not usually required. However, ambient temperatures are occasionally sufficiently high to cause bleed-through of the asphalt sealant, resulting in undesirable paving fabric adhesion to construction vehicle tires.

- X1.6.2. *Equipment:*
- X1.6.2.1. The asphalt distributor shall be capable of spraying the asphalt sealant at the prescribed uniform application rate. No streaking, skipping, or dripping will be permitted. The distributor shall also be equipped with a hand spray having a single nozzle and positive shutoff valve.
- X1.6.2.2. Mechanical or manual lay down equipment shall be capable of laying the paving fabric smoothly.
- X1.6.2.3. The following miscellaneous equipment shall be provided: stiff bristle brooms or squeegees to smooth the paving fabric; scissors or blades to cut the paving fabric; brushes for applying asphalt sealant to paving fabric overlaps.
- X1.6.2.4. Pneumatic rolling equipment to smooth the paving fabric into the sealant and sanding equipment may be required for certain jobs. Rolling is especially required on jobs where thin lifts or chip seals are being placed. Rolling helps ensure paving fabric bonds to the adjoining pavement layers in the absence of heat and weight associated with thicker lifts of asphaltic pavement.
- X1.6.3. *Construction:*
- X1.6.3.1. Neither the asphalt sealant nor the paving fabric shall be placed when the engineer deems weather conditions unsuitable. Air and pavement temperatures shall be sufficient to allow the asphalt sealant to hold the paving fabric in place. For asphalt cements, air temperature shall be 10°C and rising. For asphalt emulsions, air temperature shall be 15°C and rising.
- X1.6.3.2. The surface on which the paving fabric is to be placed shall be reasonably free of dirt, water, vegetation, or other debris. Cracks exceeding 3 mm in width shall be filled with suitable crack filler. Potholes shall be properly repaired as directed by the engineer. Fillers shall be allowed to cure prior to paving fabric placement.
- X1.6.3.3. The specified rate of asphalt sealant application must be sufficient to satisfy the asphalt retention properties of the paving fabric, and bond the paving fabric and overlay to the old pavement.  
**Note X9**—When emulsions are used, the application rate must be increased to offset water content of the emulsion.
- X1.6.3.4. Application of the sealant shall be by distributor spray bar, with hand spraying kept to a minimum. Temperature of the asphalt sealant shall be sufficiently high to permit uniform spray pattern. For asphalt cements, the minimum temperature shall be 145°C. To avoid damage to the paving fabric, however, the distributor tank temperatures shall not exceed 160°C.
- X1.6.3.5. Spray patterns for asphalt emulsions are improved by heating. Temperatures in the 55°C to 70°C range are desirable. A temperature of 70°C shall not be exceeded because higher temperatures may break the emulsion.
- X1.6.3.6. The target width of asphalt sealant application shall be the paving fabric width plus 150 mm. The asphalt sealant shall not be applied any farther in advance of paving fabric placement than the distance the contractor can maintain free of traffic.
- X1.6.3.7. Asphalt spills shall be cleaned from the road surface to avoid flushing and paving fabric movement.
- X1.6.3.8. When asphalt emulsions are used, the emulsion shall be cured prior to placing the paving fabric and final wearing surface. This means essentially no moisture remaining.

- X1.6.3.9. The paving fabric shall be placed onto the asphalt sealant with minimum wrinkling prior to the time the asphalt has cooled and lost tackiness. As directed by the engineer, wrinkles or folds in excess of 25 mm shall be slit and laid flat.
- X1.6.3.10. Brooming and/or pneumatic rolling will be required to maximize paving fabric contact with the pavement surface.
- X1.6.3.11. Overlap of paving fabric joints shall be sufficient to ensure full closure of the joint, but should not exceed 150 mm. Transverse joints shall be lapped in the direction of paving to prevent edge pickup by the paver. A second application of asphalt sealant to the paving fabric overlaps will be required if the engineer judges additional asphalt sealant is needed to ensure proper bonding of the double paving fabric layer.
- X1.6.3.12. Removal and replacement of paving fabric that is damaged will be the responsibility of the contractor.
- Note X10**—The problems associated with wrinkles are related to thickness of the asphalt lift being placed over the paving fabric. When wrinkles are large enough to be folded over, there usually is not enough asphalt available from the tack coat to satisfy the requirement of multiple layers of paving fabric. Therefore, wrinkles in excess of 25 mm in length should be slit and laid flat. Sufficient asphalt sealant should be sprayed on the top of the paving fabric to satisfy the requirement of the lapped paving fabric.
- Note X11**—In overlapping adjacent rolls of paving fabric, it is desirable to keep the lapped dimension as small as possible and still provide a positive overlap. If the lapped dimension becomes too large, the problem of inadequate tack to satisfy the two lifts of paving fabric and the old pavement may occur. If this problem does occur, then additional asphalt sealant should be added to the lapped areas. In the application of the additional sealant, care should be taken not to apply too much because excess will cause flushing.
- X1.6.3.13. Trafficking the paving fabric will be permitted for emergency and construction vehicles only.
- X1.6.3.14. Placement of the hot mix overlay should closely follow paving fabric laydown. The temperature of the mix shall not exceed 175°C for Type I paving fabrics and 160°C for Type II paving fabrics. In the event asphalt bleeds through the paving fabric causing construction problems before the overlay is placed, the affected areas shall be blotted by spreading sand. To avoid movement of, or damage to, the seal-coat saturated paving fabric, turning of the paver and other vehicles shall be gradual and kept to a minimum.
- X1.6.3.15. Prior to placing a seal coat (or thin overlay such as an open-graded friction course), lightly sand the paving fabric at a spread rate of 0.65 to 1 kg/m<sup>2</sup> and pneumatically roll the paving fabric tightly into the sealant.
- X1.7. *Geosynthetic Reinforced Soil* (See Section 11.):
- X1.7.1. *Excavation and Foundation Preparation:*
- X1.7.1.1. Excavation shall leave a smooth and uniform surface for the placement of the reinforcement material. Foundation soils found to be unsuitable shall be removed and replaced. Depressions and intrusions into the grade shall be repaired.
- X1.7.2. *Drainage:*
- X1.7.2.1. The Contractor shall direct all surface runoff from adjacent areas away from the foundation construction site. The site shall be adequately drained.

X1.7.3. *Erection and Backfill:*

- X1.7.3.1. The Contractor shall begin construction at the lowest portion of the excavation and shall place each layer horizontally as shown in the Plans. The Contractor shall complete each layer entirely in a location before beginning the next layer.

X1.7.4. *Splices:*

- X1.7.4.1. Geotextile splices shall consist of a sewn seam or a minimum 1-foot overlap. Geogrid splices shall consist of adjacent geogrid strips butted together and fastened using hog rings, or other methods acceptable to the Engineer, in such a manner to prevent the splices from separating during geogrid installation and backfilling. Splices exposed at a wall face shall prevent loss of backfill material through the face. The splicing material exposed at the wall face shall be as durable and strong as the material to which the splices are tied. The Contractor shall offset geosynthetic splices in one layer from those in the other layers such that the splices shall not line up vertically. Splices parallel to a wall face will not be allowed.

X1.7.5. *Layout:*

- X1.7.5.1. The Contractor shall stretch out the geosynthetic in the direction perpendicular to the wall face or in both directions for a roadway reinforcement application to ensure that no slack or wrinkles exist in the geosynthetic prior to backfilling.

X1.7.6. *Backfilling:*

- X1.7.6.1. The Contractor shall place fill material on the geosynthetic in lifts such that 6 in. minimum of fill material is between the vehicle or equipment tires or tracks and the geosynthetic at all times. The Contractor shall remove all particles within the backfill material greater than 3 in. in size. Turning of vehicles on the first lift above the geosynthetic will not be permitted. The Contractor shall not end dump fill material directly on the geosynthetic without the prior permission of the Engineer.

- X1.7.6.2. The Contractor shall use a temporary form system to prevent sagging of the geosynthetic facing elements during construction. A typical example of a temporary form system and sequence of wall construction required when using this form are detailed in the Plans. Soil piles or the geosynthetic manufacturer's recommended method, in combination with the forming system, shall be used to hold the geosynthetic in place until the specified cover material is placed. The Contractor shall place and compact the wall backfill in accordance with the specified construction sequence detailed in the Plans, except as follows:

- The maximum lift thickness after compaction shall not exceed 10 in.
- The Contractor shall decrease this lift thickness, if necessary, to obtain the specified density.
- Rollers shall have sufficient capacity to achieve compaction without causing distortion to the final shape of the constructed work.
- The Contractor shall not use sheepsfoot rollers or rollers with protrusions.
- The Contractor shall compact the zone within 3 ft of a wall face without causing damage to or distortion of the wall facing elements (welded wire mats, backing mats, construction geotextile for wall facing, precast concrete facing panels, and concrete blocks) by using a plate compactor.
- For wall systems with geosynthetic reinforcement, the minimum compacted backfill lift thickness of the first lift above each geosynthetic reinforcement layer shall be 6 in.

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**ADVISORY**

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It is recommended that, for safety considerations, trafficking of the paving fabric should not be allowed. However, if the contracting agency elects to allow trafficking, the following verbiage is recommended:

“If approved by the engineer, the seal-coat saturated paving fabric may be opened to traffic for 24 to 48 hours prior to installing the surface course. Warning signs shall be placed which advise the motorist that the surface may be slippery when wet. The signs shall also post the appropriate safe speed. Excess sand shall be broomed from the surface prior to placing the overlay. If, in the judgment of the engineer, the fabric surface appears dry and lacks tackiness following exposure to traffic, a light tack coat shall be applied prior to the overlay.”

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<sup>1</sup> Available from ASTM, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959.

<sup>2</sup> Geotextiles used as sheet drains are not included in the discussions in this section.