GUIDELINES FOR PROJECT SELECTION, DESIGN, AND CONSTRUCTION OF TIRE SHREDS IN EMBANKMENTS

GEOTECHNICAL ENGINEERING MANUAL
GEM-20
Revision #2

GEOTECHNICAL ENGINEERING BUREAU
JULY 2008

NEW YORK STATE DEPARTMENT OF TRANSPORTATION
GEOTECHNICAL ENGINEERING MANUAL:
GUIDELINES FOR PROJECT SELECTION, DESIGN, AND CONSTRUCTION OF TIRE SHREDS IN EMBANKMENTS

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STATE OF NEW YORK
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### TABLE OF CONTENTS

1. INTRODUCTION........................................................................................................... 3

2. PROJECT SITE SELECTION......................................................................................... 4

3. DESIGN AND CONSTRUCTION GUIDELINES - GENERAL ........................................ 4
   3.1 Design .................................................................................................................... 4
   3.2 Typical Section ...................................................................................................... 5
   3.3 Instrumentation and Monitoring ........................................................................... 6
   3.4 Construction Guidelines ....................................................................................... 6
   3.5 Special Specification ............................................................................................ 7

4. SUMMARY ................................................................................................................... 8

APPENDIX ...................................................................................................................... 9

   Typical Section and Example Construction Sequence .............................................. A-1
   Tire Shred Requirements ............................................................................................ B-1
   Useful Information ...................................................................................................... C-1
   FHWA: Design Guidelines To Minimize Internal Heating of Tire Shreds ............... D-1
   ASTM D6270: Standard Practice for Use of Scrap Tires in Civil Engineering Applications ................................................................. E-1
1. INTRODUCTION

Tire shreds are defined by New York State DOT (NYSDOT) as pieces of scrap tire between 2 in. and 12 in. (50 mm and 300 mm) in size. To be considered suitable for use in highway embankments, tire shreds must:

1. exhibit the proper engineering characteristics,
2. consistently satisfy specification requirements,
3. provide an acceptable level of performance,
4. be economically competitive with available construction materials, and
5. not harm the environment.

Exceptions to point 4 above can be made for pilot or demonstration projects, or in response to special needs of the NYSDOT.

Because of its light weight, tire shreds can be used in normal (routine) embankment construction or in a situation where a lightweight embankment material is required due to a potential settlement or stability problem.

The use of tire shreds in embankment construction involves meeting special design requirements as well as attention to environmental issues. Note that the Department of Environmental Conservation (DEC) has issued a generic Beneficial Use Determination (BUD) for using tire shreds. That means that as far as DEC is concerned, tire shreds are not considered a solid waste, and are a viable construction material. As such, they may be transported and handled without the need for special permits. (Tire shreds are addressed in Section 360-1.15 (6) of 6 NYCRR Part 360, Title 6 of the Official Compilation of Codes, Rules and Regulations, effective September 29, 1997.)

When using this material on NYSDOT projects, the guidelines and requirements contained in this manual shall be followed.
2. PROJECT SITE SELECTION

Select the sites for tire shred embankments using the following criteria:

a. The top of the tire shred layer needs to be covered by at least 5 ft. (1.5 m) of soil (the distance from the top of the tire shred layer to the top of subgrade elevation). Therefore, select projects which will have a minimum fill height of 7 ft. (2.1 m). This will allow for the thickness of the soil cover over the shreds plus the pavement section thickness, including subbase.

b. Tire shreds must be placed above the water table or the free water elevation.

c. Tire shred embankments should not be constructed in environmentally sensitive areas, such as near drinking water supplies, in wetlands, or in the New York City watershed.

3. DESIGN AND CONSTRUCTION GUIDELINES - GENERAL

When designing and constructing tire shred embankments, two things need to be kept in mind. One, tire shreds compress, after compaction, approximately 10% of their volume within 30 to 60 days after completing the embankment up to final grade (top of pavement elevation). Therefore, the contract documents should include notes requiring a surcharge and waiting period. Two, early uncontrolled tire shred embankments in other states have spontaneously combusted. These guidelines have been developed through thorough analysis, research and experimentation by the Federal Highway Administration (FHWA), Dr. Dana Humphrey of the University of Maine and others, and the methods in this manual have been proven to prevent such fires from occurring. The guidelines and specifications were explicitly designed to address both of these issues. Following these guidelines will result in a well performing, well-drained and lightweight fill that offers the added benefit of beneficially using a material that would otherwise be considered a waste.

3.1 DESIGN

a. Design and construct the tire shred embankment so that infiltration of air and water is minimized.

1. To minimize water infiltration, a paved roadway should be used on top. Also, the base of the tire shreds should lie above the seasonally high groundwater elevation.

2. To minimize air infiltration, culverts and drainage blankets should not be installed in tire shred embankment areas. Use of drainage features located at the bottom of the fill that could provide free access to air should be avoided. If a culvert or pipe is used beneath the embankment, the top of the pipe should be located at least 3 ft. (1 m) below the bottom of the tire shred layer.

b. When stockpiling tire shreds, the stockpile shall be placed on a 1 ft. (0.3 m) thick pad of crushed stone, underdrain filter stone, or some other uniform, open-graded material. Include a quantity for this item in the contract documents.

c. Tire shred layers in embankments must be completely wrapped (i.e. top, bottom, sides, and ends) with geotextile meeting the requirements of Geotextile - Slope Protection to prevent migration of soil into the tire shred volume.
d. Sides of tire shred embankments must be covered with soil (meeting the requirements of Embankment-In-Place, Item 203.03) with a soil layer that is at least 3 ft. (1 m) thick. This is to limit the infiltration of air while at the same time provide a sufficient working area for compaction equipment. In no case should there be direct contact between tire shreds and soil containing organic matter such as topsoil.

e. The top of the tire shred embankment should be a minimum of 5 ft. (1.5 m) below the top of subgrade elevation to limit infiltration of air into the tire shred embankment and to provide enough distance between the tire shreds and the pavement section (including subbase) to ensure adequate pavement performance.

f. Tire shreds compress approximately 10% of their thickness under load. Because of this, an additional lift of tire shreds can be placed to allow for this compression. To minimize settlement of the pavement section, place a 2 ft. (0.6 m) surcharge of fill above the desired subgrade elevation to simulate the pavement section that will be placed. Impose a waiting period of 60 days, unless it is a fill section where both ends can taper from full thickness to zero at a 1 vertical on 4 horizontal slope or flatter. In that case, use 30 days.

If there are tight time constraints, wait 30 days, remove the 2 ft. (0.6 m) surcharge and place the subbase and binder course, then wait 30 more days and correct any settlement with the final pavement course. Other combinations of surcharge and waiting period can be developed by the Geotechnical Engineering Bureau based on project-specific needs. The waiting period may be reduced based upon results from field settlement measurements. The placement and removal of the surcharge material should be paid for under their respective items (see Appendix A, Typical Section and Example Construction Sequence).

g. Tire shred embankments should be transitioned at a slope of 1 vertical on 4 horizontal or flatter at both ends in the longitudinal direction to mitigate any “bumps” from developing when traversing from conventional soil embankment areas to sections containing tire shred embankments.

h. Traffic cannot be maintained over the tire shred embankment due to wires from the steel belts protruding from the tire shreds that will puncture passenger car tires.

i. Tire shred layers cannot exceed 3 ft. (1 m) in thickness measured after the waiting period.

j. Tire shred embankments containing multiple tire shred layers of 3 ft. (1 m) or less can be designed, provided that a 2 ft. (0.6 m) layer of compacted soil is placed between each tire shred layer. Each tire shred layer must be completely wrapped with a geotextile and covered with compacted soil on top and on the sides as previously described. The geotextile should be Geotextile – Slope Protection.

3.2 TYPICAL SECTION

An “example” typical section has been developed which reflect the previously listed design considerations and is shown in Appendix A. Upon request, the Geotechnical Engineering Bureau will develop and provide site specific typical sections on a project-by-project basis.
3.3 INSTRUMENTATION AND MONITORING

a. Tire shred embankments may be monitored during and after construction to verify that temperatures remain at acceptable levels. The Geotechnical Engineering Bureau will determine when temperature monitoring equipment (i.e. thermistors and data logger) should be provided and installed as part of the construction contract (specification and item number to be provided by Geotechnical Engineering Bureau). Temperature data collection and analysis will be conducted by the Geotechnical Engineering Bureau.

b. Three groundwater observation wells may be installed near the tire shred embankment to establish local baseline water quality conditions prior to construction. If specified, one well should be located hydraulically up-gradient within the shallow water table to monitor any seasonal or long-term changes in background conditions and two wells should be located down-gradient to measure any contaminants that may leach from the fill. Groundwater quality samples should be collected quarterly for the first year and analyzed using NYS DOT’s contract laboratories for the following environmental parameters: barium, cadmium, lead and zinc by EPA Method 6010, and the RCRA-list of toxic metals (As, Ba, Cr, Fe, Hg, Mn, Se, Ag, Cd and Pb) by the EPA 7000-series tests.

c. Post-construction settlement may be monitored prior to commencing final paving operations, particularly if it is desired to shorten the waiting period. To this end, a method to measure settlement should be included in the contract as recommended by the Geotechnical Engineering Bureau. Based on the results of this monitoring, the waiting period associated with the construction of the tire shred fill and the surcharge may be reduced.

3.4 CONSTRUCTION GUIDELINES

Tires will be shredded and stockpiled by others under the supervision of an inspector trained and certified by NYSDOT’s Geotechnical Engineering Bureau. The location(s) of the shreds will be shown in the contract documents.

Determine the quantity for payment by weight. *There has been discussion on the selection of the payment unit as tons (metric tons). This is because shreds are processed and paid for by weight. Neither the contractor nor the tire processor has the experience to know what weight of shreds is needed to fill up a given volume. If the contractor is paid by volume and they buy the shreds by weight, the contractor is at significant financial risk if their assumed conversion factor is wrong. This risk is manifested in either a high unit cost for the shreds or as a claim for extra payment. As an example, Maine DOT previously paid for shreds by volume, but after arguing for a year with a contractor on a claim (which they ultimately paid), they switched to paying on a weight basis and have since had good results.*

Shreds should be transported in trucks that are free from contaminants and/or deleterious material.

All tire shreds stored at the project site shall be stockpiled. Stockpiled shreds placed in contact with the ground may become contaminated with soil, and fall out of the specified gradation range. Therefore, any shreds placed in a stockpile or storage pile should be placed on a 1 ft. (0.3
m) pad of crushed stone, underdrain filter stone or some other uniform, open graded granular material to keep the shreds from becoming contaminated (this item will be paid for separately). The maximum dimensions of a shred stockpile are 50 ft. wide by 200 ft. long by 20 ft. high (15 m wide by 60 m long by 6 m high). Do not incorporate contaminated shreds into the work. Contaminated shreds, along with any shreds that remain after tire shred fill construction is complete, may be used to flatten slopes or may be placed in side slope areas in accordance with §203-3.10. Be sure that any shreds used in this manner are covered with a minimum of 2 ft. (0.6 m) of soil cover.

Do not place shreds below water. Spread the shreds in a uniform thickness over the entire width of the section shown in the plans, with a maximum loose lift thickness of 1 ft. (0.3 m). Compact each lift with a minimum of eight passes of a vibratory or non-vibratory roller with a minimum nominal gross weight of 10 tons (9 metric tons). If a vibratory roller is used, the vibration action may be either on or off. Operate the roller at a maximum speed of 4.5 mph (2 m/sec).

The tire shreds must be completely wrapped with geotextile. Adjacent sections of geotextile must be placed with a minimum 1.5 ft. (0.45 m) overlap.

Be sure that shreds do not become contaminated during placement (for example, by hydraulic fluid from a ruptured hydraulic hose). If contamination does occur, remove the contaminated shreds and properly dispose of them, and replace them with clean shreds.

3.5 SPECIAL SPECIFICATION

Special specifications have been developed for the use of tire shreds as an embankment material. The general requirements for tire shreds that have been included in these specifications are shown in Appendix B.

These specifications can be used for both normal embankment construction or for lightweight embankment applications. If a lightweight application is required, site specific design must be performed and any special requirements included in the contract documents.
4. SUMMARY

Tire shreds provide a viable source of embankment material. When used in accordance with these guidelines and the embankment is constructed in accordance with the appropriate special specification, satisfactory performance on NYSDOT highway projects should result.
APPENDIX A

CROSS SECTION DURING SURCHARGE AND WAITING PERIOD A-A

NOTE 2: EMBANKMENT IN PLACE

NOTE 3: UNCLASSIFIED EXCAVATION AND SUBGRADE

NOTE 4: EMBANKMENT IN PLACE

NOTE 5: MINIMUM

NOTE 6: MINIMUM

NOTE 7: MINIMUM

NOT TO SCALE

FINAL ELEVATION

NOTE 1: EMBANKMENT IN PLACE

NOTE 2: MINIMUM

NOTE 3: MINIMUM

NOT TO SCALE

FINAL SECTION A-A

NOTE: THE GEOTECHNICAL ENGINEERING BUREAU SETS THE CRITERIA, RESTRICTIONS, FORMULATES ANY SPECIAL NOTES, PROVIDES SPECIAL SPECIFICATIONS AND WILL DEVELOP A TYPICAL CROSS SECTION OR SECTION). THE PROJECT DESIGNER WILL INCORPORATE THE TYPICAL SECTION INTO THE PROJECT DESIGN, SET THE LIMITS AND DETAIL THE APPROPRIATE VIEWS FOR THE CONTRACT DOCUMENTS.
EXAMPLE CONSTRUCTION SEQUENCE FOR AN EMBANKMENT WITH A 3 ft. (1 m) SHRED LAYER THICKNESS

INITIAL CONSTRUCTION

EMBANKMENT IN PLACE 2 ft. (0.6 m)

EMBANKMENT IN PLACE 5 ft. (1.5 m)

TIRE SHREDS 3.3 ft. (1.1 m)

AFTER WAITING PERIOD

EMBANKMENT IN PLACE 2 ft. (0.6 m)

EMBANKMENT IN PLACE 5 ft. (1.5 m)

TIRE SHREDS 3 ft. (1.0 m)

FINAL CONSTRUCTED CONDITION

PAVEMENT

SUBBASE

EMBANKMENT IN PLACE 5 ft. (1.5 m)

TIRE SHREDS 3 ft. (1.0 m)

NOT TO SCALE

1. BUILD TIRE SHRED LAYER 4 in. (0.1 m) (10%) THICKER THAN THE DESIGN FINAL THICKNESS.
2. PLACE EMBANKMENT IN PLACE (5 ft. COVER + 2 ft. SURCHARGE) (1.5 m COVER + 0.6 m SURCHARGE) TO 1 ft. (0.3 m) ABOVE PROPOSED FINAL GRADE.
3. WAIT 2 MONTHS.
4. REMOVE TOP 2 ft. (0.6 m) EMBANKMENT IN PLACE.
5. PLACE SUBBASE AND PAVEMENT.
APPENDIX B

Tire Shred Requirements

**Visual**
All shreds shall:
- have at least one sidewall severed from each shred.
- have less than 1% by weight of free steel.

**Protruding Steel**
Tire shreds shall conform to the following requirements for protruding steel:
- Metal wires protruding more than 2 in. (50 mm) from the edge of any tire shred: 0%.
- Metal wires protruding between 1 in. and 2 in. (25 mm and 50 mm) from the edge of any tire shred: 0 – 25% of the shreds by weight.
- Shreds with metal wires protruding less than 1 in. (25 mm) from the edge of any tire are acceptable.

**Gradation**
Shreds shall meet the following size and gradation requirements.
- Total weight of shreds with a maximum dimension greater than 12 in. (300 mm) and less than 16 in. (400 mm) shall be less than 10% by weight of total sample.
- Maximum dimension in any direction shall not exceed 16 in. (400 mm).
- Gradation requirements:

<table>
<thead>
<tr>
<th>Sieve Size</th>
<th>Percent Passing By Weight</th>
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<td>16 in. (400 mm)</td>
<td>100</td>
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<tr>
<td>12 in. (300 mm)</td>
<td>90 - 100</td>
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<tr>
<td>8 in. (200 mm)</td>
<td>75 – 100</td>
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<tr>
<td>1 ½ in. (38 mm)</td>
<td>0 – 25</td>
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<tr>
<td>No. 4 (4.75 mm)</td>
<td>0 – 1</td>
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</table>

**Deleterious material**
Shreds are free from contaminants and undesirable materials such as:
- Oil.
- Gasoline.
- Crumb rubber.
- Diesel fuel.
- Grease.
- Hydraulic fluid.
- Wood or other fibrous organic matter.
APPENDIX B

- Excessive dirt (a thin coating of clay which discolors the shreds is acceptable, but large chunks of clay, silt, sand or gravel are not).
- Ice and snow. Note that ice and snow on the surface of the completed stockpile is acceptable. However, ice and snow shall not be incorporated into the pile or the work.
- Remnants of tires that have been subjected to fire.
- Any other material that is determined to be deleterious by the Director, Geotechnical Engineering Bureau, NYSDOT.
- Any material that is determined to be contaminated or hazardous by the Director, Bureau of Solid Waste, Reduction and Recycling, Division of Solid and Hazardous Materials, NYSDEC.
APPENDIX C

Useful Information

1. There are 49 to 56 tires in a cubic yard of shred in its final compacted position (65 to 75 tires in a cubic meter of shred in its final compacted position).

2. The compacted density of a tire shred fill in its final compacted position is 37 to 56 pcf (0.6 to 0.9 Mg/m$^3$), depending on shred size. Shred conforming to NYSDOT specification requirements tends to have a lower density than fills using smaller shreds or tire chips. Therefore, use 37 to 44 pcf (0.6 to 0.7 metric tons/m$^3$) in place for NYSDOT projects.

3. A “DEC” pile is 20 feet high by 50 feet wide by 200 feet long (6 m high by 15 m wide by 60 m long). The volume of a pile of these dimensions is approximately 4,420 yd$^3$ ( 3,400 m$^3$).
APPENDIX D

July 1997

DESIGN GUIDELINES TO MINIMIZE INTERNAL HEATING OF TIRE SHRED FILLS

Background
Since 1988 more than 70 tire shred fills with a thickness less than 1 m and an additional ten fills less than 4 m thick have been constructed. In 1995 three tire shred fills with a thickness greater than 8 m experienced a catastrophic internal heating reaction. These unfavorable experiences have curtailed the use of all tire shred fills on highway projects.

Possible causes of the reaction are oxidation of the exposed steel belts and oxidation of the rubber. Microbes may have played a role in both reactions. Although details of the reaction are under study, the following factors are thought to create conditions favorable for oxidation of exposed steel and/or rubber: free access to air; free access to water; retention of heat caused by the high insulating value of tire shreds in combination with a large fill thickness; large amounts of exposed steel belts; smaller tire shred sizes and excessive amounts of granulated rubber particles; and the presence of inorganic and organic nutrients that would enhance microbial action.

The design guidelines given in the following section were developed to minimize the possibility of heating of tire shred fills by minimizing the conditions favorable for this reaction. As more is learned about the causes of the reaction, it may be possible to ease some of the guidelines. In developing these guidelines, the insulating effect caused by increasing fill thickness and the favorable performance of projects with tire shred fills less than 4 m thick were considered. Thus, design guidelines are less stringent for projects with thinner tire shred layers. The guidelines are divided into two classes: Class I Fills with tire shred layers less than 1 m thick and Class II Fills with tire shred layer in the range of 1 m to 3 m thick. Although there have been no projects with less than 4 m of tire shred fill that have experienced a catastrophic heating reaction, to be conservative, tire shred layers greater than 3 m thick are not recommended. In addition to the guidelines given below, the designer must choose the maximum tire shred size, thickness of overlying soil cover, etc., to meet the requirements imposed by the engineering performance of the project. The guidelines are for use in designing tires shred monofilts. Design of fills that are mixtures or alternating layers of tire shred and mineral soil that is free form organic matter should be handled on a case by case basis.

General Guidelines for All Tire Shred Fills
All tires shall be shredded such that the largest shred is the lesser of one quarter circle in shape or 0.6 m in length; and at least one sidewall shall be severed from the tire shred. The tire shreds shall be free of all contaminants such as oil, grease, gasoline, diesel fuel, etc., that could create a fire hazard. In no case shall the tire shreds contain the remains of tires that have been subjected to a fire because the heat of a fire may liberate liquid petroleum products from the tire that could create a fire hazard when the shreds are placed in a fill.

Ref: FHWA: Design Guidelines to Minimize Internal Heating of Tire Shreds, July 1997
APPENDIX D

Class I Fills

Material guidelines. The tire shreds shall have a maximum of 50% (by weight) passing the 38 mm sieve and a maximum of 5% (by weight) passing the 4.75 mm sieve.

Design guidelines. No design features are required to minimize heating of Class I Fills.

Class II Fills

Material guidelines. The tire shreds shall have a maximum of 25% *by weight) passing the 38 mm sieve and a maximum of 1% (by weight) passing the 4.75 mm sieve. The tire shreds shall be free from fragments of wood, wood chips, and other fibrous organic matter. The tire shreds shall have less than 1% (by weight) of metal fragments which are not at least partially encased in rubber. Metal fragments that are partially encased in rubber shall protrude no more than 25 mm from the cut edge of the tire shred on 75% of the pieces and no more than 50 mm on 100% of the pieces.

Design guidelines. The tire shred fill shall be construed in such a way that infiltration of water and air is minimized. Moreover, there shall be no direct contact between tire shreds and soil containing organic matter, such as topsoil. One possible way to accomplish this is to cover the top and sides of the fill with a 0.5 m thick layer of compacted mineral soil with a minimum of 30% fines. The mineral soil should be free from organic matter and should be separated from the tire shreds with a geotextile. The top of the mineral soil layer should be sloped so that water will drain away from the tire shred fill. Additional fill may be placed on top of the mineral soil layer as needed to meet the overall design of the project. If the project will be paved, it is recommended that the pavement extend to the shoulder of the embankment or that other measures be taken to minimize infiltration at the edge of the pavement.

Use of drainage features located at the bottom of the fill that could provide free access to air should be avoided. This includes, but is not limited to, open graded drainage layers daylighting on the side of the fill and drainage holes in walls. Under some conditions, it may be possible to use a well graded granular soil as a drainage layer. The thickness of the drainage layer at the point where it daylight on the side of the fill should be minimized. For tire shred fills placed against walls, it is recommended that the drainage hold in the wall be covered with well graded granular soil. The granular soil should be separated from the tire shreds with geotextile.
### General Guidelines for all Tire Shred Fills (July 1997)

- All tires shall be shredded such that the largest shred is the lesser of one quarter circle in shape or 0.6 m in length; and at least one sidewall shall be severed form the tire shred.
- Tire shreds shall be free of contaminants such as oil, grease, gasoline, diesel fuel, etc., that could create a fire hazard.
- In no case shall the tire shreds contain the remains of tires that have been subjected to a fire.

<table>
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<th>Class I Fills (&lt; 1 m thick)</th>
<th>Class II Fills (1-3 m thick)</th>
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<tr>
<td>• Maximum of 50% (by weight) passing 38 mm sieve.</td>
<td>• Maximum of 25% (by weight) passing 38 mm sieve.</td>
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<td>• Maximum of 5% (by weight) passing 4.75 mm sieve.</td>
<td>• Maximum of 1% (by weight) passing 4.75 mm sieve.</td>
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<td>• Tire shreds shall be free form fragments of wood, wood chips, and other fibrous organic matter.</td>
<td>• The tire shreds shall have less than 1% (by weight) of metal fragments that are not at least partially encased in rubber.</td>
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<tr>
<td>• Metal fragments that are partially encased in rubber shall protrude no more than 25 mm from the cut edge of the tire shred on 75% of the pieces and no more than 50 mm on 100% of the pieces.</td>
<td>• Infiltration of water into the tires shred fill shall be minimized.</td>
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<tr>
<td>• No direct contact between tire shreds and soil containing organic matter, such as topsoil.</td>
<td>• Infiltration of air into the tires shred fill shall be minimized.</td>
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<td>• Tire chips should be separated from the surrounding soil with a geotextile.</td>
<td>• Use of drainage features located at the bottom of the fill that could provide free access to air should be avoided</td>
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APPENDIX D

These guidelines were prepared by the Ad Hoc Civil Engineering Committee, a partnership of government and industry dealing with reuse of scrap tires for civil engineering purposes. The committee members are:

Michael Blumenthal, Executive Director, Scrap Tire Management Council
Mark Hope, Senior Vice President, Waste Recovery, Inc.
Dana Humphrey, Ph.D., Professor of Civil Engineering, University of Maine
James Powell, Federal Highway Administration
John Serumgard, Chairman, Scrap Tire Management Council
Mary Sikora, Scrap Tire Program Director, Internal Tire and Rubber Association
Robert Snyder, Ph.D., President, Tire Technology, Inc.
Joseph Zelibor, Ph.D., Former Science Director, Scrap Tire Management Council & Vice President, Partners in Research, Inc.

The committee can be contacted by calling the Scrap Tire Management Council at (202) 682-4880.
APPENDIX E

Ref: ASTM D6270: Standard Practice for Use of Scrap Tires
In Civil Engineering Applications
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APPENDIX E
# APPENDIX E

Ref: ASTM D6270: Standard Practice for Use of Scrap Tires in Civil Engineering Applications
APPENDIX E

Ref: ASTM D6270: Standard Practice for Use of Scrap Tires
In Civil Engineering Applications
Appendix E

Ref: ASTM D6270: Standard Practice for Use of Scrap Tires
In Civil Engineering Applications
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**Ref:** ASTM D6270: Standard Practice for Use of Scrap Tires In Civil Engineering Applications