INTERNATIONAL

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Standard Practice for Use of Scrap Tires in Civil Engineering Applications[1]

This standard is issued under the fixed designation D 6270; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1This practice provides guidance for testing the physical properties and gives data for assessment of the leachate generation potential of processed or whole scrap tires in lieu of conventional civil engineering materials, such as stone, gravel, soil, sand, or other fill materials. In addition, typical construction practices are outlined.

1.1 This practice provides guidance for testing the physical properties, design considerations, construction practices, and leachate generation potential of processed or whole scrap tires in lieu of conventional civil engineering materials, such as stone, gravel, soil, sand, lightweight aggregate, or other fill materials.

1.2 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

2. Referenced Documents

2.1 *ASTM Standards:*[2]

C 127 Test Method for Specific Gravity and Absorption of Coarse Aggregate Test Method for Density, Relative Density (Specific Gravity), and Absorption of Coarse Aggregate

D422Test Method for Particle-Size Analysis of Soils C 136 Test Method for Sieve Analysis of Fine and Coarse Aggregates

D 698 Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort (12,400(12 400 ft-lbf/ft^3(600 kN-m/m^3))

D 1557 Test Methods for Laboratory Compaction Characteristics of Soil Using Modified Effort (56,000 ft-lbf/ft^3(2,700 kN-m/m^3))

D 2434 Test Method for Permeability of Granular Soils (Constant Head)

D 3080 Test Method for Direct Shear Test of Soils Under Consolidated Drained Conditions

D 4253 Test Methods for Maximum Index Density and Unit Weight of Soils Using a Vibratory Table

2.2 *AASHTO Standard:*

T274 Standard Method of Test for Resilient Modulus of Subgrade SoilsAmerican Association of State Highway and Transportation Officials Standard:

T 274 Standard Method of Test for Resilient Modulus of Subgrade Soils[3]

2.3 *USEPA Standard:*

Method 1311 Toxicity Characteristics Leaching ProcedureU.S. Environmental Protection Agency Standard:

Method 1311 Toxicity Characteristics Leaching Procedure[4]

3. Terminology

3.1 *Definitions:*

3.1.1 *baling*, *n*—a method of volume reduction whereby tires are compressed into bales.

3.1.2 *bead*, *n*—the anchoring part of the tire which is shaped to fit the rim and is constructed of bead wire wrapped by the plies.

3.1.3 *bead wire*, *n*—a high tensile steel wire surrounded by rubber, which forms the bead of a tire that provides a firm contact to the rim.

[1] This practice is under the jurisdiction of ASTM Committee D34 on Biotechnology and is the direct responsibility of Subcommittee D34.03.03 on Industrial Recovery and Reuse.

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[1] This practice is under the jurisdiction of ASTM Committee D34 on Waste Management and is the direct responsibility of Subcommittee D34.03.03 on Industrial Recovery and Reuse.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] *Standard Specifications for Transportation Materials and Methods of Sampling and Testing, Part II: Methods of Sampling and Testing,* American Association of State Highway and Transportation Officials, Washington, D.C.DC.

[4] *Test Methods for Evaluating Solid Waste: Physical/Chemical Methods,* 3rd ed., Report No. EPA 530/SW-846, U.S. Environmental Protection Agency, Washington, D.C.DC.

3.1.4 *belt wire*, *n*—a brass plated high tensile steel wire cord used in steel belts.

3.1.5 *buffing rubber*, *n*—vulcanized rubber usually obtained from a worn or used tire in the process of removing the old tread in preparation for retreading.

3.1.6 *carcass*, *n*—see *casing*.

3.1.7 *casing*, *n*—the basic tire structure excluding the tread (Syn. *carcass*).

3.1.8 *chipped tire*, *n*—see *tire chip.*

3.1.9 *chopped tire*, *n*—a scrap tire that is cut into relatively large pieces of unspecified dimensions.

3.1.10 *granulated rubber*, *n*—particulate rubber composed of mainly non-spherical particles that span a broad range of maximum particle dimension, from below 425 µm (40 mesh) to 12 mm (also refer to *particulate rubber*).[5]

~~3.1.9~~

3.1.11 *ground rubber*, *n*—particulate rubber composed of mainly non-spherical particles that span a range of maximum particle dimensions, from below 425 µm (40 mesh) to 2 mm (also refer to *particulate rubber*).[5]

~~3.1.10~~

3.1.12 *nominal size*, *n*—the average size product ~~(chip)~~ that comprises 50 % or more of the throughput in a scrap tire processing operation; scrap tire processing operations generate products ~~(chips)~~ above and below the nominal size.

~~3.1.11~~3.1.13 *particulate rubber*, *n*—raw, uncured, compounded or vulcanized rubber that has been transformed by means of a mechanical size reduction process into a collection of particles, with or without a coating of a partitioning agent to prevent agglomeration during production, transportation, or storage (also see definition of *buffing rubber, granulated rubber, ground rubber,* and *powdered rubber*).[5]

~~3.1.12~~

3.1.14 *passenger car tire*, *n*—a tire with less than a 457-mm rim diameter for use on cars only.

~~3.1.13~~

3.1.15 *powdered rubber*, *n*—particulate rubber composed of mainly non-spherical particles that have a maximum particle dimension equal to or below 425 µm (40 mesh) (also refer to *particulate rubber*).[5]

~~3.1.14~~

3.1.16 *preliminary remediation guideline*, *n*— risk-based concentrations that the USEPA considers to be protective for lifetime exposure to humans.

3.1.17 *rough shred*, *n*—a piece of a shredded tire that is larger than 50 mm by 50 mm by 50 mm, but smaller than 762 mm by 50 mm by 100 mm.

~~3.1.15~~

3.1.18 *rubber fines*, *n*—small particles of ground rubber that result as a by-product of producing shredded rubber.

~~3.1.16~~

3.1.19 *scrap tire*, *n*—a ~~tire,~~tire which can no longer be used for its original purpose due to wear or damage.

~~3.1.17~~3.1.20 *shred sizing*, *n*—a term which generally refers to the process of particles passing through a rated screen opening rather than those which are retained on the screen.

~~3.1.18~~

3.1.21 *shredded tire*, *n*—a size reduced scrap tire where the reduction in size was accomplished by a mechanical processing device, commonly referred to as a shredder.

~~3.1.19~~

3.1.22 *shredded rubber*, *n*—pieces of scrap tires resulting from mechanical processing.

~~3.1.20~~

3.1.23 *sidewall*, *n*—the side of a tire between the tread shoulder and the rim bead.

~~3.1.21~~

3.1.24 *single pass shred*, *n*—a shredded tire that has been processed by one pass through a shear type shredder and the resulting pieces have not been classified by size.

~~3.1.22~~

3.1.25 *steel belt*, *n*—rubber coated steel cords that run diagonally under the tread of steel radial tires and extend across the tire approximately the width of the tread.

~~3.1.23~~

3.1.26 *tire chips*, *n*~~—Pieces~~—pieces of scrap tires that have a basic geometrical shape and are generally between 12 ~~mm~~ and 50 mm in size and have most of the wire removed (Syn. *chipped tire*).

~~3.1.24~~

3.1.27 *tire derived aggregate (TDA)*, *n*—pieces of scrap tires that have a basic geometrical shape and are generally between 12 and 305 mm in size and are intended for use in civil engineering applications. Also see definition of *tire chips* and *tire shreds.*

3.1.28 *tire shreds*, *n*~~—Pieces~~—pieces of scrap tires that have a basic geometrical shape and are generally between 50 ~~mm~~ and 305 mm in size.

[5] The defined term is the responsibility of Committee D11 on Rubber.

~~3.1.25~~3.1.29 *tread*, *n*—that portion of the tire which contacts the road.

~~3.1.26~~

3.1.30 *truck tire*, *n*—a tire with a rim diameter of 500 mm or larger.

~~3.1.27~~

3.1.31 *waste tire*, *n*—a tire which is no longer capable of being used for its original purpose but which has been disposed of in such a manner that it can not be used for any other purpose.

~~3.1.28~~

3.1.32 *whole tire*, *n*—a scrap tire that has been removed from a rim, but which has not been processed.

~~3.1.29~~3.1.33 *x-mm minus*, *n*~~—pieces of classified, size reduced scrap tires where the maximum size of 95 % of the pieces is less than x-mm in any dimension (that is, 25-mm minus; 50-mm minus; 75-mm minus, etc).~~ —pieces of classified, size-reduced scrap tires where a minimum of 95 % by weight passes through a standard sieve with an x-mm opening size (that is, 25-mm minus; 50-mm minus; 75-mm minus, etc.).

4. Significance and Use

4.1 This practice is intended for use of scrap tires including: tire ~~chips or tire shreds~~ derived aggregate (TDA) comprised of pieces of scrap tires, ~~tire chip/soil~~ TDA/soil mixtures, tire sidewalls, and whole ~~scarp~~scrap tires in civil engineering applications. This ~~practice~~ includes ~~the~~ use of ~~tire chips, tire shreds,~~ TDA and ~~tire chip/soil~~ TDA/soil mixtures as lightweight embankment fill, lightweight retaining wall backfill, drainage layers for roads, landfills and other applications, thermal insulation to limit frost penetration beneath roads, insulating backfill to limit heat loss from buildings, vibration damping layers for rail lines, and replacement for soil or rock in other fill applications. Use of whole scrap tires and tire sidewalls includes construction of retaining ~~walls and~~ walls, drainage culverts, road-base reinforcement, and erosion protection, as well as use as fill when whole tires have been compressed into bales. It is the responsibility of the design engineer to determine the appropriateness of using scrap tires in a particular application and to select applicable tests and specifications to facilitate construction and environmental protection. This practice is intended to encourage wider utilization of scrap tires in civil engineering applications.

4.2 Three ~~tire shred~~ TDA fills with thicknesses in excess of 7 m have experienced a serious heating ~~reaction; however,~~reaction. However, more than ~~70~~100 fills with a thickness less than 3 m have been constructed with no evidence of a deleterious heating reaction ~~(~~(**1**).[6] ~~.~~Guidelines have been developed to minimize internal heating of ~~tire shred~~ TDA fills ~~(~~(**2**) as discussed in ~~6.10~~6.11. The guidelines are applicable to fills less than 3 m ~~thick; thus,~~thick. Thus, this practice should be applied only to ~~tire shred~~TDA fills less than 3 m thick.

5. Material Characterization

5.1 The specific gravity and water absorption capacity of ~~tire shreds~~ TDA should be determined in accordance with Test Method C 127~~; however,~~. However, the specific gravity of ~~tire shreds~~ TDA is less than half the value obtained for common earthen coarse aggregate, so it is permissible to use a minimum weight of test sample that is half of the specified value. The particle density or density of solids of ~~tire shreds~~ TDA (ρ_s) may be determined from the apparent specific gravity using the following equation:

$$\rho_s = S_a(\rho_w) \tag{1}$$

where:

S_a = apparent specific gravity, and
ρ_w = density of water.

5.2 The gradation of ~~tires shreds~~ TDA should be determined in accordance with Test Method ~~D 422~~C 136~~; however,~~. However, the specific gravity of ~~tire shreds~~ TDA is less than half the values obtained for common earthen materials, so it is permissible to use a minimum weight of test sample that is half of the specified value.

5.3 The laboratory compacted dry density~~,~~ (or bulk ~~density,~~density) of ~~tire chips~~ TDA and ~~tire chip/soil~~ TDA/soil mixtures with less than 30 % retained on the 19.0-mm sieve can be determined in accordance with Test Method D 698 or D 1557. ~~Tire Shred~~However, TDA and ~~tire shred/soil~~ TDA/soil mixtures used for civil engineering ~~applications, however,~~ applications almost always have more than 30 % retained on the 19.0-mm sieve, so these methods generally are not applicable. A larger compaction mold should be used to accommodate the larger size of the ~~tire shreds.~~TDA. The sizes of typical compaction molds are summarized in Table 1. The larger mold requires that the number of layers, or the number of blows of the rammer~~/~~ per layer, or both, be increased to produce the desired compactive energy~~/~~ per unit volume. Compactive energies ranging from 60 % of Test Method D 698 (60 % × 600 kN-m/m^3 = 360 kN-m/m^3~~) to 100 % of Test Method D 1557 (2,700 kN-m/m~~) to 100 % of Test Method D 1557 (2700 kN-m/m^3) have been used. Compaction energy ~~only~~ has only a small effect on the resulting dry density ~~(~~(**3**)~~;~~; thus, for most applications it is permissible to use a compactive energy equivalent to 60 % of Test Method D 698. To achieve this energy with a mold volume of 0.0125 m^3 would require that the sample be compacted in ~~five~~5 layers with 44 blows~~/~~ per layer with a 44.5 N rammer falling 457 mm. The water content of the sample ~~only~~ has only a small effect on the compacted dry density ~~(~~(**3**) so it is permissible to perform compaction tests on air or oven-dried samples.

[6] The boldface numbers in parentheses refer to the list of references at the end of this standard.

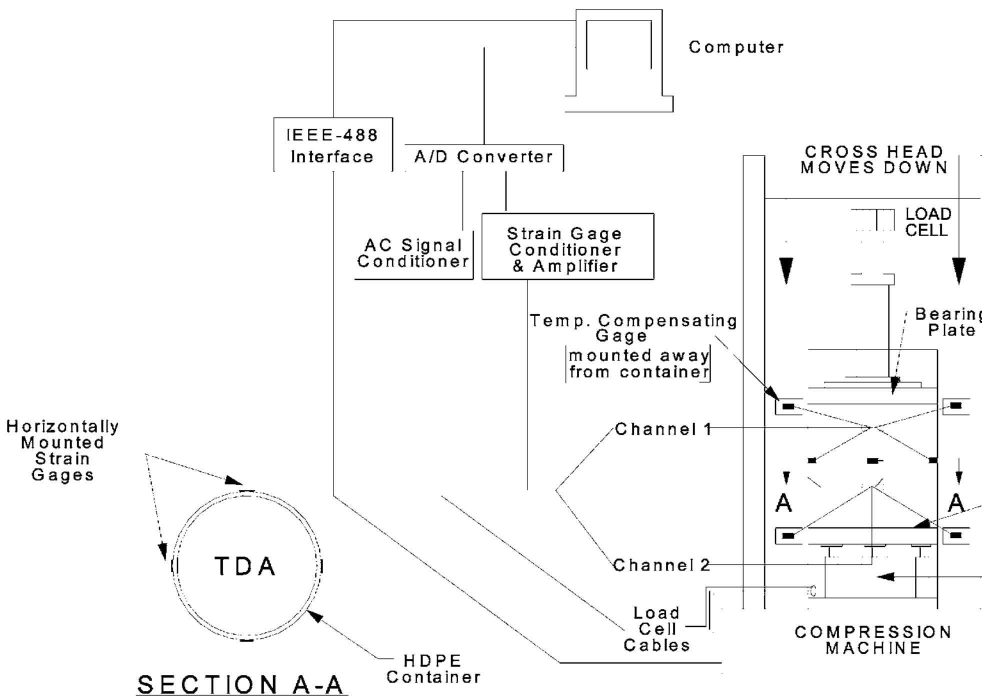

FIG. 1 Compressibility Apparatus for TDA Designed to Measured Lateral Stress and the Portion of the Vertical Load Transferred by Friction from TDA to Container (10)

TABLE 1 Size of Compaction Molds Used to Determine Dry Density of ~~Tire Shreds~~DA

Maximum Particle Size (mm)	Mold Diameter (mm)	Mold Volume (m^3)	Reference
~~75~~	~~254~~	~~0.0125~~	~~(3)~~
75	254	0.0125	(3)
~~75~~	~~305~~	~~0.0146~~	~~(4)~~
75	305	0.0146	(4)
~~51~~	~~203 and 305~~	~~N.R.~~[A]	~~(5)~~
51	203 and 305	N.R.[A]	(5)

[A] N.R. = not reported.

5.3.1 The dry densities for ~~tire shreds~~ TDA loosely dumped into a compaction mold and ~~tire shreds~~ TDA compacted by vibratory methods (similar to Test Method D 4253) are about the same ~~(~~ **(4, 5, 6**~~); thus, vibratory compaction of tire shreds in the laboratory (see Test Method D 4253~~6). Thus, vibratory compaction of TDA in the laboratory (see Test Method D 4253) should not be used.

5.3.2 When estimating an in-place density for use in design, the compression of a ~~tire shred~~TDA layer under its own self-weight and under the weight of any overlying material must be considered. The dry density determined as discussed in 5.3 are uncompressed values. In addition, short-term time dependent settlement of ~~tire shreds~~ TDA should be accounted for when estimating the final in-place density ~~(~~**(7)**~~)~~.

5.4 The compressibility of ~~tire shreds~~ TDA and ~~tire shred/soil~~ TDA/soil mixtures can be measured by placing ~~tire shreds~~TDA in a rigid cylinder with a diameter several times greater than the largest particle size and then measuring the vertical strain caused by an increasing vertical stress. If it is desired to calculate the coefficient of lateral earth pressure at rest K_O, the cylinder can be instrumented to measure the horizontal stress of the ~~tire shreds~~ TDA acting on the wall of the cylinder.

5.4.1 The high compressibility of ~~tire shreds~~ TDA necessitates the use of a relatively thick sample. In general, the ratio of the initial specimen thickness to sample diameter should be greater than one. This leads to concerns that a significant portion of the applied vertical stress could be transferred to the walls of the cylinder by friction. If the stress transferred to the walls of the cylinder is not accounted for, the compressibility of the ~~tire shreds~~ TDA will be underestimated. For all compressibility tests, the inside of the container should be lubricated to reduce the portion of the applied load that is transmitted by side friction from the sample to the walls of the cylinder. For testing where a high level of accuracy is desired, the vertical stress at the top and the bottom of the sample should be measured so that the average vertical stress in the sample can be computed. A test apparatus designed for this purpose is illustrated in Fig. 1~~(~~ **(8)** ~~)~~.

5.5 The resilient modulus (M_R) of subgrade soils can be expressed as:

$$~~M_R = A\Theta^B~~ \quad (2)$$

$$M_R = A\theta^B \quad (2)$$

where:

~~Θ~~θ = first invariant of stress (sum of the three principal stresses),
A = experimentally determined parameter, and
B = experimentally determined parameter.

5.5.1 Tests for the parameters A and B can be conducted according to AASHTO T 274. The maximum particle size typically is limited to 19 mm by the testing apparatus~~,~~ which precludes the general applicability of this procedure to the larger size ~~tire chips and shreds~~TDA typically used for civil engineering applications.

5.6 The coefficient of lateral earth pressure at rest K_O and Poisson's ratio μ can be determined from the results of confined compression tests where the horizontal stresses were measured. A test apparatus designed for this purpose is shown in ~~Fig. 1~~ *Fig. 1. K_O and μ are calculated from:*

$$K_O ~~= \sigma_h/\sigma_v~~ \quad (3)$$

= σ hσv

$$~~\mu = K_O/(1+K_O)~~ \quad (4)$$

μ = KO1 + KO

where:

σ_h = measured horizontal stress, and
σ_v = measured vertical stress.

~~5.7The shear strength of tire shreds may be determined in a direct shear apparatus in accordance with Test Method D 3080 or using a triaxial shear apparatus. The large size of tire shreds typically used for civil engineering applications requires that specimen sizes be several times greater than used for common soils. Because of the limited availability of large triaxial shear apparatus, this method is generally restricted to tire chips 25 mm in size and smaller. Extrapolation of results on small size pieces to the 75-mm and larger size shreds used for civil engineering applications is uncertain since small pieces are nearly equidimensional while larger tire chips and shreds tend to be long and flat. Furthermore, the triaxial shear apparatus generally is not suitable for tire shreds that have steel belts protruding from the cut edges of the shreds since the wires would puncture the membrane used to surround the specimen. The interface strength between tire shreds and geomembrane can be measured in a large scale direct shear test apparatus (**9**).~~

~~5.8The hydraulic conductivity (permeability) of tire shreds and tire shred/soils mixtures should be measured with a constant head permeameter with a diameter several times greater than the maximum particle size. Tire chips with a maximum size smaller than 19 mm can be determined in accordance with Test Method D 2434; however, tire shreds and tire shred/soil mixtures used for civil engineering applications almost always have a majority of their particles larger than 19 mm so this method is generally not applicable. Samples should be tested at a void ratio comparable to the value expected in the field. This may require a permeameter capable of appling a vertical stress to the sample to simulate the compression that would occur under the weight of overlying material. The high hydraulic conductivity of tire shreds should be accounted for in design of the permeameter. The design shall include provisions for an adequate supply of water and measuring the head loss across the sample using standpipes mounted on the body of the permeameter. An apparatus designed taking these factors into account is shown in~~

5.7 The shear strength of TDA may be determined in a direct shear apparatus in accordance with Test Method D 3080 or using a triaxial shear apparatus. The large size of TDA typically used for civil engineering applications requires that specimen sizes be several times greater than used for common soils. Because of the limited availability of large triaxial shear apparatus, this method is generally restricted to TDA 25 mm in size and smaller. The interface strength between TDA and geomembrane can be measured in a large scale direct shear test apparatus (**9**).

5.8 The hydraulic conductivity (permeability) of TDA and TDA/soils mixtures should be measured with a constant head permeameter with a diameter several times greater than the maximum particle size. TDA with a maximum size smaller than 19 mm can be determined in accordance with Test Method D 2434. However, TDA and TDA/soil mixtures used for civil engineering applications almost always have a majority of their particles larger than 19 mm, so this method is generally not applicable. Samples should be tested at a void ratio comparable to the value expected in the field. This may require a permeameter capable of applying a vertical stress to the sample to simulate the compression that would occur under the weight of overlying material. The high hydraulic conductivity of TDA should be accounted for in design of the permeameter. This includes provisions for an adequate supply of water and measuring the head loss across the sample using standpipes mounted on the body of the permeameter. An apparatus that takes these factors into account is shown in Fig. 2 ~~(~~(**~~10~~11**)~~.~~).

5.9 The thermal conductivity of ~~tire shreds~~ TDA is significantly lower than for common soils. For ~~tire chips~~ TDA smaller than 25 mm in size, the thermal conductivity can be measured using commercially available guarded hot plate apparatus. For ~~tire shreds~~ TDA larger than 25 mm, it is necessary to construct a large scale hot plate apparatus ~~(~~(**~~11~~12**)~~)~~. The thermal conductivity of ~~tire shreds~~ TDA also can be back-calculated from field measurements ~~(~~(**~~11~~12**)~~).~~ .

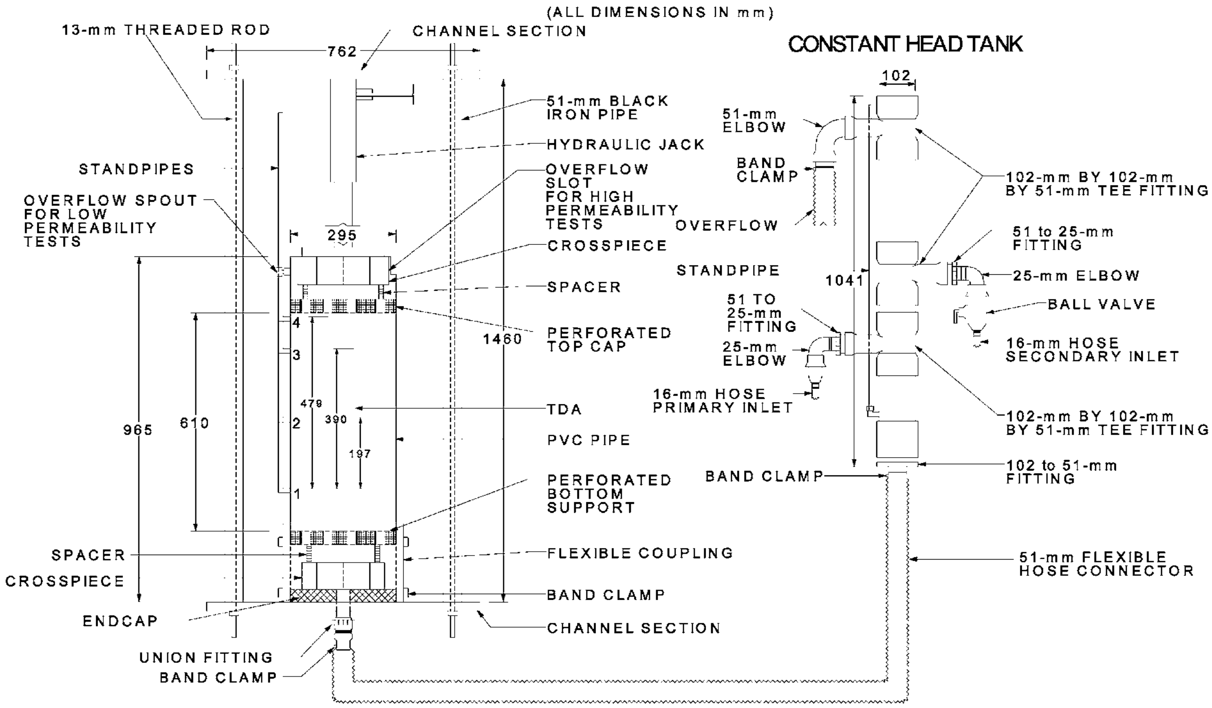

FIG. 2 Hydraulic Conductivity Apparatus for TDA with Provisions for Application of Vertical Stress (11)

6. Construction Practices

6.1Tire shreds have a compacted dry density that is one-third to one-half of the compacted dry density of typical soil. This makes them an attractive lightweight fill for embankment construction on weak, compressible soils where slope stability or excessive settlement are a concern.

6.2The thermal resistivity of tire shreds is approximately eight times greater than for typical granular soil. For this reason, tire shreds can be used as a 150 to 450-mm thick insulating layer to limit the depth of frost penetration beneath roads. This reduces frost heave in the winter and improves subgrade support during the spring thaw. In addition, tire shreds can be used as backfill around basements to limit heat lost through basement walls, thereby reducing heating costs.

6.3The low-compacted dry density, high-hydraulic conductivity, and low-thermal conductivity makes tire shreds very attractive for use as retaining wall backfill. Lateral earth pressures for tire shred backfill can be about 50 % of values obtained for soil backfill (**7**). Tire shreds also can be used as backfill for geosynthetic-reinforced retaining walls.

6.4The high hydraulic conductivity of tire shreds, generally greater than 1 cm/s, makes them suitable for many drainage applications, including French drains, drainage layers in landfill liner and cover systems, and leach fields for on-site sewage disposal systems.

6.5Two different sizes of tire shreds commonly are used for the applications discussed above. One has a maximum size of 75 mm and the other has a maximum size of 300 mm. Rough shreds also can been used for some applications provided all tires are shredded such that the largest shred is the lesser of one-quarter circle in shape or 600 mm in length. In all cases, at least one side wall should be severed from the tread.

6.6Tire shreds with a maximum size of 75 mm or 300 mm generally are placed in 300-mm thick lifts and compacted by a tracked bulldozer, sheepsfoot roller, or smooth drum vibratory roller with a minimum operating weight of 90 kN. Rough shreds generally are placed in 900-mm thick lifts and compacted by a tracked bulldozer. For most applications, a minimum of six passes of the compaction equipment should be used.

6.7Tire shreds should be covered with a sufficient thickness of soil to limit deflections of overlying pavement caused by traffic loading. Soil cover thicknesses as low as 0.8 m may be suitable for roads with light traffic. For roads with heavy traffic, 1 to 2 m of soil cover may be required. For unpaved applications, 0.3 to 0.5 m of soil cover may be suitable depending on the traffic loading. The designer should assess the actual thickness of soil cover needed based on the loading conditions, tire-shred layer thickness, pavement thickness, and other conditions as appropriate for particular project. Regardless of the application, the tire shreds should be covered with soil to prevent contact between the public and the tire shreds, which may have exposed steel belts.

6.8In applications where pavement will be placed over the tire shred layer and in drainage applications, the tire shred layer should be wrapped completely in a layer of nonwoven or woven geotextile to minimize infiltration of soil particles into the voids between the tire shreds.

~~6.9Whole tires and tire sidewalls that have been cut from the tire carcass can be used to construct retaining walls and bound together to form drainage culverts.~~

~~6.10Tire shred fills should be designed to minimize the possibility of an internal heating reaction (**2**). Possible causes of the reaction are oxidation of the exposed steel belts and oxidation of the rubber. Microbes may play 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, or rubber, or both; 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.~~

~~6.10.1The design guidelines given in the following sections have been developed to minimize the possibility for heating of tire shred fills by minimizing factors that could possibly create 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 have been 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 layers 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. These guidelines are for use in designing tire shred fills. Design of fills that are mixtures or alternating layers of tire shreds and mineral soil that is free from organic matter should be handled on a case by case basis.~~

~~6.10.2For both Class I and II Fills, 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.~~

~~6.10.3For Class I Fills, 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. No special design features are required to minimize heating of Class I Fills.~~

~~6.10.4For Class II Fills, 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 encased partially 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.~~

~~6.10.5Class II Fills shall be constructed 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 will 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 geotexile. 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.~~

~~6.10.6For Class II Fills, use of drainage features located at the bottom of the fill that could provide free access to air should be avoided. Use of drainage features 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 daylights on the side of the fill should be minimized. For tire shred fills placed against walls, it is recommended that the drainage holes in the wall be covered with well graded granular soil. The granular soil should be separated from the tire shreds with geotextile.~~

~~**7.Leachate**~~

~~7.1The Toxicity Characteristics Leaching Procedure (TCLP) (USEPA Method 1311) is used to determine if a waste is a hazardous waste, thereby posing a significant hazard to human health due to leaching of toxic compounds. The TCLP test represents the worst case scenario of acid rain percolating through the waste and exiting as leachate. For all regulated metals and organics, the results for tire shreds are well below the TCLP regulatory limits (**12,**~~

6.1 TDA have a compacted dry density that is one-third to one-half of the compacted dry density of typical soil. This makes them an attractive lightweight fill for embankment construction on weak, compressible soils where slope stability or excessive settlement are a concern as well as landslide repair.

6.2 The thermal resistivity of TDA is approximately eight times greater than for typical granular soil. For this reason, TDA can be used as a 150 to 450-mm thick insulating layer to limit the depth of frost penetration beneath roads. This reduces frost heave in the winter and improves subgrade support during the spring thaw. In addition, TDA can be used as backfill around basements to limit heat lost through basement walls, thereby reducing heating costs.

6.3 The low-compacted dry density, high-hydraulic conductivity, and low-thermal conductivity makes TDA very attractive for use as retaining wall backfill. Lateral earth pressures for TDA backfill can be about 50 % of values obtained for soil backfill (**7, 8, 9**). TDA can also be used as backfill for geosynthetic-reinforced retaining walls.

6.4 The hydraulic conductivity of TDA makes them suitable for many drainage applications including French drains, drainage layers in landfill liner and cover systems, and leach fields for on-site sewage disposal systems. For applications with a vertical stress less than 50 kPa, the hydraulic conductivity of TDA is generally greater than 1 cm/s, which is comparable to conventional uniformly graded aggregate. When TDA is used as a component of landfill leachate collection and removal systems, and other applications where the vertical stress would be greater than 50 kPa, the hydraulic conductivity and void ratio under the final design vertical stress should be considered. The hydraulic conductivity must meet applicable regulatory requirements and the void ratio must be sufficient to minimize clogging.

6.5 TDA can be used as a vibration damping layer beneath rail lines to reduce the impact of ground bourn vibrations on residences and businesses adjoining the tracks. In this application, a 300-mm thick layer of 75-mm maximum size TDA is placed beneath the conventional ballast/subballast system (**13, 14**); therefore, tire shreds are not classified as a hazardous waste.

7.2In addition to TCLP tests, laboratory leaching studies have been performed following several test protocols. Results show that metals are leached most readily at low pH and that organics are leached most readily at high pH ().

6.6 Two different sizes of TDA are commonly used for the applications discussed above. One has a maximum size of 75 mm and the other has a maximum size of 300 mm. Rough shreds can also be used for some applications provided all tires are shredded such that the largest shred is the lesser of one-quarter circle in shape or 600 mm in length. In all cases, at least one side wall should be severed from the tread.

6.7 TDA with a maximum size of 75 mm or 300 mm are generally placed in 300-mm thick lifts and compacted by a tracked bulldozer, sheepsfoot roller, or smooth drum vibratory roller with a minimum operating weight of 90 kN. Rough shreds are generally placed in 900-mm thick lifts and compacted by a tracked bulldozer. For most applications a minimum of six passes of the compaction equipment should be used.

6.8 TDA should be covered with a sufficient thickness of soil to limit deflections of overlying pavement caused by traffic loading. Soil cover thicknesses as low as 0.8 m may be suitable for paved roads with light traffic. For paved roads with heavy traffic, 1 to 2 m of soil cover may be required. For unpaved applications, 0.3 to 0.5 m of soil cover may be suitable depending on the traffic loading. The designer should assess the actual thickness of soil cover needed based on the loading conditions, TDA layer thickness, pavement thickness, and other conditions as appropriate for a particular project. Regardless of the application, the TDA should be covered with soil to prevent contact between the public and the TDA which may have exposed steel belts.

6.9 In applications where pavement will be placed over the TDA layer, highway drainage applications, and retaining wall backfill, the TDA layer should be completely wrapped in a layer of non-woven or woven geotextile to minimize infiltration of soil particles into the voids between the TDA.

6.10 Whole tires and tire sidewalls that have been cut from the tire carcass can be used to construct retaining walls, reinforcing mats beneath roads constructed on weak ground, erosion protection layers, or bound together to form drainage culverts.

6.11 TDA fills should be designed to minimize the possibility of an internal heating reaction (**2**). Possible causes of the reaction are oxidation of the exposed steel belts and oxidation of the rubber. Microbes may play a role in both reactions. The following factors are thought to create conditions favorable for oxidation of exposed steel, or rubber, or both; free access to air; free access to water; retention of heat caused by the high insulating value of TDA in combination with a large fill thickness; large amounts of exposed steel belts; smaller TDA sizes and excessive amounts of granulated rubber particles; and the presence of inorganic and organic nutrients that would enhance microbial action.

6.11.1 The design guidelines given in the following sections were developed to minimize the possibility for heating of TDA fills by minimizing factors that could create conditions favorable for this reaction. In developing these guidelines, the insulating effect caused by increasing fill thickness and the favorable performance of projects with TDA fills less than 4-m thick have been considered Thus, design guidelines are less stringent for projects with thinner TDA layers. The guidelines are divided into two classes: Class I Fills with TDA layers less than 1-m thick, and Class II Fills with TDA layers in the range of 1 to 3-m thick. Although there have been no projects with less than 4 m of TDA fill that have experienced a catastrophic heating reaction, to be conservative, TDA layers greater than 3-m thick are not recommended. The guidelines are for use in designing TDA fills. Design of fills that are mixtures or alternating layers of TDA and mineral soil that is free from organic matter should be handled on a case by case basis.

6.11.2 For Class I Fills, the material shall meet the material requirements for Type A TDA given in 7.1.1 and 7.1.2. No special design features are required to minimize heating of Class I Fills.

6.11.3 For Class II Fills, the material shall meet the material requirements for Type B TDA given in 7.1.1 and 7.1.3.

6.11.4 Class II Fills shall be constructed in such a way that infiltration of water and air is minimized. Moreover, there shall be no direct contact between TDA and soil containing organic matter, such as topsoil. One possible way to accomplish this is to cover the top and sides of the fill will 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 TDA with a geotextile. The top of the mineral soil layer should be sloped so that water will drain away from the TDA 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.

6.11.5 For Class II Fills, 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. 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 daylights on the side of the fill should be minimized. For TDA fills placed against walls, it is recommended that the drainage holes in the wall be covered with well graded granular soil. The granular soil should be separated from the TDA with geotextile.

6.11.6 Embankments constructed in accordance with the guidelines have shown no evidence of self heating (**14, 15**); thus, it is preferable to use tire shreds in environments with a near neutral pH.

7.3Field studies of tire shred fills located above the ground water table show that tire shreds tend to leach manganese, and under some circumstances, iron at levels above their secondary drinking water standard (**4, 16**). Since secondary standards are based on aesthetic factors, such as color, odor, and taste, rather than health concerns, release of manganese and iron from tire shreds is not a significant concern. Release of organics from tire shreds placed above the water table generally is below test method detection limits (**16**); thus, release of organics from tire shreds placed above the water table is not a significant concern.

7.4For tire shreds placed below the water table, tire shreds release levels of manganese and iron that are significantly above their secondary drinking water standards (**14**); thus, tire shreds should be used below the water table only where the aesthetic concerns raised by elevated levels of manganese and iron have been examined. Tire shreds placed below the water table leach low levels of a few organic compounds into the ground water (**14**). Further study is needed to determine if these levels are high enough to be of concern. Pending continued studies of the effect of tire shreds placed below the water table on organic levels, the use of tire shreds should be limited to above water table applications.).

7. Material Specifications

7.1 The material specifications for TDA that are presented below take into consideration the need to limit internal heating of TDA fills as discussed in 6.11, producing a material that can be placed and compacted with conventional construction equipment, and limiting exposed steel belts to allow for rubber to rubber contacts between the pieces when placed in a fill. Moreover, TDA meeting the specifications can be produced with reasonably well-maintained processing equipment that has been properly selected for the size product being produced. Specifications are provided for two size ranges. The first is termed Type A and is suitable for many drainage, vibration damping, and insulation applications. The second is larger and is termed Type B. It is suitable for use as lightweight embankment fill, wall backfill, and some landfill drainage and gas collection applications.

7.1.1 The TDA shall be made from scrap tires which shall be shredded into the sizes specified in 7.1.2 for Type A TDA or 7.1.3 for Type B TDA. They shall be produced by a shearing process. TDA produced by a hammer mill will not be allowed. The TDA shall be free of all contaminants including but not limited to oil, grease, gasoline, and diesel fuel that could leach into the groundwater or create a fire hazard. In no case shall the TDA 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 TDA are placed in a fill. The TDA shall be free from fragments of wood, wood chips, and other fibrous organic matter. The TDA shall have less than 1 % (by weight) of metal fragments that 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 TDA on 75 % of the pieces (by weight) and no more than 50 mm on 90 % of the pieces (by weight). The gradation shall be measured in accordance with Test Method C 136, except that the minimum sample size shall be 6 to 12 kg for Type A TDA and 16 to 23 kg for Type B TDA.

7.1.2 Type A TDA shall have a maximum dimension, measured in any direction, of 200 mm. In addition, Type A TDA shall have 100 % passing the 100-mm square mesh sieve, a minimum of 95 % passing (by weight) the 75-mm square mesh sieve, a maximum of 50 % passing (by weight) the 38-mm square mesh sieve, and a maximum of 5 % passing (by weight) the 4.75-mm sieve.

7.1.3 Type B TDA shall have a minimum of 90 % (by weight) with a maximum dimension, measured in any direction, of 300 mm and 100 % with a maximum dimension, measured in any direction, of 450 mm. At least one side wall shall be severed from the tread of each tire. A minimum of 75 % (by weight) shall pass the 200-mm square mesh sieve, a maximum of 50 % (by weight) shall pass the 75-mm square mesh sieve, a maximum of 25 % (by weight) shall pass the 38-mm square mesh sieve, and a maximum of 1 % (by weight) shall pass the 4.75-mm sieve.

8. Leachate

8.1 The Toxicity Characteristics Leaching Procedure (TCLP) (USEPA Method 1311) is used to determine if a waste is a hazardous waste, thereby posing a significant hazard to human health due to leaching of toxic compounds. The TCLP test represents the scenario of acid rain percolating through the waste and exiting as leachate. For all regulated metals and organics, the results for TDA are well below the TCLP regulatory limits **(15, 16, 17)**; therefore, TDA are not classified as a hazardous waste.

8.2 In addition to TCLP tests, laboratory leaching studies have been performed following several test protocols. Results show that metals are leached most readily at low pH and that organics are leached most readily at high pH **(17, 18)** . Thus, it is preferable to use TDA in environments with a near neutral pH.

8.3 The potential of TDA to generate leachate has been examined in field studies for both above and below groundwater table applications. The results have been compared to primary drinking water standards, secondary (aesthetic) drinking water standards, and USEPA preliminary remediation goals (PRG) **(19)**. PRG are risk-based concentrations that the USEPA considers to be protective for lifetime exposure to humans **(19)**. Freshwater aquatic toxicity has also been evaluated. These results were summarized in a literature review and statistical analysis performed for the USEPA Resource Conservation Challenge **(20)**.

8.4 In above groundwater table applications the TDA is placed above the water table and are subjected to water from infiltration.

Seven field studies have examined this category of applications **(21, 22, 23, 24, 25, 26, 27, 28)** . A statistical comparison was performed **(20)** using procedures for censored environmental data recommended by Helsel **(29)**.

8.4.1 The preponderance of evidence shows that TDA used above the water table does not cause the primary drinking water standards for metals to be exceeded. Moreover, a statistical comparison shows that TDA is unlikely to increase levels of metals with primary drinking water standards above naturally occurring background levels **(20)** .

8.4.2 For above groundwater table applications, it is likely that TDA would increase the concentrations of iron and manganese, which have secondary drinking water standards. At the point where water emerges from a TDA fill, it is likely that the levels of iron and manganese will exceed secondary drinking water standards, and the PRG for tap water for manganese will also be exceeded. However, for two of three projects where samples were taken from wells adjacent to the TDA fills, the iron and manganese levels were about the same as background levels. The prevalence of manganese in groundwater is shown by the naturally occurring concentrations at three projects being above the secondary drinking water standard and PRG. For other chemicals with secondary drinking water standards, a statistical comparison shows that there is no evidence that TDA affects naturally occurring background levels **(20)**.

8.4.3 Volatile and semivolatile organics have been monitored on two projects where TDA was placed above the water table **(22, 23, 24)**. Substances are generally below detection limits. Moreover, for those substances with drinking water standards, the levels were below the standards. The concentrations were also below the applicable PRG **(20)** . A few substances were occasionally found above the test method detection limit; however, the highest concentrations were found in a control section located uphill from the TDA **(22)**, suggesting a source associated with active roadways. There are also laboratory studies showing that TDA has the ability to absorb some organic compounds **(30)**.

8.4.4 Aquatic toxicity tests were performed on samples taken from one above groundwater table project. The results showed that water collected directly from TDA fills had no effect on survival, growth, and reproduction of two standard test species (fathead minnows and a small crustacean (*Ceriodaphnia dubia*) **(20, 23)** .

8.5 TDA placed below the water table has been studied at three different sites **(31)**. A statistical comparison was performed **(20)** using procedures for censored environmental data recommended by Helsel **(29)**.

8.5.1 A statistical analysis of the data at these sites showed that use of TDA did not cause primary drinking water standards for metals to be exceeded. Moreover, the data shows that TDA was unlikely to increase levels of metals with primary drinking water standards above naturally occurring background levels **(20)**.

8.5.2 For chemicals with secondary drinking water standards, it is likely that TDA below the groundwater table would increase the concentrations of iron, manganese, and zinc. For water that is collected directly from TDA fill below the groundwater table, it is likely that the concentrations of manganese and iron will exceed their secondary drinking water standards and PRG for tap water. The secondary drinking water standards and PRG for zinc were not exceeded even for water in direct contact with TDA. The concentration of iron, manganese, and zinc decreases to near background levels by flowing only a short distance though soil (0.6 to 3.3 m). For other chemicals with secondary drinking water standards, a statistical comparison showed little likelihood that TDA placed below the water table alters naturally occurring background levels **(20)**.

8.5.3 Trace levels of a few volatile and semivolatile organics were found from water taken directly from TDA-filled trenches. The concentration of benzene, chloroethane, cis-1,2-dichloroethene, and aniline for water in direct contact with TDA are above their respective PRG for tap water. However, chloroethane, cis-1,2-dichloroethene, and aniline concentrations were below the PRG for all samples taken from wells 0.6 and 3.3 m downgradient. Moreover, the concentrations were below the detection limits for virtually all samples, indicating that these substances have limited downgradient mobility **(17)**.

8.5.4 The data on benzene deserves additional discussion. The primary drinking water standard for benzene is 5 µg/L and its PRG is 0.35 µg/L. For six sample dates, the detection limit reported by the laboratory was 0.5 µg/L, slightly above the PRG. For the remaining four sample dates the detection limit was 5 µg/L. Focusing on the data from samples with a detection limit of 0.5 µg/L, the benzene concentration was below the detection limit in downgradient wells for all but one well, on a single date, when the concentration was 1 µg/L. This data shows that benzene also has limited downgradient mobility **(17)** .

8.5.5 Aquatic toxicity tests were performed on samples taken on two dates. The results showed that water collected directly from TDA filled trenches had no effect on survival, and growth of fathead minnows. While there were some toxic effects of TDA placed below the groundwater table on *Ceriodaphnia dubia*, a small amount of dilution (up to 3-fold) as the groundwater flowed downgradient or when it entered a surface body of water would remove the toxic effects **(20, 23)**.

8.5.6 In summary, TDA placed below the water table would be expected to have a negligible off-site effect on water quality **(20)**.

9. Keywords

~~8.1construction practices; landfills; leachate; lightweight fill; retaining walls; roads; scrap tires~~

9.1 construction practices; landfills; leachate; lightweight fill; rail lines; retaining walls; roads; scrap tires; TDA; tire chips; tire derived aggregate; tire shreds; vibration damping

APPENDIX