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A New York State Department of Environmental Conservation
Division of Solid & Hazardous Materials Presentation on the:

USING TIRE CHIPS IN LANDFILL LEACHATE COLLECTION AND
REMOVAL SYSTEMS
UNDER 6 NYCRR PART 360

Abstract:

New York State has encouraged the use waste tire derived aggregate for use in landfill primary leachate collection and removal systems via the equivalent design provisions of section 360-2.13(w). The Division has noted a recent increased interest in the use of waste tire derived aggregate in such applications.

This paper was developed to help promote the utilization of waste tire derived aggregate in a landfill’s primary leachate collection and removal system (LCRS) under New York State’s solid waste management regulations, 6 NYCRR Part 360. The beneficial use of waste tire derived aggregate in the landfill=s primary LCRS should be authorized under the equivalent design provisions of section 360-2.13(w). New York State encourages the beneficial use of waste stream derived construction materials in landfill construction and operation projects. The objective of this paper is to help promote a consistent statewide approach to the specification of waste tire derived aggregate in landfill primary leachate collection and removal system drainage layer applications.

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Background - Problems & Concerns with Waste Tires:

The Rubber Manufacturer’s Association estimates that New York State generates between 18 and 20 million waste tires per year based on the industry standard that waste tires are generated at a rate of one tire per person per year. While the literature indicates that we are making good strides at recycling more of the newly generated waste tires in recent years, however, markets need to continue to evolve if we are to make progress in cleaning up many of the stockpiles of tires generated from the years past. Many of the non-recycled waste tires generated today still can end up being illegally stockpiled or otherwise illegally disposed of.

There are a limited number of authorized waste tire disposal or recycling companies in the northeast. As of this time, New York State, has only 6 permitted tire storage facilities, of which four have some form of waste tire processing capability on-site. Beyond the permitted storage facilities there are 26 registered waste tire storage facilities. Today, these authorized waste tire storage operations attempt to keep up with the State’s annual waste tire generation rate.

More than 90 non-compliant waste tire stockpiles also exist today across New York State. It is estimated that more than 26 million waste tires have been accumulated at these illegal sites from previous years. Based on Division records, 6 of these stockpiles contain over 1 million waste tires and 2 of those stockpiles contain over 5 million waste tires.

Fortino Illegal Waste Tire Pile (AKA Pinnacle Tire Yard), Oswego County, NY, The site contains over 8,000,000 Waste Tires, Photo by Chris Glander, July 1998
The Division is concerned that many of these large stockpiles of waste tires have the potential to generate significant environmental, public health and safety impacts for each of the communities where the illegal waste tire pile is located. In New York State, there have been 20 waste tire pile fires since January 1989. Tire pile fires emit dense, toxic fumes from uncontrolled combustion which impacts on local air quality and raises health related concerns for those located near the fire and for those emergency personnel who need to extinguish the fire. This uncontrolled combustion of waste tires also results in an oily runoff, which can impact local surface and ground water resources. Each passenger tire is capable of producing approximately 2 gallons of pyrolytic oil during a fire. The United States Environmental Protection Agency (US EPA) estimates that the cost to clean up a tire pile after a fire is ten times more than it would have cost before the fire.

The largest tire pile fire in New York State was in 1989, referred to as the ACasings Fire® in Catskill, Greene County. Over 2 million stockpiled tires caught fire and the associated environmental impacts were many. The Casings Fire started on February 25, 1989 and raged for nearly a week before it was brought under control. The final cost of extinguishing and cleaning up after the fire for the town of Catskill was over 2 million dollars, substantiating that waste tire pile fires can be a large economical burden on a local community.

Beyond the threat of a potential waste tire pile fire impacts, there are also concerns for public health impacts from vectors, since these piles provide excellent breeding grounds for mosquitoes that can carry the West Nile Virus.

The existence of illegal waste tire stockpiles throughout the State invokes serious concerns for future potential adverse environmental and public health impacts. This coupled with a more than 18 million waste tires being generated annually in New York State, along with the lack of sustainable markets for waste tire products, serves to motivate the Division towards helping to ensure that all viable applications for reuse and recycling of waste tires are considered seriously.

The Evolution of Cost Effective, Environmentally Sound Practices For Reuse and Recycling of Waste Tires

Over the past 10- to-15 years, there have been an increasing number of studies done on waste tires in an attempt to find a cost effective, environmentally sound means for managing the increasing number of
waste tires generated each year.

Waste tires can provide an excellent source of supplemental fuel for industrial and utility boilers; cement kilns; and papermills. Compared to conventional fuels such as coal (BTU value of 11,500 BTU/lb.), tire derived fuel (TDF) has a far superior BTU value (15,000 BTU/lb.). On a national level, in the year 2000, 112 million of the 280 million waste tires generated nationally were used as TDF. There are a few existing markets for TDF in the northeast, only two such markets currently exist in New York State:

1. WPS Empire State (formerly CH Resources) of Niagara Falls, registered as a waste tire storage facility where the waste tires are used for on site energy recovery/production; and,

2. Nucor Steel of Auburn, registered as a waste tire storage facility capable of using 800 waste tires per day as TDF.

The process of making crumb rubber (value added products) from waste tires is another form of reuse of waste tires which is experiencing steady growth. Much of the crumb rubber produced today goes into the molded product and sport surfacing markets which include making rubber mats and ground rubber materials used in athletic fields, tracks and playgrounds. Advances for use of crumb rubber as an asphalt enhancement (rubber modified asphalt) for road paving has not grown regionally in the Northeast.

Today, in terms of growth, the most promising high volume market for waste tires appears to be associated with civil engineering applications associated with utilization of waste tire derived construction materials. As noted above, studies have demonstrated that tire shreds or chips (waste tire derived aggregate) can have similar geotechnical properties as conventional aggregate. Due to the growing demand and interest in engineering applications for waste tire derived construction materials the American Society for Testing Materials (ASTM) became involved in the late 1990s. The ASTM, in an effort to assist in ensuring proper specification of scrap tire derived materials in civil engineering applications, derived a practice guide for testing the physical properties of waste tires and waste tire products. This guidance is titled: ASTM D 6270, Standard Practice for Use of Scrap Tires in Civil Engineering Applications. This document was developed to help standardize the test methods and terms relating to the testing of waste tire derived products used in civil engineering designs.

There are numerous benefits for a design engineer to consider the use of waste tire derived aggregate in lieu of conventional soil, gravel or stone aggregate. The low dry unit weight of tire chips typically ranges from 45-58 pounds per cubic foot (pcf), where as, soil fill densities can range from 100 to 125 pcf. This characteristic makes tire shreds ideal for construction fill when lightweight fills are necessary, such as, when building on soft soil or compressible soil foundations. This low unit weight also helps to lessen transportation related costs, since the maximum highway weight limits will allow for twice the volume of tire derived aggregate to be shipped to the job site, cutting down on truck traffic and transportation related impacts and costs.

Tire shreds and chips are also compressible under loaded conditions. Under high normal loads tire shreds can compress by as much as 50 percent. This physical property can be advantageous in some geotechnical applications where lateral loadings to foundation walls need to be minimized.
Tire chips also exhibit excellent thermal insulation properties over that of conventional soil aggregate materials. Dr. Dana Humphrey and Dr. Craig Benson have found that 3-inch nominal tire chips to be 7 to 8 times better insulators than soil. The thermal property of waste tire aggregate can be a favorable characteristic in applications where the design engineer needs a thermal barrier. This property has been the basis for many recent landfill applications where the landfill operator has sought approval to utilize a layer of tire shreds as the upper part of the landfill’s primary LCRS to enhance the insulating properties of the landfill’s primary LCRS to address the regulatory requirement for liner protection from frost action [360-2.7(b)(4)]. In these applications the tire shreds replaced a portion of the conventional drainage soil aggregate, providing the needed frost protection and improving upon the protective qualities of the conventional primary LCRS and helped to reduce the landfill’s construction cost.

Improper specification of waste tire derived construction materials can result in problems if certain properties of the tire derived construction materials are not considered by the design engineer. Perhaps the biggest concern is that tire fills have the ability to generate an internal heat. The heat generated is caused by the oxidation of exposed steel wire from the tire chips. When this heat of oxidation is not adequately dissipated, in thick applications, the tire chips may continue to develop heat to the point where they will ignite.

Both tire chips and whole tires have a flash point of approximately 580 °F. Previous experience has shown that self-ignited tire chip fill fires have been associated where embankments or otherwise thick fills that were at least 20 feet in compacted thickness of tire chips. To address this concern ASTM D6270 makes recommendations for waste tire fill applications to minimize the heating concern. The most important recommendation is not to use tire chip fills in applications where a thickness of the tire shreds or chips would be greater than 10 feet in depth. Other recommendations by ASTM D 6270 to minimize oxidation and potential heat generation is to:

?? limit free access to air and water;
?? limit the amount of exposed steel;
?? limit the amount of smaller chip sizes and the presence of excessive amounts of granulated rubber; and,
?? limit the amount of inorganic and organic nutrients that could enhance microbial action, which may cause an increase in temperatures.

In summary, as engineers become more familiar with the physical properties of waste tire derived construction materials, they will become more comfortable with specifying these sort of waste stream derived materials in their designs. Another motivating factor for use of tire chip construction materials is the potential cost savings associated with using tire shreds and chips. Already an increasing number of engineers have been calling for tire shreds/chips in their civil engineering designs. For example, tire shreds/chips are being used as a lightweight fill material behind retaining walls and for bridge embankments, as a road base and subbase material, as a drainage medium in sewage disposal systems in some states and as leach field media for residential septic systems. Tire derived aggregate has been substituted for the conventional natural aggregates (i.e. sand, gravel, and stone) used in a landfill’s primary leachate and/or gas collection and removal systems at numerous landfills across New York State.
Substantial information and literature indicate that waste tire shreds and chips can be an effective substitute for conventional drainage aggregate. Landfill liner systems are required to incorporate properly specified drainage layers designed to effectively remove leachate from the landfill. The remainder of this paper will focus on the application of waste tire shreds and chips in landfill primary leachate collection and removal system designs.

How Does Part 360 Provide For The Use Of Tire Shreds In A Landfill’s Leachate Collection And Removal System?

Landfill designers are challenged to look for ways to reduce landfill construction related costs while maintaining effective system performance and regulatory compliance. The utilization of waste stream derived construction materials has the potential for significant savings and the associated benefit of converting an unusable waste material into a useful part of a landfill’s environmental containment system. New York State’s solid waste management regulations, 6 NYCRR Part 360 (Part 360), have been developed to encourage and allow for this sort of recycling or reuse of certain waste stream derived construction materials. Basis for this regulatory intent is the known fact that landfill construction can consume significant amounts of natural construction materials. That, coupled with the known fact that often times certain waste stream derived construction materials (broken glass, tires, ash, etc.) can be demonstrated to provide adequate equivalent engineering properties to natural or conventional construction materials, provides the rationale for the equivalent design provisions of the regulations.

As an example, by allowing tire shreds or chips to be used in the landfill designs, not only will natural resources be conserved, we would beneficially reuse large volumes of waste tires. Studies have shown that it takes 60 - 70 passenger vehicle tires to create 1 cubic yard of tire shreds/chips compacted and compressed to their in-place volume. For a 10 acre landfill cell calling for an 18 inch thick layer of tire chips, as a component of the landfill’s LCRS, over 1.5 million passenger tire equivalents would be consumed to produce the volume of tire shreds/chips required for such a use.

Paragraph 360-2.13 (w) Equivalent Design. These provisions of the regulations allow for a design engineer to substitute an alternate material for a component of the landfill’s liner or final cover systems. In these cases, the engineer must demonstrate that the material being substituted will have the ability to perform in the same manner as the liner or final cover system component specified in the Part 360 regulations. This provision allows the landfill designer to take advantage of the waste stream derived construction materials in the proposed landfill design without the use or need for a formal Part 360 variance.

Department staff can approve such equivalent design demonstrations as part of their review of the application. Such demonstrations are considered to be predetermined beneficial use determinations under the provisions of section 360-1.15(b)(10). This further reduces the need for special additional permitting requirements when the materials are used at a landfill site where the equivalent design application comprehensively addresses material receipt, testing, storage and its’ related construction certification requirements. These applications, which are submitted after the landfill permit has been issued, should in most cases be determined to be minor modifications minimizing administrative and regulatory permitting burdens associated with the equivalent design submission.

The equivalent design provisions from the regulations are cited below:
A360-2.13 (w) Equivalent design. The applicant may propose an equivalent design of individual components of a landfill's liner and final cover systems through the submission in the application of documentation substantiating the alternative component's ability to perform in the same manner as the component specified in this section. When the equivalent design involves the substitution of waste materials for components of the landfill’s liner or final cover system; and where it can be demonstrated that these material substitutions are within the landfill’s environmental containment system (i.e. below the upper most layer of the barrier layer of the final cover and above the secondary composite liner), such equivalency determinations are not subject to the variance requirements of this Part and this use is consistent with the beneficial use provision of paragraph 360-1.15(b)(10) of this Part. It is highly recommended that the applicant discuss equivalent component design proposals with the department in a preapplication conference.

These regulatory provisions allow Department staff to evaluate engineering submissions for equivalent use of waste stream derived materials in landfill liner and final cover system designs on component-by-component basis. That is, we cannot use the equivalent design provisions alter the intended double composite liner system design, but instead can make determinations on equivalency on a component-by-component basis for the liner or final cover system.

The waste tire derived aggregate does need to be transported to the landfill via a 6 NYCRR Part 364 waste transporter permit. Even though the equivalent design approval is a form of a predetermined beneficial use for the waste tire derived drainage material, this beneficial use authorization under section 360-1.15(b)(10) does not take effect until the material is received at the landfill.

**Figure 1 - Typical Diagram of Tire Chip Equivalent Design Proposal For Landfill LCRS**

*(Diagram provided by: Barton & Loguidice, P.C.)*

**TYPICAL FLOOR LINER DETAIL**
The engineering function for a landfill’s primary leachate collection and removal system (LCRS) is two-fold. First and foremost, the primary LCRS must effectively be able to hydraulically convey the large amounts of leachate, generated by the landfill, to the landfill’s LCRS. Per Part 360 and as required by the federal regulations for municipal solid waste landfills (40 CFR Part 258), the design engineer must demonstrate that the maximum hydraulic head on the primary liner does not exceed one foot. The second function of the 24-inch thick primary LCRS is to act as a protective separation barrier allowing for the initial placement of waste in the landfill without harming the liner system or the LCRS components.

As done with a conventional soil drainage and protective media the design engineer must demonstrate that the approved soil material meets his design criteria for hydraulic function and overall geotechnical stability. This requires certain construction quality control (CQC) and construction quality assurance (CQA) protocols to be established to support the engineer’s design and to, at a minimum, address the regulatory requirements.

When a waste stream derived construction material is considered for use in landfill construction the drill needs to be the same with respect to the design and waste material’s CQC and CQA specifications. The design engineer must treat the waste tire shreds or chips as if they were a conventional construction material and it must be demonstrated that tire derived aggregate would be equivalent to the conventional construction material and meet all the applicable regulatory design and CQC/CQA requirements for the material being substituted. Therefore, utilization of waste tire derived aggregate as a component of a landfill’s primary LCRS must be demonstrated to comply with landfill’s prescribed design and the applicable regulatory provisions of section 360-2.13(l) for soil drainage layer. The provisions of section 360-2.13(l) are cited below for reference:

**A 360-2.13 (l) Soil drainage layers. All soil material used in the primary and secondary leachate collection and removal systems of the landfill must conform to the following requirements:**

1. **Materials required.** Soil materials used to construct a drainage layer must be designed to ensure proper hydraulic operation of the leachate collection and removal system pursuant to the provisions of subdivision (g) of this section. The soil drainage layer must be free of any organic material and have less than five percent of the material by weight pass the No. 200 sieve after placement. Soil material testing must be performed in accordance with paragraph (3) of this subdivision.

2. **Construction requirements.** The soil drainage layer must be constructed and graded in accordance with the requirements of the approved engineering plans, report, and specifications along with the following requirements:

i. The minimum thickness of the soil drainage layer in the primary leachate collection and removal system must be 24 inches and provide adequate physical protection to the underlying liner materials and leachate collection pipe network placed within the primary leachate collection and removal system, and have a minimum coefficient of permeability of $1 \times 10^{-2}$ centimeters per second.
(ii) The minimum thickness of the secondary leachate collection and removal system layer must be 12 inches, and provide adequate physical protection to the underlying liner materials and leachate collection pipe network placed within the secondary leachate collection and removal system, and have a minimum coefficient of permeability of $1 \times 10^{-2}$ centimeters per second.

(iii) The soil drainage layer must be designed and placed on a minimum slope of two percent to promote efficient positive drainage to the nearest leachate collection pipe and to prevent ponding above the liner.

(3) Certification requirements. The project engineer must include in the construction certification report a discussion of the approved data resulting from quality assurance and quality control testing required in this paragraph. The results of all testing must be included in the construction certification report including any failed test results, descriptions of the procedures used to correct the failed material, and any retesting performed.

(i) The project engineer must certify the quality control testing of any soil drainage materials and ensure that the material meets the requirements of paragraph (1) and subparagraphs (2)(i) and (ii) of this subdivision and the approved engineering plans, reports, and specifications. A particle size analysis of the soil drainage layer material must be submitted to the project engineer for approval before installation of the soil drainage layer, and during installation at a frequency of at least one test for every 1,000 cubic yards of material delivered and placed. A laboratory constant head permeability test for a soil drainage layer sample shall be submitted to the project engineer for approval before placement and during construction at a frequency of at least one test for every 2,500 cubic yards of material delivered and placed.

(ii) The project engineer must certify that post-construction care procedures were carried out which, at a minimum, protected the soil drainage layers from fines related to water and wind borne sedimentation.

(iii) Quality assurance testing performed by the project engineer must ensure that the material is placed in accordance with the requirements of the engineering plans, reports, and specifications.”

It is the design engineer=s responsibility to demonstrate to the Department that their proposed tire shred/chip application will perform similarly to conventional aggregate and comply with all applicable sections of the Part 360 regulations, including the CQC and CQA requirements as stated above.

It is also important for the demonstration package to explain, how the tire chips are to be obtained and where they will be stored on site in a manner to minimize adverse impacts.

**General Considerations To Be Addressed in An Equivalent Design Demonstration for Using Tire**
Shreds In A Landfill’s Primary Leachate Collection And Removal System

The design engineer in his equivalent design demonstration needs to stipulate in the project specifications that the waste tires shreds or chips be free of any surface contaminants such as soil, petroleum products and debris to reduce the chances of clogging of the drainage layer and contamination of other landfill components. In addition, specifications need to indicate that the waste tires that were exposed to fire shall not be used to process tire shreds/chips. Tire chips or shreds shall be processed through a slow-rotating shredder cutter. Use of wood chippers or hammer mills to process tire shreds are not permissible in that inadequate product qualities will be an issue.

Design engineers should utilize ASTM D6270, *Standard Practice for Use of Scrap Tires in Civil Engineering Applications* as a guide when performing any testing of the tire shreds/chips. The following considerations should be addressed at a minimum in a waste tire derived aggregate proposal for use in a landfill’s LCRS:

**Gradation Design**

For CQC purposes an acceptable gradation for the tire shreds/chips needs to be established by the design engineer based on the site-specific application for the intended use. In all cases for supplementing a landfill’s LCRS with waste tire derived aggregate, under the equivalent design provisions of section 360-2.13(w), the maximum dimension of any tire shred should not be larger than 12 inches, measured in any direction. The gradation should be specified so as not to impede leachate flow into the landfill’s LCRS. For example, guidance from the State of California on this topic recommends the following gradation for tire shreds for a hydraulic conveyance considerations:

<table>
<thead>
<tr>
<th>Sieve Size in. (mm)</th>
<th>Minimum % Passing by weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>12 (300)</td>
<td>100</td>
</tr>
<tr>
<td>6 (150)</td>
<td>95</td>
</tr>
<tr>
<td>3 (75)</td>
<td>85</td>
</tr>
<tr>
<td>2 (50)</td>
<td>50</td>
</tr>
<tr>
<td>#4 sieve (4.75)</td>
<td>5</td>
</tr>
</tbody>
</table>

The above gradation is merely presented as a recommendation as to what has been proposed as guidance in California, however, under Part 360 it is imperative that the design engineers evaluate the gradation specification for the site-specific application at hand. For instance, if the application at hand involved the use tire derived aggregate layer for both the purpose of hydraulic conveyance and to enhance the frost protection value of the landfill’s LCRS, concern would need to be given to the amount of larger shreds being used in the gradation. It is obvious that
the larger shreds will promote larger void spaces and thus increase hydraulic performance of the tire shred aggregate layer, however, larger shred sizes will have an adverse impact on thermal properties of the tire shred aggregate layer.

To that end, the maximum amount of larger tire shreds will need to be limited in the gradation if the tire shred layer is used as a thermal enhancement barrier. The following gradation has been recommended by Dr. Dana Humphrey, a nationally known advocate for use of tire shreds in civil engineering applications, as to what he likes to refer to as a “Type A Drainage and Insulating Media”:

<table>
<thead>
<tr>
<th>Sieve Size in. (mm)</th>
<th>Minimum % passing by weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 (100)</td>
<td>100</td>
</tr>
<tr>
<td>3 (75)</td>
<td>90</td>
</tr>
<tr>
<td>#4 (4.75)</td>
<td>5</td>
</tr>
</tbody>
</table>

By: Dr. Dana Humphrey

**Smaller Tire Chips = Better Insulator**

**Larger Tire Shreds = Poor Insulator**

To ensure the engineer’s gradation specifications are met, and to meet the requirements of section 360-2.13(l)(3)(i) it is recommended that one grain size analysis (ASTM D422) be performed for every 1000 cubic yards of material placed or stockpiled on site. This is the same as would be required for a conventional soil or stone drainage media.

**Compressibility Issue**

The provisions of section 360-2.13(l)(2)(i) requires that the landfill’s primary LCRS be a minimum of 24 inches in thickness. Given the compressibility of the tire shreds/chips, the in-place thickness of the drainage layer may have to be increased in order to achieve the required thickness needed for liner system protection during the initial placement of waste. Depending on the primary LCRS’s configuration, the equivalency demonstration may not need to maintain the required 2-foot thickness of the primary LCRS for landfill’s anticipated final design load conditions (i.e. waste mass and cover system are in place) providing the tire chip layer at a prescribed thickness is not needed.
to achieve required hydraulic capacity for the primary LCRS. In this case the design engineer should demonstrate that this proposed tire shred/chip application complies with the minimum drainage layer thickness requirements of section 360-2.13(l)(2)(i) to allow for the initial lift placement of waste. This criterion is to ensure physical protection of geomembrane liner located beneath the primary LCRS drainage layer and the other components of the primary LCRS. The engineer must demonstrate the minimum required thickness is achieved for at least the placement of the first 10 to 20 feet of waste. Thus as the landfill’s height increases the tire shred layer will continue to compress under the growing normal load, however, the equivalency demonstration will need to ensure that the required drainage function of the primary LCRS is met under the full/maximum weight of waste to be placed in the landfill.

It should also be realized that tire shreds tend to produce an armored type surface which exhibits superior protective properties over a conventional soil layer when the shreds are used in the upper portion of the landfill’s LCRS. This benefit is also enhanced realizing that the layer of tire shreds can act as a visual barrier when it maybe necessary to excavate into the waste, where as a conventional soil layer may not be so noticeable. While the compressibility property of tire derived aggregate in many cases is a positive physical property, design engineers need to realize that this property diminishes the lateral support sometimes needed to provide structural support to primary LCRS piping networks. Thus this matter needs to be addressed by the design engineer and with some thought and use of conventional soil drainage media bedding around leachate collection pipes this issue can be easily resolved.

Given the variability in the size and shape of the tire shreds/chips, an adequate number of measurements of the drainage layer thickness should be made to ensure the specifications are met. Due to the nature of the tire shreds or chips construction tolerances specified in project specifications may need to be stated as a range affording some variability in the thickness for this type of application.

**Tire Shred Permeability**

The major issue with using tire shreds as a component of the landfill’s primary LCRS is the demonstration of the tire aggregate layer’s ability to transmit leachate. The design engineer will need to demonstrate that the tire derived aggregate gradation as specified will meet or exceed the minimum regulatory required permeability of $1 \times 10^{-2}$ cm/sec, or the minimum permeability called for in the landfill’s primary LCRS design to ensure that the maximum one foot head design criterion is achieved.

While tire chip gradation is an important specification for an equivalency demonstration, the design engineer needs ensure that the required long-term permeability will be achieved under expected high normal loads. However, since tire chips and shreds will under go considerable compression under loading, altering the drainage material’s void ratio, the design engineer will need to test the permeability of the tire derived aggregate gradation at the maximum design load for the landfill to ensure adequate hydraulic performance under load. In addressing this concern the design engineer likewise needs to consider the resulting void ratio of the tire derived aggregate under loaded conditions. For an equivalency determination the design engineer may want to establish a void ratio based on what would be exhibited by a conventional gravel layer. For instance a well
graded, clean granular soil compacted to a relative density of 100%, would have avoid ratio of 0.2. The designer’s goal should be to have a void ratio that is large enough such that it can withstand some clogging and still have an acceptable long-term permeability. Because the void ratio for tire derived aggregate decreases with high vertical stresses it may be necessary to incorporate a conventional high permeability drainage aggregate in the primary LCRS configuration as shown in Figure 1 above.

The permeability of the tire shreds/chips should be measured using standard test methods ASTM D2434 & D6270. It is recommended that a minimum of one long-term constant head permeability test (ASTM D2434) be performed on the tire shreds/chips for a minimum seating time of 100 hours under the design load, for each source of tire chips/shreds, or when the engineer determines that it is necessary. This 100 hour constant head test should address concerns for long-term creep induced reductions in hydraulic function and is similar to way that we test geosynthetic drainage layers for the same concern.

In addition, to comply with provisions of section 360-2.13(l)(3)(i) one laboratory constant head permeability test at the maximum design load shall be submitted to the project engineer for approval before placement and during construction at a frequency of at least one test for every 2,500 cubic yards of material delivered and placed. These laboratory permeability tests should be performed for every 2500 cubic yards of material placed to attest that the minimum permeability will comply with requirements of section 360-2.13(l), or the approved landfill design, which ever is greater. It is important to monitor in relation to compression versus time in performing ASTM 2423 to ensure that the test has stabilized.

**Exposed Wire Concerns**

In order to protect the geomembrane liner from punctures and to allow for more uniform placement of the tire shreds/chips, exposed metal bead and belt wire needs to be considered in the tire chip or shred specifications. It is also important to consider the limiting of exposed wire to minimize potential damage to construction equipment. The limiting of exposed wire in the chipping or shredding process can be a difficult and costly task. Often times the amount of exposed wires from the tire chips is merely a function of the maintenance of the chipping equipment. As the chipper’s cutting surfaces dull the amount of exposed wire increases. Thus chipper maintenance is key to attaining quality tire chips with minimal wire exposure. However, for landfill LCRS equivalent design considerations it is not necessary to require tire chips or shreds to be totally free of exposed wire, although, the amount of exposed excess metal wire needs to be limited so as not to significantly impair the required testing and placement of the material.

Long strands of tire shreds and wire indicates the chipper blades are in need of replacement. These tire chips are from a tire chipper in good working order.
Exposed wire can present a significant puncture hazard for any geosynthetic layers and as such tire shreds should not be placed directly upon the geomembrane. At a minimum, it is recommended that all tire derived aggregate equivalent design proposals incorporate an appropriately specified 9-12 inch layer of soil or stone between the geomembrane and the tire derived aggregate layer. This 9-12 inch soil layer thickness is proposed to minimize concern for the exposed wire in the tire shreds or chips puncturing the geomembrane liner. If the design engineer determines due to the quality of the particular tire shreds or chips that additional soil thickness is needed to protect the liner then thicker soil separation can be specified.

Many landfill designers frequently incorporate either a geocomposite drainage layer and or geotextile cushions directly on top of the primary geomembrane, however, it is recognized that such geosynthetic materials do not provide adequate protection to the underlying geomembrane with tire derived aggregate applications.

The decision to specify a geotextile separation fabric between the tire chips or tire shred layer and the overlying waste is up to the design engineer. The design engineer needs to consider the nature of the first lift of waste and concern for storm water runoff and the quality of the daily cover material being used in these decisions. Typically tire derived aggregate will be of a larger and more uniform size then conventional aggregate media. This characteristic could increase the potential for clogging and as such needs to be evaluated by the design engineer.

Other problems associated with excessive amount of exposed wire in tire derived aggregate material are that it contributes to increased oxidation and thus heat generation in stockpiles and can hinder material placement. For these reasons it is recommended that maximum length of exposed wire be limited to 2-3 inches measured from the edge of the tire shred or chip. The provision of ASTM D 6270 also contains exposed wire limits for civil applications, which would be considered applicable for tire chip or shred utilization in landfill LCRS equivalent design submissions.

**Tire Shred/Chip Storage Concerns**

One of the major impediments to the use of tire chips or shreds in landfill primary LCRS construction has been the ability to find sufficient quantities of tire derived aggregate materials such that the supplier can keep pace with the rate of landfill construction. To address this concern landfill owners will need to safely store or bank these materials at the landfill site prior to construction. At
an already permitted landfill, such storage locations would not typically need to be additionally permitted providing the landfill’s equivalent design submission adequately demonstrates to the Department where and how the storage piles will be managed in a manner to ensure material integrity, minimize the risk from fire, and so as not to congest the landfill site.

Tire shreds/chips stored at the landfill should minimally comply with the storage provisions in section 360-13.2(i). Specifically, the waste tire piles must not exceed 20 feet in height; the horizontal dimension of the tire piles at the base must not have a surface area greater than 10,000 square feet, with the width not exceeding 50 feet; and the minimum separation between tire piles must be 50 feet. In addition, the tire piles should not be located near potential ignition sources, and should not be placed within 100 feet of any environmental monitoring location for the landfill. The tire derived aggregate stockpiles should be placed on a prepared surface to ease tire product removal and should not be placed in areas where they will impede storm water runoff from the landfill.

Based on the ASTM 6270’s suggestions to minimize fire potential from tire chip piles it is recommended that for tire chip piles exceeding 12 feet in height, that the contractor or landfill owner include a plan to monitor internal temperatures of the tire chip piles to protect against spontaneous combustion. In such cases, the design engineer should specify how the internal pile temperatures are to be monitored and the procedures to be followed to dissipate heat in the event that the internal pile temperature exceeds 180 degrees Fahrenheit (F). The flash point for whole and shredded tires ranges between 550 and 650 degrees (F). It should be noted that, temperature monitoring of waste tire material piles, which comply with the storage provisions of Subpart 360-13, is not required by the regulations. In fact, the Department is not aware of tire material stock piles which comply with the appropriate requirements of Subpart 360-13 experiencing a problem with internal heat generation. However, in absence of any temperature monitoring data, this paper is recommending temperature monitoring of tire material piles that will be greater then 12 feet in height based solely on the information and recommendations made in ASTM 6270 relative to concerns for fire potential of stock piled waste tire derived materials.
Efforts should be made to maintain integrity of the tire-derived aggregate placed in the on-site stockpiles. This becomes even more important if the product is not going to be used within the time frame of one year or more, effort to keep the stockpiles free of wind blown debris and or soil should be made.

**Thermal Property Issues**

Tire shreds/chips can be incorporated in the design of the landfill’s liner to provide added frost protection prior to waste placement. As discussed in section 360-2.9(l) *winter and inclement weather operations*, provisions must be taken to prevent frost action upon the liner system in areas where refuse has not been placed. Studies have shown that tire chips exhibit thermal conductivities eight times lower than soils which makes them a good insulator. In cold climates they have been used to limit frost penetration and reduce the effects of frost heave. The key to ensuring adequate thermal properties for a layer of tire chips is to ensure that an adequate amount of smaller chips are specified in the gradation analysis and that the percentage of tire chips which are above 4 inches in dimension is limited. See Table 2 above for a recommended sample gradation spec, which would provide thermal insulating properties.

**Fire Protection**

The equivalent design application needs to not only address concerns for fires with respect to the stockpiled tire derived aggregate, but also for the tire shreds or chips which have been placed as the exposed portion of the landfill’s upper LCRS. While limiting of the tire aggregate stockpile size and monitoring of stockpile internal temperatures should address the concern for self heat generation in the piles it is prudent that the landfill operator take extreme care in controlling landfill fires in adjacent landfill areas to those areas where the tire chips have been placed. Self-heating of tire chip or shred layers do not pose a problem providing these layers are less then 10 feet in thickness, per ASTM D6270. Thus spreading of tire chips in relatively thin layers, as in a landfill’s primary LCRS, is not anticipated to produce a self-heating problem.

However, it is not without reason to be concerned for a landfill fire originating in the adjacent landfill area to where the tire derived aggregate is placed causing a potential fire hazard. Thus, during first lift placement landfill personnel will need to keep hot loads adequately away from...
In the spring of 1998 a landfill fire at the Granger Landfill in Michigan spread to an exposed layer of tire chips covering the floor of an adjacent landfill cell. Due to high winds during this event the fire spread quickly throughout the adjacent area covered with tire chips. In this case, the fire fighters initial efforts to control a 12 inch thick tire chip layer fire with water were unsuccessful and in retrospect was thought to have delayed the extinguishing of the fire. Successful fire control involved placement of soil and moisture so as to effectively smoother the fire in the tire chip layer. Quick response to this fire incident was critical to minimizing the impacts to the lower liner system, which was protected by a 12-inch soil layer. In discussions with facility representatives at this landfill they suggested that for very large areas of placed tire derived aggregate it may be prudent to consider the use of soil fire-breaks to limit the amount of exposed tire derived aggregate, thereby, limiting potential fire hazards.

Construction Related Concerns

Construction contractors and design engineers need to be aware that electrical resistivity leak location services cannot be performed on tire derived aggregate layers placed above a landfill liner system. This is critical since an increasing number of landfill construction contracts have been calling out for the use of this CQA test method to find defects in critical containment areas of a landfill's geomembrane liner system. The problem is caused by both the insulating properties of the rubber material and the high permeability of these drainage layers, such that it is difficult, if not impossible, to ensure a conductive path between the electrical resistivity testing equipment and the conductive layer beneath the geomembrane, as necessary to locate a geomembrane defect.

To rectify this problem, electrical resistivity contractors will need to be called in prior to placement of the tire chip layer to perform the leak location services.

Summary

As noted above the Division supports the use of waste tire derived aggregate in landfill LCRSs via the equivalent design provisions of section 360-2.13(w). The Division is aware that the States of California and Ohio both have guidance documents available which address the use of tire chips or shreds in landfill LCRS. In New York State, the longest known use of waste tire derived aggregate in a landfill’s primary LCRS has been at the Modern Landfill in Region 9. The Modern Landfill was approved in 1991 to substitute a 16-inch layer of tire chips for the upper portion of the landfill’s primary LCRS. To date, no data or information has been submitted which indicates that the performance of the 16-inch tire chip layer used in this case has diminished or otherwise been comprised during this time frame. Tire shreds/chips have been previously approved for use at numerous landfills across New York State. Several of these uses are highlighted below:

Modern Landfill, Region 9 - Tire chips were used in conjunction with a granular soil layer in the leachate collection system.

Seneca Meadows Landfill, Region 8 - Tire chips were approved for use in the gas collection trenches. An 18-inch layer of 3-inch nominal tire chips has been approved as a substitute for the upper 12 inches of the primary LCRS.
High Acres Landfill, Region 8 - Tire shreds substituted for the upper portion of the landfill’s primary LCRS.

Madison County Landfill, Region 7 - Tire shreds were recently used in the upper layer of the primary LCRS, saving an estimated $120,000 in related construction costs for the 7 acre cell.

Broome County Landfill, Region 7 - Tire shreds have been recently approved for use as a component of the LCRS for a new 12-acre cell. Preliminary engineering estimates indicate that the County will shave $300,000 dollars off landfill construction costs.

Albany County Landfill, Region 4 - Tire chips were used as the drainage medium in the gas extraction system.

Delaware County Landfill, Region 4 - Tire shreds were used as part of the landfill’s primary LCRS.

Colonie Landfill, Region 4 - Tire chips were used as the drainage medium in the gas collection system trenches for the cover system.

Hudson Landfill, Region 4 – Tire chips were used as part of the gas venting layer on a trial basis, mainly to investigate the feasibility of compacting a clay barrier layer over tire chips.

While the Division’s records do not indicate any negative impacts from the above specified uses of tire derived aggregate in these numerous landfill applications, it is hoped that this paper will help to promote a consistent statewide approach to the specification of waste tire derived aggregate in landfill primary LCRS in New York State. It is hoped that this paper will assist those involved in making equivalent design demonstrations, under Part 360, for the use of waste tire derived aggregate in a landfill’s primary LCRS design to better ensure that such designs are derived using appropriate testing and design criteria to ensure the long-term operational performance of the landfill’s liner system.

References


