STATE-OF-THE-PRACTICE LITERATURE SCAN FOR FOUNDRY SAND

QUICK SEARCH

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Contents

Introduction

According to the Federal Highway Administration (FHWA) and the US Environmental Protection Agency (EPA), using the waste product of foundry sand in transportation applications (e.g. in embankments and for ice/snow mitigation) is "technically sound, commercially competitive and environmentally safe" (FHWA 2004). The EPA has estimated that using foundry sand in construction applications could prevent 20,000 tons of CO_2 emissions and save more than 200 billion BTUs of energy (AFS-FIRST 2016). Reuse of foundry sand is also an effective way to "conserve landfill capacity and save virgin sands" (MarylandDOT 2016). Therefore, advancing the use of foundry sand has become the focus of "intensive market development efforts by the [EPA] and [FHWA]" (AFS-FIRST 2016).

In 2016, a synthesis effort evaluated current practices and studies related to foundry sand use in transportation construction (MarylandDOT 2016). The study identified "potential concerns related to material performance, environmental considerations, design and field performance". A survey was conducted through the AASHTO Subcommittee on Materials. Of the 15 responding DOTs, three reported limited use of foundry sand. Specification revisions and implementation actions were recommended.

This report will focus on the salient findings of the synthesis, as well as other studies and published literature related to DOT foundry-sand experience. Additionally, it will provide state and DOT foundry-sand requirements and specifications.

Foundry Sand

Metal foundries produce and reuse 100 million tons of foundry sand annually to facilitate the metal casting process (Benson and Bradshaw 2011). When the sand becomes unusable by the foundry, it is discarded, resulting in approximately 10 million tons of spent sand per year (FHWA 2004). Recently, foundries in the US have established the goal of achieving 50 percent of spent sands being diverted to non-landfill applications, which represents an increase from the current 28 percent diversion rate (AFS-FIRST 2016). Figure 1 shows the magnification of foundry sand, which is a high-quality silica sand (Benson and Bradshaw 2011).

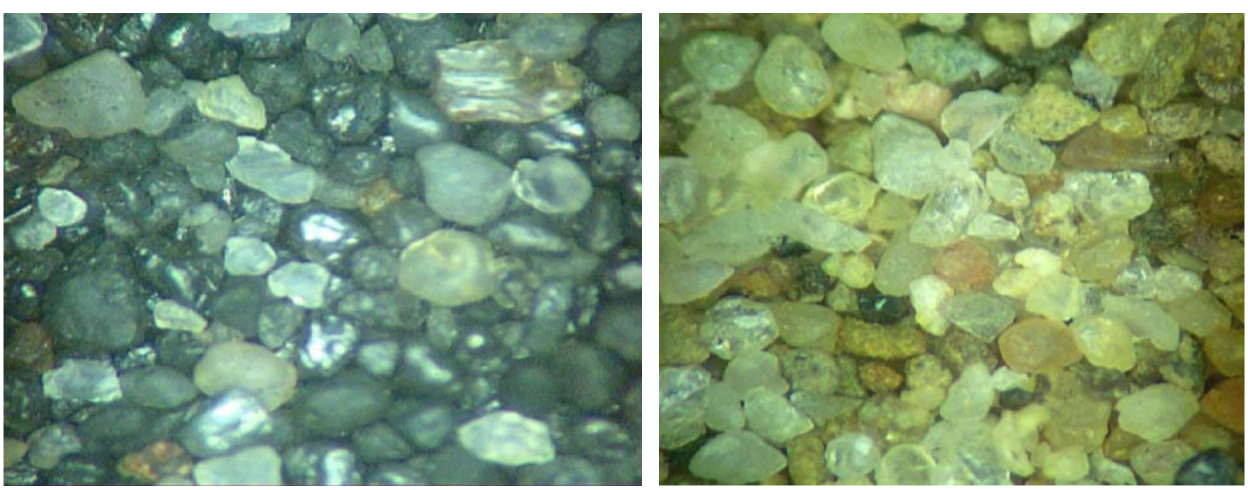

Figure 1 Foundry Sand (left) compared to Natural Sand (right) at 45x Magnification (Olenbush 2007)

Foundries work with nonferrous metals (aluminum, brass or bronze) and/or ferrous metals (steel, iron, stainless steel). Therefore, spent foundry sand may contain leachable contaminants, including heavy metals and phenols that are absorbed by the sand during foundry operations (FHWA 2016). Nonferrous source materials have limited application because they are often classified as hazardous materials due to potentially high concentrations of heavy metals (e.g. cadmium, lead, copper, nickel, and zinc), although the EPA has removed any characterization of nonferrous foundry sands as hazardous in its final guideline (TxDOT 2005, TxDOT 1999). Foundry sand from sources that work with ferrous materials have greater potential for highway applications because the spent sand is generally considered environmentally benign (TxDOT 1999).

Foundries produce sand that is classified as green sand ("clay-bonded" sand) or resin sand ("chemically-bonded" sand). The most common is green sand, which makes up about 90% of the spent foundry sand supply (Benson and Bradshaw 2011). Its physical and mechanical properties are listed in Tables 1 and 2, respectively. It contains:

- silica sand,
- 5% to 10% bentonite clay,
- 2% to 5% water and
- less than 5 percent sea coal.

Resin sand is silica sand held together with "organic binder in conjunction with catalysts and different hardening/setting procedures" used by foundries for special applications (Benson and Bradshaw 2011).

Table 1 Typical Physical Properties of Spent Green Foundry Sand (FHWA 2016)

Property	Results	Test Method
Specific Gravity[3]	2.39 - 2.55	ASTM D854
Bulk Relative Density, kg/m^3 (lb/ft^3)[7]	2590 (160)	ASTM C48/AASHTO T84
Absorption, %[1,3,7]	0.45	ASTM C128
Moisture Content, %[3]	0.1 - 10.1	ASTM D2216
Clay Lumps and Friable Particles[1,3]	1 - 44	ASTM C142/AASHTO T112
Coefficient of Permeability (cm/sec)[3]	10^{-3} - 10^{-6}	AASHTO T215/ASTM D2434
Plastic limit/plastic index[7]	Nonplastic	AASHTO T90/ASTM D4318

Table 2 Typical Mechanical Properties of Spent Foundry Sand (FHWA 2016)

Property	Results	Test Method
Micro-Deval Abrasion Loss, %[5]	< 2	–
Magnesium Sulfate Soundness Loss, %	5 - 15[1,5] 6 - 47[3]	ASTM C88
Friction Angle (deg)[3]	33 - 40	–
California Bearing Ratio, %[3]	4 - 20	ASTM D1883

The following was also noted about foundry sand physical properties (FHWA 2016):

- grain size distribution of spent foundry sand is very uniform
- 85 to 95% is sized between 0.6 mm and 0.15 mm (No. 30 and No. 100 sieve)
- 5 to 12% is smaller than 0.075 mm (No. 200 sieve)
- particle shape is typically subangular to rounded
- gradations have been found to be too fine to satisfy some specifications for fine aggregate
- has low absorption and is nonplastic
- reported values of absorption were found to vary widely, which can also be attributed to the presence of binders and additives
- content of organic impurities (particularly from sea coal binder systems) can vary widely and can be quite high, which may preclude its use in applications where organic impurities could be important (e.g., Portland cement concrete aggregate)
- the spent material often contains metal and core material containing partially degraded binder

The following was noted about foundry sand chemical properties (FHWA 2016):

- hydrophilic, which could lead to moisture-accelerated damage and associated stripping problems in asphalt pavement (may require antistripping additives)
- depending on the binder and type of metal cast, the pH of spent foundry sand can vary from approximately 4 to 8
- some spent foundry sands have been reported to be corrosive to metals
- phenols may be discharged into surface/groundwater supplies due to precipitation percolating through stockpiles; therefore, must be monitored.

Foundry Sand in Highway Applications

Since the late 1980s, foundry sands have had limited use in road construction applications for items such as base and subbase, asphalt and concrete pavement, concrete-related products, cement, soil amendments, and landfill cover (TxDOT 1999). FHWA suggests another possible use of foundry sand is as an anti-skid material for roads covered with snow and ice (FHWA 2004). However, there have been environmental and engineering challenges associated with its use (MarylandDOT 2016). The FHWA published guidance in 2004 entitled "Foundry Sand Facts for Civil Engineers" to provide technical information about using foundry sand in highway applications (FHWA 2004). Highway embankments and flowable fill are the most common applications (MarylandDOT 2016, TxDOT 1999). The Maryland DOT synthesis authors compiled literature information and made specification revision recommendations related to foundry sand (FS) use in the following applications (MarylandDOT 2016):

<u>Foundry Sand in Flowable Fill</u>

- increase in FS content lowers the workability, so amount of superplasticizer required increases
- for self-compacted concrete applications with FS, temperature has little effect on compressive strength, but slightly weakens splitting tensile strength
- concrete with 10-15% FS replacement has the highest strength
- compressive strength decreases with increasing FS replacement of natural sand
- FS should be combined with natural sand (i.e., round sand) to achieve desirable performance

- drying shrinkage of SCC mixtures increases with increasing FS content
- carbonation depth of concrete increases with increasing FS content
- substitution of FS increases permeability; significant increase when rate exceeds 30%
- FS enhances the resistance to chloride penetration
- increasing FS content weakens sulfate resistance (10% is the maximum FS content for acceptable sulfate attack resistance)
- pH increases as cement or lime is added into FS mixtures
- performance tests should be conducted on FS prior to recycling
- metal concentrations from flowable fill materials with FS are lower than EPA maximum limits
- leachate from FS originated from the production of iron, steel, and aluminum are below the regulatory limits for hazardous waste

Foundry Sand in Embankment and Base

- provides sufficient shear strength and compressibility
- has sufficient strength to resist breakdown under compaction
- CBR is 11%-30% higher than that of granular sands, but the friction angle of FS is 30°-36°, comparable to that of natural sands
- prolonging curing time helps improve the strength of cement-amended or lime-amended FS-crushed rock mixtures
- more compressible than natural sand
- swelling is negligible, even for those with high bentonite content (4.7-10.5%)
- when bentonite clay content exceeds 6%, permeability value of FS decreases significantly
- FS containing clays should be compacted to optimum water content in structural fill, and a consistent moisture content should be maintained during compaction
- high cement ratios (>10% by weight) may make cement-stabilized FS more brittle, leading to cracking in base which can be reflected to upper layers
- green sand requires moisture during transportation and placement for dusting
- can be transported, placed and compacted with conventional construction equipment
- TCLP (Toxicity Characteristic Leaching Procedure) extracts of FS without any additives may have high concentrations of copper, lead and zinc, over the limits of 5mg/L; however, adding iron to the TCLP extraction can significantly decrease copper and lead concentrations
- does not cause groundwater or surface water contamination

Foundry Sand in Hot Mix Asphalt (HMA) or Crack Sealant

- AASHTO pavement design method can be used to design asphalt pavements incorporating FS as fine aggregate in HMA
- satisfactory performance has been obtained from hot mix pavements incorporating up to 15 percent clean, spent foundry sand (FHWA 2016)
- use same field-testing procedures, methods and equipment used for conventional HMA mixes
- typically has more consistent composition and higher quality compared to natural sands used in construction
- density of HMA decreases with increasing FS content
- FS replacements of less than 10% yield desirable Marshall stability

- flow value decreases as FS content increases due to increased fine content, indicating lower plasticity and lower durability
- when FS replacement is higher than 15%, asphalt mix may become more sensitive to moisture damage (i.e., stripping) due to the presence of silica
- moisture resistance of FS depends on the clay content and organic additives used
- clay content and organic-based additives should be limited in producing HMA
- clay-bonded FS (green sands) may typically be more sensitive to moisture
- bentonite should be processed to reduce fines contents
- for most FS, the sand equivalent test is not applicable, but methylene blue test is encouraged for measuring the clay content
- indirect tensile strength (ITS) of HMA mixtures decrease with increasing FS content, in either wet or dry conditions, due to the FS clay content
- HMA containing FS does not release hazardous substances into the environment
- ferrous and aluminum based FS are safe substitutes for virgin sands in construction applications
- can reduce the costs of HMA pavements for both producers and end users
- use as a fine aggregate reduces the carbon footprint

<u>Foundry Sand in Portland Cement Concrete</u>

- water absorption of concrete with 5% FS is higher than that of conventional concrete
- water absorption decreases when the substitution rate of FS exceeds 5%
- reduces workability with slump decreasing as FS replacement increases
- modulus of elasticity range from 5.2% to 12% depending on the FS content and curing time
- increases drying shrinkage
- exacerbates carbonation
- sodium silicate binder systems are not desirable in Portland cement
- one study showed reduction in compressive and tensile strengths, and the elasticity modulus which is directly related to waste foundry inclusion in concrete (Guney et al. 2010)
- although the freezing and thawing significantly reduces the mechanical and physical properties of the concrete, the obtained results satisfies the acceptable limits set by the American Concrete Institute (Guney et al. 2010)
- metal concentrations tested by TCLP are below the EPA limits for hazardous waste
- only arsenic may exceed National Primary Drinking Water Standard tested by SPLP

<u>Foundry Sand in Drainage</u>

- with 6%-10% clay, liquid limit is more than 20, and plastic index is more than 2
- low water absorption, varying with different binders and additive types
- hydraulic conductivity is 6x10-4- 5x10-3 cm/sec, high enough to provide good drainage capacity for highway applications
- when bentonite clay content is more than 6% by weight, permeability value decreases significantly to 1x10-7- 3x10-6 cm/sec

Foundry Sand in Snow/Ice Mitigation (FHWA 2004)

- to be used as an anti-skid material, the foundry sand must meet each State's requirements
- angular particles improve traction of pavement surface
- its black color will hold heat longer and will melt the ice faster
- typically, foundry sand is too fine to comply with anti-skid regulations, but when mixed with a coarser material, it does comply
- trial mixes should be formulated and evaluated prior to use
- should be free from glass, metals, or other substances that could be harmful to cars and vehicles

Additionally, it has been noted that the foundry should be responsible for testing and evaluating these materials before they are categorized and approved for use (WisconsinDOT 1999). When it is ready for use, crushing or screening of the material is required to reduce or separate any oversized materials (FHWA 2016). Stockpiles of sufficient size typically need to be accumulated so that a consistent and uniform product can be produced (i.e., day-to-day variations in the material characteristics can be overcome by blending in a comparatively large stockpile) (FHWA 2016).

DOT Experience with Foundry Sand and Related Studies

By 2002, eighteen states had programs that regulated beneficial reuse activities for foundry sand, including Wisconsin, Michigan, Illinois, Iowa, Indiana, Minnesota, Pennsylvania, Ohio, California, Texas, and Louisiana (FHWA 2004). However, literature reveals that DOTs have limited experience with the use of foundry sand, providing experimental case study information and no standard methods for establishing suitability of foundry sand use (Maryland DOT 2016, FHWA 2016). There was little published evidence that foundry sand has been used or is allowable by most DOTs for anything (including snow and ice mitigation) except embankments and flowable fill. Some DOTs have noted "opportunity" and "success" related to limited foundry sand projects, while other DOTs question its viability and safety.

The 2016 Maryland DOT synthesis conducted a survey related to use of recyclable materials, including foundry sand, in various applications (Table 3). The following 15 states responded to the survey: Alaska, Alabama, Colorado, Connecticut, Delaware, Florida, Georgia, Montana, North Dakota, Ohio, South Dakota, Texas, Virginia, Wisconsin and Wyoming. The three states that reported using foundry sand were Wisconsin, Ohio and Alabama and application was restricted to flowable fill (self-consolidating concrete).

Table 3 Use of Foundry Sand in Highway Applications (MarylandDOT 2016)

Applications / Byproducts	Crack Sealant	Base	Drainage/ Embankment	Flowable Fill/ SCC	HMA	PCC
Foundry Sand	-	-	-	WI,OH,AL	-	-

PennDOT recently showed that it has not used foundry sand, but presented "project opportunities" related to its potential use in fine aggregate and flowable fill applications (PennDOT 2013). A recent analysis of PennDOT road construction activities and materials source sites in the Pittsburgh area found that using "locally sourced recycled materials (including foundry sand) instead of virgin materials would reduce energy used in transportation by about 50%" (NCHRP 2010).

The Texas DOT conducted a study in 2005 to determine if foundry sand was appropriate for flowable fill and cemented sand applications in Texas (TxDOT 2005). [Note: Texas did not report use of foundry sand in the 2016 Maryland DOT survey.] It identified local foundry sand sources and evaluated material quality based upon environmental and engineering properties. It developed the following protocol to determine suitability of foundry sand:

- collected samples from 10 sources
- created a QA/QC plan for foundry sand testing
- verified if foundry sand met TxDOT Specification DMS 1100 for "Non-Hazardous Recyclable Materials"
- characterized geotechnical properties
- determined leaching characteristics using EPA and [TxDEQ] testing methods
- verified that properties of local materials were in range of values reported in literature
- tested more than 200 laboratory and field specimens over a period of one year
- developed specifications and MSDS

The study concluded that local foundry sands could be used for flowable fill and cemented sand applications in the state. It recommended that other studies be conducted to evaluate the long-term performance of foundry sand.

Worker Exposure: Airborne Contaminants from Foundry Sand

In 1996, foundry sand was used in the construction of a roadway embankment in northeastern Indiana. Previous investigations of the sand had found that it was safe to use as a construction material and had no detrimental effects. However, several days after the laying and compaction of the sand, tire interaction with the compacted and now dried sand caused the generation of copious black dust clouds that coated the backs of the construction vehicles in a layer of fine black dust. This led to worker concern regarding airborne silica and silicosis.

A study was conducted by the Indiana DOT to determine if the threat of overexposure to airborne crystalline silica existed in regard to Occupation Health and Safety Administration's (OSHA) Permissible Exposure Limit (PEL). It found that the respirable crystalline silica dust did not overexpose the workers according to the OSHA PEL.

The study showed that adding up to an average of 20% by weight of respirable size dust (such as baghouse hopper dust) is allowable in the waste foundry sand. Specifying this amount of fine dust for waste foundry sand will provide a worker exposure safety factor of about 2.0 for protection against overexposure to crystalline silica dust. Removing the baghouse hopper dust material from the waste sand would reduce dust generation considerably. Recommended methods of dust abatement include watering down the dust during transportation, dumping, and compacting and keeping the sand wet during construction (IndianaDOT 2002).

According to a Wisconsin DOT Transportation Bulletin (1999), the state has had some successful projects using waste materials, including foundry sand (Table 4).

Table 4 Wisconsin DOT Project List of "Successful Application" of Waste Products (1999)

	Material	Application	Location
1.	Fly Ash	Fill	USH 41, Brown Co., Kaukauna–DePere/CTH F Int G/G
2.	Fly Ash	Fill	STH 441 Outagamie Co.,Tri-County/CTH CE-USH 41
3.	Fly Ash	Fill	STH 441 Outagamie Co., CTH OO/USH 41 So. Sect.
4.	Fly Ash	Fill	STH 441 Outagamie Co., Tri-County/CTH OO/USH 41/North
5.	Fly Ash, Foundry Sand	Fill	STH 441, Calumet Co., Tri-County/USH 10-CTH KK
6.	Fly Ash	Fill	USH 10, Winnebago Co., USH 45-USH 41, USH 10 Ext. (3 installations)
7.	Fly Ash, Foundry Sand	Fill	USH 45, Outagamie Co., New London Bypass/Wolf River - STH 54
8.	Fly Ash	Fill	STH 28, Sheboygan Co., Sheboygan Falls-IH 43/28-CTH PP
9.	Fly Ash	Fill	USH 10, Outagamie Co., STH 76 Interchange
10.	Foundry Sand	Fill	STH 54, Waupaca Co., Soo Line RR approach
11.	Foundry Sand	Fill	STH 29, Shawano Co., CTH K overhead
12.	Foundry Sand, Fly Ash	Flowable Fill	CTH D, CTH G, Sheboygan Co.
13.	Fly Ash CL C&F	CLSM	I-90/94, Columbia Co., fill for several culverts
14.	Screened Bottom Ash	Base course	STH 35, Crawford Co., STH 82 for 14 & 15 to DeSoto Rd.
15.	Natural Bottom Ash	Base course	STH 35, Crawford Co., CTH C to STH 82
16.	Cupola Slag	Base course	USH 10, Waupaca Co.
17.	Tire	Chipped tire noise berm	STH 172, Brown Co., Ashwaubenon
18.	Foundry Materials	Fill	STH 100, Ryan Rd., Milwaukee Co.
19.	Papermill Ash	Fill	Mosinee Airport, Marathon Co.
20.	Glass	Base course fill	STH 44, Columbia Co.
21.	Glass	OGBC edge drains	STH 54, Brown Co., West Mason St., City of Green Bay
22.	Bottom Ash	Fill	STH 29, Clark/Marathon Co., STH 29/STH 13 Interchange
23.	Fly Ash	Fill	Just south of USH 41 on STH 441, Outagamie Co.
24.	Fly/Bottom Ash	Fill	Airport Spur Freeway, Milwaukee Co.
25.	Bottom Ash Glass Pottery Cull, Foundry Sand, Steel Slag	Base course fill	US 12 Cottage Grove to Cambridege, Dane Co.

FHWA on Foundry Sand in Asphalt Pavements

Currently, the FHWA website states that there is no performance record for asphalt pavements containing foundry sand since "there are no documented field uses of foundry sand in asphalt paving mixes" (FHWA 2016a). However, its 2004 report states the following:

Pennsylvania, Michigan and Tennessee Departments of Transportation allow the use of recycled foundry sand in HMA. Pennsylvania DOT allows the use of 8 to 10% of the total aggregate portion to be recycled foundry sand in the asphalt wearing course. One hot mix producer in Michigan consistently supplies HMA with 10-20% recycled foundry sand to replace the conventional aggregate, and it meets Michigan DOT specifications. Another hot mix supplier in Tennessee claims that hot mix with foundry sand replacing 10% of the fine aggregate compacts better and outperforms the HMA containing washed river sand. In addition, a hot mix producer in Ontario, Canada has used foundry sand as a fine aggregate substitute for the past 10 years in both foundation and surface HMA layers. (FHWA 2004)

An Ohio DOT report states that foundry sand is rarely used, although it is a competitive bid item (OhioDOT 2008). The report also states that "recent attempts by the foundry sand industry have found limited success and failures". It further states:

> "Recycled materials need to be economically viable. Mandates generally have not worked. The foundry sand industry pushed their product as clean, which it generally is, but construction of embankments with clean sand is not stable. The cost of containing and stabilizing the sand along with the additional construction time created its own limits even when the material was initially cheaper". (OhioDOT 2008)

Additionally, in its specification for recycled materials, the statements in the "Benefits" section are (OhioDOT 2005, in Appendix):

> "By using these [recycled] materials, the Department will save land fill space in the state. The Department may minimize the potential future legislation that would require the use of these materials. (Note: A few years ago, the state legislators required us to allow petroleum contaminated soil for embankment material.)"

An Ohio EPA Policy document entitled "Beneficial Use of Nontoxic Bottom Ash, Fly Ash and Spent Foundry Sand, and Other Exempt Waste," was developed in 1998 but removed in 2003. It included information regarding "the use as an anti-skid material (i.e. snow/ice control) or road surface preparation material, if such use is consistent with Ohio Department of Transportation (ODOT) specifications or other applicable specifications" (OhioEPA 2003).

Although the FHWA reported that Illinois was one of the states that had programs to regulate beneficial reuse activities for foundry sand, the Illinois DOT does not "currently considered [foundry sand] a viable resource" due to "economic or technical reasons" and is therefore not used by the Department (IllinoisDOT 2011, FHWA 2004). Concerns specifically relate to the material's origin, physical properties, potential engineering value, potential application and other department concerns as noted (IllinoisDOT 2011):

<u>Origin</u>

- presence of heavy metals (i.e. cadmium, lead, copper, nickel, and zinc) is of concern

<u>Physical Properties</u>

- sand contains metal casting pieces and partially degraded binder
- may also contain some leachable contaminants, including heavy metals and phenols

<u>Engineering Value</u>

- may result in stripping of the asphalt cement coating aggregate

<u>Potential Application</u>

- commercial use is extremely limited in the United States

- two main challenges to using waste foundry sand are environmental issues and an engineering value
- transportation cost of foundry sand is the most limiting factor to its use

<u>Department Concerns</u>

- environmental safety of sand depends on chemical additives and casted metals utilized with the sand
- The Illinois DOT does not allow use of ferrous foundry waste sand because it is often contaminated with traces of hazardous elements

State Regulations and DOT Specifications

State regulations and DOT specifications for foundry sand reuse vary from state to state. Some states have a single set of requirements for all industrial by-products, while others have rules specifically guiding the reuse of foundry sand (Wisconsin RMRC 2016). The EPA produced the "State Toolkit for Developing Beneficial Reuse Programs for Foundry Sand" that establishes a "roadmap for creating a foundry sands beneficial reuse program" (Figure 2) and provides links to regulations in ten example states including: Illinois, Indiana, Louisiana, Maine, Michigan, New York, Pennsylvania, Texas, West Virginia, and Wisconsin (EPA 2006). The guidance for Indiana produced by the Indiana Department of Environmental Management in 2007 is located in the Appendix for reference.

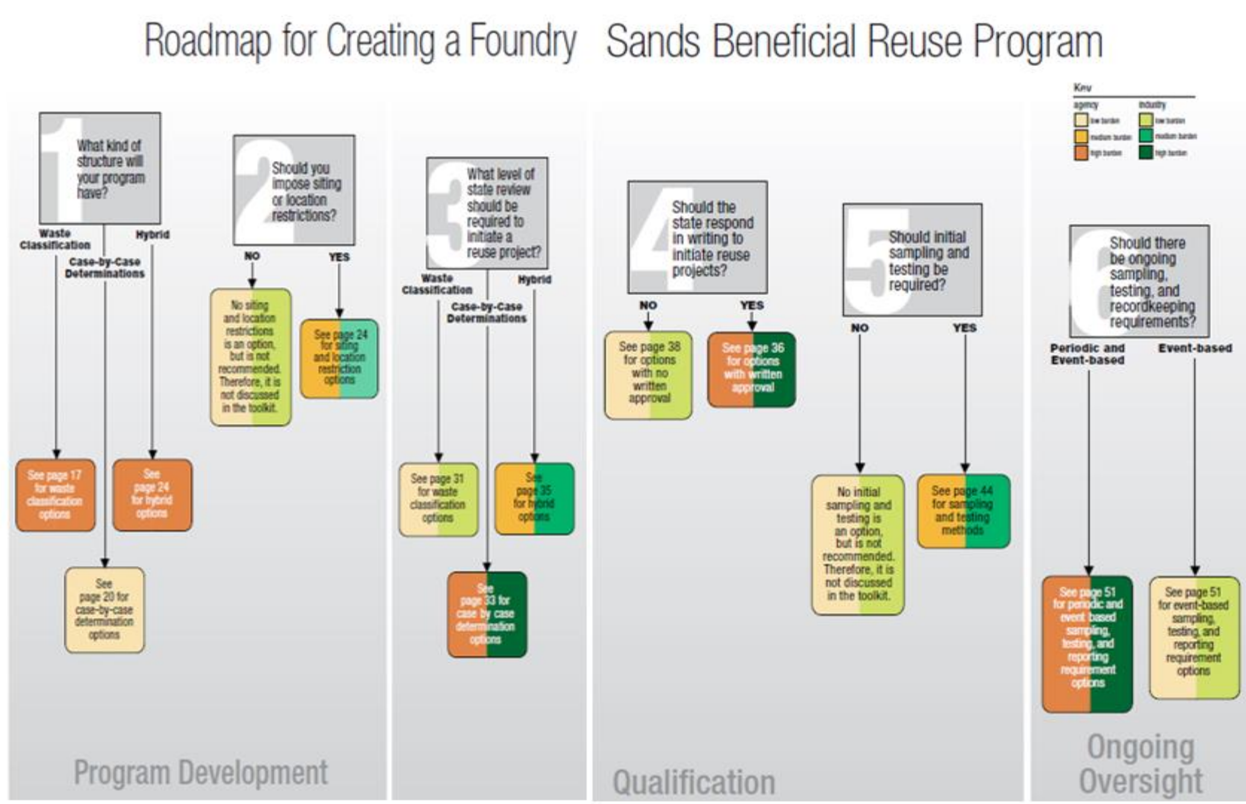

Figure 2 Roadmap for Creating a Foundry Sands Beneficial Reuse Program (EPA 2006)

According to the Maryland DOT synthesis, most requirements for foundry sand primarily relate to the gradation and percentage of recycled material (MarylandDOT 2016). Specifications for the Indiana DOT and Ohio DOT are in the Appendix, for reference. The Ohio DOT specification also includes leaching test requirements, as shown in Figure 3 (MarylandDOT 2016).

- **Mix design**
  - Conform to the requirements of OHDOT 703.05 for gradation. Use fine aggregate that is fine enough to stay in suspension within the mixture to ensure proper flow.
  - Meet the requirements of the Division of Surface Water Policy 400.007 "Beneficial Use of Non-Toxic Bottom Ash, Fly Ash and Spent Foundry Sand and Other Exempt Wastes," and all other regulations.
    - The following requirements should be met:

Leachate	Selenium	Phenol	Cyanide	Fluoride
Maximum content (mg/L)	1	10.5	0.6	12.0

    - The solution must be analyzed for the following parameters: acidity, alkalinity, aluminum, arsenic, barium, cadmium, chlorides, chromium, copper, fluoride, iron, lead, manganese, mercury, pH, selenium, specific conductance, sulfates, total dissolved solids, vanadium and zinc.
    - At a minimum, annual tests must be performed on the materials.
- The applications of nontoxic FS are stabilization/solidification of other waste, soil blending ingredient, landfill, structural fill, pipe bedding, borrow pits and surfacing.

Figure 3 Ohio DOT Foundry Sand Requirements

Conclusions

The state-of-the-practice shows limited use of foundry sand in highway applications, with use being primarily restricted to embankments and flowable fill. This is attributed to the engineering and environmental challenges associated with the material. There are also no standard methods for establishing suitability of foundry sand use and long-term performance is unknown. Some DOTs have noted "opportunity" and "success" related to the limited foundry sand projects, while other DOTs question its viability and safety.

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Appendices – FHWA Guidance, Example State Requirements and Specifications

FHWA User Guideline for Foundry Sand in Asphalt Concrete (2016)

FHWA User Guideline for Foundry Sand in Flowable Fill (2016)

Indiana Department of Environmental Management Guidance Document for Foundry Sand Reuse (2007)

Indiana DOT Specification for Foundry Sand (2015)

Ohio DOT Specification for Foundry Sand in Embankments (2005)

Publication Number: FHWA-RD-97-148

User Guidelines for Waste and Byproduct Materials in Pavement Construction

FOUNDRY SAND **User Guideline**

Asphalt Concrete

INTRODUCTION

Ferrous spent foundry sand can be used as fine aggregate in hot mix asphalt pavements.[1,2,3] Satisfactory performance has been obtained from hot mix pavements incorporating up to 15 percent clean, spent foundry sand.

Hot mix asphalt pavements with more than 15 percent of clean spent foundry sand content (blended with natural sand) are susceptible to moisture damage due to the hydrophilic nature of the (primarily silica) foundry sand, resulting in stripping of the asphalt cement coating surrounding the aggregate grains, loss of fine aggregate, and accelerated pavement deterioration. The problem can be mitigated by using antistripping additives.

Spent sands from nonferrous foundries and foundry baghouse dust can contain a high concentration of heavy metals that could preclude their use as an aggregate in pavement construction.

PERFORMANCE RECORD

The commercial use of spent foundry sand in the United States is extremely limited. There are no documented field uses of foundry sand in asphalt paving mixes. In an American Foundrymen's Society study of asphalt concrete properties (using 10 percent foundry sand) compared with control mixes (without foundry sand), the results indicated little difference in Marshall design properties (e.g., voids, voids in mineral aggregate, stability, flow, and unit weight).[4] A more recent study was undertaken at Purdue University with samples containing up to 30 percent foundry sand. Increasing foundry sand blends above 15 percent lowered the unit weight, increased the air voids, decreased the flow and stability of the mixes, and reduced the indirect tensile strength (after immersion in a hot water bath), which is indicative of samples that are susceptible to stripping problems.[4]

MATERIAL PROCESSING REQUIREMENTS

Crushing and Screening

It may be necessary to crush and screen the spent foundry sand to reduce the size of any oversize core butts or uncollapsed molds prior to use as aggregate. This is readily accomplished using conventional aggregate processing equipment (closed loop crushing and screening process, equipped with magnetic separator, as necessary).

It is also important that consistency (primarily gradation) be maintained for hot mix asphalt production. Variations between foundries require that spent foundry sands be examined and evaluated on a source-specific basis.

Quality Control

For spent foundry sand to be suitable as a partial replacement for natural fine aggregates in asphalt pavements, it should be free of objectionable materials such as wood, garbage, and metal, which can be introduced at the foundry. Spent foundry sand should also be free of thick coatings of burnt carbon, binders, and mold additives. These constituents can inhibit adhesion of the asphalt cement binder to the foundry sand.

Storage and Blending

Stockpiles of sufficient size should be accumulated so that product uniformity can be achieved. This may necessitate the accumulation of a substantial quantity of spent foundry sand in a central site at a specific foundry or group of foundries before transferring the material to hot mix producers.

To satisfy the gradation requirements for hot mix asphalt fine aggregates (AASHTO M29),[5] the spent foundry sand must be blended with natural sand at the hot mix plant.

ENGINEERING PROPERTIES

Some of the properties of spent foundry sand that are of particular interest when foundry sand is used in asphalt paving applications include particle shape, gradation, durability, and plasticity. With the exception of gradation, clean, processed foundry sands can generally satisfy the physical requirements for hot mix asphalt fine aggregate (AASHTO M29).

Particle Shape: The grain size distribution of spent foundry sand is very uniform, with approximately 85 to 95 percent of the material between 0.6 mm and 0.15 mm (No. 30 and No. 100) sieve sizes. The grains are generally rounded to subangular in shape.

Gradation: The gradation tends to fall within the limits for a poorly graded fine sand that has relatively uniform size (passing 0.3 mm and retained 0.15 mm), with fines content (less than 0.075 mm (No. 200 sieve)) ranging from 5 to 15 percent.

Durability: Spent foundry sands display good durability characteristics with resistance to weathering.[6,7]

Plasticity: Spent foundry sand generated by foundries using green sand molding systems, in which bentonite clay and sea coal are added to the casting, should be examined to ensure that plasticity levels comply with AASHTO requirements for fine aggregates.

Stripping is one of the more critical properties that should be assessed when foundry sand is incorporated into an asphalt mix.

Stripping: Spent foundry sand is composed primarily of silica sand, coated with a thin film of burnt carbon, residual binder (bentonite, sea coal, resins), and dust. The hydrophilic nature of the (primarily silica) foundry sand, however, can result in stripping of the asphalt cement coating surrounding the aggregate grains, with resulting loss of fine aggregate and accelerated pavement deterioration. This problem can be mitigated by limiting the content of spent foundry sand in the mix to 15 percent of the total mass of aggregate or using an antistripping additive.

DESIGN CONSIDERATIONS

Mix Design

Asphalt mixes containing foundry sand can be designed using standard asphalt mix design methods (Marshall, Hveem).

The potential for stripping of asphalt mixes containing spent foundry sand should be assessed in the laboratory as part of the overall mix design. Several tests are available, with the most common including: AASHTO T283-85,[8] which compares the tensile strength ratio of wet and dry specimens; T182-84,[9] T195-67,[10] or the Immersion Marshall test following the MTO LS-283[11] procedure, which compares the retained Marshall stability and visual appearance of Marshall briquettes before and after immersion in a heated water bath. Stripping resistance can be enhanced by adding hydrated lime or commercially available antistripping additives.

Structural Design

Conventional AASHTO pavement design methods are appropriate for asphalt paving incorporating spent foundry sand as fine aggregate.

CONSTRUCTION PROCEDURES

Material Handling and Storage

The same general methods and equipment used to handle conventional aggregates are applicable for foundry sand.

Foundry sand, which is usually obtained in a dry form, can be stored in covered structures to preserve this condition and reduce energy required for drying. Special measures may be required to control the leachate (containing phenols) from open stockpiles (including temporary stockpiles).[12] The use of an impervious pad (to collect surface moisture or precipitation passing through the stockpile) and subsequent filtration (using an activated carbon filter) of the leachate has proven to be effective (but potentially expensive) in limiting the phenol concentration of the discharge.[6,7]

Mixing, Placing, and Compacting

The same methods and equipment used for conventional hot mix asphalt pavement are applicable to pavements containing spent foundry sand. If it is dry (less than 5 percent moisture), spent foundry sand can be metered directly into a pugmill (batch plants only) or through a recycled asphalt feed (drum plants) where it can be further dried, if necessary, by the already heated conventional aggregates.[13]

The presence of bentonite and organic binder materials can increase the time required for drying and can increase the load on the hot mix plant dust collection system (baghouse). Any coal and organic binders that are present are usually combusted in the process.

The same methods and equipment used for placing and compacting conventional pavements are applicable for pavements incorporating foundry sand.

Quality Control

The same field testing procedures used for conventional hot mix asphalt mixes should be used for mixes containing foundry sand. Mixes should be sampled in accordance with AASHTO T168,[14] and tested for specific gravity in accordance with ASTM D2726[15] and in-place density in accordance with ASTM D2950.[16]

UNRESOLVED ISSUES

There is a need to establish standard methods of assessing the suitability of foundry sand for hot mix asphalt use. The Immersion Marshall test appears to be appropriate for assessing stripping potential.

Additional performance data are required to determine the maximum amount of foundry sand that can be incorporated in hot mix asphalt without deleterious effects.

There is a need to define the potential environmental problems associated with phenol discharges from foundry sand stockpiles, and to determine appropriate treatment strategies, if necessary.

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User Guidelines for Waste and Byproduct Materials in Pavement Construction

FOUNDRY SAND **User Guideline**

Flowable Fill

INTRODUCTION

Ferrous spent foundry sand can be used as substitute for natural sand (fine aggregate) in flowable fill(1,2). Natural sand is a major component of most flowable fill mixes. Spent sands from nonferrous foundries and foundry baghouse dust can contain high concentrations of heavy metals that may preclude their use in flowable fill applications.

Flowable fill or controlled low strength material (CLSM) is generally composed of a mixture of sand, fly ash from coal-fired power plants, a small amount of cement, water, and admixtures. It is defined by the ACI Committee 229(3) as a cementitious material that is in a flowable state at the time of placement and that has a specified compressive strength of 1400 kPa (200 lb/in^2) or less at 28 days. This makes it possible for the material to be removed should future excavation be necessary. The applications of flowable fill are numerous and include restoration of utility cuts in county roads, backfilling structures, filling abandoned wells, filling voids under existing pavements, and pipe embedments. (See references 4,5,6,7,8 and 9.)

The specifications in most jurisdictions for flowable fill materials require that aggregates satisfy ASTM C33.(9) While spent foundry sand may not satisfy the gradation requirements of ASTM C33 for fine aggregates, the uniform, spherical nature of the particles produces a relatively free-flowing mixture.

PERFORMANCE RECORD

There has been limited reported use of spent foundry sand in flowable fills or cementitious applications. It is reportedly being used in flowable fill applications in the Buffalo, New York area.(10)Pennsylvania has reported successful use of foundry sand as a sand substitute in flowable fill. Illinois, however, has tried spent foundry sand and considered such use unsuitable due to poor performance or economics.(11)

MATERIAL PROCESSING REQUIREMENTS

Crushing and Screening

It may be necessary to crush the spent foundry sand to reduce the size of oversize core butts or uncollapsed molds. The spent foundry sand can also be screened and oversize material (from molds and cores that have not completely collapsed) removed.

Quality Control

For spent foundry sand to be suitable as a replacement for fine aggregate in flowable fill, it should be free of objectionable material such as wood, garbage, and metal that can be introduced at the foundry. It should be free of foreign material and thick coatings of burnt carbon, binders, and mold additives that could inhibit cement hydration.

Storage and Blending

Stockpiles of sufficient size should be accumulated and blended so that a consistent gradation can be achieved before transferring the material to ready-mix concrete plants/flowable fill producers.[12] Where it is specified that aggregates must satisfy the requirements of ASTM C33, the spent foundry sand must be blended with natural or other suitable fine aggregate materials to meet gradation requirements. The presence of organics (from some binder systems such as bentonite clay) may exceed ASTM C33 criteria and must therefore be closely monitored.

ENGINEERING PROPERTIES

Some of the engineering properties of spent foundry sand that are of particular interest when foundry sand is used in flowable fill applications include particle shape, gradation, strength characteristics, soundness, deleterious substances, and corrosivity.

Particle Shape: The grain size distribution of spent foundry sand is more uniform and somewhat finer than conventional concrete sand.[13] The fineness of spent foundry sand contributes to good suspension, limiting segregation of flowable fill. The spherical shape of spent foundry sand particles contributes to good flow characteristics. However, increased particle fineness and sphericity also result in lower strength bearing capacity (CBR) of the hardened flowable fill.[14]

Gradation: Spent foundry sand may not satisfy the ASTM C33 gradation requirement for concrete aggregate and, therefore, it may need to be blended with natural sand or other suitable fine aggregate materials to meet the requirements.

Strength Characteristics: Although some organic binder materials can interfere with cement hydration, low (rather than high) strength development is in most cases more desirable with flowable fill to permit excavation at a later date. It has been reported that the flowable fill incorporating spent foundry sand aggregates, fly ash, a small quantity of Portland cement, and water readily satisfies specified limited strength criteria.[15]

Soundness: The performance of spent foundry sands in soundness tests depends on the amount of clay binder materials present in the spent foundry sand, the amount of agglomeration of the fines, and the coating on the individual particles. The greater amount of clay binder or agglomeration, or the thicker the coatings, the higher the soundness loss. Regardless, spent foundry sands generally exhibit favorable performance in soundness testing, with soundness losses less than 10 percent (indicative of durable aggregate).[13]

Deleterious Substances: Poorly managed spent foundry sand could contain objectionable materials such as wood, garbage, metal, carbon, and dust as well as large chunks of sand. For use in flowable fill, spent foundry sand must be managed to ensure that the sand is clean and processed to the proper sand size. Foundry sand is often contaminated with organic material and can have an organic content of up to 12 percent.[16,17]

Corrosivity: Depending on the binder and type of metal cast, the pH of spent foundry sand can vary from approximately 4 to 8.[18] It has been reported that some spent foundry sand can be corrosive to metals.[19] Others have indicated that flowable fill mixes containing spent foundry sand are noncorrosive in nature because of the absence of chlorides and high pH values obtained (11.4 to 12.3).[1]

DESIGN CONSIDERATIONS

Mix Design

Flowable fill mixes are usually designed on the basis of compressive strength, generally after 28 days of ambient temperature curing, but sometimes on the basis of longer term (90 days or more) strength. They are designed to have high fluidity during placement (typical slump of 150 mm to 200 mm (6 to 8 inches)) and to develop limited strength (typically between 340 kPa and 1400 kPa (50 and 200 lb/in^2)), which is sufficient to support traffic without settling, yet can be readily excavated.[20]

Many jurisdictions specify the use of fine aggregates conforming to ASTM C33 in flowable fill, which generally precludes using spent foundry sand unless it is blended with natural sand or other suitable materials.

Structural Design

Structural design procedures for flowable fill materials are no different than geotechnical design procedures for conventional earth backfill materials. The procedures are based on using the unit weight and shear strength of the flowable fill to calculate the bearing capacity and lateral pressure of the material under given site conditions.

CONSTRUCTION PROCEDURES

The same methods and equipment used to mix, transpor, and place flowable fill made with conventional aggregates may be used for flowable fill incorporating spent foundry sand.

Material Handling and Storage

The same general methods and equipment used to handle conventional aggregates are applicable for foundry sand. Special measures may be required to control the early contact water leachate (containing phenols) from spent foundry sand stockpiles. The construction of an impervious pad (to collect surface moisture or precipitation passing through the stockpile) and subsequent filtration (through an activated carbon filter) of the leachate has reportedly been effective in limiting the phenol concentration of the discharge.[19]

Mixing, Placing, and Compacting

Flowable fill can be produced at a central concrete mixing plant in accordance with ASTM C94[21] and delivered by concrete truck mixers or using a mobile, volumetric mixer for small jobs. It is important that high fluidity (slump greater than 150 mm (6 in)) be maintained to ensure that the flowable fill material entirely fills all voids beneath pavements and around structures and utilities.

Quality Control

Various standard field and laboratory tests for flowable fill mixes are given by AASHTO T27,[22] ASTM Provisional Standard 28 - Provisional Test Method for Flow Consistency of Controlled Low Strength Materials; and ASTM Provisional Standard 29 - Provisional Test Method for Unit Weight, Yield, and Air Content (Gravimetric) of Controlled Low Strength Material.

UNRESOLVED ISSUES

Most existing specifications require that the fine aggregate for flowable fill satisfy ASTM C33. Since foundry sand does not meet the gradation requirements of this standard, there is a need to review gradation requirements and investigate the impact of alternative gradations to permit wider use of spent foundry sand for this application. There also is a need to develop standardized mix design methods for assessing the suitability of foundry sand in flowable fill as well as a need to assess the environmental suitability of spent foundry sand for flowable fill from ferrous and particularly nonferrous foundries.

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[**Material Description**] [**Asphalt Concrete**]

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GUIDANCE

FOUNDRY WASTE CLASSIFICATION GUIDELINES

A waste classification must be issued by Indiana Department of Environmental Management (IDEM) when a foundry wishes to:

- dispose of **foundry wastes** (restricted waste) into a restricted waste site.
- use **foundry sand** in accordance with Indiana's law allowing the use of foundry sand (IC 13-19-3-7).

A waste classification does not need to be issued from IDEM when a foundry wishes to:

- dispose of **foundry wastes** in a municipal solid waste landfill as a nonhazardous solid waste in accordance with Indiana's Solid Waste Land Disposal Facilities Rule (329 IAC 10).
- dispose or use **foundry wastes** outside of Indiana.

Foundries generate several waste streams. This guidance is specifically for nonhazardous wastes. **Foundry wastes** may include foundry sands, slag, refractory, baghouse dust, and pattern shop waste. The term **foundry sand** is used in Indiana regulations that govern the use of foundry sand. For this purpose, **foundry sand** is generally accepted as molding sand and core sand. Baghouse dust from sand handling systems if made up of only fine sand particles may be used under IC 13-19-3-7. Baghouse dust from other processes such as furnace emissions, grinding, or shot blasting may not be used under the statute.

A particular classification level is assigned to a waste based upon a complete and thorough waste characterization, including a well-planned representative sampling program. IDEM staff have prepared this waste classification guideline to describe how to sample and analyze foundry wastes as required under ***329 IAC 10-9-4***.

Foundry wastes may be disposed as nonhazardous solid waste in any permitted municipal solid waste landfill designed and operated in accordance with the *Solid Waste Land Disposal Facilities* rule (329 IAC 10) without obtaining a waste classification. However, if the waste is to be sent to a restricted waste site or used, it must be tested and classified according to 329 IAC 10-9-4. Additional testing is required for use in land application or as a soil amendment. The additional testing requirements can be found in IDEM Guidance titled "Use of Foundry Sand in Land Application and as a Soil Amendment" (ID No. WASTE-040-NPD).

Please note that the restricted waste site classification, (Type I, II, III, and IV), must be certified in writing by the IDEM.

Prior to obtaining a waste classification, generators of solid waste are responsible for maintaining information on their wastes as required under 329 IAC 10-7.2. That rule references the hazardous waste determination found in Indiana's Hazardous Waste Management rules (329 IAC 3.1) as well as other characteristics that may affect disposal at a permitted land disposal facility. 329 IAC 10-7.2 includes an evaluation for Polychlorinated Biphenyls, asbestos, pesticides, or any other risk posed during handling use or disposal of a waste. It should also be noted that the agency retains authority to ask for any other information relevant to compliance with Indiana's environmental regulations. Wastes that are determined to be nonhazardous and do not contain Polychlorinated Biphenyls, asbestos, or pesticide residues regulated by the Federal Insecticide, Fungicide, Rodenticide Act (FIFRA) may be evaluated for a **Waste Classification**.
The waste classification is used to determine restricted waste site disposal requirements and identify potential risks for legitimate use applications.

This guidance has been developed by Office of Land Quality staff to assist foundries in the waste classification process. Since every generating facility is unique, some factors or situations may not be addressed in this guidance document. Any questions about the requirements outlined in this guidance should be discussed with Industrial Waste Section staff at 317/308-3103.

A copy of all applicable statutes (IC 13) and rules (329 IAC 10 and 329 IAC 3.1) may be obtained from the Legislative Services Agency by calling 317/232-9556 or through the Internet at http://www.in.gov/legislative/ic_iac/. Guidance regarding foundry sand storage, foundry sand use, and making a hazardous waste determination may be obtained through the Internet at http://www.in.gov/idem/rules/policies/#land or by calling Industrial Waste Section Staff at 317/308-3103. A list of referenced and related rules and guidance can be found at the end of this guidance.

A. Generator Responsibilities for Waste Information

329 IAC 10-7.2 lists generator responsibilities for collecting information on wastes they generate. This information is used to determine how a waste may be properly disposed in a permitted disposal facility or processed in a permitted processing facility. The waste determination must specifically look at hazardous waste (characterisitic and listed), asbestos, PCBs, heat or capability of generating heat, or any other risk that a particular waste may present. It should also be noted that the agency retains authority to ask for any other information relevant to compliance with Indiana's environmental regulations. This determination may be based on testing or use of generator knowledge. **Information must be collected on individual waste streams.**

Hazardous Waste Determination

State and Federal regulations require generators of solid waste to make a hazardous waste determination (40 CFR 262.11, adopted under 329 IAC 3.1-6). To make this determination, generators must do one or more of the following for each separate waste stream:

- Identify the process that generated the waste (Is it a "listed" waste?),
- Apply knowledge of typical waste composition and/or
- Conduct waste testing or analysis**.**

NOTE: Some solid wastes may be excluded from hazardous waste regulations (see 40 CFR 261). Even if you have determined that your waste is excluded from hazardous waste regulation, you need to re-evaluate your status periodically to verify that conditions affecting the composition of your waste have not changed. Some excluded wastes may exhibit hazardous waste characteristics.

Hazardous Waste Listing Determination

If you find that your waste is not excluded from hazardous waste regulations, then you must determine if the waste meets one or more of the hazardous waste ***listing*** descriptions found in 40 CFR 261.31, 261.32 and 261.33. The lists include wastes from non-specific sources [termed "F-listed wastes," such as F002 wastes, spent halogenated solvents (i.e., perchloroethylene, trichloroethylene, methylene chloride.)] The hazardous waste listings also include wastes from specific sources, K-listed wastes, such as K062 waste, spent pickle liquor from the steel finishing industries. The third group of hazardous waste listings includes discarded unused commercial chemical products, off-specification products and spill residues of such products (i.e., P- and U-listed wastes.) While there are no source specific listings for foundries, if another listed waste (such as an F-listed waste) is mixed with another waste, the mixture is considered a hazardous waste.

Hazardous Waste Characteristic Determination

If the waste is not listed, you must determine if it exhibits any of the four ***characteristics*** of a hazardous waste: **ignitability**, **corrosivity**, **reactivity**, and **toxicity**. This evaluation involves testing the waste or using knowledge of the process or materials used to produce the waste.

A waste is ***ignitable*** if it is a liquid and its flash point is less than 140° F (60° C). A waste also may be defined as ignitable if it is an oxidizer or an ignitable compressed gas as defined by the U.S. Department of Transportation (DOT) regulations in 49 CFR Part 173, or if it has the potential to ignite under standard temperature and pressure and burn persistently and vigorously once ignited. Wastes that are ignitable are classified as EPA Hazardous Waste Code D001. Examples of ignitable wastes include certain spent solvents such as some mineral spirits. Guidance titled "Ignitable Solid Hazardous Waste" is available for further assistance.

A waste is ***corrosive*** if it is aqueous and its pH is less than or equal to 2 or greater than or equal to 12.5. A waste also is corrosive if it is a liquid and it corrodes steel at a rate of more than 0.25 inches per year under conditions specified in EPA Test Method 1110. Corrosive wastes are designated as EPA Hazardous Waste Code D002. Examples of corrosive wastes include spent sulfuric acid and concentrated waste sodium hydroxide solutions that have not been neutralized.

A waste exhibits ***reactivity*** if it is unstable and explodes or produces fumes, gases, and vapors when mixed with water or under other conditions such as heat or pressure. A waste also may be defined as reactive if it is a forbidden explosive or a Class A or Class B explosive as defined in 49 CFR Part 173. Wastes that exhibit the characteristic of reactivity are classified as EPA Hazardous Waste Code D003. Examples of reactive wastes include certain cyanide or sulfide-bearing wastes.

The ***toxicity characteristic*** of a waste is determined by having a laboratory analyze an extract of the waste using the Toxicity Characteristic Leaching Procedure. The results of the analysis are compared to the regulatory thresholds of 40 constituents, primarily heavy metals, organic compounds, and pesticide/herbicides. If the extract from the TCLP procedure contains levels of any of the 40 constituents at or above regulatory thresholds, the waste is considered a hazardous waste. Wastes that exhibit the toxicity characteristic are classified as EPA Hazardous Waste Codes D004 through D043. Examples of toxic wastes may include wastewater treatment sludges, wastes from organic chemical manufacturing and pesticide/herbicide wastes.

You can meet general waste analysis requirements using several methods or combinations of methods. The preferred method for hazardous waste characteristics is to conduct sampling and analysis of the waste as this method is more accurate and defensible than other options. (The procedures and equipment for both obtaining and analyzing samples are described in Appendices I and II of 40 CFR Part 261.)

When conducting analysis, a ***representative*** sample from each waste stream is required. **A representative sample is defined as a sample of a universe or whole that can be expected to exhibit the average properties of the universe or whole**. Guidance regarding methods for statistical determination of a valid number of samples, sampling methods, sampling strategies and applicable sampling equipment are found in Chapter 9 of “Test Methods for Evaluating Solid Waste, Physical/Chemical Methods” SW-846, 3rd Edition. It is recommended that you prepare a sampling and analysis plan prior to sample collection and testing. Examples of information that should be included in a sampling and analysis plan are found in this document (see Section E).

Other Constituents (asbestos, PCBs, heat or capability of generating heat, or other risks)

Evaluation for these constituents is required by 329 IAC 10-7.2. As with the hazardous waste determination process outlined above, generator knowledge or analysis may be used to determine the presence and/or concentration of any of these constituents. If a constituent is not present, analysis is not required. Asbestos may be found in building materials such as building siding or insulation and is usually not found in typical foundry waste streams. PCBs may be found in hydraulic or dielectric fluids. PCBs may be found in foundry wastes if the scrap source includes items such as engine blocks and electrical equipment. If other unique risks are known to the generator, they must also be evaluated. The generator must identify and quantify any other risks. **Upon completion of a waste determination, if the foundry wastes are nonhazardous and don't contain other regulated constituents, they may be disposed as a solid waste in accordance with 329 IAC 10.**

B. Waste Classification

Prior to obtaining a waste classification, a **Waste Information** as required by 329 IAC 10-7.2 must be completed. **Complete waste information documentation must be submitted with any request for waste classification. Classification must occur if the foundry wastes:**

- **will be disposed at a restricted waste site;**
- **are to be excluded from the provisions of Indiana's solid waste rules as a type IV waste; or**
- **are to be used in accordance with IC 13-19-3-7 (foundry sand only).**

In order to obtain waste classification of restricted waste site Type I, II, III, or IV, the waste must be evaluated in accordance with 329 IAC 10-9-4. Waste that is classified may be disposed in a restricted waste site (see Section H). 329 IAC 10-9-4 (o) lists the test methods and constituent lists for wastes that will be disposed in a restricted waste site. A waste classification stating the restricted waste site type (I, II, III or IV) must be issued by IDEM prior to submitting an application for a restricted waste facility permit of those types. The waste classification must be kept current as long as disposal occurs at the facility. Questions regarding the restricted waste site facility permit application and/or permit process may be directed to staff of the Solid Waste Permit Management Section at 317/233-2711.

If the foundry sand will be used in accordance with IC 13-19-3-7, the foundry sand must meet Type III criteria and the generator must obtain a waste classification and keep it current as long as the foundry sand is used. IDEM has the authority to grant case-by-case approvals for Type I or Type II foundry sand or for other foundry wastes [329 IAC 10-3-1 (16)]. Other uses not specified under the statute may also be considered for case-by-case approval. In most cases, IDEM will require the completion of a waste classification. If an alternative test method is desired, IDEM approval of the alternative method is required. Questions regarding use of foundry sand may be directed to staff of the Industrial Waste Section at 317/308-3103.

Foundry sand that meets Type IV criteria are excluded from the provisions of the Solid Waste Rules in accordance with 329 IAC 10-3-4. Please note that several restrictions to the placement and control requirements are also found in 329 IAC 10-3-4. Foundry sands receiving a Type IV waste classification are also eligible for use under the statute.

The restricted waste site type may be determined through sampling and analysis or by applying the generator's knowledge. "Generator knowledge" is discussed in the next section (see Section C). For analytes where the use of generator knowledge is not possible, or appear as constituents of the waste stream, testing must occur. This involves taking a statistically valid number of representative samples of the individual waste streams, testing the individual waste streams using acceptable methods, and applying a statistical analysis to determine a waste type (see Section F). The restricted waste site type is determined by the upper confidence limit for the constituent limit in the highest category. The calculation is based on the 90% confidence limits. For example, if the upper confidence limit for lead is in the Type III range, but all other constituents (barium, cadmium, chromium, phenols, etc.) are in the Type IV range, the overall classification will be Type III.

C. Generator Knowledge

Indiana's Solid and Hazardous Waste Rules allow use of generator knowledge as part of the waste determination process [329 IAC 10-2-78.1 and 262.11 (c)(2)]. In fact, generator knowledge is crucial in evaluating listed wastes. Generator knowledge is defined under 329 IAC 10-2-78.1 as:

> *"... the relevant, accurate and reliable information available to or developed by the generator about a waste that allows a person to determine the correct regulatory status of that waste. This information may include, but is not limited to the following categories of information:*
>
> > *(1) Information provided by the manufacturer or supplier of the materials used in the process.*
> > *(2) Information provided in reference materials.*
> > *(3) Information describing the process generating the waste.*
> > *(4) Information describing the materials used in the process that generates the waste.*
> > *(5) Information describing principles of science, including chemistry and physics, applied to the raw materials and process used.*
> > *(6) Information developed through prior testing of the waste."*

To save time and money on unnecessary testing, the generator may determine which analytes can be excluded or which analytes need to be tested using generator knowledge, if applicable. Generator knowledge may render testing unnecessary for certain analytes, provided that specific circumstances are met, such as adequate proof that the analyte in question is neither introduced into, nor generated by the process producing the waste.

Note: Material Safety Data Sheets (MSDS) are only required to list ingredients that comprise 1% or more of the material it addresses. This level of reporting is inadequate to ascertain the constituent levels in the wastes to be characterized. The threshold values listed in Tables I and II contained in this guidance are typically well below 1% of the waste. Therefore, the MSDS should be viewed in a supporting fashion and not as the sole means of providing generator

knowledge.

For cases where generator knowledge is incomplete, unprovable or indicates the presence of regulated analytes, sampling and analysis must occur to meet waste classification requirements. Prior to sampling and analysis for waste classification purposes, a Sampling and Analysis Plan (SAP) should be prepared and may be submitted to IDEM for review.

D. Request for Waste Classification

A formal request for waste classification must be sent to the Industrial Waste Section. Please note that the same laboratory documentation and sampling information listed in **Sections E, F, and G** are to be provided with all analyses. Restricted waste classifications (Types I, II, III, and IV) will be certified in writing by the IDEM in accordance with 329 IAC 10-9-4 (k).

The following information and results must be submitted to IDEM in order to obtain a waste classification:

A narrative description of the process.
Raw materials used to generate the waste.
Volume and frequency of disposal (for wastes going to a restricted waste site).
Documentation used to make the waste determination.
Complete waste sampling and laboratory analysis documentation including all laboratory analyses and Quality Assurance/Quality Control (QA/QC) information as enumerated in Chapter 1, "Test Methods for Evaluating Solid Waste, Physical/Chemical Methods" SW-846, 3rd Edition, and/or the "Guidance to the Performance and Presentation of Analytical Chemistry Data" (available from IDEM).
A signed statement attesting that the information provided is true and accurate that states, “I certify under penalty of law that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the persons who managed the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations. I further certify that I am authorized to submit this information.” [As required by 329 IAC 10-9-4 (j)]

Please note that wastes cannot be officially classified as Type II, III, or IV without adequate generator knowledge or completion of the analytical requirements outlined in the previous sections. IDEM staff will conduct an inspection to verify information submitted as part of the request.

Request for Renewal

It is the generating facility's responsibility to maintain a current waste classification. As stated earlier, a current waste classification is required for disposal in a restricted waste site or for use under IC 13-19-3-7.

In accordance with 329 IAC 10-9-4 (e)(2), resampling must occur every two (2) years, whenever the process changes or according to a schedule specified by the commissioner for the purposes of maintaining a waste classification. The expiration date on the waste classification usually corresponds with the schedule for resampling unless there is a change to the process. Indiana Statute allows IDEM to issue new permits for up to five (5) years [IC 13-15-3-2 (a)]. Foundries may expect initial requests to be granted for two (2) years to five (5) years depending on site specific conditions. Those conditions include variability of the process, consistency of raw materials, overall facility compliance and disposition of the foundry sand. Please note that resampling for hazardous waste determination purposes may not be necessary if there has been no change to the process or the raw materials used. If the characteristics of the foundry sand or the process generating the waste changes, IDEM may revoke or suspend a waste classification until resampling has been conducted.

Indiana Statute allows for continued operation under a permit provided a timely and sufficient renewal request is submitted. Under IC 13-15-3-6 (a), the permit does not expire until IDEM makes a final decision on the application. No time frame is specified for waste classification renewal. Therefore, the agency will consider the following as a timely and sufficient renewal request:

Ninety (90) days: A renewal request which includes either a proposed sampling and analysis plan (SAP) or all items listed under Section D must be requested ninety (90) days prior to expiration. Please see Section E for more information about the SAP content.

One-hundred twenty (120) days: The generating facility may request IDEM to reduce or waive testing requirements. Such a request must be submitted 120 days prior to the expiration. IDEM will consider the following in reducing or waiving testing requirements:

- variability of the generating process and raw materials
- consistency of previous analytical results
- facility compliance rates

IDEM reserves the right to refuse any request to reduce or waive testing and may require a full documentation (generator knowledge and/or analytical results) for waste determination and waste classification purposes.

If timely renewal is not made, the waste classification will expire. No extensions will be granted.

A new waste classification will be issued upon completion of all requirements. If the waste does not remain within the concentration limits for that restricted waste site type, a new waste classification will be issued indicating the new restricted waste site type.

E. Sampling Description/Sampling and Analysis Plan

Samples taken for hazardous waste determination purposes must be "representative" according to federal regulations (40 CFR 261.24). Additionally, Indiana's Solid Waste Rule requires sufficient documentation of representative sampling for waste classification purposes [329 IAC 10-9-4 (i)]. Both of these regulations can be satisfied with a sampling description.

Although a sampling description would meet minimum regulatory requirements, IDEM staff have observed that preparation of a more comprehensive sampling and analysis plan (SAP) can assist the generator, laboratory, IDEM and other personnel involved in the process. ***Chapter 1 and Chapter 9 of "Test Methods for Evaluating Solid Waste, Physical/Chemical Methods", SW-846, 3rd Edition, is an excellent source of information on sampling and analysis. This document is used by IDEM staff in SAP preparation. It should also be used by the generator as a source of information in preparing a SAP.*** The generator of a waste prepares a SAP prior to sample collection and testing. This SAP may be submitted to Industrial Waste Compliance Section staff for review. A SAP should be used by laboratory and facility personnel as a reference during all phases of sample collection and analysis to ensure communication of standards and methods. Occasionally, problems are encountered during sampling or testing and portions of the SAP are not followed. Any deviation from the prescribed sampling and/or analysis may be noted in sampling logs, chain of custody sheets, or laboratory reports and then submitted with the request for waste classification.

Examples of the types of information to be included in the SAP are:

- sample collection methods,
- sampling equipment,
- sampling equipment decontamination procedures (when applicable),
- site map illustrating collection points,
- description of processes generating the wastes,
- MSDS, raw material specifications, or similar data illustrating the materials used in the processes,
- the calculations used in determining a statistically valid number of samples for characterization,
- volumes of individual waste streams,
- analytical method number(s),
- detection limits.

F. Sampling

This section contains several subsections related to sampling. Including:

- Generating Events
- Determination of Correct Number of Samples
- Individual Waste Stream Sampling
- Resampling

Note: Multiple waste stream compositing is no longer allowed in accordance with 329 IAC 10-9-4 (m).

Generating Events

For waste classification purposes, samples must be collected from separate generating events to ensure that the ordinary range of variation in waste materials is captured. Generating events are considered independent processes using a different batch of the same raw material. To illustrate and clarify the concept of separate generating events, consider the following example. Foundry "A" took delivery of a batch of scrap metal, raw sand and chemical binders to be used in the process. All the foundry wastes (molding sand, cores, shakeout sand, etc.) generated during this time were from ***the same generating event***. When the shipments of raw materials were used up, the next shipment of raw materials were prepared for the process. When the second batch of materials were being used, the process and the waste streams generated were the same, but the wastes were from ***a separate generating event***. If the raw materials come into the process on a more or less continuous basis, this is less well defined and may be determined by the storage capacity at the facility and the rate of use. A reasonable assumption in this case is that a one (1) week time lapse between collecting samples from the same waste stream ensures sampling from separate generating events for most foundries.

Number of Samples

To determine the restricted waste site Type (I, II, III, or IV), sampling and analysis of a statistically valid number of samples is required unless generator knowledge can be used (see Section C). Methods for statistical determination of a valid number of samples, recommended sampling methods, sampling strategies, and applicable sampling equipment are found in Chapter 9 of "Test Methods for Evaluating Solid Waste, Physical/Chemical Methods" SW-846, 3rd Edition. Over the years, IDEM staff have reviewed analytical results from foundries and found that some foundry wastes can be variable. IDEM recommends following the statistical evaluation in Chapter 9 of SW-846 for both waste determinations and waste classifications. Should the generator desire, technical assistance may be provided by IDEM, Office of Land Quality, Industrial Waste Section. **Please note that three sample sets are the accepted minimum number for waste classification purposes if generator knowledge is not used.** A proper standard deviation calculation cannot be performed on less than three sample results. The standard deviation calculation is integral to the statistical analysis that the analytical results are subjected to in both the waste determination and waste classification processes. If you have questions about using generator knowledge to reduce the number of samples, please contact Industrial Waste Section staff at 317/308-3103.

Individual Waste Stream Sampling

Individual samples must be collected from each waste stream for waste determination purposes. Each waste stream must also be evaluated separately for waste classification purposes [329 IAC 10-9-4 (m)]. Please be reminded that a waste classification is only necessary for use under Indiana Statute, disposal in a restricted waste site, or as specifically directed by IDEM.

Usually, a sample is taken either as a grab sample or a composite sample. IDEM recommends composite sampling for individual waste streams. A composite is a sample made up of many separate subsamples of the individual waste stream.

To illustrate and clarify the concept of individual composite samples, consider the following example:

Foundry “A” identified three individual waste streams: molding sand, cores and shake out sand. Based on prior knowledge Foundry “A” determined that three composite samples for each waste stream would be appropriate. Foundry "A" also found that a one week time lapse between sampling events would guarantee sampling from separate generating events because raw materials were shipped on a continuous basis and their storage capacity would allow them to operate for a week if shipments stopped. Foundry "A" determined a sampling point for each waste stream. Then, Foundry "A" collected samples at a sampling point every 5 minutes, for 30 minutes as the wastes passed by on a conveyor system. This resulted in seven small, equally sized subsamples from the waste stream. The subsamples collected from this point were mixed together after collection was completed. In mixing the subsamples together, Foundry "A" formed a composite sample for an individual waste stream. Foundry "A" decontaminated their sampling equipment, went to the next sample collection point, and repeated the sampling and compositing process. The same steps were followed with the third waste stream. The composite samples were sent to the laboratory for analysis. One week after the first sampling event, Foundry "A" repeated the entire process. The second set of samples was sent to the laboratory for analysis. One week after that, the third and final composite sample set was taken. The last set of composite samples from each waste stream was sent to the laboratory for analysis. Foundry "A" has collected three composite samples for each individual waste stream, each taken during separate generating events.

Resampling

Note: Resampling is required whenever the process generating the waste changes in accordance with 329 IAC 10-9-4 (e)(2).

G. Analysis

Two separate subsections follow for analysis for the purpose of **Waste Determination** and **Waste Classification**:

Waste Determination Analysis

As stated earlier, if generator knowledge is insufficient, inconclusive or indicates a need to perform testing, analysis must occur for the purposes of waste determination.

Also as stated earlier, information must be collected on individual waste streams. 329 IAC 10-9-4 (o) specifies the required extraction methods, constituents for analysis, and the analytical methods, The complete list of TCLP constituents and regulatory limits are found in 40 CFR 261.24, Table 1 and in **Table III** of this document. Testing is not required for any constituents not introduced or created during the process. For example, the TCLP list includes several herbicides and pesticides that are not used by industry or created in the manufacturing process. Those pesticides and herbicides can be eliminated from consideration for testing.

Waste Classification Analysis

329 IAC 10-9-4 (o) specifies the required extraction methods, constituent for analysis and the analytical methods for waste classification purposes. The commissioner may accept additional or alternative testing methods if the test methods provide an equivalent level of accuracy and reliability per 329 IAC 10-9-4 (l).

329 IAC 10-9-4 contains the constituent concentration for each restricted waste site type. This information is also included in **Table I and Table II** of this guidance.

As with the procedures for waste determinations, testing for analytes listed in Table I will be performed using TCLP extraction procedures or totals analysis. In specific cases, totals testing for metals may be acceptable in lieu of TCLP testing. Totals testing may be accepted only when the 90% single-tailed upper confidence limits derived from Student's *t* analysis for all observed constituent levels are below twenty (20) times the TCLP regulatory threshold for each constituent. Regardless of whether TCLP or total levels are analyzed, the same parameters require testing.

Testing for analytes in Table II will be performed using Leaching Method (Neutral) extraction procedures. Leaching Method (Neutral) is an extraction procedure that is performed in the same manner as TCLP, with two major differences. These differences are that no acidification of the sample occurs, and the extraction fluid is deionized water instead of a buffered acidic aqueous solution. Please note that testing for Table II constituents is not required for Type I restricted wastes. IDEM will issue a Type I waste classification based on the waste determination data (see Section A).

A note concerning common analytical errors: Notice that the pH measurement listed in Table II is the pH of the Neutral Leach extract, measured and documented immediately at the end of the 18 hour extraction period. Please advise the laboratory to include adequate documentation to ensure the pH was measured using this method. It is also important to complete the analysis within the holding time and to provide the chain of custody documentation.

After any testing, the data set obtained from the waste determination and classification analyses as well as supporting documentation must be submitted to the IDEM. IDEM personnel will review the data validation documentation. If the data is considered valid and usable, IDEM personnel will perform a Student's *t* statistical analysis on the data (using standard error calculations). The 90% upper confidence limit generated as a result of this manipulation will be compared to the regulatory thresholds listed in Table I, and/or Table II to determine the waste classification [329 IAC 10-9-4 (k)]. The method and mathematical formulas for performing the Student's *t* statistical analysis are found in Chapter 9 of "Test Methods for Evaluating Solid Waste, Physical/Chemical Methods" SW-846, 3rd Edition. The generator may perform the statistical analyses using the above model, however, IDEM's findings will be used to determine the restricted waste type.

H. Waste Classification and Disposal

IDEM staff will notify the facility, in writing, of the classification of its waste(s) after reviewing the analyses and accompanying information in accordance with 329 IAC 10-9-4 (k). This includes waste classification renewals. **Once the waste classification has been issued**, the generator has the following options:

- **Type I, II, III, and IV** waste may be disposed of in restricted waste sites permitted for that waste type or better. For example, a Type II waste may be disposed of in a Type I or II landfill but a Type I waste may only be disposed of in a Type I landfill.

- **Type III** foundry sand is also eligible for use in accordance with IC 13-19-3-7; no IDEM approval is required once the waste classification is issued provided IDEM guidance for use is followed. Please note that any use at a permitted landfill may require a modification to the landfill's permit.

- Materials which are certified as **Type IV** by IDEM do not require permitted waste disposal sites. However, there are restrictions on Type IV disposal locations and disposal control requirements, set forth in ***329 IAC 10-3-4***.

Note: All nonhazardous foundry wastes may be disposed in a Municipal Solid Waste Landfill as an nonhazardous solid waste in accordance with Indiana's Solid Waste Land Disposal Facilities Rule (329 IAC 10) without obtaining a waste classification.

Titles of Rules and Guidance

Rules
Solid Waste Land Disposal Facilities Rule (329 IAC 10)
Hazardous Waste Management Permit Program (329 IAC 3.1)

Guidance
"Storage of Type III Foundry Sands Prior to Legitimate Use" (ID No. WASTE-0027-NPD)
"Use of Foundry Sands in Accordance with House Enrolled At 1541" (ID No. WASTE-0028-NPD)
"Use of Foundry Sand in Land Application and as a Soil Amendment" (ID No. WASTE-040-NPD)
"Understanding the Hazardous Waste Determination Process" (ID No. 00056-01-HW)
"Guidance to the Performance and Presentation of Analytical Chemistry Data" (ID No. WASTE-032-NPD)

Table I.

Parameters and Classification Ranges using TCLP Methods

Parameter Concentrations (mg/l)

	Type I	Type II	Type III	Type IV
Arsenic	<5.0	≤1.3	≤0.50	≤0.05
Barium	<100	≤25	≤10	≤1.0
Cadmium	<1.0	≤0.25	≤0.10	≤0.01
Chromium	<5.0	≤1.3	≤0.50	≤0.05
Lead	<5.0	≤1.3	≤0.50	≤0.05
Mercury	<0.2	≤0.05	≤0.02	≤0.002
Selenium	<1.0	≤0.25	≤0.10	≤0.01
Silver	<5.0	≤1.3	≤0.50	≤0.05

Table II.
Parameters and Classification Ranges for the Leaching Method (Neutral)

Parameter Concentrations (mg/l)

	Type I	**Type II**	**Type III**	**Type IV**
Chlorides	*	≤6,300	≤2,500	≤250
Copper	*	≤6.3	≤2.5	≤.25
Cyanide (Total)	*	≤5.0	≤2.0	≤0.20
Fluoride	*	≤35	≤14	≤1.4
Iron	*	*	≤15.0	≤1.5
Manganese	*	*	≤.50	≤.05
Nickel	*	≤5.0	≤2.0	≤.20
Phenols	*	≤7.5	≤3.0	≤.30
Sodium	*	≤6,300	≤2,500	≤250
Sulfate	*	≤6,300	≤2,500	≤250
Sulfide (Total)	*	≤13.0	≤5.0	≤1.0
Total Dissolved Solids	*	≤12,500	≤5,000	≤500
Zinc	*	≤63	≤25	≤2.5
pH (Standard Units)	*	≥4.0-≤11.0	≥5.0-≤10.0	≥6.0-≤9.0

* Testing is not required

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This will allow you to insert a file here. To do this go to the top menu and selecting Insert, then File..., and then selecting the name of your existing document text file and click on the Insert button. You will get a message asking if you want to "Insert the file into the current document", just tell it Yes/OK. A copy of the file will be inserted wherever the cursor was before you told it to insert the file. The text is red is hidden text and it will not print out. If you do not want to see the "hidden text" on your screen, just go the to menu above and go to View, then click on Hid

Table III
Parameters and Regulatory Limits Using TCLP Methods

EPA HAZ. WASTE NO.	CHARACTERISTIC/CONTAMINANTS	REG. LEVEL (mg/L)
D004	Arsenic	5.0
D005	Barium	100.0
D018	Benzene	0.5
D006	Cadmium	1.0
D019	Carbon Tetrachloride	0.5
D020	Chlordane	0.03
D021	Chlorobenzene	100.0
D022	Chloroform	6.0
D007	Chromium	5.0
D023	O-Cresol	200.0
D024	M-Cresol	200.0
D025	P-Cresol	200.0
D026	Cresol	200.0
D016	2,4-D	10.0
D027	1,4 -Dichlorobenzene	7.5
D028	1,2 - Dichloroethane	0.5
D029	1,1 - Dichloroethylene	0.7
D030	2,4 - Dinitrotoluene	0.13
D012	Endrin	0.02
D031	Heptachlor (and its Hydroxide)	0.008
D032	Hexachlorobenzene	0.13
D033	Hexachlorobutadiene	0.5
D034	Hexachloroethane	3.0
D008	Lead	5.0
D013	Lindane	0.4
D009	Mercury	0.2
D014	Methoxychlor	10.0
D035	Methyl Ethyl Ketone	200.0
D036	Nitrobenzene	2.0
D037	Pentachlorophenol	100.0
D038	Pyridine	5.0
D010	Selenium	1.0
D011	Silver	5.0
D039	Tetrachloroethylene	0.7
D015	Toxaphene	0.5
D040	Trichloroethylene	0.5
D041	2,4,5 - Trichlorophenol	400.0
D042	2,4,6 - Trichlorophenol	2.0
D017	2,4,5 - TP (Silvex)	1.0
D043	Vinyl Chloride	0.2

Indiana DOT Specification for Foundry Sand (2015)

200-R-401 RECYCLED FOUNDRY SAND *(Revised 06-18-15)*

Description

Recycled foundry sand, RFS, consists of a mixture of residual materials used from ferrous or non-ferrous metal castings and natural sands. The Contractor shall have the option of incorporating RFS into applicable operations in accordance with 105.03.

Materials

RFS sources are to be selected from the Department's list of approved Foundry Sand Sources. RFS may be substituted for B borrow or Borrow upon the approval of the Office of Geotechnical Services.

The Contractor shall provide a copy of the Indiana Department of Environmental Management's, IDEM, waste classification certification for Type III or IV residual sands prior to use. The IDEM certification shall clearly identify the stockpiles with regard to their extent and geographical location.

The Contractor shall provide the Engineer with a type A certification in accordance with 916 for RFS prior to use of the materials. The type A certification shall consist of applicable laboratory tests results of gradation. Consultants on the Department's list of approved Geotechnical Consultants shall perform the testing of RFS materials.

RFS use is restricted to the following additional requirements:

1. RFS derived from Type III residual sand shall not be allowed within 100 ft, horizontally, of a stream, river, lake, reservoir, wetland or any other protected environmental resource area.
2. RFS derived from Type III or Type IV residual sand shall not be placed within 150 ft, horizontally, of a well, spring, or other ground source of potable water.
3. RFS shall not be allowed adjacent to metallic pipes, or other metallic structures.
4. RFS shall not be used as encasement material.
5. RFS shall not be used in MSE wall applications.
6. RFS placement shall be at least 2 ft above ground water elevation.

If RFS is used in embankment, excavation and replacement operations as a replacement for B borrow or borrow, the following additional restrictions will be required.

1. Borrow: RFS shall be in accordance with 203.
2. B borrow: RFS shall be in accordance with 211.

Construction Requirements

RFS shall be transported in a manner that prevents the release of fugitive dust and loss of material. Adequate measures shall be taken during construction operations to control fugitive dust from RFS. RFS shall not be applied when wind conditions result in problems in adjacent areas or result in a hazard to traffic on any adjacent roadway. The spreading of RFS shall be limited to an amount that shall be encased within the same workday. If weather causes stoppage of work or exposes the RFS to washing or blowing, additional RFS may be spread when the work resumes. Spraying with water, limewater, or other sealing type sprays will be considered to be acceptable methods for dust control.

When RFS is used as borrow or B borrow, the lift thickness and compaction of the materials shall be in accordance with 203.23. The dynamic cone penetrometer, DCP, criteria will be determined by a test section in accordance with ITM 514. The DCP testing will be performed in accordance with ITM 509. The moisture content shall be controlled in accordance with 203.23. The test section shall be constructed in the presence of a representative of the Office of Geotechnical Services. When RFS is used as B borrow, the DCP criteria for the granular soils shall be used in accordance with 203.23. Nuclear density testing of RFS will not be allowed.

When RFS is used in embankment construction, the sideslopes of the RFS shall be encased with 1.5 ft of non-RFS borrow materials. All RFS shall be encased with a minimum of 1 ft of non-RFS borrow materials prior to the completion of construction operations in a calendar year. The encasement materials shall be placed and compacted concurrently with the RFS lifts. Encasement materials not meeting the AASHTO M 145 Classifications of A-6 and A-7 shall be submitted to the Office of Geotechnical Services for approvals.

Method of Measurement

RFS applications will be measured in accordance to the respective uses for borrow or B borrow.

Basis of Payment

RFS will be paid for at the contract unit price in accordance with the respective uses for borrow or B borrow.

No payment will be made for the transportation, handling, or any special construction requirements such as alternative compaction means or encasement activities, when using RFS materials.

The cost of the use of water, limewater, sprays, or other activities necessary for dust control, shall be included in the cost of the respective pay item.

The cost of geotechnical testing for the use of RFS materials shall be included in the cost of the respective pay item.

RECYCLED FOUNDRY SAND SOURCE APPROVAL CRITERIA

The following procedures covers the requirements for Foundry Sand source approvals or otherwise prescribed subject matter to be added, maintained and removed from a Department’s approved list.

The procedures for approval may involve hazardous materials, operations, and equipment. These procedures do not purport to address all of the safety problems associated with the use of the product. The source’s responsibility is to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

General Requirements

1. A source, requesting approval for addition to the Department's list, shall provide to the Office of Materials Management the following:

   (a) Name and location of source or manufacturer,
   (b) List of material and specification reference for the material that the approval is being requested,
   (c) Average monthly production of the material by size, type or grade,
   (d) Name, address, and telephone number of responsible contact person,
   (e) Facility layout or production process of the material,
   (f) Quality parameters of the material,
   (g) Raw material sampling and testing frequency,
   (h) Procedures for conforming materials which provides a positive linkage between the furnished materials and the quality control test data,
   (i) Procedures for non-conforming materials,
   (j) Procedures for marking and tracking materials,
   (k) Procedures for documentation maintenance,
   (l) Finished material sampling and testing frequency,
   (m) Procedures for reviewing and updating the source operations,
   (n) Testing laboratory quality system,
   (o) Names, titles and qualifications of sampling and testing personnel,
   (p) Location and telephone number of the laboratory testing office,
   (q) Sample management describing procedures for samples identification, maintenance of the samples prior to testing, sample retention and disposal of samples,
   (r) Testing report procedures,
   (s) Methods used to identify improper test results and procedures followed when testing deficiencies occur,
   (t) Statistical analysis of test results, and
   (u) Maintenance of test records

The application shall be signed and dated by the source's or manufacturer's representative at the time the application is submitted for acceptance. The application shall be maintained to reflect the current status and revisions shall be provided to the Department in writing.

2. Testing may be required which will be performed outside the Department's laboratories. A recognized laboratory shall be the following:

   (a) A State transportation agency testing laboratory,
   (b) A testing laboratory regularly inspected by the AMRL, or
   (c) A testing facility approved by the Department.

Approval Requirements

In addition to the general requirements, the source shall also submit the following to the Office of Materials Management.

(a) Name of Testing Facility
(b) Dates samples were obtained
(c) Dates samples were tested

(d) Test method used for IDEM classification
(e) Letter from IDEM indicating the waste classification of the materials
(f) Test results for TCLP and neutral leachate
(g) Stockpile sampling locations, including depths and available historical testing results
(h) Gradation test results
(i) Recycled Foundry Sand (RFS) Source Certification

The Recycled Foundry Sand (RFS) source certification is included as Attachment A. A new approval submission shall be required when re-sampling is required in accordance with 329 IAC 10-9-4(e) (2). (In accordance with 329 IAC 10-9-4 (e)(2) for foundry waste, re-sampling is conducted: at two-year intervals whenever the process changes or according to a schedule for re-sampling by the IDEM Commissioner based on variability noted in previous sampling and other factors affecting the predictability of waste characteristics.)

When metal concentration of the Type III residual sand exceeds 80% of the allowable limits within IDEM classification, an indemnification clause is required. The "Recycled Foundry Sand (RFS) Indemnification Clause" is included as Attachment B.

Maintaining Approval

Test reports shall be generated in accordance with specification requirements for the material and submitted monthly to the Office of Materials Management. If the material is not produced by the source in a given month, the monthly submittal shall state:

"No _____________ was manufactured during _____________________."
Material month/year

Samples of material may be obtained randomly for verification at the source or at the point of incorporation into the work in accordance with 106.02.

The source shall provide written notification of any changes, revisions or updates of their operations, source name or address, contact person or product name to the Office of Materials Management.

To maintain approval, a summary of new stockpile test results for the acceptance analysis shall be submitted monthly indicating testing every 2,000 t. Tested and approved RFS stockpiles shall be properly signed for easy identification. If no new stockpiles are created in a given month, a letter indicating, "no new RFS stockpiles for month/year were created" shall be submitted to the Office of Materials Management.

Removal from Approved List

A source will be removed from the approved list for the following, but not limited to, reasons:

(a) Test failures determined by Department verification sampling,
(b) Monthly test reports not provided for three consecutive months,
(c) Test reports generated by the source which indicate non-compliance with specification requirements, or
(d) Performance of the product no longer meets the intended purpose.

Attachment A

RECYCLED FOUNDRY SAND (RFS) SOURCE CERTIFICATION

This is to certify recycled foundry sand (RFS) stockpiles geographically located as follows:
RFS ____
____

RFS was produced by the ________________________ __________________ Company located in ___________________ (City), and _________________ (State) and was shipped for use on Indiana Department of Transportation projects is Type _________________ (III or IV) material according to the IDEM's restricted waste criteria. If any metal concentration exceeds 80% of the allowable limits for a Type III material the foundry shall provide the Department with an acceptable indemnification clause. The _________________ RFS source also agree that processes and stockpiles associated with the production of such RFS may be inspected and sampled at regular intervals by properly identified representatives of the Department or a duly assigned representative.

_______________(Date of Signing)___________________ (RFS Producer)

____ (Title)

____ (Signature)

State of ____________________ SS: County of _____________________

Subscribed and sworn to before me by __________________________________

of the firm of __________________ this ________ day of ________ 20__

________________________ Notary Public

My Commission Expires: ________

This certification has been reviewed and approved by:

____
(INDOT Representative) Date

Attachment B

RECYCLED FOUNDRY SAND (RFS) INDEMNIFICATION CLAUSE

______________ RFS producer shall indemnify, defend, exculpate, and hold harmless the State of Indiana, its officials, and employees from any liability of the State of Indiana for loss, damage, injury, or other casualty of whatever kind or to whomever caused, arising out of or resulting from a violation of the federal or Indiana Occupational Safety and Health Acts (OSHA), the Resource Conservation and Recovery Act (RCRA), the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA), or any other environmental law, regulation, ordinance, order or decree (collectively referred to hereinafter as "Environmental Laws"), as a result of the supply, testing, and application of residual sand or other materials supplied under this Contract by ______________________________ source, whether due in whole or in part of the negligent acts or omissions of: (1) ________________ Foundry, its agents, officers, or employees, or other persons engaged in the performance of the contract; or (2) the joint negligence of them and the State Of Indiana, its officials, agents, or employees.

This contract shall include, but not be limited to, indemnification from: (1) any environmental contamination liability due to the supply, testing, and application of residual sand in road base, embankments, or other projects designated by the Department as agreed to by the parties, and (2) any liability for the clean up or removal of residual sand, or materials incorporating such sand, pursuant to any Environmental Law.

The RFS producer also agrees to defend any such action on behalf of the State of Indiana, to pay all reasonable expenses and attorneys fees for such defense, and shall have the right to settle all such claims. Provided, however, that no liability shall arise for any such fees or expenses incurred prior to the time that ______________ Foundry shall have first received actual and timely written notice of any claim against the State which is covered by this Indemnification Agreement. If timely written notice of any claim hereunder is not received by _______________ Foundry, and _________________ Foundry is thereby prejudiced in its ability to defend or indemnify, then to the extent of such prejudice, this Indemnification Agreement shall be void.

This Indemnification Agreement does not create any rights in any third party, and is solely for the benefit of the State of Indiana and its agents, officials, and employees.

STATE OF OHIO
DEPARTMENT OF TRANSPORTATION
SUPPLEMENTAL SPECIFICATION 871
EMBANKMENT CONSTRUCTION USING RECYCLED MATERIALS
APRIL 15, 2005

871.01 Description. This work consists of constructing embankments with recycled material and material from other approved sources as necessary to complete the planned embankments. Item 203, Roadway Excavation and Embankment shall apply as modified herein.

871.02. Materials. Only these materials will be allowed:

A. Fly Ash. Furnish Fly Ash conforming to ASTM E-2277.

B. Bottom Ash. Furnish Bottom Ash conforming to ASTM E-2277.

C. Foundry Sand. Furnish Foundry Sand that is generated from foundry operations.

D. Glass. Furnish Glass, Ceramic, or Earthenware with a maximum dimension of 1 inch any direction and, by visual inspection, 95 percent free from foreign material. Glass containing hazardous wastes or hazardous substances such as glass from automobiles, light bulbs of any kind, laboratory glass, television glass, computer or other cathode monitor tubes is not suitable.

E. Tire Shreds. Furnish Tire Shreds as defined in ASTM D 6270 and the following:

1. Class 1 tire shreds shall have a maximum of 50 percent passing the 1-1/2 inch (38 mm) square mesh sieve, and a maximum of 5 percent passing the No. 4 (4.75mm) sieve. All percentages are calculated by weight.

2. Class 2 tire shreds shall have a maximum of 25 percent passing the 1-1/2 inch (38 mm) square mesh sieve and a maximum of 1 percent passing the No. 4 (4.75 mm) sieve. All percentages are calculated by weight.

3. Restrictions on all tire shreds are as follows:

a. Furnish tire shreds, which are not contaminated with fuels or lubricants.

b. Furnish tire shreds that have not been subjected to a fire.

c. Furnish tire shreds containing no more than 1 percent metal fragments which are not at least partially encased in rubber. Metal fragments that are partially encased in rubber shall protrude no more than 1 inch (25 mm) from the edge of the tire shred on 75 percent of the pieces and no more than 2 inches (50 mm) on 100 percent of the pieces. All percentages are calculated by weight.

d. Furnish tire shreds with at least one sidewall severed from the tread of each tire.

e. Furnish tire shreds with a maximum dimension of 8 inches (200mm) measures in any direction.

f. Furnish tire shreds free from wood chips, other fibrous organic matter, ice and snow.

F. Natural soil. Furnish natural soil conforming to 203.02.I.

G. Natural Granular Material. Furnish natural granular material conforming to 203.02.H and conforming to the gradation and physical requirements of 703.16.C, Granular Material Type B.

H. Drainage Material. Furnish aggregate drains conforming to Item 605. Completely wrap the aggregate drains with geotextile fabric. As an alternative, 707.45 pipe may be furnished, provided that the inner end of the pipe is completely wrapped with 712.09 Type A fabric.

I. Geotextile Fabric. Furnish geotextile fabric conforming to 712.09 Type A.

871.03. Environmental Requirements. Use recycled materials that conform to all current environmental policies, rules, and regulations and the following:

Fly Ash, Bottom Ash, and Foundry Sand. Ohio EPA, Division of Surface Water, Policy 0400.007 "A Beneficial use of Nontoxic Bottom Ash, Fly Ash and Spent Foundry Sand and other Exempt Wastes." Provide a certified letter from the Local Ohio EPA Chief allowing the use of this material on the project.

Glass. Provide a certified letter from the Local Ohio EPA Chief allowing the use of glass on the project.

Tire Shreds. Ohio Administrative Code 3745-27-78.

Select an independent consultant pre-qualified by the Department for environmental site assessment and remedial design to prepare the notification documents. The consultant shall coordinate all Ohio EPA required meetings, documentation, and testing. The consultant shall monitor the construction according to 203.03.I. to ensure that the environmental requirements are carried out on the project. The consultant shall report any discrepancies to the Department and the Contractor. The consultant shall certify the report or reports to the Department.

Submit to the Engineer for approval, prior to use, documentation that demonstrates compliance with all current environmental policies, rules and regulations.

871.04. Geotechnical Requirements. Select an independent soils consultant pre-qualified by the Department. The consultant shall:

A. Classify the Materials. Classify Fly Ash, Bottom Ash and Foundry Sand according to Ohio Department of Transportation, Division of Planning, Office of Geotechnical Engineering, Specifications for Subsurface Investigations. When fly ash is used, clearly identify it as self-hardening, (Class C), or non self-hardening fly ash, (Class F).

Classify Tire Shreds according to ASTM D-6270.

B. Perform an Engineering Analysis to demonstrate that the material is suitable to construct the planned embankments. The engineering analysis shall include;

1. a stability analysis
2. a stability sensitivity analysis
3. a total settlement analysis
4. a total settlement sensitivity analysis
5. a differential settlement analysis
6. a differential settlement sensitivity analysis

Perform the appropriate laboratory tests necessary to validate the assumptions used in the engineering analysis.

C. Prepare moisture density curves or relative density results for the recycled materials that is required for compaction acceptance.

D. Submit to Engineer 30 days prior to use:

1. The location where recycled materials will be used for embankment construction in the project plan, profile, and cross-section views.

2. The estimated volume of embankment to be constructed using recycled materials.

3. All electronic files for the Engineering Analyses.

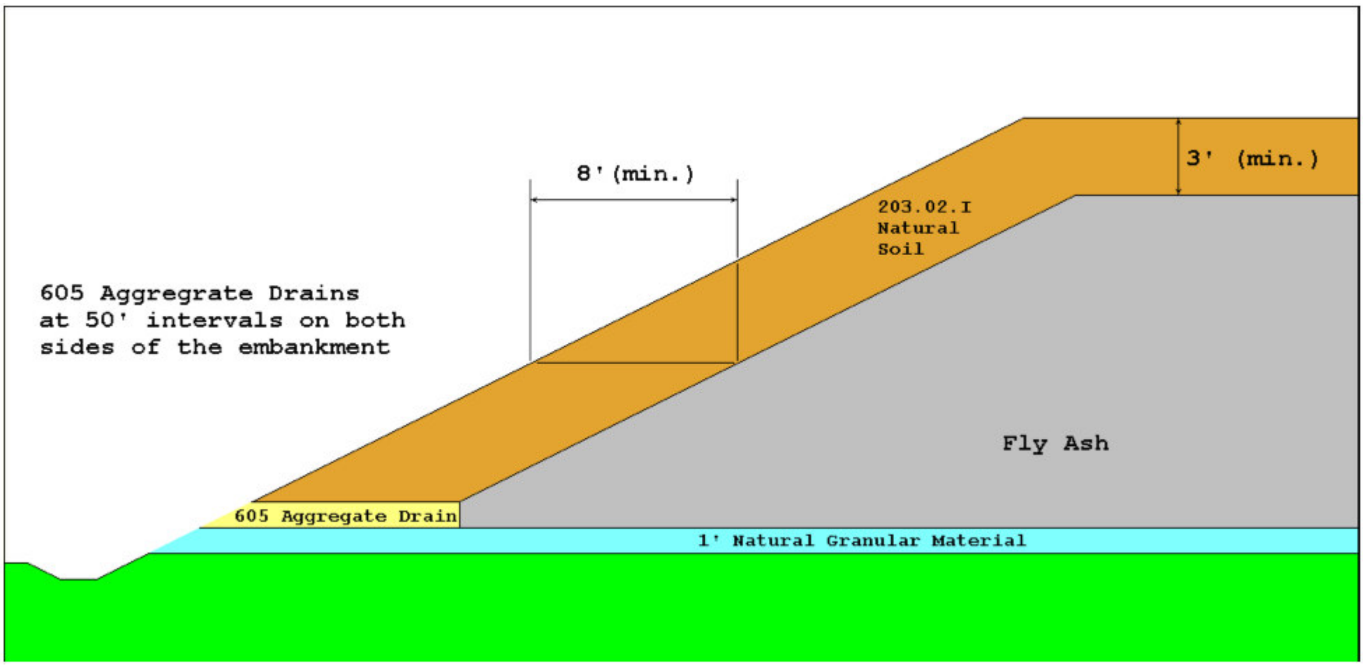
4. A summary of the Engineering Analysis, tests and proposed compaction acceptance information.

E. Receive Engineer’s approval prior to use.

871.05. Construction Requirements.

A. Fly Ash.

Figure 871.05.A



Place and compact a 1 foot (0.3 m) layer of natural granular material on the prepared foundation. Spread Fly Ash in horizontal loose lifts not to exceed 8 inches (200 mm). Compact Fly Ash at 3 percent below optimum moisture or dryer. Uniformly apply and evenly mix water into dry material. Disc and aerate wet material.

Compact the lifts to a stable, durable condition with at least eight passes of a vibratory steel wheel roller. The roller shall have a minimum weight of 10 tons (9 metric tons) or its centrifugal equivalent.

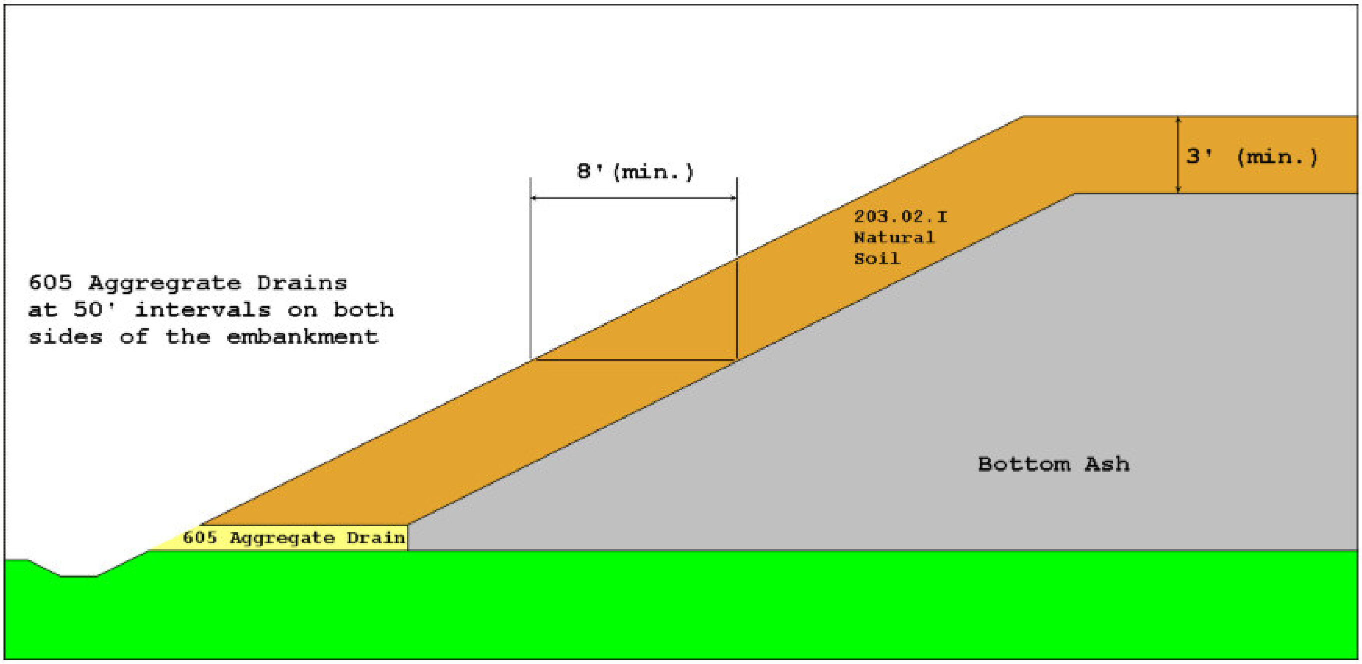
Compact lifts to: 100 percent of the AASHTO T-99 Maximum Density or, 98 percent of the Supplement 1015 Test Section Maximum Density.

Cover the sides and top of Fly Ash embankment with natural soil. The minimum vertical cover is 3 feet, (1.0 m) (measured from subgrade elevation). The minimum horizontal cover is 8 feet, (2.5 m) (measured from final slope line).

Install the drains detailed in 871.02.H at 50 foot (15 m) intervals on both sides of the embankment.

B. Bottom Ash.

Figure 871.05.B



Place Bottom Ash on the prepared foundation in horizontal loose lifts not to exceed 8 inches (200 mm).

Compact Bottom Ash at 3 percent below optimum moisture or dryer. Uniformly apply and evenly mix water into dry material. Disc and aerate wet material.

Compact the lifts to a stable, durable condition with at least eight passes of a vibratory steel wheel roller. The roller shall have a minimum weight of 10 tons (9 metric tons) or its centrifugal equivalent.

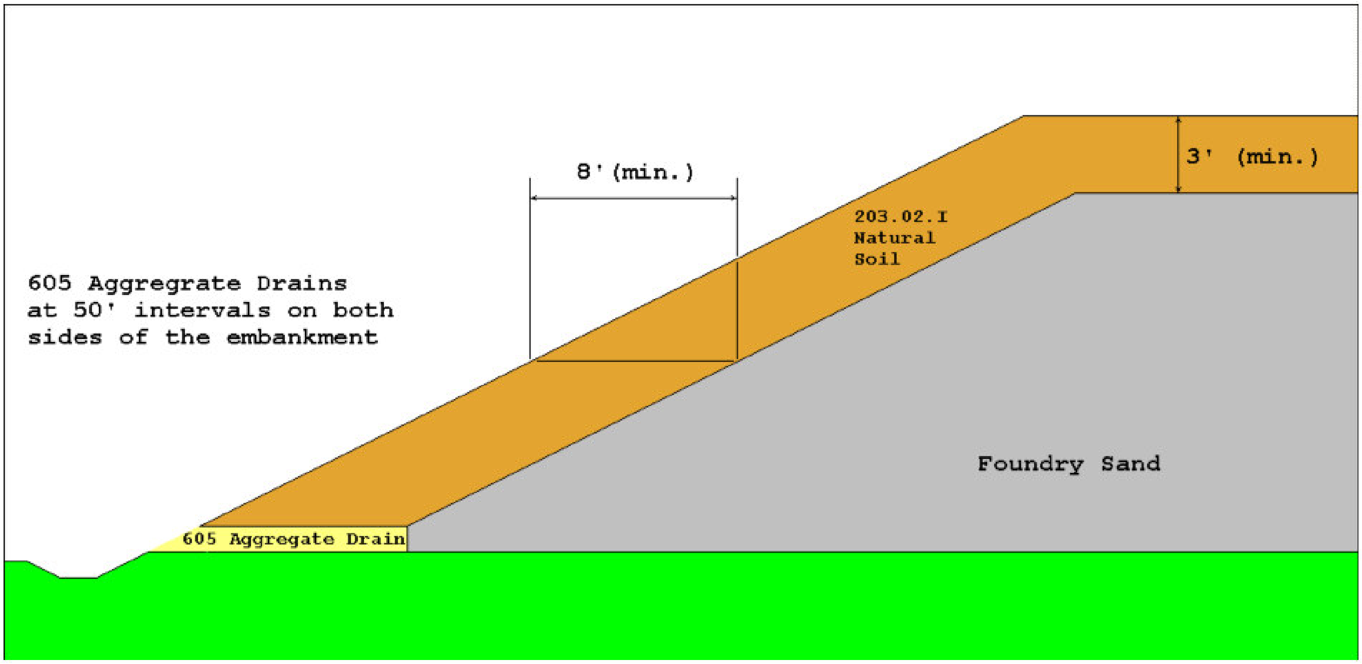
Compact lifts to: An ASTM D-4253/D-4254 Relative Density of 70 percent or, 100 percent of the AASHTO T-99 Maximum Density or, 98 percent of the Supplement 1015 Test Section Maximum Density.

The Engineer will use the density determined by Supplement 1015 to resolve conflicts that may occur using the other methods.

Cover the sides and top of Bottom Ash embankment with natural soil. The minimum vertical cover is 3 feet, (1 0m) (measured from subgrade elevation). The minimum horizontal cover is 8 feet, (2.5 m) (measured from final slope line). Install the drains detailed in 871.02.H at 50 foot (15 m) intervals on both sides of the embankment.

C. Foundry Sand.

Figure 871.05.C



Place Foundry Sand on the prepared foundation in horizontal loose lifts not to exceed 8 inches (200 mm). Compact the lifts to a stable, durable condition with at least eight passes of a vibratory steel wheel roller. The roller shall have a minimum weight of 10 tons (9 metric tons) or its centrifugal equivalent. Compact lifts to 98 percent of the Supplement 1015.06 Test Section Method B Maximum Density.

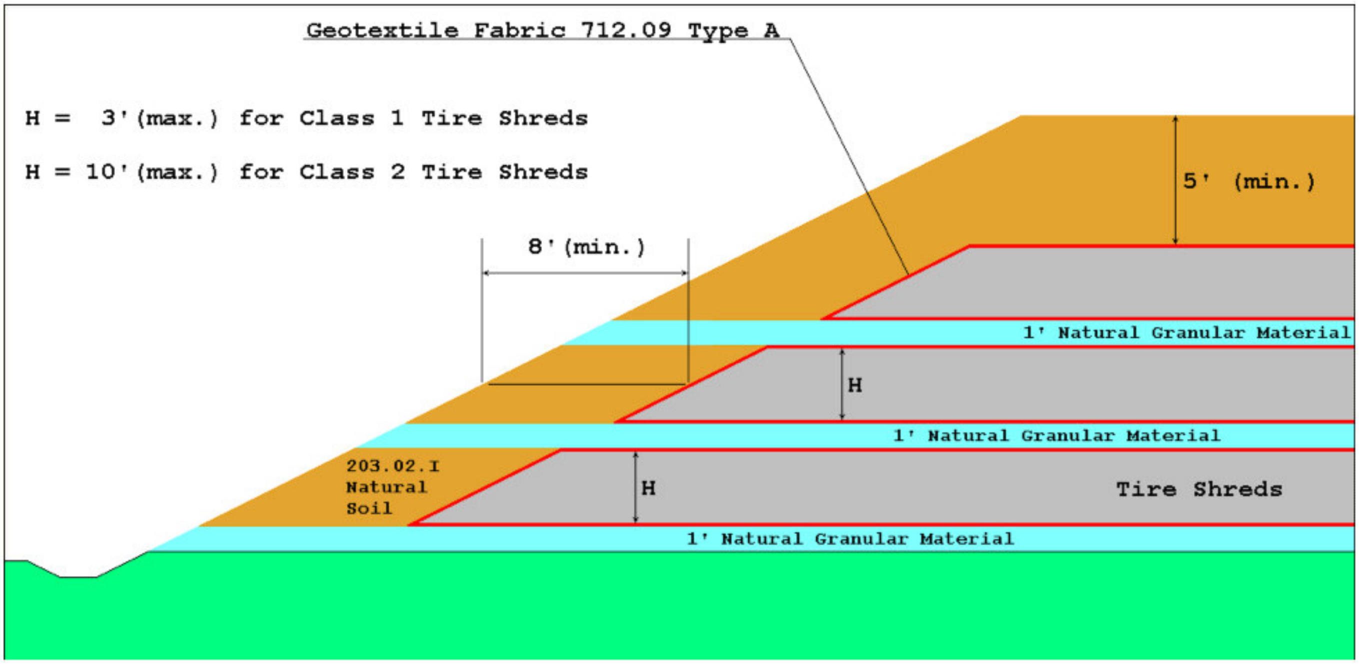
Cover the sides and top of Foundry Sand embankment with natural soil. The minimum vertical cover is 3 feet, (1.0m) (measured from subgrade elevation). The minimum horizontal cover is 8 feet, (2.5 m) (measured from final slope line).

Install the drains detailed in 871.02.H at 50 foot (15 m) intervals on both sides of the embankment.

D. Glass. Place Glass on the prepared foundation in horizontal loose lifts not to exceed 8 inches (200 mm). Water is not needed to aid compaction of Glass lifts. Compact the lifts to a stable, durable condition with at least eight passes of a vibratory steel wheel roller. The roller shall have a minimum weight of 10 tons (9 metric tons) or its centrifugal equivalent. Compact lifts to 98 percent of the Supplement 1015 Test Section Maximum Density. Alternate lifts of glass with lifts of natural soil. Construct 4 inches (100mm) of natural soil on the outside slopes using the construction details for topsoil placement in 659.11. Do not use glass within 3.0 feet (1.0m) of the subgrade.

E. Tire Shreds.

Figure 871.05.E



Place and compact a 1 foot (0.3 m) layer of natural granular material on a prepared foundation.

Place a layer of Geotextile Fabric, (712.09 Type A) on top of the Natural Granular Material. Place Tire Shreds in horizontal loose lifts not to exceed 8 inches (200 mm).

Compact each lift of Tire Shreds to a stable, durable condition with eight passes of a steel wheel roller. The steel wheel roller shall have a minimum weight of 10 tons (9 metric tons) or its centrifugal equivalent.

Place additional Tire Shred lifts to construct a Tire Shred layer. The maximum layer thickness for Class 1 Tire Shreds is 3 feet (1.0 m). The maximum layer thickness for Class 2 Tire Shreds is 10 feet (3.3 m).

Separate Tire Shred layers completely from natural granular material and natural soil by enclosing the top, bottom and sides of the of Tire Shreds with Geotextile Fabric. Alternate natural granular material layers with Geotextile Fabric enclosed Tire Shred layers. Cover sides and top of Tire Shred embankment with natural soil. The minimum vertical cover is 5 feet, (1.5 m) (measured from subgrade elevation). The minimum horizontal cover is 8 feet, (2.5 m) (measured from final slope line).

Place a 1 foot (0.3 m) of natural soil surcharge on the subgrade for 60 days. Do not use tire shreds for the bedding and backfill of any conduit or retaining wall. Do not use tire shreds for embankment construction within 100 feet, (30.0m) of any structure.

Designer Note for Supplemental Specification 871, Embankment Using Recycled Material

This specification was written to allow the Districts to use recycled materials in embankment construction.

It was written to safely use these recycled products without jeopardizing the embankment or pavement integrity or long-term performance. The Department does not require the use of recycled materials because this specification does not eliminate all risk or liability to the Department, it only minimizes such risks.

The utilization of this specification is totally at the Districts discretion. Districts are advised to consider all the plusses and potential problems prior to allowing these materials.

Benefits:

Recycled materials can be cheaper and provided engineering improvements to the embankment construction. For example, fly ash and tires can provide lighter weight materials.

By using these materials, the Department will save land fill space in the state. The Department may minimize the potential future legislation that would require the use of these materials. (Note: A few years ago, the state legislators required us to allow petroleum contaminated soil for embankment material.)

Potential Problems:

Once these materials are placed on ODOT property, then the recycled materials will become the responsibility of the Department. ODOT will assume any future liability and costs for removal and proper disposal of material according to future EPA regulations. In the future, if this embankment is repaired then the material may have to be disposed of in a landfill, if required by EPA regulations.

A small percentage of tire fills have spontaneously combust into fires. Fly ash is silt and may be susceptible to frost heave and capillary action. Both problems are minimized by the engineering controls in the specification.

The District may pick and choose which recycled material to use or allow all of the recycled materials.

The District may allow different materials at certain locations along the project.

No change in the cross sections are needed to include SS-871 in the plans. This specification delineates the areas that the recycled materials are allowed.

Use the following plan note to incorporate SS 871 in the contract.

Embankment Construction Using Recycled Materials.

On this project, Supplemental Specification 871 Embankment Construction Using Recycled Materials applies. ____________________________(Put in the materials wanted or needed) may be substituted for Item 203 Embankment in the contract.

The Department will measure and pay for all work detailed in SS-871 according to the Unit Bid Price for Item 203 Embankment.