FOUNDRY SANDS

AFS-FIRST

Foundry Sand as MSE Wall Backfill

Introduction

Foundry sand is a very high grade sand used for making molds in the metal casting industry. The sand is typically around 94% silicon dioxide (SiO_2) and is composed of angular grains. Over time, the foundry sand becomes worn, going from angular grains to subangular or subrounded grains which do not work as well in the casting molds. The worn sand is removed, approximately 10 million tons a year across the United States, and stockpiled. In the past, foundry sand was often sent to landfills; however, used foundry sand is still high quality sand and there is potential to use this foundry sand for infrastructure construction and renewal. Foundry sand can be used in most applications that require fine aggregate and is particularly suitable for structural fills and embankments, road base layers, hot mix asphalt and flowable fill. Reusing foundry sands has a positive impact on the environment in a number of areas. Substituting foundry sands for virgin aggregates produces significant energy and water savings, in addition to reductions in greenhouse gas emissions and particulate matter emissions. Where foundry sands are locally available, they are competitively priced and may also reduce aggregate transportation costs and impacts.

Ohio is one of the top foundry sand producing states in the nation because of its heavy industry. Kurtz Bros., Inc. has been working with excess foundry sand in Ohio transportation projects for nearly two decades. The foundry sand that they use is considered a narrowly graded fine sand, with roughly 98% passing the #30 mesh and roughly 75% larger than the #70 mesh. Bentonite and sea coal were added to the sand to make it more workable for the molding process, so there are some fine materials. Approximately 10% of the sand mixture is bentonite while the sea coal content is around 3%. Foundry sand with these additives is called "green sand," though the sea coal turns the sand black during the casting process. The following project describes how 11,500 tons of foundry sand were used to raise the grade of Schaaf Road in Cuyahoga County, Ohio.

Project Description

In 2005, Great Lakes Construction bid on a project to remove and replace a bridge over a rail line, as well as to raise the grade of two connecting roads. Kurtz Bros., Inc. proposed that Great Lakes Construction use 11,500 tons of foundry sand from a Ford casting facility. The bid proposed to use the foundry sand as reinforced structural fill under the approaches to the bridge (See Figure 1). The bid included engineering and environmental test data to show that the sand met Ohio DOT Supplemental Specification 871 "Embankment Construction Using Recycled Materials" as well as Ohio EPA's water pollution regulations. Great Lakes Construction won the project and construction began in 2007.

Figure 1: Compacted foundry sand behind MSE wall.

Contact Information: Mr. Jason Harrington, FHWA Office of Pavement Technology
PHN: (202) 366-1576, Jason.Harrington@fhwa.dot.gov

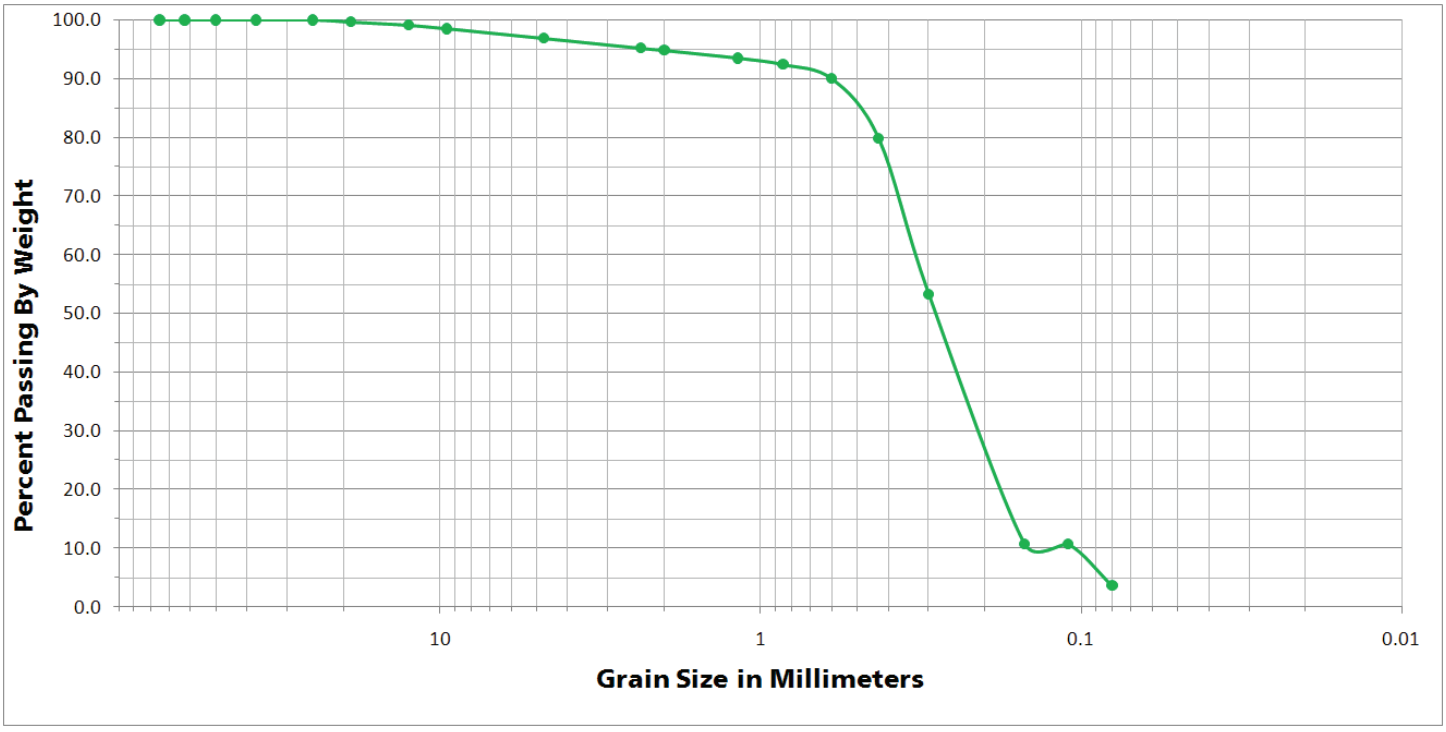
Engineering Properties

Ohio DOT Supplemental Specification 871 defines the geotechnical properties required for use of foundry sand in embankment and fill type applications. Laboratory testing of the foundry sand was conducted by an independent consultant (EDP Consultants, Inc.). The sand was extensively tested, looking at the Atterberg limits, gradation, the moisture-density relationship, shear strength, pH, chloride and sulfate levels, as well as the corresponding soil classification. Table 1 lists the properties tested, the AASHTO standards used to test the foundry sand, and the results of the tests. Figure 2 shows the grain size distribution of the foundry sand as determined by AASHTO T11 and T27 (ODOT 203), and Table 2 lists the data for Figure 2.

Table 1: Summary of Test Procedures and Results.

Property	AASHTO Standard	Results
Plastic Limit & Plasticity Index	T 90-96	Non Plastic
Liquid Limit	T 89-96	N/A
Moisture-Density Relationship	T 99-95	γ_d=107.0 pcf @ 14%
Direct Shear	T 236-92	$\phi = 35°$, tan = 0.70
Sodium Sulfate Soundness	T 104-94	3%
Resistivity	T 288-91	5,600 Ω-cm
pH	T 289-91	9.2
Sulfate Level	T 290-95	87.8 mg/kg
Chloride Level	T 291-94	35 mg/kg
N/A = Non-Applicable, the liquid limit test was not conducted because the material was non plastic.		

Figure 2: Percent of foundry sand passing by weight.



Even though the foundry sand contained bentonite and sea coal, the amount of material passing the #200 mesh was only 3.6% (Table 2), so the material was non plastic. At the same time, more than 93% of the sand passed the #15 mesh (1.18 mm, 0.05"), so the material is confined to a very narrow range of grain sizes. It is actually classified as a poorly graded fine sand according to the Unified Soil Classification System. A material with such a uniform grain size would normally be difficult to compact in the field, and could be unstable in slopes, but the presence of the clay and seacoal helps with the compaction and provides additional shear strength. The friction angle for the foundry sand was 35°, which passed the Ohio DOT Standard 203 that required a friction angle ≥ 34°. One important property of such a grain size distribution is that it drains very easily. For applications such as this fill project, drainage is important because the sand will be backfilled behind a wall and water must drain quickly from the backfill to prevent lateral pressures from building on the wall.

There is sometimes concern that foundry sands will cause corrosion of metal in the structure. However, the resistivity of this sand is above 5,000 Ω-cm, which is the lower limit often used by states. Many states allow aggregates with a resistivity below 5,000 Ω-cm if the sulfate and chloride levels are low, and the levels measured in the foundry sand are low enough to allow use, even if the resistivity was between 3,000 Ω-cm and 5,000 Ω-cm. In this case, ODOT and the MSE wall manufacturer both required resistivity to be greater than 3,000 Ω-cm.

Table 2: Percent Passing on Each Sieve.

Sieve Size (US)	Sieve Size (mm)	Total Percent Passing (%)
1"	25	100.0
3/4"	19	99.7
1/2"	12.5	99.2
3/8"	9.5	98.5
#4	4.75	96.9
#8	2.36	95.2
#10	2	94.9
#15	1.18	93.5
#20	0.85	92.5
#30	0.6	90.0
#40	0.43	79.8
#50	0.3	53.3
#100	0.15	10.7
#140	0.11	10.7
#200	0.08	3.6

Construction Properties

Ohio DOT Supplemental Specification 871 required that the foundry sand be placed in loose lifts not to exceed 8 inches (200 mm) and compacted with at least eight passes of a vibratory steel wheel roller of at least 10 tons. The sand was required to be compacted to 98% of the Supplement 1015.06 Test Section Method B Maximum Density, which is a field compacted maximum density. The specification also required the Installation of drains every 50 feet, and a natural soil cover over the foundry sand. It should be noted that the cover was not a clay liner, but rather a soil layer to support vegetation for erosion control and aesthetic appeal.

Environmental Properties

Ohio DOT Supplemental Specification 871 requires that the foundry sand meet the Ohio EPA, Division of Surface Water, Policy 0400.007 (DSW-0400.007) "Beneficial Use of Nontoxic Bottom Ash, Fly Ash and Spent Foundry Sand and other Exempt Wastes." Under this policy, nontoxic foundry sand could be used in beneficial use applications in lieu of competing raw materials. Foundry sand used in this way was exempted from Ohio's hazardous or residual solid waste regulations, and was instead regulated under Ohio's water pollution regulations. Foundry sand was characterized as nontoxic if leaching tests (TCLP, USEPA 1311 or modified TCLP, ASTM D 3987) showed that the constituents of interest had concentrations less than 30 times the Ohio Primary Maximum Contaminant levels. In addition, the modified TCLP test was required for the evaluation of phenol, cyanide and fluoride. All of the constituents of interest and the nontoxic concentration criteria are shown in Table 3. The project design and foundry sand material was reviewed according to the Ohio Revised Code Chapter 6111 for potential surface water pollution and was found to be nontoxic. This policy has been subsequently withdrawn by Ohio EPA while a more formal rules process was instituted, but this was the policy in place at the time.

Table 3. Leaching Criteria Applied to the Foundry Sand and Measured Results.

Constituent of Interest	Nontoxic Criteria (mg/L)	Measured Concentration (mg/L)
Arsenic	1.5	ND (<0.01)
Barium	60.0	0.004
Cadmium	0.15	ND (<0.005)
Chromium	3.0	ND (<0.010)
Lead	1.5	ND (<0.003)
Mercury	0.06	ND (<0.002)
Selenium	1.0	ND (<0.005)
Phenol	10.5	0.051
Fluoride	12.0	0.18
ND = Non-Detectable		
mg/L = milligram per liter		

Economics

This was a demonstration project for Kurtz Brothers, so they went in knowing that they would only break even on the bid price of $8.60/yd^3 for the delivered sand. However, Ohio DOT was able to save money by using the foundry sand compared to what they would have paid for natural sand. While the delivered price will vary from site to site due to hauling costs and local economics, Ohio DOT has the opportunity to realize cost savings when using foundry sand that is nearby and readily available, instead of trucking in conventional materials from a distant quarry.

Project Contacts

Project Owner Cuyahoga County, Ohio	Contractor Great Lakes Construction	Sand Supplier Kurtz Bros., Inc.
Robert C. Klaiber Jr. Cuyahoga County Engineer's Office 2100 Superior Viaduct Cleveland, OH 44113 (216) 348-3800 rklaiber@cuyahogacounty.us	**Mark Bacon, P.E.** Great Lakes Construction 2608 Great Lakes Way Hinkley, OH 44233-9590 (330) 220-3982	**John Kurtz** Kurtz Bros., Inc. 6415 Granger Road Independence, OH 44131 (216) 986-7000 johnk@kurtz-bros.com

Consulting Engineer EDP Consultants	Industry Trade Group AFS-FIRST
John Dingledein Geotechnical Engineer EDP Consultants, Inc. 9375 Chillicothe Rd. Kirtland, OH 44094 (440) 256-6500 johnd@edpconsultants.com	**AFS-FIRST, Inc.** Schaumburg, IL (800) 537-4237 afs-first@afsinc.org http://www.foundryrecycling.org

References

AASHTO T 11 Standard Method of Test for Materials Finer Than 75-um (No. 200) Sieve in Mineral Aggregates by Washing

AASHTO T 27 Standard Method of Test for Sieve Analysis of Fine and Coarse Aggregates

AASHTO T 89 Determining the Liquid Limit of Soils

AASHTO T 90 Standard Method of Test for Determining the Plastic Limit and Plasticity Index of Soils

AASHTO T 99 Standard Method of Test for Moisture-Density Relations of Soils Using a 2.5-kg (5.5-lb) Rammer and a 305-mm (12-in.) Drop

AASHTO T 104 Standard Method of Test for Soundness of Aggregate by Use of Sodium Sulfate or Magnesium Sulfate

AASHTO T 236 Standard Method of Test for Direct Shear Test of Soils under Consolidated Drained Conditions

AASHTO T 288 Standard Method of Test for Determining Minimum Laboratory Soil Resistivity

AASHTO T 289 Standard Method of Test for Determining pH of Soil for Use in Corrosion Testing

AASHTO T 290 Standard Method of Test for Determining Water-Soluble Sulfate Ion Content in Soil

AASHTO T 291 Standard Method of Test for Determining Water-Soluble Chloride Ion Content in Soil

ASTM D 3987 Standard Test Method for Shake Extraction of Solid Waste with Water

Ohio Department of Transportation Supplemental Specification 871 - Embankment Construction Using Recycled Materials (http://www.dot.state.oh.us/Divisions/ConstructionMgt/Specification%20Files/871_04152005_for_2008.PDF)

US EPA Method 1311 Toxicity Characteristic Leaching Procedure

Recycled Materials Resource Center foundry sand portal - http://www.rmrc.unh.edu/materials/fs/

FHWA Recycling Webpage - http://www.fhwa.dot.gov/pavement/recycling/