U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION

REPORT ON USE OF RECYCLED FOUNDRY SAND IN THE CLEVELAND AREA

January 29, 2003

Introduction

The Federal Highway Administration's Office of Pavement Technology conducted a review of the uses of recycled foundry sand in the Cleveland, Ohio area. The review was coordinated by Mr. Joe Alexander, Project Sales Manager, for Kurtz Bros. Kurtz Bros. is a materials broker that collects used foundry sand from various foundries and transports the material to projects where fill material is needed.

Foundry Sand

Foundry sand is manufactured by mining some of the best sand available from the Upper Peninsula in Michigan. This sand is 94% silicon dioxide (SiO_2). Bentonite and seacoal are added to the sand to make it more workable for the molding process. Approximately 10% of the sand mixture is bentonite while the seacoal content is around 3%. The gradation of the sand meets AFS 52 grade sand. This is a three screen gradation (#50, #70, and #100) with the bulk of the material being retained on the #70 sieve. AFS 52 gradation is shown below.

Sieve Size	Percent Retained on Individual Sieve	Percent Passing
No. 20	0.1	99.9
No. 30	1.5	98.4
No. 40	8.1	90.3
No. 50	21.4	68.9
No. 70	42.0	26.9
No. 100	23.4	3.5
No. 140	3.4	0.1
No. 200	0.1	

Seacoal is a combustible coal, which is used, in the casting process to prevent the sand from sticking to the casting. Unfortunately, seacoal turns the sand black, which implies that there is considerable organic material in the sand; however, this is not true. The resulting sand meets American Foundry Sand Standard, AFS 50-53 "Lake Sand." Foundry sand is also called "Green Sand"

Recycled foundry sand should be a better material for highway embankments than most virgin aggregate sources.

Foundry sand is used to create molds to cast the engine blocks. Foundry sand can be reused several times; however, it will "wear out" in that the sand will lose its angular with the sand particles becoming rounded. When this happens, the foundry sand must be replaced. What should we do with the discarded sand? The answer is to recycle the sand by using it in highway construction.

One of the main foundries in the area, Ford Motor Company's motor assembly plant in Cleveland, assembles motors for different types of Ford cars. This facility alone produces 325,000 tons of foundry sand per year.

Foundry sand is stockpiled at Kurtz Bros. until it is needed. Vertical walls of the stockpile indicate that the material has considerable clay or binder material.

Abrams Creek Improvement Project

The Abrams Creek Improvement project in which Abrams Creek was being enclosed by four 120" (10 ft) diameter concrete pipes so that a major extension of a runway for the Cleveland Hopkins International Airport could be constructed. The creek was situated in a deep ravine. Approximately 65 ft feet of fill had been placed over the pipes to bring the area up to grade.

A flowable fill was used to place the pipe bedding material around the pipe. Flowable material was provided up to ¾ of the pipe diameter. Pipe bedding was extremely important so that the adequate pipe strength could be developed to resist an average of 65 feet of fill that would be placed over the pipes. Only 12 inches was provided between the concrete pipes. It would have been impossible to compact normal trench backfill material.

Foundry sand was delivered to the Concrete Ready mix plant where it was mixed with 150 lbs/yd^3 of cement and 60 gals/yd^3 of water. Cylinders taken of the fill material had a strength of 125–300 lbs/in^2. None of the mixing water drained from the flowable fill; it was bound up in the hydration process.

The cost of the material delivered to the site was \$30/yd^3.

The flowable fill can be seen between the pipes.

Four 120-inch reinforced concrete pipes being placed.

SR 271 Embankment Repair

ODOT selected recycled foundry sand repairing an embankment failure on SR 271. ODOT engineers selected foundry sand for two reasons. The first reason was the availability of the material, while the second reason was that the engineers believed that foundry sand had the necessary strength and permeability for this particular application.

ODOT personnel believe that foundry sand is a good material for highway construction and that its role will increase as engineers become more familiar with it. They believe that it was the proper moisture content that produced adequate compaction and made the project a success. The Contractor entered a bid price of $\$8.60/yd^3$ for the delivered material.

The real merit of this project was the amount of testing that was performed on the sand. Laboratory testing of the foundry sand by an independent consultant (EPD Consultants, Inc.) produced the following results:

Overview of the project.

Water was periodically added to the mixture to maintain optimum compaction conditions.

PROPERTY	AASHTO	Results	SPEC	PASS/FAIL
Grain Size Analysis	T 11-91 T 27-93	See Attached	ODOT 203	Pass
Sodium Sulfate Soundness	T 104-94	3%	N/A	N/A
Liquid Limit	T 89-96	N/A	N/A	N/A
Plastic Limit & Plasticity Index	T 90-96	Nonplastic	N/A	N/A
Moisture-Density Relationship	T 99-95	γ_d = 107.0 pcf @ 14.0% γ_t = 122.0 pcf	$\geq$ 120 pcf	N/A
Direct Shear Test	T 236-92	N = 35^0	$\geq 34^0$	N/A
Resistivity	T 288-91	5,600 Ω-cm	N/A	N/A
PH	T 289-91	9.2	N/A	N/A
Sulfate Level	T 290-95	87.8	N/A	N/A
Chloride	T 291-94	35	N/A	N/A

The midpoints of ODOT's 203 gradation are shown below:

Sieve Size	Sieve Size (mm)	Percent Passing
1"	25.0	100
¾"	19.0	99.7
½"	12.5	99.2
3/8"	9.5	98.5
No. 4	4.75	96.9
No. 8	2.36	95.2
No.10	2.00	94.9
No. 16	1.18	93.5
No. 20	0.85	92.5
No. 30	0.60	90.0
No. 40	0.425	79.8
No. 50	0.300	53.3
No. 100	0.150	10.7
No. 140	0.106	10.7
No. 200	0.075	3.6

A gradation analysis using the FHWA's drainage microcomputer program DRIP "Drainage Requirements in Pavements" Sieve Analysis module produced the following particle sizes for key percent passing values:

Percent Passing	Particle Size (mm)
D_{10}	0.1422
D_{12}	0.1549
D_{15}	0.1626
D_{30}	0.2108
D_{50}	0.2870
D_{60}	0.3302
D_{85}	0.5105

The analysis also determined the following values:

Percent Passing #200 Sieve = 3.6%

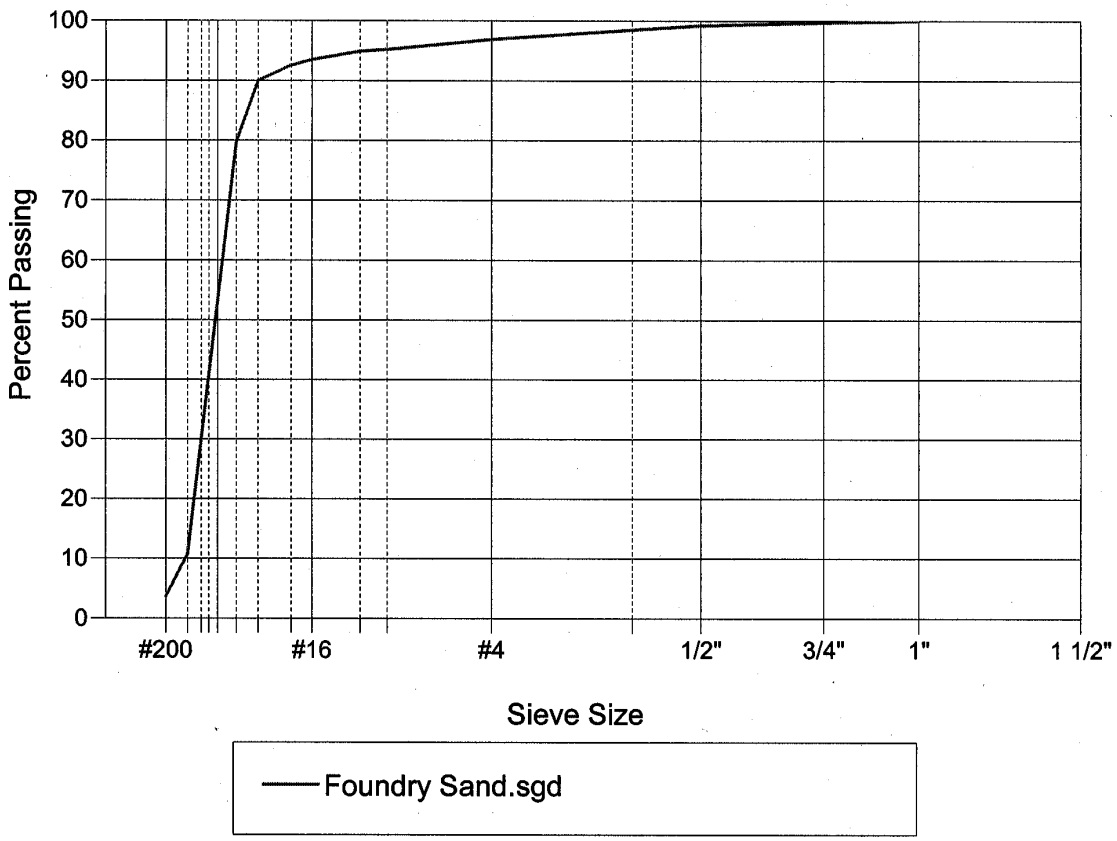
Effective Size (D_{10}) = 0.1422 mm

Coefficient of Uniformity (C_U) = 2.33

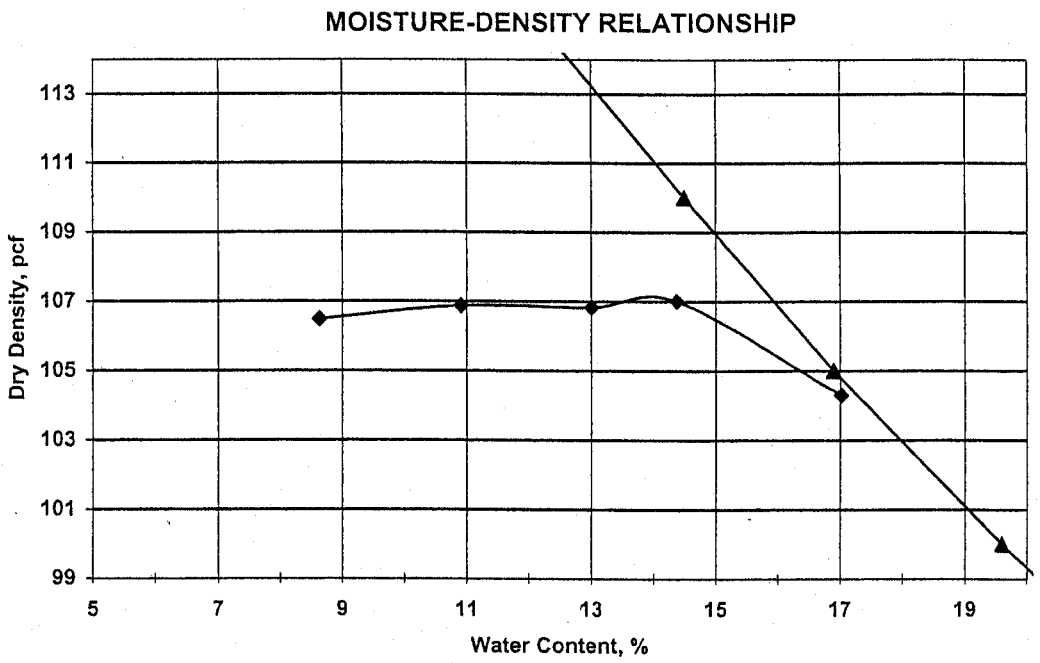
Coefficient of Curvature (C_C) = 0.96

The Coefficient of Uniformity ($C_U = 2.33$) indicates that the gradation is "open" and would be somewhat unstable; however, since bentonite and seacoal have been added to the sand, these additives will act as binders giving the sand mixture strength. The Coefficient of Curvature ($C_C = 0.96$) indicates that the gradation will be a straight line between the D_{10} and D_{60} particle sizes.

A FHWA Power 0.45 plot is shown below. This provides a visual image of the gradation. Foundry sand is classified as a poorly graded, fine sand according to Unified Soil Classification System.



A moisture-density curve relationship was developed as shown below. This test shows that the relationship is very flat at the peak of the curve, which means that the material is not overly sensitive to changes in moisture content.



In a review of the project, Ohio's EPA stated in part:

"I have reviewed this proposal for water pollution concerns and have not found any."

ODOT Specification 871, Embankment Construction Using Recycled Materials

ODOT's Specification 871, Embankment Construction Using Recycled Materials, provides guidance for placing and compacting foundry sand. The specification states:

"C. Foundry Sand

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 Supplemental 1015.06 Test Section Method B Maximum Density.

Cover the sides and top of the Foundry Sand 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."

Oak Tree Boulevard Extension

The extension of Oak Tree Boulevard in the City of Independence, Ohio required a large amount of fill since the extension was over a deep ravine. The existing ravine was approximately 2,000 ft long by 600 ft wide with a maximum depth of 50ft. Approximate 30,000 yd^3 of fill was required to fill in the ravine. Approximately half of the fill material was provided by foundry sand. The primary reason for using foundry sand was the availability of material.

The Solar Testing Laboratories, Inc. tested and approved the use of foundry sand as a fill material. As long as the material was contained and the proper moisture content was used in the construction of fill no problems were anticipated. The embankment material was contained by the ravine on two sides and the existing roadway on the third side. It was necessary to construct a clay dike on the open end of the embankment to retain the fill material. A 3 ft clay cap will be placed over the completed embankment.

Attached are photographs of the construction actives. The delivery trucks had no trouble operating on the surface of the newly placed foundry sand. Periodically water would be added to the mixture to maintain optimum condition.

Sand for Asphalt Mixes

Kurtz Bros. and Ohio DOT did not have much experience using foundry sands in asphalt mixes. Indiana DOT could be contacted for information in this area.

Costs

Kurtz Bros. removes and processes foundry sand for a fee. The sand is then distributed to the various contractors as needed. It is estimated that a contractor would save 25 to 30 percent using foundry sand over virgin material.

To recap the cost, the flowable fill for the Abrams Creek Improvement project cost $30/$yd^3$, while the foundry sand fill material for the SR 271 Embankment Repair cost $8.60/$yd^3$.

Conclusions

Based on the information gathered on the field the following conclusions can be made:

- Foundry sand should be classified as a poorly graded, fine sand according to Unified Soil Classification System.
- Foundry sand presents no environmental problems.
- Recycled foundry sand is an adequate material for highway embankments.
- Recycled foundry sand is a cost effective material when the highway project is located near a foundry site.