Weighing Sand Reuse Options
From the Customer’s Perspective

Widespread beneficial reuse of spent foundry sand depends on understanding each application and the needs of the end-user, and marketing accordingly.

Raymond W. Regan, Michael Heaney, and James A. Dunkelberger
Pennsylvania State Univ.
University Park, Pennsylvania

Although many of the environmental monitoring requirements that once prevented beneficial reuse (BRU) of foundry residuals have been relaxed, more than 90% of all spent foundry sand is still disposed of in landfill—at a huge cost to the industry. To make a significant dent in that number, foundries must change their perception, and view spent sand from the customer’s perspective—not as a waste, but as a product.

Any marketable product needs a name, and a suggested generic name for spent sand is Fine Foundry Aggregate (FFA), where “fine” refers to the grain size relative to other construction aggregates. But developing a marketing perspective toward FFA involves more than just semantics. It means getting to know the customer’s sand needs and specifications.

A consortia of Pennsylvania foundries, the Pennsylvania Foundrymen’s Assoc. (PFA) and the Metal Casting Center and the Environmental Resources Research Institute at Penn State Univ. are involved in a USEPA funded investigation to study BRU metalcasting industry residuals. This group is addressing the technical and institutional impediments to BRU on a comprehensive national level. This article discusses the needs of various potential FFA customers, and the market feasibility of each application.

Sand Specifications

Table 1 gives the results of an informal survey of 125 foundries attending the 1996 AFS Environmental Affairs Conference, in which foundries were asked in what BRU applications their sand found a home. This survey indicates that most FFA applications are as fill material, and not in concrete or asphalt pavement where high compressive strengths are required. Often, the selected alternative is limited to a local use because transportation costs can exceed any revenue from the BRU activity.

In order for foundry residual to be considered for BRU in Pennsylvania and other states, certain conditions apply. The residual must have substantially similar physical and chemical characteristics as material it is replacing. In a physical sense, the material must have similar performance characteristics as the replaced aggregate. For example, makers of concrete specify a mix of fine aggregate material that must have a certain percentage of very fine particles and a certain percentage of medium-sized particles in the mix. Hence, in order for FFA to be substituted for the fine aggregate fraction, it must be similarly sized and have a similar range of sizes as the fraction being replaced.

In addition to the size distribution of the particles, the shape of the particles can sometimes play a major role. Some products, such as cement concrete, require rounded particles. Rounded particles need less water and cement to maintain the same water/cement ratio and overall strength compared to angular “manufactured” sand. If FFA is substituted into concrete, this product should now have the same compressive strength, tensile strength, durability and resistance to freeze-thaw cycles as normal concrete. Producers of asphalt concrete, however, prefer angular aggregate to increase the frictional resistance of the mix, thereby increasing its shear strength. Shear strength is vital for asphalt so that the pavement does not flow under load. In general, for all BRU, there cannot be any deterioration in the performance of the product. For most applications, the FFA must be a consistent size and free of floor sweepings and core butts. It may be necessary to install additional sand storage equipment to keep the sand dry and ready to load.

Sources of Solid Wastes

In addition to FFA, other waste materials from the metalcasting industry include core sand, slag and baghouse dust. The combination of process waste streams from 54 Pennsylvania foundries is shown in Table 2. The table indicates that, on average, excess system sand comprises 67% of the materials generated from a typical foundry. Baghouse dust and slag generation comprise 17% and 16%, respectively, of the solid waste generated. Other lesser sources of spent materials include cupola ash and refractories, which are sometimes combined with the residual slag materials.

In the past, all of these wastes were combined in a common stockpile at the foundry prior to disposal. However, segregation of the waste piles is recommended to keep a more uniform stock of material if the wastes are to be managed for BRU.
Characterization

Penn State researchers conducted a study to determine the physical characteristics of typical Pennsylvania foundry excess systems sand using samples obtained from either iron or steel foundries. Residual green sand was tested since it is the most common molding medium.

The results from this analysis provided the following observations:

1. The FFA were generally considered to be fine-grained when compared to Type B. No. 2 bituminous fine aggregate material. Furthermore, these sands were too fine when compared to the gradation required for Cement Concrete Sand, type A, used in the production of concrete.

2. The FFA had a narrower distribution of particle sizes than do most fine aggregates used in construction. Therefore, typical FFA do not completely fulfill the full spectrum of gradation requirements of typical construction aggregate material. To meet the specification for fine aggregate, a larger proportion of the material between 0.25-0.375 in. was required. It was suggested that slag could improve the gradation distribution.

3. FFA exhibited typical compaction behavior of construction materials. The ability to compact is important for such applications as fill and roadbed material, where the material undergoes high compressive loads. The test showed that FFA had higher compactability (as demonstrated by its higher maximum bulk unit weights) than the virgin sand. In addition, the optimum moisture content (OMC) of the FFA was similar to that of the virgin sand. The OMC is the moisture content of the specimen at the point of maximum bulk unit weight. Soils that have similar maximum bulk unit weights and optimum moisture contents tend to exhibit similar compressive strengths.

4. FFA has insufficient shear strength for use in compacted fills and embankments. This is a particularly important observation since most of the loading that will occur on fill material will need very large shear strengths to prevent the shifting of the fill material under load. Therefore, typical Pennsylvania FFA have comparable shear strengths to sand usually used in construction material.

5. It was suggested that some processing of the FFA may be needed for some beneficial uses. For example, in addition to removing large core butts, the FFA may need to be washed to remove some debris. The removal of core butts and other sources of organic material would increase the strength characteristics of the FFA, since the primary reason for a lowered strength potential is due to the organic material and clay, in the FFA.

Overall, based on physical properties alone, the FFA may be used as a partial replacement for some fine aggregates used in construction material. Complete gradation for construction aggregate may be met by blending FFA with coarser material.

Rating the Applications

Some of the BRU applications are highlighted here to provide an overview of potential applications and their feasibility.

Landfill Daily Cover -- Because the open section of a landfill must be covered daily, this application is considered a BRU. Specifications for daily cover are fairly tolerant. In Pennsylvania, for example, the main requirements for daily cover are to: produce 25-55% runoff; maintain a slope of 3%; and be capable of supporting vegetation.

Virtually every foundry could take advantage of this application. A landfill of 100 acres uses about 1700 tons per day of cover material. A much larger quantity is needed for the final cover when the landfill is closed. Because landfills generally have low-cost daily cover available on-site, they typically do not pay for cover material, but cost savings on reduced disposal fees for FFA are possible.

Flowable Fill -- Also called controlled low-strength material (CLSM), flowable fill is a weakly cemented material used in place of conventional backfill. A relatively new construction practice, the use of flowable fill has grown dramatically in some states because it saves time, equipment and labor. The product is typically made from a mixture of sand, portland cement, fly ash, and water. The mixture ratios vary depending on the intended use. Applications include backfill for sewer and utility cuts, underground storage tank bedding, bridge abutments and many other structural applications. FFA must be blended with coarser sand to achieve proper grain size distribution. Because it can tolerate some fines and does not need to be supplied in large quantity, flowable fill is one of the best applications for FFA from many types of foundries.

Grout or Mortar -- FFA can be used as a complete or partial replacement of fine aggregate in grout or mortar mixtures. Similar to flowable fill, grout is used to fill voids, fissures or cavities in soil, rock or brick formations. Grouting is also used to improve the strength and durability of such formations. To reduce permeability, bentonite is often added to grout.

Potting Soil Amendment -- FFA is currently being successfully used in potting soil at levels as high as 50%. Potting soil is a mixture of sand, peat, fertilizer, topsoil or compost with the blend differing widely between greenhouses. Demonstrating the FFA’s ability to support plant growth on a case-by-case basis will probably be necessary to obtain acceptance by greenhouses.

Topsoil-FFA can be used as a topsoil or as a partial or complete replacement of fine aggregate material in a topsoil mixture. Similar to landfill daily cover, the use of topsoil is a large volume, low value application.

Construction Fill or Roadbase Material -- FFA is easily compacted in place. In some applications the shrink-swell characteristics of the bentonite fraction may be a problem. Like daily cover, this is a large volume, low value application. Sampling and groundwater monitoring costs required by the state regulatory agency should be evaluated before selecting this alternative.

Portland Cement Raw Material -- FFA is a good source of silica for the production of portland cement. Cement manufacturers require that the sand be uniform, free of excess metal and low in heavy metals. FFA generally meets these criteria. Cement plants require high quantities of silica (typically 50,000-plus tons annually) and because of differences in the product manufacturing requirements generally pay much less for their sand supply than foundries. The feasibility of this alternative often comes down to distance and transportation costs. Compared to other potential users of FFA, there are a relatively small number of cement manufacturers, so most foundries will be a long distance from the nearest one.

Asphalt and Ready-Mix Concrete Aggregate -- Neither of these two po-
Potential large-scale BRU applications appear as promising as once reported. Although FFA has been used successfully in field tests of both asphalt pavement and concrete, these past tests have shown that FFA is too fine to meet the normal grain size specifications for either application. Even if the FFA were blended with a high ratio of coarse sand, the resulting aggregate would not meet the grain size specification. Fine-grained aggregate produces low-strength pavement. Limitations are illustrated by the following examples.

1. The specifications for asphalt pavement aggregate for publicly funded projects are set by state Departments of Transportation, which are in turn driven by the Federal Highway Administration (FHWA) standards. The FHWA's Strategic Highway Research Program (SHRP) initiative to increase the durability of roads effectively eliminated the use of any fine aggregate such as FFA, no matter how much coarse, uniform sand it is mixed with. However, some FFA has been used for non-publicly funded projects such as parking lots and private driveways where specifications are not as much an issue.

2. The specification for fine aggregate used in concrete is ASTM C 33. FFA can be blended with coarser sands to meet this specification, but the FFA must first be scalped of fine clay particles and then continuously blended with coarse sand for the product to maintain the aggregate fineness modulus to a variation of less than 0.20% per shipment of concrete. (The fineness modulus for FFA, which is similar to the AFS grain fineness number, is typically 0.8-1.6. ASTM C 33 requires a fineness modulus of 2.3-3.1.) The FFA and a custom-sized coarse sand may require expensive proportioning and conveying equipment. In addition, this modification would be risky for the aggregate supplier because major concrete users stipulate that no aggregate will be purchased from an out-of-spec supplier for a six-month period prior to its use. Few aggregate suppliers would be willing to risk an assignment increase in process complexity for a change that would be perceived as a down-grading in quality for a cost savings on a small portion of their sand. So the ASTM C 33 standard effectively precludes the use of FFA for any concrete customers with penalty clauses in their contract, unless the foundry is willing to remove the clay fraction, purchase blending equipment and stockpile the sand.

Precast Concrete-Sand used in concrete blocks and pavers are generally not subject to the ASTM C 33 specifications for ready-mix concrete. Typically the only specifications for precast concrete are for the strength of the finished product. The clay content of most FFA would weaken concrete, but not all blocks need to be high-strength. For foundries with a block manufacturer in the vicinity, this could be a good potential market.

The preliminary Penn State assessment of BRU uses and market compatibilities are shown in Table 3.

Table 3. Summary of Potential Beneficial Uses and Market Compatibility

<table>
<thead>
<tr>
<th>Beneficial Use</th>
<th>Likely Income or Sale Potential</th>
<th>Number of Customers</th>
<th>Opportunities for Large Foundries and Cooperators</th>
<th>Opportunities for Small Foundries</th>
<th>Significant Regulatory Barriers</th>
<th>Significant Market Barriers</th>
<th>Specification Compatibility</th>
<th>Overall Evaluation</th>
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<td>Landfill</td>
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<td>No</td>
<td>Yes</td>
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Excellent = ☐ Good = ☐ Poor = ☐

*Cement Kilns may believe they are disposing a foundries FFA and may want to charge the foundry.
**This is a good opportunity for a small foundry if it is willing to invest in screening equipment, stockpile aggregate, and monitor aggregategradation requirements by the user.
***This beneficial use currently is technically feasible but the regulators, public, and users need to be educated about the low risks associated with this particular use.