Recycled Foundry Sand Sources and Properties

By Chuck Hughes, P.E.

This is part one of a two-part series on the use of recycled foundry sand (RFS) in Hot Mix Asphalt (HMA) pavements. Part one focuses on the availability, processing and some properties of RFS. Part two will address additional properties of RFS, how to use it in HMA mixtures, and its impact on performance.

HMA producers are intimately familiar with recycling. But metalcasters are some of the world’s first recyclers. For centuries, foundries have been making new metal objects by remelting old ones. However, they also recycle sand used in the metalcasting. There are about 2,300 foundries in the United States that use 100 million tons of sand for castings.¹

The sand from foundries that is potentially available for use in HMA comes from the foundry spent sand stream(s) (sand that can no longer be used to make molds). Estimates of the amount of sand in the spent stream typically range anywhere from about 2 to 15 percent or more of the sand used by the foundry. Some foundries do not reuse any spent sand, making 100 percent available for reuse. The amount of spent sand depends on the foundry, mold type, and sand type.

It has been estimated that 8 to 15 million tons of spent sand may be available for beneficial reuse in applications such as HMA. Since the HMA industry uses many million tons of sand annually, the RFS from the foundry industry is and can continue to be a very good source of hard, angular sand. This would provide a win-win situation for both the foundry and HMA industries.

However, as with any waste material used in HMA, recycled foundry sand must meet the “Three E’s”:

- Engineering – The material should be equal to, or better than the material it replaces.
- Environment – The material should not pose any health or safety problems in handling or production. And, it should not hinder the future recycling of the pavement.
- Economics – The material should not increase the cost of the mix unless offset by improved performance.

Sources of Recycled Foundry Sand

Although there are four major types of sand used for metal casting, silica sand is the most common. The virgin sand used in the foundry industry may be either natural sand from a pit or manufactured, Close-up Foundry Sand
quarried sand from rich, pure quartz deposits. In either case, the sand is produced through a sophisticated process that has rigid controls on not only gradation, but also on such properties as iron content, pH, final moisture content, etc.

A high degree of quality control is essential to provide a product that will be consistent as it goes through the molding processes and is one reason that the cost of sand to the foundry industry is higher than for the sand that is typically used in the HMA industry. This means that when recycled, the spent foundry sand also has the potential of being a very high quality material.3

**Clay-bonded (Green) Sand.**

Nationally, the majority of spent foundry sand is “green sand.” It has been estimated that green sand constitutes approximately 90 percent of the sand used in foundries1. A typical gradation of this material is a uniform gradation from the #40 sieve (450 μm) to below the #100 sieve (150 μm).

Clay, sand, and water form the basic green sand mixture. There are also additives such as carbon-based materials added to improve the casting properties of the sand mixture and reduce the occurrence of casting defects. Their combinations, in various proportions, produce the bonding strength necessary for sand molding. Either coarse or fine sands are used, depending on the required surface finish of the completed product.4

The clay is used to bond the sand together. It provides cohesion and plasticity in the fresh state and high strength when dried. The typical range of clay is 5 to 15 percent of the total composition and the percent passing the #200 (75 μm) sieve is generally from 1 to 12 percent. For the use of green sand in HMA, it is important that most of the clay be removed. RSF produced from “green sand,” is usually uniformly graded and finer than conventional sand. Thus, it may be necessary to blend the RSF with coarser sand to meet the needs of the HMA mixture.

**Chemically-bonded Sand.** In “chemically-bonded sand,” a wide variety of agents are used to bond the system. Chemically-bonded sand, according to a Wisconsin study, only constitutes about 6 percent of foundry sand. However, in some geographic areas the percentage is much higher, even as high as 70 percent.1 Organic binders such as oil, cereal and wood proteins, and inorganic binders such as portland cement or sodium silicate may be used for bonding in this process. The cores and core “butts” made by this process either break down through handling or must be crushed and screened to make them available for use in HMA either as sand or as a coarser aggregate.

For use as an HMA material, it is important to note that the chemically-bonded sand typically will be drier and have lower fines content than spent green sand.

As can be inferred, from a foundry standpoint, many different spent sand streams are produced depending on the myriad variables of the foundry. However, from a HMA producer standpoint, it is important to know:

- The type(s) of spent sand stream(s) produced;
- Whether there is a single spent sand stream or multiple streams; and
- How the sand streams are separated, commingled, etc.

If the spent sand is processed into RFS by an independent recycling operator, which is done for the majority of RFS, many of these concerns are addressed in their operations.

**Assuring Consistency of Composition and Supply**

Reprocessing spent foundry sand can be done by any of the following industries:

- Foundries;
- Independent material recycling operation; or
- HMA producer or aggregate supplier.

Reprocessing the spent sand into a RFS product that is useable in HMA is a necessary and important step. The sand must be reprocessed into a consistent, high-quality product comparable to virgin sand used by the industry. The RFS production should have sufficient incoming material to assure that a sufficient quantity of RFS is outgoing to allow the HMA producer to maintain a consistent production.

Most foundries have not undertaken the task of processing the spent sand into a form that can be used as RFS by HMA producers. For the foundry that does not desire to process the spent sand itself, independent material recycling operations and HMA producers have found recycling the spent foundry sand to be economically advantageous. There are many different processes that can be used to accomplish the recycling. Some operations only screen the spent foundry sand, others crush and screen, and some crush, screen, and remove fines through a baghouse. The operations have been developed based on the form of spent sand available from the foundries.

*Processes Used to Produce Spent Sand for Use in HMA*

**Processing Within the Foundry.**

The foundries that want to internally process their spent sand into a RFS understand the need to install reprocessing systems to produce a quality product available to their customers. Spent foundry sand must be contaminant-free and, with very few exceptions, screened to a given size distribution in order to be marketable.

Most foundries that choose to process their spent sand, either invest in screening, crushing, and magnetic separation themselves, or form a business partnership with a
company who can provide that service for them.

Processing requirements are ultimately determined by the local end markets for RFS, but there are three basic steps common to all markets:

- Removal of general refuse and other contaminants;
- Removal of metals; and
- Processing and sizing to produce a uniform, consistent product.

Fines content is of special concern when evaluating spent sand, particularly from green sand operations, for use as RFS in HMA. HMA mix designs generally limit the amount of material passing the #200 (75 μm) sieve from 4 to 5 percent. Just as processors of virgin materials control the fines prior to use in HMA, foundry sands containing a large percentage of fines also need to be processed to meet HMA mix design requirements.

Three foundries that have developed successful sand recycling programs are the Kingsport Tennessee foundry and two Grede Wisconsin foundries, one is the Reedsburg foundry and the other is the DePere foundry.

The Kingsport Tennessee foundry is a model example of a small foundry that has found recycling sand to be an economical option. They send about 3,000 tons per year of spent sand to a nearby asphalt plant. This arrangement has cut the foundry’s disposal costs by 80 percent.

The Grede-Reedsburg foundry produces two sand streams and is working with a local asphalt contractor to use the spent sand in HMA on several pilot projects. The Grede-DePere is also looking for opportunities to beneficially reuse their spent sand in HMA.

RFS by Independent Recycling Operations. For many small- to medium-size foundries, the capital costs and expertise required for entry into beneficial reuse markets have been considered to be prohibitive. So, for some foundries, co-processing of spent sand streams from multiple foundries that is handled by a materials processing partner represents a cost-effective way to participate in beneficial reuse markets. The following are examples of these partnerships.

Process Recovery Corp. (PRC) was established in 1985 by a consortium of 33 iron, brass, and steel foundries in southeastern Pennsylvania and the Pennsylvania Foundry Association. PRC accepts only non-hazardous foundry sand, slag, refractories, and dust from foundries within 100 miles of its landfill. Between 1990 and 1998, more than 1.1 million tons of material were brought to PRC’s site. Participating foundries are charged a fee for each haul which is considerably lower than the average statewide tipping fee of $35.00. PRC President Tom Hartman, an industry veteran, estimates that member foundries have saved more than $15 million in tipping fees since the monofil began operation in 1990.

PRC is able to recycle about 75 percent of the spent sand for HMA use. The other 25 percent consists of metal, refractory, core butts, and slag that have other markets.

Resource Recovery Corp. (RRC) of West Michigan is a consortium of West Michigan foundries formed for the long-term, cost-effective, and environmentally sound management of foundry process residual materials. RRC’s emphasis is upon the implementation of appropriate beneficial reuses outside the foundry industry. To this end, RRC operates a sand processing facility where it reduces mold and core sand to particle size, removing fines and recovering metallic materials. Participating foundries separate their non-hazardous residual waste streams into 20 or 26 cubic yard rolloff boxes supplied by RRC.

RRC’s process converts 99.5 percent of the incoming sand streams to finished grain size fine aggregate. The largest proportion of RRC’s sand production is used by the HMA plant, which meets Michigan Department of Transportation specifications. There has been a gradual increase in the amount of RFS produced by RRC resulting in approximately 17,000 tons of RFS produced in 1999 for HMA. RFS delivered to the HMA plant is dumped into an enclosed containment facility. From the
foundry sands are non-hazardous. However, more definitive descriptions of the environmental characteristics of the sand are desirable.

**Characterization of RFS by TCLP.**

A common characterization of RFS is the determination of leaching potential utilizing the Toxicity Characteristic Leaching Procedure (TCLP). The TCLP is used by the EPA to determine if a material is considered hazardous: it estimates the amount of chemicals that would be expected to leach from materials placed in a municipal landfill. The leachate results for both green sand and chemically-bonded sand have been compared with the EPA TCLP standards and found to be non-hazardous.

**Characterization of HMA Utilizing SPLP.**

The Synthetic Precipitation Leaching Procedure (SPLP) has been used to characterize the leachate potential for RFS in HMA mixtures. The SPLP estimates the amount of chemicals expected to leach from a material when exposed to naturally acidic precipitation: thus, the test is very representative of actual field conditions and RFS environmental performance. For example, tests have been done by RRC on HMA mixture design blends with and without asphalt. Baseline tests were also done on all virgin materials. The tests compared SPLP results of HMA mixtures with RFS to those with virgin aggregate. The HMA utilizing RFS when subjected to SPLP leachate analysis met Michigan groundwater standards for all parameters tested except aluminum. However, the HMA design blend without asphalt tested for total aluminum showed levels below those found in natural soils. In many instances, HMA mixture design blends without asphalt leached at higher levels with all virgin material blends than when RFS was substituted. For both, all virgin material blends and blends with RFS, leachate levels were

---

commercial aggregate companies are known to reprocess foundry sand. However, it is certainly feasible that a commercial aggregate supplier could undertake such an operation. According to Pat Peterson, Division Manager for Rochester Sand and Gravel, Rochester, Minnesota (a division of Mathy Construction), most aggregate producers have equipment on hand that, with the addition of magnetic separation, can process foundry sands and slags for use as aggregates.

**Safety and Environmental Issues**

The HMA industry has been challenged to incorporate a wide variety of recycled materials into highway projects. At the same time, there is a concern about the potential environmental impact of these materials. Thus, it is of paramount interest to the HMA industry to ensure that the use of any recycled products in HMA are environmentally friendly and will in turn allow the HMA that incorporates these materials to be recycled when the time comes. Several studies of foundry sands, including those from Indiana and Wisconsin, as well as a Transportation Research Board Synthesis Report, state that spent

---

containment facility, the RFS is loaded into computer controlled weigh hoppers where the RFS is blended with other aggregates and fed to the HMA plant.

**Tri-State Sand Co., Johnson County, Tennessee, is a strong believer in beneficial reuse of products in HMA. Tri-State Sand Co.’s largest operation in Chattanooga, Tennessee worked out of a monofill at the Mullen Foundry in 1998 and 1999. This landfill contains a stockpile of about 300,000 tons of spent sand. In the first 6 months of operation, Tri-State produced about 50,000 tons of RFS. The finished product typically had less than 5 percent minus #200 (75μm) material. As found with all processes that produce the RFS, separating the metal from the RFS stream is not only desirable for the use of the RFS in HMA, but is a sizable income producer for the processing company. The percentage of RFS used in the mixtures varies from HMA producer to producer but tends to be from 10 to 25 percent.

**RFS by HMA Producer or Aggregate Supplier.** No commercial HMA producers are processing RFS in-house at present, although some are looking at the potential economic benefits. Likewise, no
Foundry Sand continued

typically lower when incorporated into HMA. Thus, test results support the appropriateness for specific use of RFS in HMA in place of virgin aggregate.

Emissions
When the RFS is used in HMA, the emissions from the HMA plant must be no higher than when virgin sand is used. Emissions testing at all HMA plants using RFS have passed EPA regulations or they would not be allowed to use the material. Specifically, emission tests have been conducted on the Washington County Tennessee HMA plant when using 10 percent RFS and were found to be no different than tests performed on the plant when using conventional processed river gravel. Emission modeling performed by RRC on HMA mixtures containing green sand, chemically-bound sand and foundry slag all passed EPA regulations.

Recycled Foundry Sand should be a viable source of high quality sand for HMA mixtures. With an estimated 8 to 15 million tons of RFS potentially available for use in HMA there is a sufficient quantity of material available to make its use worthwhile. Processing of the sand is necessary to remove fines, slag and metal particles from the RFS. Processing has been successfully accomplished at the foundries and central processing facilities. Environmental testing has shown that RFS can be stored and used at HMA facilities without adverse environmental effects.

Chuck Hughes, P. E. is an engineering consultant.

3 [Site visit McConway & Torley Foundry, October 1999.]
4 [Personal conversation with Dave Walborn, RRC, August 2000.]
5 Kinias, Leslie and Elizabeth Olenbush, "Adopt Processing Standards for Your Best Beneficial Reuse Options," Modern Casting, August 1999, Pg. 40.
6 [Personal conversation with Brian Gibson February 17, 2000.]
7 [Personal conversations with Chuck Marek, Vulcan Materials Company and David John, Martin Marietta Aggregates, May 17, 2000.]
10 [Personal conversation with Ed Canters, February 16, 2000.]