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A Study on Foundry Sand: Opportunities for Sustainable and Economical Concrete

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ABSTRACT

Foundries for the metal-casting industry generate by- products such as used foundry sand. Metal foundries use large amounts of the metal casting process. Foundries successfully recycle and reuse the sand many times in a foundry and the remaining sand that is termed as foundry sand is removed from foundry. Foundry sand is uniformly sized, high-quality silica sand that is combined with a binder and used to form molds for ferrous and nonferrous castings. Used foundry-sand properties vary due to the type of equipment used for foundry processing, the types of additives, the number of times the sand is reused, and the type and amount of binder. Within the concrete industry, the most successful examples have been using coal fly ash to make high-quality, durable concrete and recycling old, demolished concrete as aggregate for new concrete. This study presents the information about the opportunities for sustainable and economical concrete. Applications of foundry sand, which is technically, sound, environmentally safe for sustainable development. Use of foundry sand in various engineering applications can solve the problem of disposal of foundry sand and other purposes. Foundry sand consists primarily of silica sand, coated with a thin film of burnt carbon, residual and dust. Foundry sand can be used in concrete to improve its strength and other durability factors. Foundry Sand can be used as a partial replacement of cement or as a partial replacement of fine aggregates or total replacement of fine aggregate and as supplementary addition to achieve different properties of concrete.

KEYWORDS: foundry waste, foundry sand, concrete, strength, industrial waste, utilization.

INTRODUCTION

Foundry sand is high quality silica sand with uniform physical characteristics. It is a by- product of ferrous and nonferrous metal casting industries, where sand has been used for centuries as a molding material because of its thermal conductivity. It is a byproduct from the production of both ferrous and nonferrous metal castings.

The physical and chemical characteristics of foundry sand will depend in great part on the type of casting process and the industry sector from which it originates. In modern foundry practice, sand is typically recycled and reused through many production cycles. Industry estimates that approximately 100 million tons of sand is used in production annually of that 6 - 10 million tons are discarded annually and are available to be recycled into other products and in industry. The automotive industries and its parts are the major generators of foundry sand. Foundries purchase high quality size-specific silica sands for use in their molding and casting operations.

The raw sand is normally of a higher quality than the typical bank run or natural sands used in fill construction sites. The sands form the outer shape of the mold cavity. These sands normally rely upon a small amount of bentonite clay to act as the binder material. Chemical binders are also used to create sand "cores". Depending upon the geometry of the casting, sands cores are inserted into the mold cavity to form internal passages for the molten metal. Once the metal has solidified, the casting is separated from the molding and core sands in the shake-out process.

In the casting process, molding sands are recycled and reused multiple times. Eventually, however, the recycled sand degrades to the point that it can no longer be reused in the casting process. At that point, the old sand is displaced from the cycle as byproduct, new sand is introduced, and the cycle begins again.

PRODUCTION OF FOUNDRY INDUSTRY IN INDIA AND WORLD

The World Scenario

There are about 35,000 foundries in the world with annual production of 90 million tonnes. In terms of number of foundries China has the highest score (9374), followed by India (6000). The share of Iron foundries is the maximum i.e. almost 56%, followed by steel with 14% and then the non-ferrous ones with 30%. The growing environmental concerns and globalization of economies have led to a closure of some 8000 foundries in Europe. These countries have been contemplating to shift their business to the low labour cost centres i.e. the developing countries.

TABLE: 1
COUNTRY V/S FOUNDRY PRODUCTION: SCENARIO OF WORLD

Country	2009		2010		2011	
	M.T.	R	M.T.	R	M.T.	R
China	35.3	1	39.6	1	41.26	1
US	7.40	2	8.24	3	10.01	2
Japan	4.40	4	4.76	5	5.47	4
India	7.40	3	9.05	2	9.99	3
Germany	3.90	5	4.79	4	5.46	5
Brazil	2.30	7	3.24	7	3.34	7
Italy	1.67	9	1.97	9	2.21	9
France	1.74	10	1.96	10	2.04	10
Korea	2.10	8	2.23	8	2.34	8
Russia	4.20	6	4.20	6	4.3	6

M.T. = million tons, R= Rank

Source: Census of World Casting Production

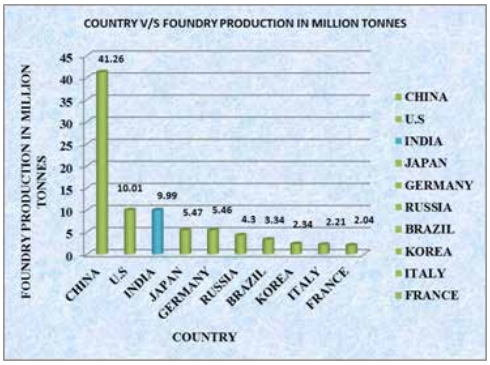

Figure 1 Foundry Production in World
Source: Census of World Casting Production

THE INDIAN FOUNDRY INDUSTRY

The impetus for foundry sector in India was given by the Jute industry in Bengal and the cotton industry in Mumbai in late 19th century. The establishment of TISCO, Bengal Iron Company and the IISCO led to some remarkable new uses of castings, in domestic as well as industrial areas.

India ranks second in the world based on the number of foundry units present (4550 units) - after China – and fourth in terms of total production (7.8 million tonnes) (42nd Census of World Casting Production – 2007). Apart from the registered 4550 units there are several unregistered units, which according to various sources range approximately from 1500 to 5000 units. As per the IREDA- CII Report 2004, there are around 10,000 foundry units present in India including registered and unregistered units. Considering that 4550 units are registered, the total number of units unregistered is around 5450 units. As per estimation of experts of the foundry sector, there are around 1500 unregistered foundry units that are scattered across the country. This discrepancy in unregistered units is mainly due to the fact that the 5450 units included all kinds of micro and small units engaged in castings. Whereas the 1500 units data incorporates only those foundry units that are engaged in grey iron casting and use conventional cupola and excludes those units that are too micro in nature and use crucible for melting of metals. Also several foundry units had closed due to non compliance with the pollution standard set by the government for example Howrah, Agra and nearby areas.

The foundry produces a wide variety of castings such as manhole covers, pipe and pipe fittings, sanitary items, tube well body, metric weights, automobile components, railway parts, electric motor, fan body etc. 90% of the castings produced are from the SSI sector. Most of these units are situated in clusters, with cluster size ranging from 30-500 units.

EXPORTS OF CASTINGS FROM INDIA

The export of Castings from India (both sanitary and industrial combined) has witnessed a steady growth consistently year after year from Rs.1,404 crores in 2001-02 to Rs.2,997 crores in 2005-06, almost doubled in five years. Year-wise break – up of exports is tabulated below: India today ranks tenth among casting exporting countries.

TABLE: 2
COUNTRY V/S FOUNDRY PRODUCTIONS: SCENARIO OF WORLD

Year	Sanitary Castings	Industrial Casting	Total
2001-02	524.00	880.00	1,404.00
2002-03	609.00	1,038.00	1,647.00
2003-04	867.00	1,058.00	1,925.00
2004-05	1,242.00	1,383.00	2,652.00
2005-06	1,530.00	1,467.00	2,997.00
Predicted 2011-12	2,536.00	2,054.00	4,590.00

Sources: Census of World Casting Production

FOUNDRY CLUSTERS OF INDIA

Figure: 2 Foundry Clusters
Source: Institute of Indian Foundry Man

AREA UTILIZATION

Foundry sand can be suitable for a variety of beneficial reuses. Terminology for defining uses varies across states. For the purposes of this study, common uses of sand in consultation with industry experts. The following are uses of foundry sand approved in one or more states:

Structural Fill

Foundry sand can be used as support for structures such as roadways, parking lots, buildings, and pieces of equipment. "Encapsulated" structural fill may involve the use of a liner, cap, or cover, generally made of a clay material, which prevents water from percolating through the foundry sand and minimizes the potential for leaching.

Manufacturing another Product

Foundry sand is useful as a raw material in manufacturing other products, such as controlled, low-strength material (CLSM or flowable fill), asphalt, cement, concrete, grout, lightweight aggregate, concrete block, bricks, roofing materials, plastics, paint, glass, ceramics, and rockwool.

Specific examples of these uses include:

- Flowable fill: Flowable fill is a liquid-like material that self-compacts and is used as a substitute for conventional soil backfill. The product is easily transported and can be readily re-excavated. The typical mixture contains sand, fly ash, portland cement, and water. Foundry sand can readily be substituted for virgin sand in flowable fill mixtures.
- Cement and Concrete: Sand is a component of Portland cement and concrete. Portland cement requires sand with a silica content of at least 80 percent, which most foundry sands meet. It also requires certain minerals such as iron and aluminum oxides, which are found in many foundry sands. Cement and additional sand or gravel are components of concrete, allowing further reuse of foundry sand.

Soil Manufacturing and Amendment

Commercial soil blending operations can use foundry sand to produce horticultural soils, topsoil, potting soil, and turf mixes. These soil products are typically mixtures of sand or gravel with peat, fertilizers, and/or top soil. Foundry sand can also improve the performance of agricultural soils, and can be used as a composting ingredient.

Landfill Uses

Foundry sand can be used as a cover for the working face of an active landfill, for road construction within the active cell, or as a substitute for virgin aggregate in the construction of drainage layers for landfill leachate collection systems.

Pipe Bedding and Backfill

Foundry sand can serve as backfill for trenches created by the installation of storm and sanitary sewer lines.

TYPES OF FOUNDRY SAND

Two general types of binder systems are used in metal casting depending upon which the foundry sands are classified as: clay bonded systems (Green sand) and chemically- bonded systems. Both types of sands are suitable for beneficial use but they have different physical and environmental characteristics

Green sand molds are used to produce about 90% of casting volume in the U.S. Green sand is composed of naturally occurring materials which are blended together; high quality silica sand (85-95%), bentonite clay (4-10%) as a binder, a carbonaceous additive (2-10%) to improve the casting surface finish and water (2- 5%). Green sand is the most commonly used recycled foundry sand for beneficial reuse. It is black in color, due to carbon content, has a clay content that results in percentage of material that passes a 200 sieve and adheres together due to clay and water.

Chemically bonded sands are used both in core making where high strengths are necessary to withstand the heat of molten metal, and in mold making. Most chemical binder systems consist of an organic binder that is activated by a catalyst although some systems use inorganic binders. Chemically bonded sands are generally light in color and in texture than clay bonded sands.

Figure: 3 chemically bonded sands
Source: foundry industry, GIDC, Vallabh Vidyanagar

Figure: 4 chemically bonded sands
Source: foundry industry, GIDC, Vallabh Vidyanagar

PHYSICAL CHARACTERISTICS OF FOUNDRY SAND

Foundry sand is typically sub angular to round in shape. After being used in the foundry process, a significant number of sand agglomerations form. When these are broken down, the shape of individual sand grains is apparent.

Figure: 5 Unprocessed Foundry Sand
Source: R. Siddique, Waste Materials and By-Products in Concrete, Springer-2008

Green sands are typically black, or gray, not green chemically bonded sand is typically a medium tan or off-white color Figures.5 & 6 shows the unprocessed foundry sand and green sand respectively

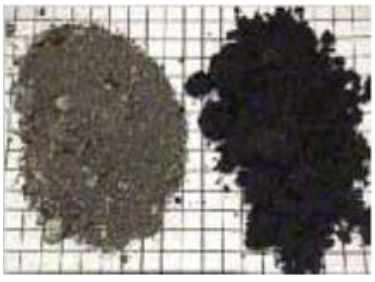

Figure: 6 Green Sands from a gray iron Industry
Source: R. Siddique, Waste Materials and By-Products in Concrete, Springer-2008

TYPICAL PHYSICAL PROPERTIES OF SPENT GREEN FOUNDRY SAND

TABLE: 3
TYPICAL PHYSICAL PROPERTIES OF SPENT GREEN FOUNDRY SAND
[American Foundry man's Society, 1991]

Property	Results	Test Method
Specific Gravity	2.39-2.55	ASTM D854
Bulk Relative Density, kg/m3 (lb/ft3)	2589(160)	ASTMC48 / AASTHO T84
Absorption, %	0.45	ASTM C128
Moisture content, %	0.1-10.1	ASTM D2216
Clay Lumps and Friable Particles	1- 44	ASTM C142/ AASTHO T112
Coefficient of Permeability (cm/sec)	10-3-10-6	AASTHO T215/ ASTM D2434
Plastic Limit/Plastic Index	Non plastic	AASTHO T90/ ASTM D4318

Source: R. Siddique, Waste Materials and By-Products in Concrete, Springer-2008

CHEMICAL COMPOSITION OF FOUNDRY SAND

TABLE: 4
CHEMICAL COMPOSITION OF FOUNDRY SAND

Constituents	Value (%)
SiO2	87.91
Al2O3	4.70
Fe2O3	0.94
CaO	0.14
MgO	0.30
SO3	0.09
Na2O3	0.19
K2O	0.25
TiO2	0.15
SrO	0.03
LOI	5.15

Source: R. Siddique, Waste Materials and By-Products in Concrete, Springer-2008

ADVANTAGES OF FOUNDRY SAND

- In Embankments
- In Barrier layers construction
- In Flowable fills
- In Road way construction
- As Soil reinforcement
- In Hot mix asphalt
- In Portland cement concrete

Other Engineering Application:

- Portland cement manufacturing
- Mortars
- Agriculture /soil amendments
- Verification of hazardous materials
- Smelting
- Rockwool manufacturing
- Fiberglass manufacturing
- Landfill cover or hydraulic barriers

LIMITATION

- Foundry sand is black. In some concretes, this may cause the finished concrete to have a grayish/black tint, which may not be desirable.
- A 15% fine aggregate replacement with foundry sand produces a minimal color change.
- Also, the foundry must be able to meet the quantity requirements of the precast manufacturer.
- Foundry sand reduced workability of concrete.

PROCESS FLOW DIAGRAM OF A FOUNDRY INDUSTRY

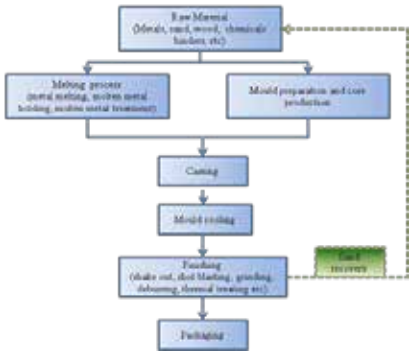

Figure: 7 Process Flow Diagram of a Foundry Industry
Source: Google Image

CASE STUDY

In the present study, effect of foundry sand as fine aggregate replacement on the compressive strength of concrete having mix proportions of 1:1.45:2.20:1.103 was investigated. The percentages of replacements were 0%, 10 %, 20% and 30 % by weight of fine aggregate. Tests were performed for compressive strength for all replacement levels of foundry sand at different curing periods (28-days & 56-days).

TABLE: 5
PROPORTION OF M-20 GRADE CONCRETE

Mix	C Kg/ m^3	F.A. kg/ m^3	C.A. (10 mm) Kg/m^3	C.A.(20 mm) Kg/m^3	F.S,Kg/ m^3	W (Lts/ m^3)	P(Lts/ m^3)
M-1	372	538.45	410.4	818.85	0	186	0.288
M-2	372	538.45	410.4	818.85	54	186	0.384
M-3	372	538.45	410.4	818.85	108	186	0.384
M-4	372	538.45	410.4	818.85	162	186	0.384

C=Cement, F.A. =Fine Aggregate, C.A. =Course Aggregate, F.S. =Foundry Sand, W=Water, P= Plasticizer

Source:dspace.thapar.edu:8080/dspace/bit tream/123456789/.../8042307.pdf

TABLE:6
COMPRESSIVE STRENGTH (MPA) OF CONCRETE WITH FOUNDRY SAND

Foundry Sand	Content, %	Mix	Avg.Compressive Strength, (MPa)
	28 days	56 days	0
M1	28.50	32.80	10
M2	29.70	33.13	20
M3	30.00	34.50	30
M4	31.30	37.50	

Source:dspace.thapar.edu:8080/dspace/bit-stream/123456789/.../8042307.pdf

CONCLUSIONS

We can say that for 1m3 M20 grade of concrete consumption of fine aggregate is 538.45 kg. Here in specimen M-4 we replace fine aggregate by 162 kg of foundry sand for 1m3 M20 grades of concrete. So, we can say that up to 30% foundry sand utilized for economical and sustainable development of concrete. Uses of foundry sand in concrete can save the metal industry disposal costs and produce a 'greener' concrete for construction. An innovative supplementary Construction Material is formed through this study.

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