An Experimental Investigation on Effects of Foundry sand on Concrete Interms of Characteristics of Strength

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Abstract : Foundry sand is a byproduct of ferrous and non ferrous metal casting industries. Because of its thermal conductivity sand has been used as a molding material. In metal foundries the metal is used for casting purpose. The sand used for foundries will be recycled and reused. The waste sand which is not reused will be removed from foundry. Here we will study about the applications of foundry sand in civil engineering disciplines which is environmentally safe. By this the problem of disposal of foundry sand is solved.

Foundry sand consists of silica sand, coated with a thin film of burnt carbon, residual binder and dust. Foundry sand can be used as partial replacement of fine aggregates or total replacement of fine aggregate. The percentages of replacements were 10, 20 and 30% by weight of fine aggregate. Here we investigated about the effects of foundry sand on properties of concrete in terms of compressive strength, split tensile strength and modulus of elasticity. Tests were performed at different curing periods i.e. 7, 14, 28 and 56 days respectively. Test results showed that there is an increase of compressive strength, split tensile strength and modulus of elasticity. So the use of foundry sand is safe in concrete for strength and durability purpose

***IndexTerms* – Foundry sand, Fine aggregate, Compressive Strength, Split Tensile strength, Flexure strength**

I. 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 shakeout 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. A schematic of the flow of sands through a typical foundry is shown in Fig.1.3. Although there are other casting methods used, including die casting and permanent mold casting, sand casting is by far most prevalent mold casting technique. Sand is used in two different ways in metal castings as a molding material, which focuses the external shape of the cast part and as cores that form internal void spaces in products such as engine blocks. Since sand grains do not naturally adhere to each other so binders must be introduced to cause the sand to stick together and holds its shape during the introduction of molten metal into mold and cooling of casting.

1.2 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.

Foundries produce Recycled Foundry Sand (RFS) generally in their overall production volume although there are different sand to metal ratios employed in different casting processes and products. Most foundries have two sand systems one feeding the external molding lines and the other feeding the internal core lines. After the metal is poured and the part is cooling, green sand is literally shaken off the castings, recovered and reconditioned for continual reuse. Used cores are also captured during this cooling and shake out process; these break down and are crushed and reintroduced into green sand systems to replace a portion of sand lost in the process. Broken cores are cores, which do not break down, are discarded. Depending on the projected end use, it may be important to segregate sand streams at the foundry as each stream can have different characteristics. Additionally some sand is typically unrecoverable during shake off and finishing processes. These sands may be contaminated with metals or very large chunks of burnt cores and will need to undergo some type of segregation, crushing and screening before recycling.

1.3 Material Properties

1.3.1 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. Green sands are typically black, or gray, not green chemically bonded sand is typically a medium tan or off-white color Figs.1 & 2 shows the unprocessed foundry sand and green sand respectively.

1.3.2 Physical Properties

Typical physical properties of spent foundry sand from green sand systems are given in Table-1.1. The grain size distribution of spent foundry sand is very uniform, with approximately 85 to 95 percent of the material between 0.6 mm and 0.15 mm (No. 30 and No. 100) sieve sizes. Five to 12 percent of foundry sand can be expected to be smaller than 0.075 mm (No. 200 sieve). The particle shape is typically sub angular to round. Waste foundry sand gradations have been found to be too fine to satisfy some specifications for fine aggregate.

Spent foundry sand has low absorption and is nonplastic. Reported values of absorption were found to vary widely, which can also be attributed to the presence of binders and additives. The content of organic impurities (particularly from sea coal binder systems) can vary widely and can be quite high. This may preclude its use in applications where organic impurities could be important (e.g., Portland cement concrete aggregate). The specific gravity of foundry sand has been found to vary from 2.39 to 2.55. This variability has been attributed to the variability in fines and additive contents in different samples .In general, foundry sands are dry, with moisture contents less than 2 percent. A large fraction of clay lumps and friable particles have been reported, which are attributed to the lumps associated with the molded sand, which are easily disintegrated in the test procedure. The variation in permeability, listed in Table-1.1, is a direct result of the fraction of fines in the samples collected.

Table-1.1 Typical physical properties of spent green foundry sand

[American Foundryman's Society, 1991]

Property	Results	Test methods
Specific gravity	2.39-2.55	ASTM D854
Bulk relative density, kg/m^3	2589(160)	ASTMC48/AASTHO T84
Absorption, %	0.45	ASTM C128
Moisture content, %	0.1-10.1	ASTM D2216

The quality of foundry sand can be quantified by its durability and soundness, chemical composition, and variability. Various aspects of foundry sand production influence these three characteristics. Durability/Soundness of foundry sand is important to ensure the long-term performance of civil engineering applications. Durability of the foundry sand depends on how the sand was used at the foundry. Successive molding can cause the foundry sand to weaken due to temperature shock. At later stages of mold use, this can lead to the accelerated deterioration of the original sand particles. However, in civil engineering uses, the foundry sand will not normally be subjected to such severe conditions. In geotechnical applications, foundry sand often demonstrates high durability.

1.3.3 Chemical Composition

Chemical Composition of the foundry sand relates directly to the metal molded at the foundry. This determines the binder that was used, as well as the combustible additives. Typically, there is some variation in the foundry sand chemical composition from foundry to foundry. Sands produced by a single foundry, however, will not likely show significant variation over time. Moreover, blended sands produced by consortia of foundries often produce consistent sands. The chemical composition of the foundry sand can impact its performance. Spent foundry sand consists primarily of silica sand, coated with a thin film of burnt carbon, residual binder (bentonite, sea coal, resins) and dust.

Silica sand is hydrophilic and consequently attracts water to its surface. This property could lead to moisture -accelerated damage and associated stripping problems in an asphalt pavement. Antis tripping additives may be required to counteract such problems. Depending on the binder and type of metal cast, the pH of spent foundry sand can vary from approximately 4 to 8 . It has been reported that some spent foundry sands can be corrosive to metals. Because of the presence of phenols in foundry sand, there is some concern that precipitation percolating through stockpiles could mobilize leach able fractions, resulting in phenol discharges into surface or ground water supplies. Foundry sand sources and stockpiles must be monitored to assess the need to establish controls for potential phenol discharges.

1.3.4 Mechanical Properties

Typical mechanical properties of spent foundry sand are listed in Table–1.2. Spent foundry sand has good durability characteristics as measured by low Micro-Deval abrasion and magnesium sulfate soundness loss tests. The Micro-Deval abrasion test is an attrition/abrasion test where a sample of the fine aggregate is placed in a stainless steel jar with water and steel bearings and rotated at 100 rpm for 15 minutes. The percent loss has been determined to correlate very well with magnesium sulfate soundness and other physical properties. Recent studies have reported relatively high soundness loss, which is attributed to samples of bound sand loss and not a breakdown of individual sand particles. The angle of shearing resistance (friction angle) of foundry sand has been reported to be in the range of 33 to 40 degrees, which is comparable to that of conventional sands.

Table-1.2. Typical mechanical properties of spent foundry sand
[American Foundryman's Society, 1991]

Property	Results	Test Methods
Micro-Devil Abrasion Loss, %	< 2	_
Magnesium Sulphate Soundness Loss, %	5-15 6-47	ASTM C88
Friction Angle (deg)	33-40	_
California Bearing Ratio	4-20	ASTM D1883

1.4 Handling of Foundry Sand

Foundry sand is most often collected and stockpiled outside of the foundries, exposed to the environment. Prior to use in an engineering application, the majority of foundry sand is:

- Collected in closed trucks and transported to a central collection facility
- Processed, screened, and sometimes crushed to reduce the size of residual core sand pieces. Other objectionable material, such as metals, is removed.

1.5 Foundry Sand Economics

The success of using foundry sand depends upon economics. The bottom line issues are cost, availability of the foundry sand and availability of similar natural aggregates in the region. If these issues can be successfully resolved, the competitiveness of using foundry sand will increase for the foundries and for the end users of the sand. This is true of any recycled Material.

1.6 Foundry Sand Engg. Characteristics

Since foundry sand has nearly all the properties of natural or manufactured sands, it can normally be used as a sand replacement. It can be used directly as a fill material in embankments. It can be used as a sand replacement in hot mix asphalt, flowable fills, and Portland cement concrete. It can also be blended with either coarse or fine aggregates and used as a road base or sub base material.

1.7 Foundry Sand Environmental Characterization

Trace element concentrations present in most clay-bonded iron and aluminum foundry sands are similar to those found in naturally occurring soils. The leachate from these sands may contain trace element concentrations that exceed water quality standards; but the concentrations are no different than those from other construction materials such as native soils or fly ashes. Environmental regulatory agencies will guide both the foundry sand supplier and the user through applicable test procedures and water quality standards. If additional protection from leachate is desired, mechanical methods such as compacting and grading can prevent and further minimize leachate development. In summary, foundry sand suppliers will work with all potential users to ensure that the product meets environmental requirements for the engineering application under consideration. Foundry sand can be used to produce a quality product at a competitive cost under normal circumstances.

1.8 Current Management Options

1.8.1 Recycling

In typical foundry processes, sand from collapsed molds or cores can be reclaimed and reused. Some new sand and binder is typically added to maintain the quality of the casting and to make up for sand lost during normal operations. Five different foundry classes produce foundry sand. The ferrous foundries (gray iron, ductile iron and steel) produce the most sand and the rest is produced by Aluminum, copper, brass and bronze. The 3,000 foundries in the United States generate 6 million to 10 million tons of foundry sand per year. While the sand is typically used multiple times within the foundry before it becomes a byproduct, only 10 percent of the foundry sand was reused elsewhere outside of the foundry industry in 2001. The sands from the brass, bronze and copper foundries are generally not reused. While exact numbers are not available, the best estimate is that approximately 10 million tons of foundry sand can beneficially be used annually. Fig.3 shows how the sand is reused and becomes foundry sand. Little information is available regarding the amount of foundry sand that is used for purposes other than in-plant reclamation, but spent foundry sand has been used as a fine aggregate substitute in construction applications and as kiln feed in the manufacture of Portland cement.

1.8.2 Disposal

Most of the spent foundry sand from green sand operations is land filled, sometimes being used as a supplemental cover. This is true of any recycled material.

1.8.3 Market Sources

Foundry sand can be obtained directly from foundries. Foundry sand, prior to use, is a uniformly graded material. The spent material, however, often contains metal from the casting and oversized mold and core material containing partially degraded binder. Spent foundry sand may also contain some leach able contaminants, including heavy metals and phenols that are absorbed by the sand during the molding process and casting operations. Phenols are formed through high-temperature thermal decomposition and rearrangement of organic binders during the metal pouring process. Heavy metals are of greater concern in nonferrous foundry sands generated from nonferrous foundries. Spent foundry sand from brass or bronze foundries, in particular, may contain high concentrations of cadmium, lead, copper, nickel, and zinc. Foundry sand can be used to produce a quality product at a competitive cost under normal circumstances.

II. EXPERIMENTAL PROGRAMME

2.1 Object of Testing

The main objective of testing was to know the behavior of concrete with replacement of ordinary sand with foundry sand at room temperature. The main parameters studied were compressive strength, split tensile strength, modulus of elasticity. The materials used for casting concrete samples along with tested results are described.

2.2 Test Results of Materials Used In Present Work

2.2.1 Cement

IS mark 43 grade cement (Brand-ACC cement) was used for all concrete mixes. The cement used was fresh and without any lumps. Testing of cement was done as per IS: 8112-1989. The various tests results conducted on the cement are reported in Table 2.1

Table 2.1 Properties of cement

S.NO	Characteristics	Values Obtained	Standard Value
1.	Normal Consistency	34%	-
2.	Initial Setting Time (Minutes)	48 min.	Not less than 30
3.	Final Setting Time (Minutes)	240 min.	Not greater than 600
4.	Fineness (%)	3.5%	< 10
5.	Specific Gravity	3.07	-

2.2.2 Coarse aggregate

Locally available coarse aggregates having the maximum size of 10 mm and 20mm were used in the present work. Testing of coarse aggregates was done as per IS: 383 -1970. The 10mm aggregates used were first sieved through 10mm sieve and then through 4.75 mm sieve and 20mm aggregates were firstly sieved through 20mm sieve. They were then washed to remove dust and dirt and were dried to surface dry condition. The results of various tests conducted on coarse aggregate are given in Table 2.2

Table 2.2 Properties of Coarse aggregates

S.No	Characteristics	Value
1.	Type	Crushed
2.	Maximum Size	20 mm
3.	Specific Gravity (10mm)	2.704
4.	Specific Gravity (20mm)	2.825
5.	Total Water absorption (10mm)	1.6432 %
6.	Total Water absorption (20mm)	3.645 %
7.	Moisture content (10mm)	0.806 %
8.	Moisture content (20mm)	0.7049 %
9.	Fine modulus (10mm)	6.46
10.	Fine modulus (20mm)	7.68

2.2.3 Fine Aggregate

Fine aggregate are soil particles that pass through a 4.25 mm sieve, the soil or aggregate retained on this seive is classified as coarse aggregates. Fine aggregates are usually river Sand or Machine sand. The sand used for the experimental programme was locally procured and conformed to grading zone III as per IS: 383-1970.

The sand was first sieved through 4.75 mm sieve to remove any particles greater than 4.75 mm and then was washed to remove the dust. Properties of the fine aggregate used in the experimental work are tabulated in Table 2.3

Table 2.3 Properties of fine aggregates

S.No	Characteristics	Value
1.	Type	Uncrushed (natural)
2.	Specific Gravity	2.68
3.	Total Water absorption	1.02 %
4.	Moisture content	0.16 %
5.	Fine modulus	2.507
6.	Grading Zone	III

2.2.4 Foundry Sand

Investigations were made on foundry sand procured from Janta Foundries, Mandi Gobindgarh and Punjab. The chemical and physical properties of the foundry sand used in this investigation are listed in Table 2.4

Table 2.4 Physical Properties of Foundry Sand

Property	Results	Test methods
Specific gravity	2.47	ASTM D854
Bulk relative density, kg/m^3	2589(160)	ASTMC48/AASTHO T84
Absorption, %	0.45	ASTM C128
Moisture content, %	0.1-10.1	ASTM D2216
Plastic limit/Plastic Index	Nonplastic	AASTHO T90/ASTM D4318
Coefficient of Permeability (cm/sec)	10^{-3}-10^{-6}	AASTHO T215/ASTM D2434

2.2.5 Water

Potable tap water was used for the concrete preparation and for the curing of specimens.

2.2.6 Super plasticizer

Super plasticizer complies with IS: 9103: 1999, ASTM C – 494 Type F, BS 5057 part III. The dosage of super plasticizer varied from 0.5% to 2% by weight of cement in plain concrete, concrete incorporating foundry sand. Technical data of Super plasticizer are listed in Table 2.5

Table 2.5 Technical data of Super plasticizer

S.No	Characteristics	Value
1.	Color	Dark Brown Liquid
2.	Specific Gravity @ 30° C	1.220 to 1.225
3.	Air Entrainment	Maximum 1 %
4.	Chloride Content	Nil

III. RESULTS AND DISCUSSIONS

Various properties of concrete incorporating foundry sand at various replacement levels with fine aggregate were studied, results were compared and checked for compressive strength, split tensile strength and flexure strength of foundry sand mix with ordinary mix.

3.1 Compressive Strength

In this research the values of compressive strength for different replacement levels of foundry sand contents (0%, 10%, 20% and 30%) at the end of different curing periods (7, 14, 28 & 56 days) are given in Table 3.1. These values are plotted in figures below, which show the variation of compressive strength with fine aggregate replacements at different curing ages respectively.

Table 3.1: Compressive Strength (MPa) of Concrete with Foundry Sand

COMPRESSIVE STRENGTH (MPa)					
FOUNDRY SAND CONTENT (%)	DESIGNATION	7 DAYS	14 DAYS	28 DAYS	56 DAYS
0	M1	18.81	25.08	28.5	32.8
10	M2	19.602	26.136	29.7	33.13
20	M3	19.8	26.40	30	34.5
30	M4	20.658	27.544	31.3	37.5

3.2 Split Tensile Strength

It was found that split tensile strength of concrete incorporating foundry sand (using 10 %, 20 % and 30 % replacement levels with fine aggregate and a w/c of 0.5) depended on the percentage of foundry sand used The variation of split tensile strength was shown in below Table. In this experiment the split tensile strength increases with the increase in replacement of percentage of sand with foundry sand at 28 & 56 days.

Table 3.2: SPLIT TENSILE STRENGTH (MPa) OF CONCRETE WITH FOUNDRY SAND

Split Tensile Strength (MPa)					
Foundry sand content (%)	Designation	7Days	14 DAYS	28 Days	56 Days
0	M1	1.6	2.18	2.5	3
10	M2	1.79	2.44	2.8	3.2
20	M3	1.82	2.45	2.85	3.3
30	M4	1.92	3.61	3.00	3.6

3.3 Flexure strength

In this experiment it was found that flexural strength of concrete incorporating foundry sand (using 10 %, 20 % and 30 % replacement levels with fine aggregate and a w/c of 0.5) depended on the percentage of foundry sand used. The variation of flexural strength was shown in below Table.

Table 3.3:
FLEXURE STRENGTH (MPa) OF CONCRETE WITH FOUNDRY SAND

Flexure Strength (MPa)					
Foundry sand content (%)	*Designation*	*7Days*	*14 DAYS*	*28 Days*	*56 Days*
0	M1	5.33	5.78	6.78	7.13
10	M2	5.78	6.35	7.17	7.89
20	M3	6.38	6.80	7.90	8.36
30	M4	7.10	7.67	8.67	8.83

IV. RESULTS AND DISCUSSIONS

The following conclusions are drawn from this study:

1. Compressive strength of concrete increased with the increase in sand replacement with different replacement levels of foundry sand. However, at each replacement level of fine aggregate with foundry sand, an increase in strength was observed with the increase in age.
2. The compressive strength increased by 4.2%, 5.2%, & 9.8% when compared to ordinary mix without foundry sand at 14-days.
3. Compressive strength at 28 days increased by 1.0 %, 5.18 %, & 14.3% compared to ordinary mix.
4. Compressive strength at 56 days increased by 1.2 %, 5.7 %, & 15.8% compared to ordinary mix.
5. Split Tensile Strength also showed an increase with increase in replacement levels of Foundry Sand with fine aggregate. Split Tensile Strength also increased with increase in age.

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