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TO EXAMINE CHARACTERISTIC STRENGTH OF CONCRETE WITH THE REPLACEMENT OF SAND BY FOUNDRY SAND

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ABSTRACT

With increasing quantities of waste materials and industrial by-products, solid waste management is the prime concern in the world. Metal casting processes in metal foundaries consumes large amount of sand. During these processes, foundries recycle and reuse the sand many times and the remaining sand which is left as waste is removed. This waste sand is termed as foundry sand. Due to scarcity of land-filling space and its ever increasing cost, recycling and utilization of industrial by-products and waste materials has become an attractive proposition to disposal. So, such a byproduct of metal casting industries can be used in construction, building materials and in other fields for reduction of environmental problems. Research has being carried out for its possible utilization in making concrete as partial replacement of fine aggregate. In India, approximately 1.71 million tons of waste foundry sand and in Punjab region, approximately 0.17 million tons of waste foundry is produced yearly. This study reveals the information about the applications foundry sand in civil engineering.

Foundry sand consists of silica sand, coated with a thin film of burnt carbon, residual binder (such as bentonite, sea coal, resins) and dust. Foundry sand of such an suitable physical properties can be used in concrete to enhance its strength and workability. Fine aggregates can be partially replaced with foundry sand or cement with foundry sand or total replacement of fine aggregate to attain different properties of concrete.

In the present study, foundry sand is used as fine aggregate replacement on the compressive strength, split tensile strength and flexural strength of concrete having mix proportions of 1:1.95:2.17:1.403 was being investigated. Fine aggregates were being replaced with four percentages of foundry sand. The percentages of replacements were 0%, 15%, 30%, 45% and 60 % by weight of fine aggregate. Laboratory tests that were being performed for compressive strength, split tensile strength and flexural strength for all replacement levels of foundry sand at different curing periods (28-days & 56-days). Workability of each level of foundry sand concrete were being investigated.

Test results concluded that there is some increase in compressive strength, split tensile strength and flexural strength after replacing the fine aggregates with certain percentage of foundry sand. Hence, foundry sand can be safely used in concrete for durability and strength purposes.

I. INTRODUCTION

General

Foundry sand consists uniformly sized, high-quality silica sand or lake sand that is bonded to form molds for ferrous (iron and steel) and nonferrous (aluminium, copper, brass) metal castings. Although, foundry sand is typically recycled and reused through many production cycles. In an industrial estimate around the globe, approximately 100 million tons of sand is used during production. Ferrous (iron and steel) industries consumes approximately 95 percent of foundry sand for castings. The automotive industry and its parts makers are the major generators of foundry sand.

The raw sand used in casting is of higher quality than typical bank run or natural sands. The sands forms the outer shape of the mold cavity. These sands consist of a small amount of bentonite clay to act as the binder material. In addition, chemical binders are used to create sand "cores". While depending upon the geometry of the casting, sands cores are inserted into the mold cavity to allow internal passages for the molten metal. When the metal becomes solid, the casting is separated from the mold and core sands during the shakeout process. Molding sands used are recycled and reused multiple number of times in the casting process. Eventually, a stage occur when the recycled sand start degrading and it could not be further reused in the casting process. At that situation, the old sand is being taken out from the cycle as byproduct and instead of it new sand is introduced, and the cycle continues. Although there are some other casting methods used, like die casting and permanent mold casting. Foundry sand is being used in two different ways during metal castings process as a molding material, one focuses on the external shape of the cast part and while the other on cores that forms internal void spaces in products such as engine blocks. Moreover, sand grains do not naturally adhere to each other so binders must be introduced to allow the sand to stick together and form firm to hold its shape during the introduction of molten metal into mold and cooling of casting.

The waste sand is sand that cannot be reused in the foundry because it does not confirm to the foundry standards for input sand. It is sent out of the system boundary for reuse in cement industries or disposal to Landfill. Used foundry sand can be reused in various applications as an alternative to sending it to landfill, and reuse options are well established in England, Europe and North America. Reuse options include cement manufacture, asphalt, concrete, bricks and free-flow fill for certain construction applications. Some of these alternatives are starting to be adopted in India, but is still in early stage. Overseas examples show that it is not only better for the environment but is profitable for the foundry to use the sand alternatively. These foundries have significantly reduced the volume of waste sand going to landfill.

II. LITERATURE REVIEW

Reddi et al., 1995 reported that compressive strength of stabilized foundry sands decreases as the replacement proportion of foundry sand increases in the mixes and the strength is achieved relatively faster with fly ash than with cement. Cement and fly ash mixtures were prepared using 0%, 25%, 50%, 75%, & 100% levels of replacement of silica sand by foundry sand. . Initial experiments with class F fly ash were unsuccessful because it lacked cementitious properties to form a stable mix therefore subsequent experiments were restricted to class C fly ash only. The ratio of water to the cementious binder was chosen to be 1.0 in the case of Portland cement and 0.35

in the case of fly ash.

The samples were founded in PVC pipes, 2.85 cm in dia. and 5.72 cm long. The mixtures of sands and the binders were poured into these pipes and then vibrated on a vibrating table to

minimize air pockets. For each of the replacement levels, compressive strengths were obtained after 3, 7, 14, 28,

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& 56 days in order to evaluate the difference due to curing time. The clay bonded foundry sand reduced the strength of the stabilized mixes more than the resin- bonded foundry sands. A similar observation is made in context of fly ash stabilization. The drastic reduction in strength with an increase in clay- bonded foundry sand replacement is apparent in the cases of both fly ash & cement. Cement – stabilized mixes acquired their strength considerably slower than fly ash stabilized mixes. After 7 days of curing the cement-stabilized RBS reached only 30% of peak strength whereas its fly ash counterpart achieved 80% of its peak strength.

Tikalsky et al., 1998 reported that the swelling potential and instability of bentonite-stabilized mixes render the leachable quality unpredictable. The data on total phenolic obtained from leachability experiments were normalized to account for difference in volumes of leachates collected for each stabilized mix. In the experiments with cement & fly ash mixtures were prepared using 0%, 25%, 50%, 70%, &100% levels of silica sand by foundry sand. This normalization was important for unequal amounts of foundry sand used with each of four binders. To provide a basis for comparison among the four binders, treatment efficiencies were calculated representing the percentage of total phenolics immobilized due to stabilization process. The treatment efficiencies

III. EXPERIMENTAL PROGRAMME

Object of testing

The main objective of doing this research work was to study the behaviour of concrete with replacement of ordinary sand with foundry sand at room temperature.

The main parameters covered were compressive strength, split tensile strength, flexural strength. All the materials used for casting concrete samples along with tested results are illustrated.

Test Results of Materials Used In Present Work

Cement

IS mark 43 grade cement (Brand-ACC cement) was used in 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 3.1.

Table 3.1 Properties of cement

S. No.	Characteristics	Values obtained	Standard value
1.	Normal consistency	34%	-
2.	Initial setting time (minutes)	45 min.	Not less than 30
3.	Final setting time (minutes)	245 min.	Not greater than 600
4.	Fineness (%)	3.5 %	<10
5.	Specific gravity	3.05	-

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Coarse aggregates

Maximum size of 10 mm and 20 mm locally available coarse aggregates were used in the present work. Testing of coarse aggregates was done as per IS: 383-1970. Firstly, 10mm aggregates were sieved through 10mm sieve

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and then through 4.75 mm sieve. Secondl y, 20mm aggregates were sieved through 20mm sieve. Then they were 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 3.2, Table 3.3 & Table 3.4

Table 3.2 Properties of Coarse aggregates

S. No.	Characteristics	Value
1.	Type	Crushed
2.	Maximum size	20 mm
3.	Specific gravity (10 mm)	2.703
4.	Specific gravity (20 mm)	2.823
5.	Total water absorption (10 mm)	1.6432 %
6.	Total water absorption (20 mm)	3.645 %
7.	Moisture content (10 mm)	0.806 %
8.	Moisture content (20 mm)	0.7049 %
9.	Fineness modulus (10 mm)	6.46
10.	Fineness modulus (20 mm)	7.82

Table 3.3 Sieve analysis of 10 mm aggregates

S. No.	Sieve No.	Mass Retained (gms)	Percentage Retained, %	Percentage Passing, %	Cumulative %age Retained
1.	80 mm	-	0.00	100	0.00
2.	40 mm	-	0.00	100	0.00
3.	20 mm	-	0 .00	100	0.00
4.	12.5 mm	556	18.5	81.5	18.5
5.	10 mm	892	29.73	51.77	48.23
6.	4.75 mm	955	31.83	19.94	80.06
7.	Pan	597	19.9	0.04	99.96
				ΣC =	146.79

Fineness Modulus of Coarse aggregate (10 mm) = ΣC+500/100 = 146.79+500/ 100 = 6.46.

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Table 3.6 Sieve analysis of fine aggregate

S. No.	Sieve No.	Mass Retained (gms)	Percentage Retained, %	Percentage Passing, %	Cumulative %age Retained
1.	4.75 mm	10	1.0	99	1.0
2.	2.36 mm	64	6.4	92.6	7.4
3.	1.18 mm	233	23.3	69.3	30.7
4.	600 µm	171	17.1	52.2	47.8
5.	300 µm	337	33.7	18.5	81.5
6.	150 µm	147	14.7	3.8	96.2
7.	Pan	38	3.8	0	100
				ΣF =	264.6

Fineness Modulus of fine aggregate = ΣF/100 = 264.6/100 = 2.64

Foundry Sand

Investigations were made on foundry sand occupied Insaf foundry, Mandi Gobindgarh, Punjab. The physical and chemical properties of the foundry sand used in experimental work are listed as in Table 3.7 and Table 3.8 respectively. Tables 3.9 to 3.12 shows the sieve analysis for various replacement levels of sand with foundry sand.

Table 3.7 Physical Properties of Foundry Sand

Property	Results	Test Method
Specific Gravity	2.47	ASTM D854
Bulk Relative Density, kg/m^3	2589	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	Nonplastic	AASTHO T90/ASTM D4318

Superplasticizer

Increase in waste foundry sand content in concrete mixes may lead to decrease the slump value of concrete. Although, increase in fine particle of waste foundry sand in concrete mixes can lead to increase the surface area of the fine aggregate with constant water cement ratio. To maintain the slump value, a poly-carboxylic ether

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based superplasticizer (Sika viscocrete-10R) of SIKA brand complying with BIS: 9103–1999 was being used. Specifications of superplasticizer are given in Table 3.13

Table 3.13 Technical data of Superplasticizer

S. No	Characteristics	Value
1.	Colour	Brown liquid
2.	Specific gravity @ 30˚ C	1.220 to 1.225
3.	pH	Approx. 5.0
4.	Chloride content	Nil

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specimens to the determinations of split tensile strength. All the specimens were prepared as per Indian Standard Specifications IS: 516-1959.All the moulds were first cleaned and t h e n oiled properly. Moulds were securely tightened to correct dimensions before casting. Care was being taken that there is no gaps left for leakage of slurry.

Mix designation

Concrete mix has been designed based according to Indian Standard Recommended Guidelines IS: 10262-2009. The proportions for the concrete, as determined were 1:1.95:2.17:1.403 with a water cement ratio of 0.44 by weight. The mix designation and quantities of various materials for each designed concrete mix have been listed in Table 3.14 and 3.15 for cubes and cylinders.

Table 3.14 Mix Designation

Grade of concrete	Concrete Type	Designation	Percentage binder ratio		Slump Test (mm)
			Sand (%)	Foundry Sand (%)	Results
M-30	Control Mix	M-1	100	0	85
	Foundry Sand concrete	M-2	85	15	82
		M-3	70	30	78

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		M-4	55	45	75
		M-5	40	60	70

Table 3.15 Proportion of M-30 Grade Concrete

Concrete Type	Cement Kg/m^3	Fine Aggregate kg/m^3	Course Aggregate (10mm) Kg/m^3	Course Aggregate (20mm) Kg/m^3	Foundry Sand Kg/m^3	Water (Lts/m^3)
M-1	360	704.38	522	782	0	156
M-2	360	598.78	522	782	105.6	156
M-3	360	493.5	522	782	211.31	156
M-4	360	387.33	522	782	316.97	156
M-5	360	281	522	782	422.58	156

Batching, Mixing and Casting of Specimens

During the batching, mixing and casting operations proper procedure was adopted. The coarse aggregates and fine aggregates were b e i n g weighed first with an accuracy of 0.5 grams. The concrete mixture was being prepared by hand mixing on a watertight platform. OPC having 43 grades was b e i n g used in casting. Four proportions of fine aggregates were replaced with foundry sand and w a s thoroughly mixed. After that the coarse aggregates were being added to it. Superplasticizer was added to the required quantity of water separately in different containers. Then water was added carefully so that no water was lost during mixing. Six clean and oiled moulds for each category were placed on the vibrating table respectively for the cubical samples for compression strength testing and six for cylindrical moulds for split tensile and flexural mould for flexural strength . Vibrations were stopped as soon as the cement slurry appeared on the top surface of the mould.

The specimens were allowed to remain in the steel mould for the first 24 hours at room condition. After that these were demoulded with proper care so that no edges were broken and were placed in the curing tank at the room temperature for curing. The room temperature for curing was 27 ± 2^0

VI. CONCLUSIONS

The following conclusions are drawn from this study:

1. The Compressive strength of concrete increases with the increase in sand replacement with different replacement levels of foundry sand. However, there was decrease in the compressive strength as compared to normal concrete mixture with replacement level more than 45% of foundry sand. Although, an increase in

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strength was observed with the increase in age.

2. The compressive strength increased by 1.01%, 3.18%, & 6% when compared to ordinary mix without foundry sand at 28-days.
3. Compressive strength at 56 days increased by 1.6 %, 4.04 %, & 5.55% compared to ordinary mix.
4. In this study, maximum compressive strength is obtained at 45% replacement of fine aggregate by waste foundry sand.
5. Split Tensile Strength also showed an increase with increase in different replacement levels of Foundry Sand with fine aggregate. But after 45% of foundry sand replacement it showed marginal decrease.
6. Split Tensile Strength also increased with increase in age.
7. There was increase in flexural strength of concrete upto 45% replacement.
8. Use of foundry sand in concrete reduces the production and disposal of waste through metal industries.
9. With the increase in percentage of foundry sand in concrete, the slump value decreases.

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