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An Experimental Study on Strength of Concrete by Partial Replacement of Cement with Foundry Sand

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ABSTRACT: Foundry Sand is clean, very uniformly sized, high quality silica Sand used by metal foundries as part of metal casting and moulding processes. After several cycles of reuse within the Foundry industry, the Sand degrades and eventually becomes a waste, constituting one of the most voluminous bi-products from foundries. This creates a serious solid waste management problem, mainly due to the large amounts of Foundry Sand produced worldwide. Until recently, this Sand was either disposed on-site or to a local landfill site. As landfill space is declining, and land filling prices rising, the main business problem for foundries is the cost issue linked with the disposal of spent Foundry Sand. Reuse and recycling opportunities for used Foundry Sand instead of land filling are therefore better option. [Foundry Sand can be used in Concrete to improve its strength and other durability factors. It was shown that despite its fineness foundry sand could be mixed with concrete without apparent difficulty and give highly workable mixes. In the present paper, effect of Foundry Sand as fine aggregate replacement on the Compressive strength, split Tensile strength and Modulus of Elasticity of Concrete having mix proportions of 1:1.45:2.20:1.103 was investigated. Fine aggregates were replaced with three percentages of foundry sand. The percentages of replacements were 10, 20 and 30 % by weight of fine aggregate at different curing periods (28,-days & 56-days). Test results showed that there is some increase in compressive strength, split tensile strength and modulus of elasticity after replacing the fine aggregates with certain percentage of foundry sand.

Key Words: Foundry Sand, Compressive Strength, Split Tensile Strength, Modulus of Elasticity.

I. INTRODUCTION

Foundry Sand is clean, very uniformly sized, high quality silica Sand used by metal foundries as part of their metal casting and moulding processes. The primary metals that are cast include iron and steel (ferrous) and aluminium, copper, brass and bronze (non-ferrous). Bonding agents can be clay (producing the so called 'green Sand') or chemical binders [2]. The Sand used for metal casting can be repeatedly recycled, crushed down to a raw Sand material and used again for casting (especially so in foundries that use green Sand); however, at a certain point, old Foundry Sand degrades and becomes unsuitable A-704 for further recycling within the Foundry [3] . At this point it is discarded as a Foundry by-product, and new Sand is used for the casting process. This spent (waste) Foundry Sand is one of the most voluminous by-products from foundries that has been historically disposed of in landfills. This creates a serious solid waste management problem, mainly due to the large amounts of Foundry Sand produced world wide [7]. As Foundry Sand is basically a fine aggregate, it is reasonable to anticipate that it could be used in many of the applications where natural Sands are used. This would have the additional advantage of saving in natural aggregate, conserved due to the substitution of primary natural Sand with Foundry Sand [1]. 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 clown and are crushed and reintroduced into Sand systems to replace a portion of Sand lost in the process. Broken cores are cores, which do not break down, are discarded [6]. Depending on the projected end use, it may he 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 sans 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 [4].

Typical physical properties of spent Foundry Sand from green Sand systems are given in Table 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). [5]. 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. Typical mechanical properties of spent Foundry Sand are listed in Table 2. Waste Foundry Sand has good durability properties as measured by low Micro-Deval abrasion (Ontario Ministry of Transportation, Canada 1996). Javed and Lovell (1994) have revealed relatively high soundness loss.

Table1: Typical Physical Properties of Spent Green Foundry Sand[American Foundrymans Society, 1991].

Property	**Results**	**Test Method**
Specific Gravity	2.39-2.55	ASTM D854
Bulk Relative Density, kg/m^3 ($1b/ft^{3)}$	2589 (160)	ASTM C48/AASTHO T84
Absorption, %	.45	ASTM C 128
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
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Plastic Limit/Plastic Index	Non Plastic	AASTHO T90/ASTM D4318

Table 2: Typical Mechanical Properties of Spent Foundry Sand [American Foundryman's Society, 1991].

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

II. EXPERIMENTAL PROGRAMME

The main objective of testing was to know the behaviour 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.

Testing of cement was done as per IS : 8112-1989. The various tests results conducted on the cement are reported in Table 3.

A. 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 20 mm aggregates were firstly sieved through 20mm sieve. They were then washed to remove dust and dirt and were dried to surface dry condition.

Table 3: Properties of Cement.

S.No.	Characteristics	Values obtained	Standard Value
1.	Normal Consistency	31%	-
2.	Initial Setting Time (minutes)	46 min.	>= 30
3.	Final Setting Time (minutes)	243 min.	<= 600
4.	Fineness (%)	3.6%	<10
5.	Specific Gravity	3.09	-

Table 4: Properties of Coarse Aggregates.

S.No.	Characteristics	Value
1.	Type	Crushed
2.	Maximum Size	20 mm
3.	Specific Gravity (10 mm)	2.668
4.	Specific Gravity (10 mm)	2.821
5	Total Water Absorption (10mm)	1.6448%
6.	Total Water Absorption (20 mm)	0.7054%
7.	Moisture Content (10 mm)	0.811%
8.	Moisture Content (20 mm)	0.7056%
9.	Fineness Modulus (10mm)	6.51
10.	Fineness Modulus (20 mm)	7.64

The results of various tests conducted on coarse aggregate are given in Table 4.

III. RESULTS & DISCUSSION

The values of Compressive strength & Split Tensile Strength for different replacement levels of Foundry Sand contents (0%, 10%, 20% and 30%) at the end of different curing periods (28 days, 56 days) are given in Table 5 & 6 respectively. These values are plotted in figs. 2 &4, which show the variation of Compressive Strength & Split Tensile Strength with fine aggregate replacements at different curing ages respectively. . It is evident from Fig. 2 & 4 that Compressive Strength & Split Tensile Strength of Concrete mixtures with 10%, 20% and 30 % of Foundry Sand as Sand replacement was higher than the control mixture (M-1) at all ages and that the strength of all mixtures continued to increase with the age. Fig. 2 shows that Compressive strength increases with the increase in Foundry Sand. The Compressive strength increases by 4.2%, 5.2%, & 9.8% when compared to ordinary mix without Foundry Sand at 28-days. Figs. 4 show the Split Tensile Strength (at 28 and 56 days) with respect to percentage replacement of Sand by Foundry Sand. Compressive strength at 56 days increases by 1.0 %, 5.18 %, & 14.3% compared to ordinary mix. Compressive strength at 56 days was 15%, 12%, 15%, & 20% higher than the 28 days Compressive strength. Figs. 5 shows the Modulus of Elasticity (at 23 and 56 days) with respect to different replacement levels. Compressive strength increases with age at different replacement levels.

Table 5: Compressive Strength of Concrete with Foundry Sand with various levels of Replacement of Foundry Sand.

Foundry Sand Content, %	Designation	Compressive Strength, MPa	
		28 Days	56 Days
0	M-1	27.5	33.8
10	M-2	28.7	34.13
20	M-3	30.0	33.50
30	M-4	31.30	36.50

Fig. 1. Testing Cube Failure on Compression Testing Machine (CTM).

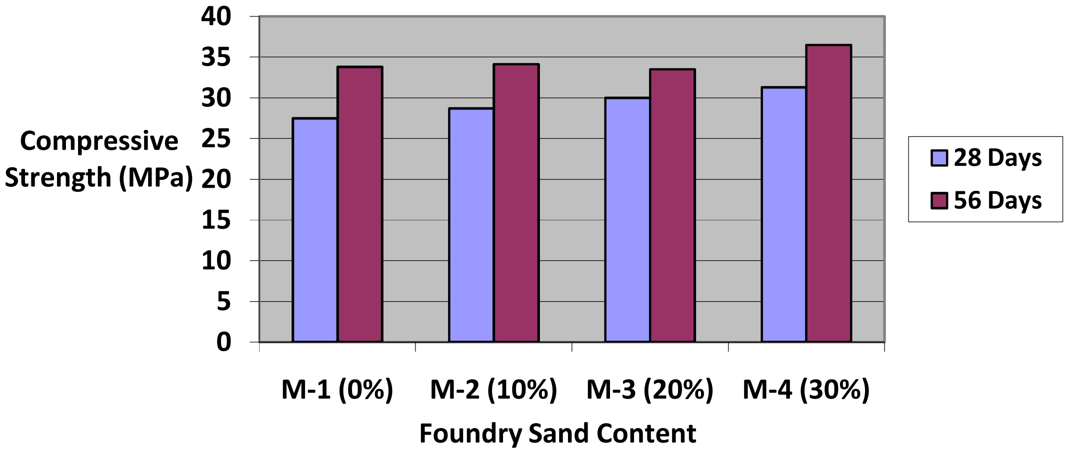

Fig. 2. Compressive Strength of Concrete with various levels of replacement of Foundry Sand after 28 & 56 days.

A.Split Tensile Strength

It was found that split Tensile strength of Concrete incorporating Foundry Sand (using 10%, 205 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 Table 6. Fig. 3 shows the variation of Split Tensile strength with replacements of Foundry Sand with various levels of fine aggregate at 28-days.

It shows that Split Tensile Strength increases with the increase in replacement of percentage of Sand with Foundry Sand at 56-days. For control mix, split Tensile strength was increase by 12%, 14%, and 20% with respect to different replacement levels of Sand with Foundry Sand at 28 days. At 56 days the Split Tensile Strength varies as 6%, 10% & 20% than control mix without Foundry Sand to the various replacement levels.

Table 6: Split Tensile Strength (MPa) of Concrete with various levels of replacement of Foundry Sand.

Foundry Sand Content, %	**Designation**	**Split Tensile Strength, MPa**	
		28 Days	**56 Days**
0	M-1	2.6	3.1
10	M-2	2.9	3.3
20	M-3	2.89	3.4
30	M-4	3.1	3.7

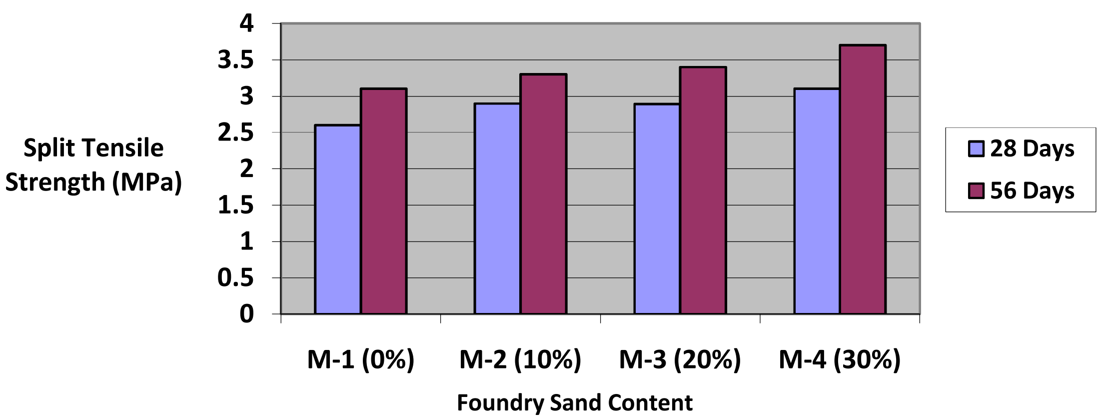

Fig. 3. Split Tensile Strength (MPa) of Concrete with various levels of replacement of Foundry Sand after 28 & 56 Days.

B. Modulus of Elasticity

In this investigation, the Modulus of Elasticity of Concrete mixtures were determined at the age of 28 & 56 days at various levels of replacement of fine aggregates with Foundry Sand with w/c ratio of 0.5.At 28-days, control mix M-1 (with 0% replacement level of Foundry Sand) achieved Modulus of Elasticity of 25.10 GPa, whereas mixtures M-2 (10% Foundry Sand), M-3 (20% Foundry Sand), and M-4 (30% Foundry Sand) achieved Modulus of Elasticity of 26.74, 29.11, and 31.11 GPa, respectively. However at 56-days it also showed a increase in values of Modulus of Elasticity by achieving the values of 27.19, 29.11, 31.12 and 33.20 MPa for mixtures M-1, M-2, M-3, & M-4 respectively. So the results show that Modulus of Elasticity increase with age as well as replacement of Foundry Sand. Table 7 shows the results for Modulus of Elasticity of Concrete for various levels of Replacement of Foundry Sand.. Fig. 4 shows the variation of Modulus of Elasticity at (at 28 and 56 days) with respect to age at various replacement levels of fine aggregates by Foundry Sand.

Table 7: Modulus of Elasticity (GPa) of Concrete with Various levels of Replacement of Foundry Sand.

Foundry Sand Content, %	**Designation**	**Modulus of Elasticity (GPa)**	
		28 Days	**56 Days**
0	M-1	26.13	28.17
10	M-2	27.79	30.23
20	M-3	29.34	31.19
30	M-4	32.18	34.37

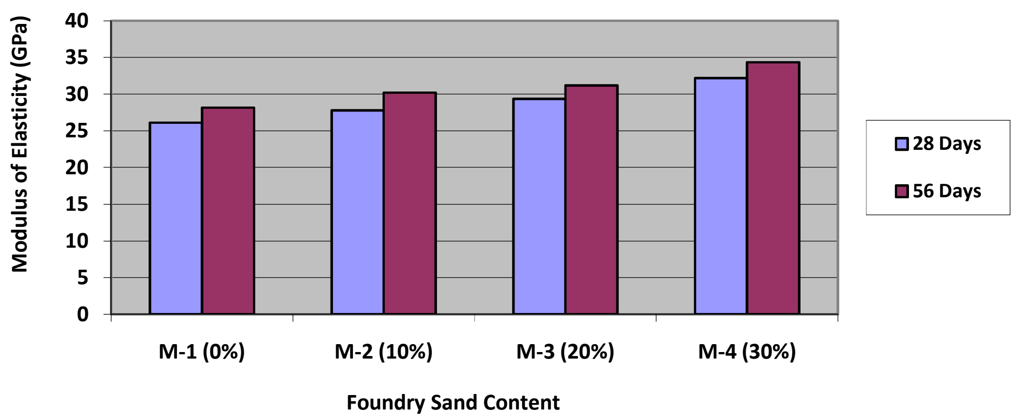

Fig. 4. Modulus of Elasticity (GPa) of Concrete with Various levels of Replacement of Foundry Sand.

IV. CONCLUSIONS

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 28-days.
3. Compressive strength at 56 days increased by 1.0 %, 5.18 %, & 14.3% compared to ordinary mix.
4. Split Tensile Strength also showed an increase with increase in replacement levels of Foundry Sand with fine aggregate.
5. Split Tensile Strength also increased with increase in age.
6. At 28-days, control mix M-1 (with 0% replacement level of Foundry Sand) achieved Modulus of Elasticity of 25.10 MPa, whereas mixtures M-2 (10% Foundry Sand), M-3 (20% Foundry Sand), and M-4 (30% Foundry Sand) achieved Modulus of Elasticity of 26.74, 29.11, and 31.11 GPa respectively.
7. At 56-days it also showed an increase in values of Modulus of Elasticity by achieving the values of 27.19, 29.11, 31.12 and 33.20 GPa for mixtures M-1, M-2, M-3, & M-4 respectively. So the results showed that Modulus of Elasticity increase with age as well as replacement of Foundry Sand.

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