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Strength Properties of Concrete Incorporating Foundry Sand and Ceramic Aggregates

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ABSTRACT: - The paper present, an attempt has been made to assess the suitability of Used Foundry Sand and ceramic waste in concrete making. In the laboratory Used Foundry Sand has been tried as fine aggregate in place of sand and ceramic waste has been used as partial substitute to conventional coarse aggregate by 15%, 20%, and 30% in concrete making. Cubes, cylinders and prisms were cast and tested for compressive strength, split tensile strength and modulus of rupture after a curing period of 28 days. The results indicated effectiveness of Used Foundry Sand as fine aggregate and partial replacement of conventional coarse aggregate by ceramic waste up to 15%, 20% with out affecting the design strength.

Keywords: *Ceramic Waste, Compressive Strength, Foundry Sand, Flexural Strength, Tensile Strength*

I. INTRODUCTION

In recent years, initiatives have been taken on a global and national level to regulate waste management. Regulations have become increasingly rigorous and consequently, options which are still rarely used at present, such as minimizing or recycling waste, are becoming economically attractive. All recycling and reuse of waste products involves research aimed at acquiring a full understanding of such products in order to determine suitable and specific applications.

Foundry sand is high quality silica sand with uniform physical characteristics. Foundries attempt to reuse as much of sand as possible within the foundry process itself, but eventually a fraction becomes spent and unsuitable for further foundry processes. At the moment, 90% of this waste is disposed of to landfill as non-hazardous waste while only 10% is beneficially reused. The disposing of UFS to landfill is becoming increasingly cost prohibitive and is likely to become more difficult as legislation governing waste disposal becomes more stringent. Currently about 500,000 to 700,000 tons of foundry sand is used annually in engineering applications. In the present study, steps have been taken to partially replace the fine aggregate with Used Foundry Sand. Used foundry sand (UFS) contains a variety of inorganic and organic binding agents required for the production of sand casts in the foundry process.

Large metal contaminants in the UFS can be removed by using screening or magnetic separators, which generally ensure that in terms of metal and inorganic contaminants, UFS can be classified as a non-hazardous industrial by-product. However, organic contaminants are also a major component of the binder and may be retained within the sand to various degrees depending on the foundry process. In particular, aluminium casting, which generally occurs at lower temperatures, is likely to result in higher concentrations of organic residues. Depending on the particular foundry, these organic residues could include phenolic, PAHs, isocyanides and a variety of organic compounds formed during the foundry process.

There is also considerable variability in the contaminant profiles of UFS between foundries and often within a foundry due to temporal variations. Foundries attempt to reuse as much of the sand as possible within the foundry process itself, but eventually a fraction becomes spent and unsuitable for further foundry processes. In US, ferrous and non-ferrous foundries generate more than six million tonnes of UFS that can no longer be recycled in the foundry process (Dungan et al. 2006). At the moment 90% of this waste is disposed of to landfill as non-hazardous waste while only 10% is beneficially reused (US EPA 2002).

The practice of disposing of UFS to landfill is becoming increasingly cost prohibitive and is likely to become more difficult as legislation governing waste disposal becomes more stringent. A more cost-effective alternative is to utilise the spent foundry sand in a by-product that generates revenue for the foundry. Considerable savings to industry are therefore possible through development of a reuse application for UFS.

In typical foundry processes, sand from collapsed moulds 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 (grey iron, ductile iron and steel) produce the most sand and the rest is produced by Aluminium, copper, brass and bronze foundries. While the sand is typically used multiple times within the foundry before it becomes a by-product, only 10 percent of the foundry sand was reused elsewhere outside of the foundry industry. The sand from the brass, bronze and copper foundries is 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.1 shows how the sand is reused and becomes foundry sand.

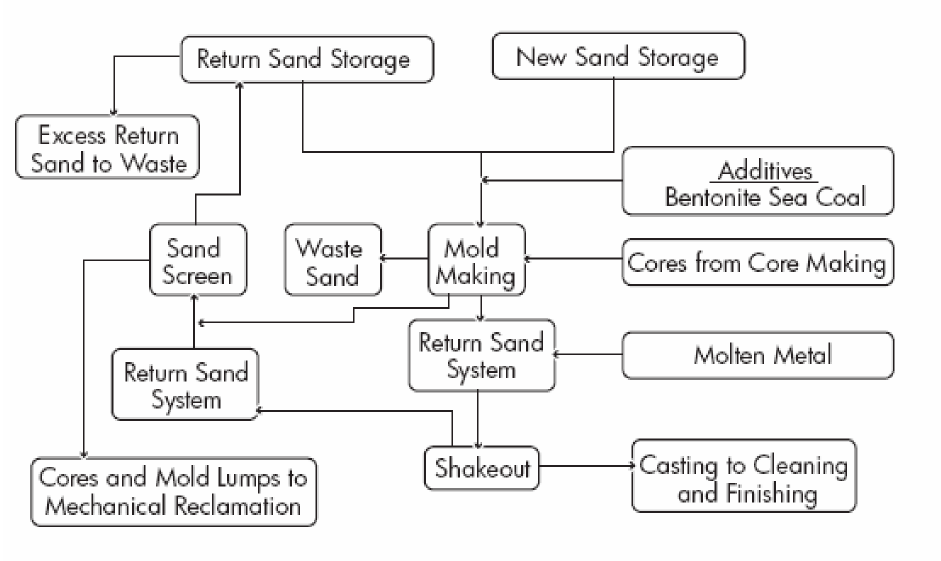

Fig. 1 Recycling of Foundry Sand

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. An attempt has been made to examine the effect of replacing sand with foundry sand on concrete properties relating to strength.

II. MATERIALS AND PROPERTIES

2.1 Cement

Cement is the most important ingredient of concrete. One of the important criteria for the selection of cement is its ability to produce improved microstructure in concrete. Ordinary Portland Cement 43 grade is used.

2.2 Fine Aggregate - Regular Sand

Aggregates are important constituent of concrete. Ordinary river sand was used as fine aggregate. Fine Aggregate passing through 4.75 mm was used in the concrete mixes. Testing of aggregates was done as per IS: 383-1970. Various tests for fine aggregate were conducted. Properties of regular sand are presented in Table.1.

2.3 Fine Aggregate - Foundry Sand

Sand is typically sub - angular to round in shape. Foundry Sand 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 grey, not green chemically bonded sand is typically a medium tan or off-white colour. Various tests for fine aggregate were conducted. Properties of foundry sand are presented in Table.2. Fig.2 and Fig. 3 show the Unprocessed Foundry and Green Sands from Iron.

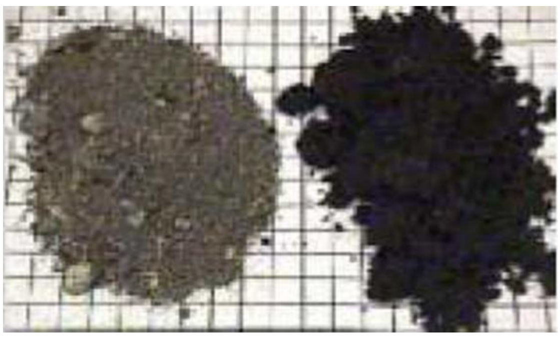

Fig.2 Unprocessed Foundry

Fig. 3 Green Sands from Iron

Table 1 Properties of Regular Sand

Characteristics	Value
Specific Gravity	2.65
Fineness Modulus	5.182%
Bulking of Sand	1286 kg/m³
Grading Zone	Zone III

Table 2 Properties of Foundry Sand

Characteristics	Value
Specific Gravity	2.39-2.55
Bulk Relative Density Kg/ m^3	2589
Absorption (%)	0.45
Moisture content (%)	0.1-1.1

2.4 Coarse Aggregate - Blue Metal

Machine crushed granite obtained from a local Quarry was used as coarse aggregate. Coarse aggregate having a maximum size of 12 mm was used in the present study. Testing of aggregates was done as per IS: 383-1970 and properties of blue metal are presented in Table 3.

Table 3 Properties of Blue Metal

Characteristics	Value
Maximum Size	10mm
Specific Gravity	2.65
Crushing Value	22.47%
Fineness Modulus	3.65
Bulking of Aggregates	1537.33 Kg/ m^3

2.5 Ceramic Waste

The ceramic wastes such as sanitary waste were broken into small pieces about 5 – 40 mm sizes. These small pieces are then fed into vibrator sieved to get the required 12.5 mm size. Fig. 4 shows the sample of ceramic waste coarse aggregates.

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Fig. 4 Ceramic Waste

2.6 Water

Water is an important ingredient of concrete as it chemically participates in the reactions with cement to form hydration product, C-S-H gel. The strength of cement concrete depends mainly on the binding action of the hydrated cement paste gel. A higher water cement ratio or water binder ratio will decrease the strength, durability, water- tightness and other related properties of concrete.

2.7 Super plasticizer

Super plasticizers are chemicals used as admixtures where well dispersed particle suspension are required. Hyper plasticizer, a concrete super plasticizer based on Sulphated Naphthalene Polymer was used as a water-reducing admixture to improve the workability of concrete containing foundry sand. GLENIUM B233 has been specially formulated to give high water reductions up to 25% without loss of workability or to produce high quality concrete of reduced permeability. Technical data of Super plasticizer is listed in Table 4.

III. EXPIREMENTAL PROGRAMME

M 30 grade of concrete was designed as per IS code. The proportion of concrete was presented in Table 5.

Table 4 Technical data of Super plasticizer

Sl. No	Characteristics	Value
1	Colour	Dark Brown liquid
2	Specific gravity @ 30˚ C	1.220 to 1.225
3	Air entrainment	Maximum 1%
4	Chloride content	Nil

Table 5 Proportion of Concrete Mix

1	Mass of Cement in kg/m^3	585
2	Mass of Water in kg/m^3	220
3	Mass of Fine Aggregate in kg/m^3	584
4	Mass of Coarse Aggregate in kg/m^3	1018
5	Mass of Admixture in kg/m^3	2.925
6	Water Cement Ratio	0.375

3.1 CASTING

Cube of size 150 mm were cast by replacement of coarse aggregate by ceramic waste and fine aggregate by foundry sand starting from 0 to 30% with an increment of their weight and are represented as 0%, 15%, 20% and 30% respectively. The earlier procedure was followed for Cylinders of size 150 mm x 300 mm and prisms of size100 mm x 100 mm x 500 mm respectively. Details of specimens are presented in Table.6. The cleaning of mould, preparation of concrete, curing of specimens and drying of specimens are shown in Figs. 5 to 8.

Table 6 Details of Specimens

Sl. No.	Specimen Description	Cubes (nos)	Cylinder (nos)	Prism (nos)
1.	Conventional Concrete	3	3	3
2.	(15% replacement of C.A & F.A)	3	3	3
3.	(20% replacement of C.A & F.A)	3	3	3
4.	(30% replacement of C.A & F.A)	3	3	3

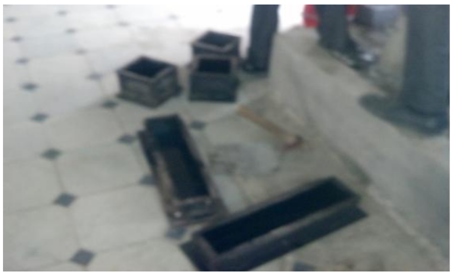

Fig. 5 Cleaning of Mould

Fig. 6 Preparation of Concrete

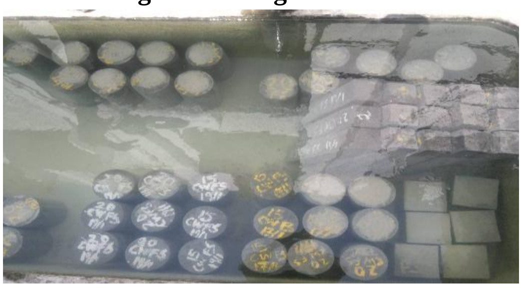

Fig. 7 Curing of Specimens

Fig. 8 Drying of Specimens

IV. RESULTS AND DISCUSSION

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

4.1 Compressive Strength

The values of compressive strength for different replacement levels of foundry sand and ceramic waste contents (0%, 15%, 20% and 30%) at the end of different curing periods (7 days, 14 days and 28 days). These values are plotted in Fig.10, which show the variation of compressive strength with fine aggregate and coarse aggregate replacements at different curing ages respectively. The test set up for compressive strength test on the cube specimen and typical failure pattern is shown in Fig. 9.

Fig. 9 Test Set - up for Cube Specimen

It is evident from Fig. 10 that cube compressive strength of concrete with 15%, 20% and 30% of foundry sand and ceramic waste replacement was higher than the control concrete at all ages and that the strength continued to decrease with age. Compressive strength for different replacement levels of foundry sand and ceramic waste (0%, 15%, 20% and 30%) at the end of different curing periods (7 days, 14 days and 28 days). Fig.11 shows that compressive strength of cylinder also increases with the increase in ceramic waste and foundry sand. The compressive strength increases by 4.2%, 5.2%, in the 15% and 20% replacement& decreases at 30% replacement when compared to ordinary mix without foundry sand at 28-days.

4.2 Split Tensile Test of Concrete Cylinder

This is an indirect test to determine the tensile strength of the specimen. Splitting tensile strength tests were carried out on 150 mm x 300 mm cylinder specimen at the age of 28days, using 400 T capacities HEICO compression testing machine as per BIS: 516-1970. The load was applied gradually till the specimen splits and readings were noted.

The splitting tensile strength has been calculated using the following formula

$$f_{sp} = 2P / \pi DL$$

Where

f_{sp} = split tensile strength of the specimen in MPa
P = maximum load in "N"applies to the specimen
D = measured diameter in 'mm' of the specimen, and
L = measures length in 'mm' of the specimen

Fig.12 shows that split tensile strength increases with the increase in replacement of percentage of ceramic waste and foundry sand at 28-days but it decreases as it. For control mix, split tensile strength was increase by 15% with respect to 20% replacement levels where the 0% replacement is 2.28 MPa and 20% is 2.91MPa and there was a decreases with 15% and 30% replacement of sand with foundry sand and ceramic waste at 28 days.

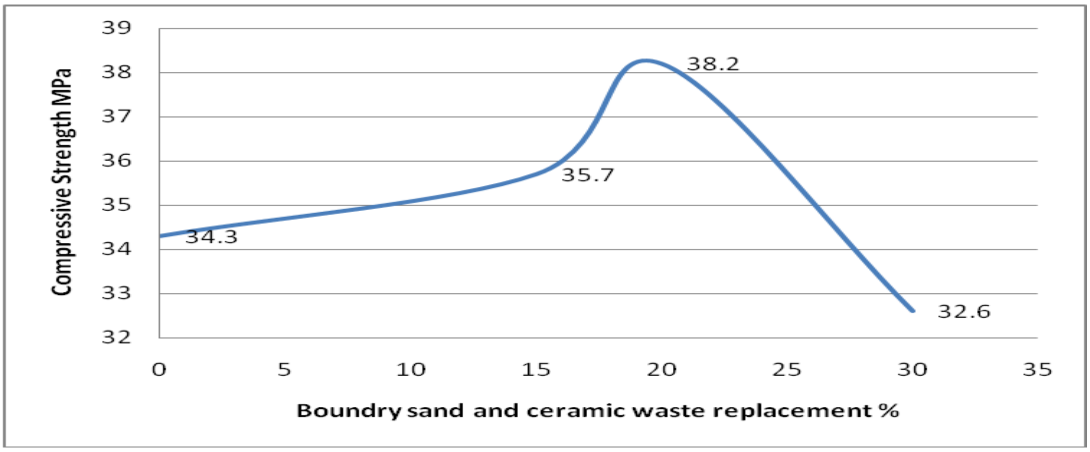

Fig. 10.Compressive Strength of Concrete Cube with Foundry Sand and Ceramic Waste

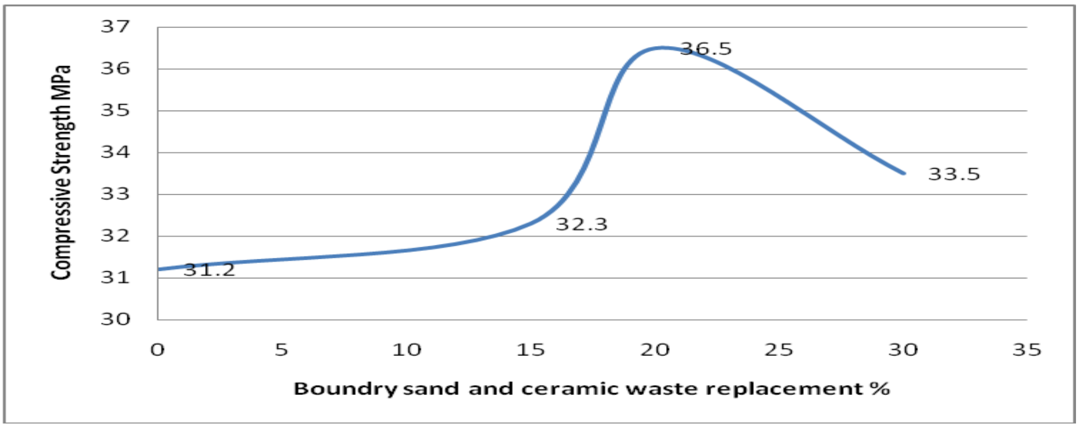

Fig. 11 Compressive Strength of Concrete Cylinder with Foundry Sand and Ceramic Waste

4.3 Flexure Test

Flexural strength test was carried out on 100 mm x 100 mm x 500 mm specimens at the age of 28 days, using 10 Tons capacity CTM by subjecting the specimen to two point loading to determine the flexural strength as per BIS: 516-1970. The test was conducted in two different types of loading applied at single point and at two points (third point loading). The test set - up for the flexural strength test with the necessary settings and typical failure pattern is shown in Fig.13.

The flexural strength or modulus of rupture has been calculated using the following formula for the applications of the various systems of loads

For single point load

$f_b = (P \times L) / b\,d^2$

For three point load

$f_b = (2P \times L) / 3b\,d^2$

Where

F_b = flexural tensile strength of the specimen in MPa

P = Maximum load in "N" applied to the specimen

L = length in "mm" of the span on which the specimen was supported

b = measured width in "mm" of the specimen and

d = measured depth in "mm" of the specimen at the point of failure.

Fig.14 shows that flexural strength of prism for replacement of percentage of ceramic waste and foundry sand at 28-days.

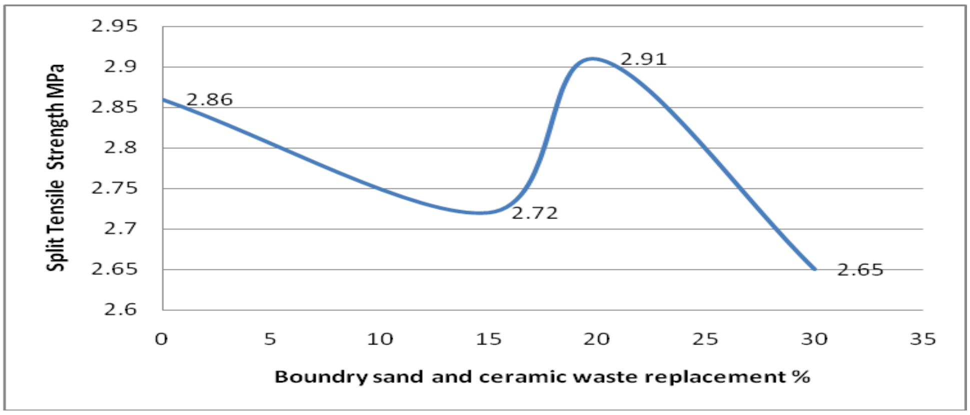

Fig.12 Split Tensile Strength of Concrete with Foundry Sand and Ceramic

Fig. 13 Test Set - up for Prism Specimen

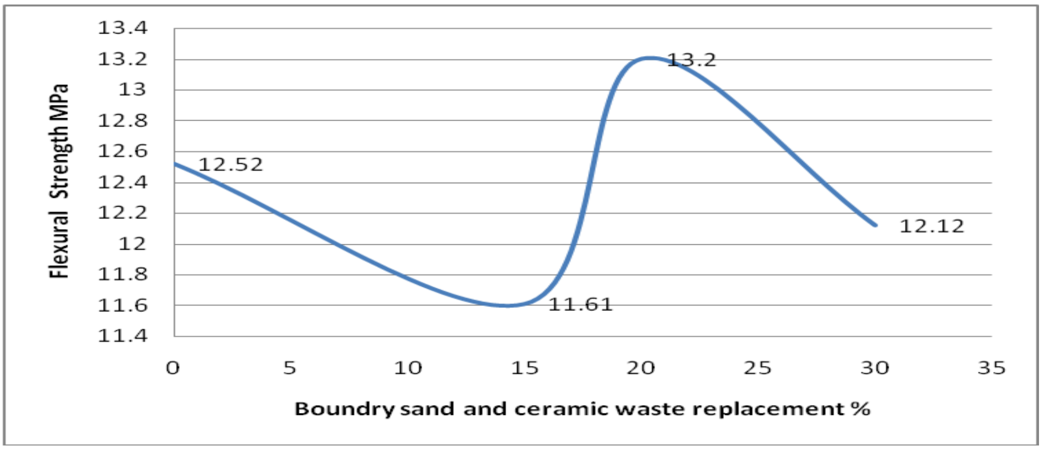

Fig. 14 Flexural Strength of Concrete with Foundry Sand and Ceramic Waste

V. CONCLUSION

Based on results of experimental investigations the following conclusions were made

- Compressive strength of concrete increases in 20% replacement of fine aggregate and coarse aggregate with foundry sand and ceramic waste were observed
- Split Tensile Strength concrete increases in 20% replacement of fine aggregate and coarse aggregate with foundry sand and ceramic waste were observed
- Flexural strength concrete increases in 20% replacement of fine aggregate and coarse aggregate with foundry sand and ceramic waste were observed
- Ceramic waste and foundry sand were partially used to replacement of conventional aggregates and the replacement of 15% and 30% shows decrease in all strength parameter and 20% replacement shows an increase in strength parameter.

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