DESIGN & DEVELOPMENT OF CONCRETE USING WASTE FOUNDRY SAND AS PARTIAL REPLACEMENT OF FINE AGGREGATE

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ABSTRACT

Due to ever increasing quantities of waste materials and industrial by-products, solid waste management is the prime concern in the world. Scarcity of land-filling space and because of its ever increasing cost, recycling and utilization of industrial by-products and waste materials has become an attractive proposition to disposal. There are several types of industrial by-products and waste materials. The utilization of such materials in concrete not only makes it economical, but also helps in reducing disposal concerns. One such industrial by-product is Waste Foundry Sand (WFS).

This paper investigate the effect of waste foundry sand content on compressive strength, splitting tensile strength and chloride ion permeability of M30 (46 MPa) Grade of concrete. Fine aggregate was replaced by 0, 5, 10, 15 and 20% of WFS by mass. All tests were conducted at the age of 28 and 365 days.

Keywords: Compressive strength, splitting tensile strength, RCPT, waste foundry sand.

1. INTRODUCTION

Waste Foundry sand (WFS) is a byproduct from the production of both ferrous and nonferrous metal castings. It is high quality silica sand. Foundries use high quality size-specific silica sands for use in their molding and casting operations. In the casting process, molding sands are recycled and reused many times. When it is not possible to further reuse sand in the foundry, it is removed from the foundry and is termed as waste foundry sand.

As per American Foundry men's Society in United States alone, foundry 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 are used in other industries and Indian foundries produce approximately 1.71 million tons of waste foundry sand each year, Metal World.

Classification of foundry sands depends upon the type of binder systems used in metal casting. Two types of binder systems are generally used, and on the basis of that foundry sands are categorized as: clay-bonded sands (green sand) and chemically-bonded sands. Clay-bonded (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%). It is black in color due to carbon content.

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. Chemically bonded sand consists of 93-

99% silica and 1-3% chemical binder. The most common chemical binder systems used are phenolic-urethanes, epoxy-resins, furfyl alcohol and sodium silicates. Chemically bonded sands are generally light in color and in texture than clay bonded sands.

There is not much published work on the use of WFS in concrete. Use of waste foundry sand in concrete and concrete related products like bricks, blocks and paving stones has been reported by Khatib and Ellis (2001) , Naik et al. (2003, 2004) , Siddique et al. (2009), Etxeberria et al.(2010) and Guney et al.(2010) .

Khatib and Ellis (2001) investigated compressive strength of concrete containing foundry sand as a partial replacement of natural sand. Natural sand replaced by three type of foundry sand white fine sand without the addition of clay and coal, the foundry sand (blended) and WFS. Replacement % of natural fine sand class M with foundry sand was 0%, 25%, 50% and 100%. They concluded that (i) strength of concrete was decreased due to increasing the replacement % of foundry sand; and (ii) concrete incorporating white sand and WFS gives more strength than concrete made with blended foundry sand.

Naik et al. (2003) concluded that cast concrete products could be suitably made and up to 35% of sand in brick and block could be replaced with either bottom ash (BA) or used foundry sand (UFS) for use where forest action is not a concern. Naik et al. (2004) showed that, wet cast brick unit that meet the minimum compressive strength requirement of ASTM for grade N brick (24 MPa) could be produced using WFS, fly ash and bottom ash.

Siddique et al. (2009) reported that (i) compressive strength, splitting tensile strength, flexure strength and MOE of concrete mixes increased with increase in waste foundry sand (0 to 30% at an increment of 10%); (i) Mechanical properties of concrete mixes increase with age(up to 365 days) for all the foundry sand content; (iii) 8% to 19% compressive strength increased depending upon WFS % and testing age and (iv) 6.5% to 14.5% splitting tensile strength, 7% to 12% flexure strength and 5% to 12% modulus of elasticity increased with age and waste foundry sand content.

Etxeberria et al. (2010) investigated the properties of concrete using metallurgical industrial by product as aggregate**.** They used chemical foundry sand (QFS), green foundry sand (GFS) as a partial replacement of fine aggregate and blast furnace slag (BFS) as a partial replacement of coarse raw aggregate.. They concluded that concrete made with chemically foundry sand and green foundry sand obtained more compressive strength, tensile strength and modulus of elasticity than conventional concrete when made with high water cement ratio.

Guney et al.(2010) investigated the re-usage of WFS (0, 5, 10, and 15%) in high strength concrete. It was observed that increase in the replacement level of standard fine sand with WFS, decrease the compressive strength, tensile strength and MOE of concrete, but similar compressive, tensile and MOE were obtained from the specimen with 10% WFS and control one.

2. EXPERIMENTAL

2.1 Materials

The mixes constituent were cement, fine aggregate, coarse aggregate and waste foundry sand. Pozzolana Portland cement (fly ash based) was used. Various tests on cement were performed as per Indian standard BIS-1489 part 1:1991 (given in Table 1). Fine aggregate was grade II sand which conformed to BIS- 383-1970 and coarse aggregate was 12.5 mm size crushed. Waste foundry sand was obtained from the foundry unit. Superplasticizer was used for maintain the flow workability Various physical properties of Fine and coarse aggregate were given in Table 2 and chemical properties of waste foundry sand are given in Table 3.

Table 1: Properties of Cement

Cement	Specific gravity	Compressive St (28 days)	Consistency	Initial setting time	Final setting time
PPC	3.07	47.8 MPa	35%	92 min	248min

Table 2: Physical Properties of Aggregate

Properties	Natural Sand	Coarse Aggregate	WFS
Specific Gravity	2.68	2.7	2.18
Fineness Modules	2.64	6.35	1.89
Water absorption (%)	1.2	1.14	0.42
Moisture content (%)	0.16	Nil	0.11
Material finer than 75 µ (%)	0.5	------	8
Clay lumps and friable particles (%)	------	------	0.8

Table 3: Chemical Composition of WFS

Constituent	SiO_2	Al_2O_3	TiO_2	CaO	MgO	Fe_2O_3	Na_2O	K_2O	SO_3	Mn_3O_4	SrO
Value (%)	83.8	0.81	0.22	1.42	0.86	5.39	0.87	1.14	0.21	0.047	----

2.2 Mix proportations

A control concrete mixture (CM-1) was designed as per (BIS: 10262-1982) to have 28 day compressive strength of 40 MPa. Four more concrete mixes (CM-2, CM-3, CM-4 and CM-5) were made by replacement of fine aggregate with waste foundry sand. Replacement percentage was 5%, 10%, 15% and 20%. Concrete mix proportions are given in Table 4

Table 4: Concrete Mix Proportions.

Mix	Cement (Kg/m^3)	Fine Agg. (Kg/m^3)	Coarse Agg. (Kg/m^3)	WFS %	WFS (Kg/m^3)	W/C ratio
CM1	450	554	1139	0	0	0.42
CM2	450	524	1139	5	27	0.42
CM3	450	500	1139	10	54	0.42

CM4	450	471	1139	15	80	0.42
CM5	450	443	1139	20	111	0.42

2.3 Casting, curing and testing

150 mm cubes were cast for conducting the compression test. 150 x 300 mm cylinders were cast to conduct the splitting tensile strength test. Cylindrical specimens (100 x 200mm) were cast for conducting Rapid Chloride Permeability Test (RCPT). After casting the test specimen, all specimens were cured for 24 h in air. After 24 h, all test specimens were taken out from the mould, and placed in tank for water curing. All specimens were casted at room temperature

Compressive strength test was conducted on 150 mm cube in accordance with (BIS: 516-1959). 150 x 300 mm cylinders were used for splitting tensile strength test (BIS: 5816-1999). Tests were performed at the age of 28 and 365 days. For determined the durability properties of concrete, Rapid Chloride Permeability Test (ASTM 1202 C) was performed on 200 x100 mm cylindrical specimen.

3. RESULTS

3.1 Compressive Strength

Compressive strength of concrete mixes CM-1, CM-2, CM-3, CM-4 and CM-5 (M30 grade concrete) with and without WFS sand was determined at the age of 28 and 365days shown in Figure 1. It was observed that concrete mixes made with WFS exhibited higher compressive strength than control mix (CM-1). Compressive strength of control mix was 40 MPa at the age of 28 days. From these results, it was found that 28-day compressive strength increased by 8.25%, 12.25%, 17% and 13.25% for mixes CM-2,CM-3, CM-4 and CM-5 respectively than the strength (40 MPa) of control mix CM-1 (0% WFS). At 365 days, increase in strength was 7.17%, 14.99%, 16.29% and 15.21% for CM-2, CM-3, CM-4 and CM-5 mixes respectively. It was also observed that compressive strength of all concrete mixes increased with age (28 to 365 days).

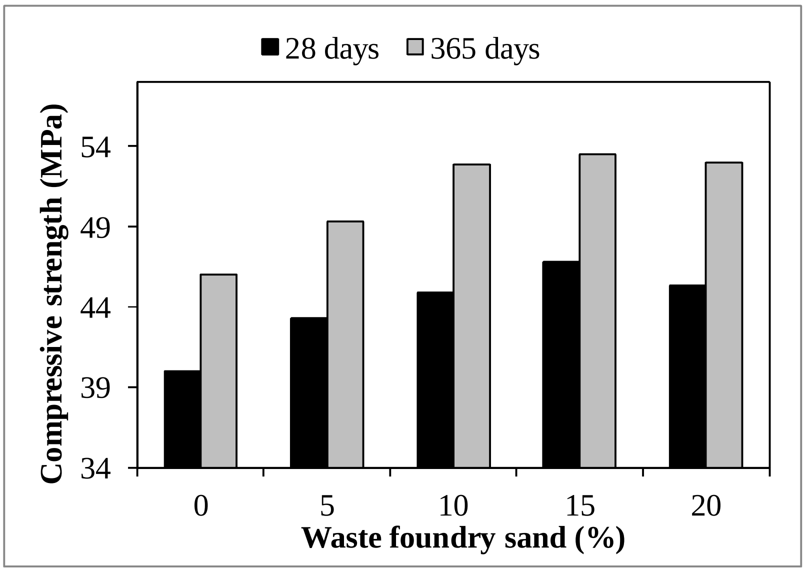

Figure 1: Compressive Strength verse Waste Foundry Sand

3.2 Splitting Tensile Strength

Splitting tensile strength of concrete mixes CM-1, CM-2, CM-3, CM-4 and CM-5 (M30 grade concrete) with and without WFS sand were determined at the age of 28 and 365 days (figure 2). It was observed that concrete mixes made with WFS exhibited higher splitting tensile strength than control concrete mix (CM-1). Splitting tensile strength of control mix was 4.23 MPa at 28 days. From these results, it was seen that 28-day splitting tensile strength increased by 3.54, 8.27, 10.40 AND 6.38% for mixes CM-2, CM-3, CM-4 and CM-5 respectively than the strength (4.23 MPa) of control mix CM-1 (0% WFS). At 365 days, increase in strength was 5%, 9.13%, 14.15% AND 11.87% for CM-2, CM-3, CM-4 and CM-5 mix respectively

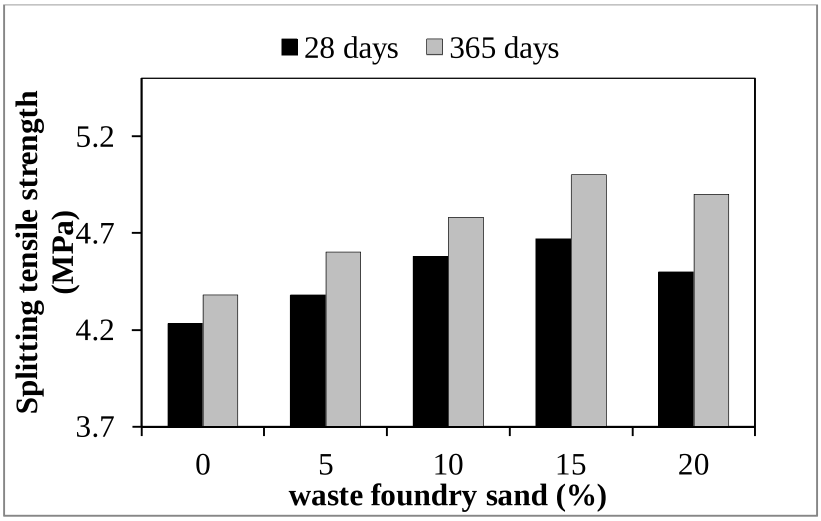

Figure 2: Splitting Tensile Strength verses Waste Foundry Sand

3.3 Rapid Chloride Permeability test

Results of rapid chloride permeability are shown in Figure 3. At 28 days, for mixes CM-1 (0% WFS), CM-2 (5% WFS), CM-3 (10% WFS), CM-4 (15% WFS) and fM-5% WFS), coulomb charges passed were 1368, 1250, 1150, 1060 and 1140 coulombs. Similarly, coulombs charge passed were 1090, 950, 855, 820 and 840 at the age of 365 days. Coulomb value decreased in mix CM-4 with the increase in WFS content up to 15% WFS, which indicate that concrete became more dense. This aspect has also been reflected by the compressive strength results concrete mix made with WFS up to 15% WFS. However, at 20% WFS (CM-5), there is slight increase in coulomb value with references to 15% WFS. At 28 days, all concrete mixes have low Permeability (coulombs between 1000 and 2000) and at the age of 365 days, concrete mixes CM2, CM3, CM4 AND CM5 comes under very low permeability (less than 1000) as per ASTM C1202.

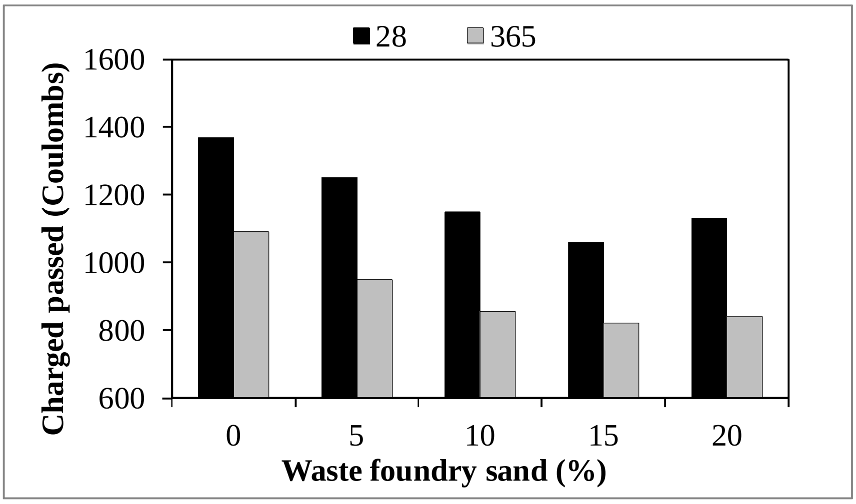

Figure 3: RCPT verses Waste Foundry Sand

3.4 Relationship between Strength Properties and RCPT

Figs 4-5 show the relationship between compressive strength, splitting tensile strength with that of RCPT. In each of the figures, equation and correlation coefficient are shown. A polynomial relationship in the form of $y = ax^2+bx+c$ seems to best fit the data with R^2 values of more than 0.84. The high values of correlation coefficient indicates that chloride ion permeability has a strong relationship with strength properties (compressive and splitting tensile). Generally, an increase in waste foundry sand content in concrete mix leads to an increase in permeability of concrete.

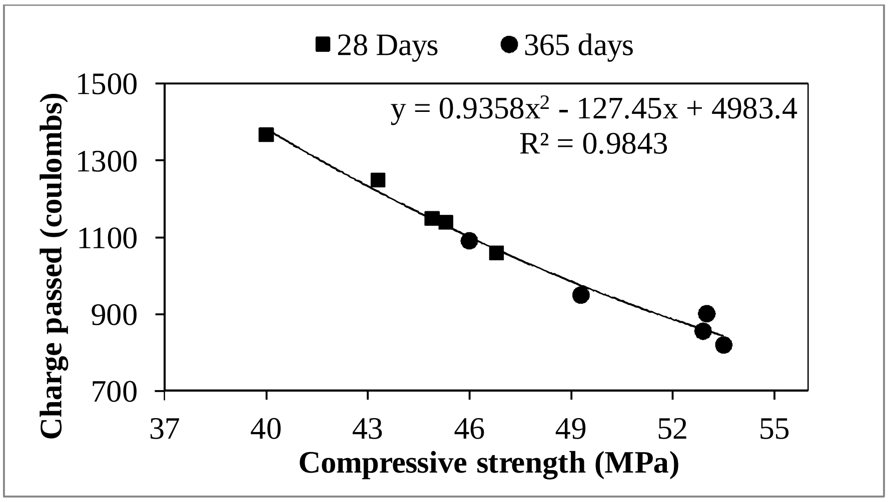

Figure 4: Compressive Strength verses RCPT

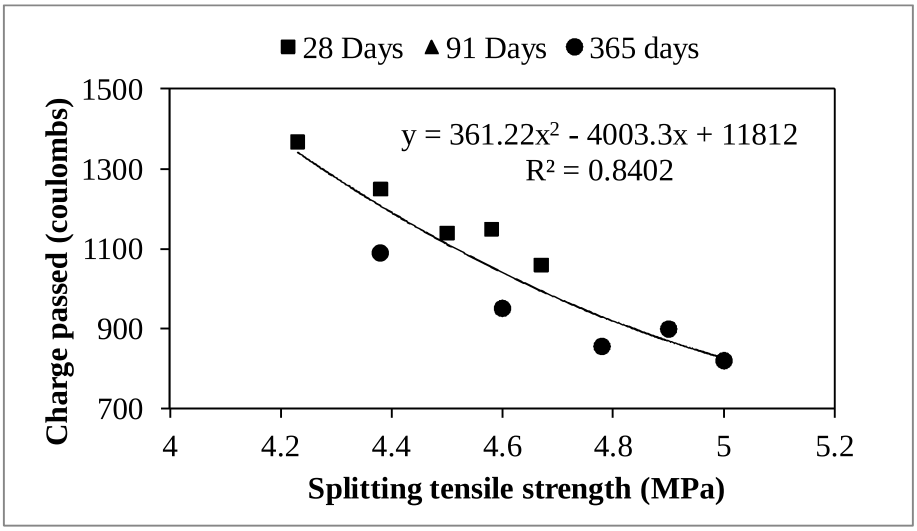

Figure 5: Splitting Tensile Strength verses RCPT

5. DISCUSSIONS

In present investigation, compressive strength and splitting tensile strength of concrete increased with the increase in WFS content up to 15% as partial replacement of sand. This could be due to dense matrix because WFS is fine sand and its particle size varies between 600µ to 150µ. Reduction in compressive strength with the inclusion of 20% WFS could probably due to increase in surface area of fine particles led to the reduction the water cement gel in matrix, hence; binding process of coarse and fine aggregate does not take place properly.

Coulombs charges passed at 365 days are less than those of 28 days, which indicate that concrete microstructure become denser. This is possible because of presence of fine particle of WFS in concrete mixes. These fine particles reduce the voids between ingredient of concrete and makes dense matrix. It also helps to decrease the electrical conductance of concrete.

6. CONCLUSIONS

- Replacement of fine aggregate with WFS enhanced the strength properties of concrete with the increase in WFS content at all ages.
- Maximum strength was achieved with 15% replacement of fine aggregate with WFS. Beyond 15% replacement it goes to decrease, but was still higher than control concretes.
- The rate of compressive and splitting tensile development of waste foundry sand concrete mixes were higher compared to no waste foundry sand concrete mixes.
- Chloride permeability resistance of concrete mixes increased with the increase in waste foundry sand content in concrete mixes.
- Results have indicated that concrete made with (up to 15%) WFS could suitable be used for making structural concretes.

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