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Design and Development of High Strength Heavyweight Concrete Using SBR

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Abstract— Heavyweight concrete is used in many applications such as bascule and lift bridges, radiation shielding structures in nuclear plants etc. In this study an industrial waste material produced by shot blasting of metallic chains is being used as heavy material in concrete due to its high density. The material is called as Sand Blast Residue (SBR). In this attempt some tests were carried to check the compability of SBR with cement and aggregate. The concrete mix as per IS-10262-(2009) is used for M20 grade of concrete and 50% sand is replaced with SBR. The workability obtained in this test is 25 mm slump and the strength is 23 MPa. These results were satisfactory as compared to control mix.

Further it is planed to design a concrete as per D.O.E (British Standard) to acheive M60, M70, and M80 grade of concrete replacing fine aggregates with SBR. The replacement starts from 0 – 100% with fraction of 20%. Due to presence of high iron in SBR some durability tests also would be conducted with compressive and tensile tests.

Index Terms— Admixture, Aggregates, Cement, Compression test, Concrete, Durability tests, Mix Design, Slump test, Tensile test,High density, High strength

1 INTRODUCTION

A composite material that consists essentially of a binding medium, such as a mixture of Portland cement and water, within which are embedded particles or fragments of aggregate, usually a combination of fine and coarse aggregate is called concrete. Concrete is by far the most versatile and most widely used construction material worldover. It can be engineered to satisfy a wide range of performance specifications, unlike other building materials, such as natural stone or steel, which generally have to be used as they are. Because the tensile strength of concrete is much lower than its compressive strength, it is typically reinforced with steel bars, in which case it is known as reinforced concrete. [1]

Heavyweight concretes can be designed in the same way as normal weight concretes, but the additional self weight should be taken into account. They can be transported and placed in the same way as normal weight concretes but the additional density means that smaller volumes can be transported and placed.

1.1High Density Concrete

Density of normal concrete is in the order of 2400 kilograms per cubic meter, whereas that of light weight concrete is less than normal density i.e. 1900 kilograms per cubic meter or so. To call the concrete as high density concrete, it must have unit weight ranging about 3360 to 3840 kilograms per cubic meter, which is about 50% higher than the unit weight of conventional concrete. They can however be produced with density up to about 5280 kilograms per cubic meter using iron as fine and coarse aggregate. [6]

Heavyweight concrete is used in counterweights of bascule and lift bridges, but it is generally used in radiation shielding structures. It differs from normal weight concrete by having a higher density and special compositions to improve its attenuation properties. When the heavyweight concrete is used to absorb gamma rays, the density and materials costs are of prime importance.

1.2 High Density Aggregates

High density aggregates such as barite, ferrophosphorus, goethite, hematite, ilmenite, limonite, magnetite, and degreased steel punching and shot are used to produce high-density concrete. Where high fixed-water content is desirable, serpentine (which is slightly heavier than normal weight aggregate) or bauxite can be used. Heavyweight aggregates should be reasonably free of fine material, oil, and foreign substances that may affect either the bond of paste to aggregate particle or the hydration of cement. For good workability, maximum density, and economy, aggregates should be roughly cubical in shape and free of excessive flat or elongated particles.[2]

In this experiment, the fine particals, named SBR, formed during sand blasting of metallic chains produced in industries are used as a replacement of fine aggregate in concrete. Being heavy material, it is expected to produce heavyweight concrete when it is used as partial replacement of sand in the concrete.

2 MATERIALS AND METHODS

The ingredients of concrete used in this attempt i.e. cement, fine aggregate (river sand), course aggregate are tested before use in sample test of concrete. The relevant Indian standard codes were followed for conducting various tests on the materials.

2.1 Cement

The cement used in this experimental work is **53 grade ordinary Portland Cement. Its** properties tested as per IS 12269-1987 [36] are shown in table 1.

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TABLE 1
PHYSICAL PROPERTIES OF CEMENT

Sr. No	Description of test	Results
1.	Fineness of cement	3.12%
2.	Specific gravity	3.15
3.	Standard constancy	30%
4.	Setting time	
	a) Initial setting time	160 minutes
	b) Final setting time	250 minutes
5.	Soundness by Le-Chatelier's method	1.0mm
6.	28 days compressive strength	66 N/mm^2

2.2 Aggregate

Natural sand from Paithan river near Aurangabad is used. Various tests such as specific gravity, water absorption, moisture content, sieve analysis, etc. have been conducted as per Indian Standard. The test results are presented in Table 2. The crushed well graded aggregate of size 20 mm confirming the requirements of IS 383-1970 [37] is used as coarse aggregate. Storage should be as near the batch plant as possible, and protected from moisture.

TABLE 2
PHYSICAL PROPERTIES OF FINE AND COARSE AGGREGATE (CA)

Sr.No	Properties	Results	
		River sand	C A
1.	Particle shape size	Rounded 4.75mm	Angular 20mm
2.	Fineness modulus	3.07	7.03
3.	Specific gravity	2.63	2.73
4.	Silt/ dust content	7.27%	Nil
5.	Surface moisture	1.24%	0.42%
6.	Water absorption	2.50%	2.30%

2.3 Water

Potable laboratory tap water was used for mixing of concrete. In addition, water should be clean and free from injurious amounts of oil, acid, alkali, organic matter, or other deleterious substances.

2.4 Industrial Waste Material (SBR)

The SBR used in this experimental work is produced at an industry in the neighbourhood of Aurangabad in the State of Maharashtra. It has a very high content of iron oxide available in the dry powder form. Properties of SBR are presented in Table 3 and Table 4.

TABLE 3
PHYSICAL PROPERTIES OF SBR

Sr.No	Properties	Details
1.	Color	Blackish
2.	Specific gravity	5.98
3.	Water absorption	4.15%

TABLE 4
CHEMICAL PROPERTIES OF SBR

Sr.No	Description	(% by mass)
1.	Calcium Oxide (CaO)	2.20
2.	Iron Oxide (Fe_2O_3)	93.02
3.	Magnesium Oxide(MgO)	1.30
4.	Silicon dioxide (SiO_2)	1.37
5.	Titanium Dioxide (TiO_2)	0.80
6.	Alumina (Al_2O_3)	0.61
7.	Cupric Oxide (CuO)	0.07
8.	Manganese Oxide (MnO)	0.62

2.5 Superplasticiser (SP)

Conplast SP430 is the chloride free, superplasticiser based on sulphonated naphthalene polymers super plasticizer is a unique workability retaining high performance superplasticiser with high strength properties. The properties of SP as reported by manufactured are presented in Table 5. Conplast SP430 conforms with BSEN 934-2, BS 5075 Part 3 and with ASTM C494 as Type A and Type F, depending on dosage used.

TABLE 5
PROPERTIES OF SUPER PLASTICIZER

Sr. No	Properties	Details
1.	Appearance	Brown liquid
2.	Specific gravity	1.220 – 1.225 @ 30°C
3.	Water soluble chloride	Nil
4.	Alkali content	Less than 55g. Na2O
5.	Chloride content	0.2% Max
6.	Air entrainment	Nil
7.	Nitrate content	Nil

Uses

- To produce pumpable concrete
- To produce high strength, high grade concrete M30 & above by substantial reduction in water resulting in low permeability and high early strength
- To produce high workability concrete requiring little or no vibration during placing

Advantages

- Improved workability - Easier, quicker placing and compaction.
- Increased strength - Provides high early strength for precast concrete with the advantage of higher water reduction ability.
- Improved quality - Denser, close textured concrete with reduced porosity and hence more durable.
- Higher cohesion - Risk of segregation and bleeding minimised; thus aids pumping of concrete
- Chloride free - Safe in prestressed concrete and with sulphate resisting cements and marine aggregates.

Compatibility

It **c**an be used with all types of cements except high alumina cement. Conplast SP430 is compatible with other types of Fosroc admixtures when added seperately to the mix. Site trials should be carried out to optimise dosages.

Effect on Compressive strength

Early strength is increased upto 20% if water reduction is taken advantage of. Generally, there is improvement in strength upto 20% depending upon W/C ratio and other mix parameters.

3 MIX PROPORTION TRIALS

By performing number of trails on mix design and adding various percentage of super plasticizer, the mix proportions of normal concrete with varying percentage of SBR, replacing sand were tried. Selected proportions of ingredients after several trials, is used for final mixing. Properties of fresh state of concrete is checked by using slump cone test as well as compacting factor test and hardened properties like compressive strength of trial mix results are given in below.

4 PROPERTIES OF CONCRETE

The various properties of concrete produced in this work are discussed in the following sections. The properties of concrete prepared with SBR in different amounts in the concrte replacing sand by 25 and 50% were determined.

4.1 Density of Concrete

The increase in percentage of SBR increases the density of concrete. In other words, we can say that the density is directly proportional to percentage of SBR. The details are shown in fig. 1 where SA represents the concrete made with conventional materials, SB represents sample of concrete prepared with SBR replacing 25% sand, and SC represents sample of concrete prepared with SBR replacing 50% sand.

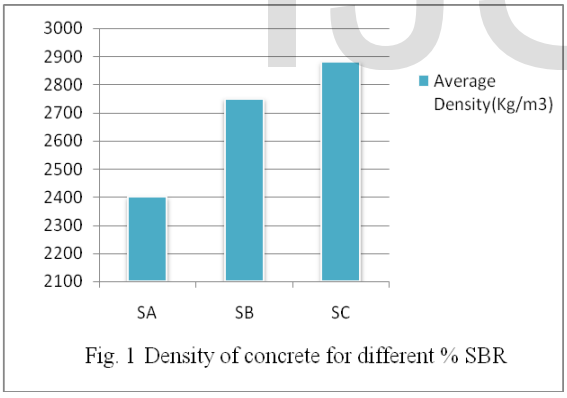

Fig. 1 Density of concrete for different % SBR

4.2 Workability of Concrete

The workability of concrete gets affected as the percentage of SBR increases. It may be due to high water absorption of SBR. The results are in Table 6.

TABLE 6
WORKABILITY OF TRIALS SAMPLES

Sr. No.		Slump(mm)	Compacting Factor
1	SA	180	--
2	SB	47.5	--
3	SC	--	0.74

4.3 Compressive Strength of Concrete

In many codes the compressive strength is named a concrete rank because of its importance; the compressive strength test was carried out on samples. The specimens were tested at 7 and 28 days age for all mixes. The result shows that the compressive strength of concrete is independent of percentage SBR used. The reason is in all sample strength of concrete is near about same shown in Fig. 2.

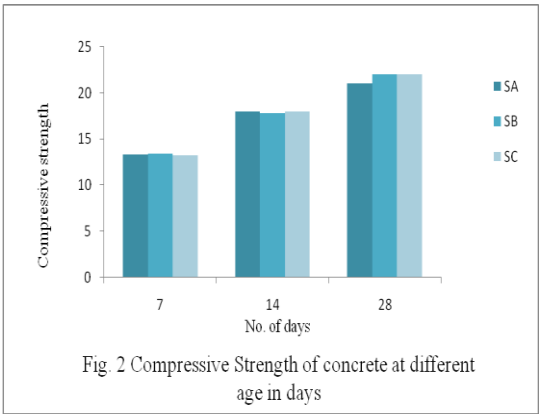

Fig. 2 Compressive Strength of concrete at different age in days

5. CONCLUSION

The primary objective of this study was to evaluate the use of industrial waste material (SBR) as an additive in the concrete to make it a heavy weight material, as a replacement of sand. Based on the results obtained from the tests considered in this study, it may be seen that SBR could be used for making heavyweight concrete, without affecting much the compressive strength.

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