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Experimental Study on Durability Characteristics of High Performance Concrete Incorporating With Silica Fume, Bottom Ash & Steel Slag Aggregate

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ABSTRACT
High performance concrete (HPC) is developed gradually over the last 15 years with respect to production of concrete with higher and higher strength. To enhance the properties such as durability, strength, workability, economy has increased due to the usage of mineral admixtures in making high performance concrete. The scope of the present study is to investigate the effect of mineral admixtures and by-products towards the performance of HPC. An effort has been made to concentrate on the mineral admixture of silica fume towards their pozzolanic reaction and industrial by-product of bottom ash and steel slag towards their hydration reaction can be contributed towards their strength and durability properties. The strength characteristics such as compressive strength, tensile strength and flexural strength were investigated to find the optimum replacement of mineral admixture and by-product admixture. HPC with mineral admixture of silica fume at the replacement levels of 0%, 5%, 10%, 15% & 20% were studied at the age of 28 days and industrial by-products of bottom ash and steel slag aggregate at the replacement level of 10%, 20%, 30%, 40% & 50% were studied at the age of 28 days. There were a total of 15 mixes created with different material contents. Out of 14 were HPC mixes and 1 were conventional concrete mixes. Finally strength has enhanced with the mix of silica fume can replaced by cement with 5% and bottom ash and steel slag can replaced by fine and coarse aggregate with 10% can be achieved higher strength when compared with other percentage of mixes. The combination mixes can be classified as binary and ternary mixes. Binary mixes involved combinations of silica fume and bottom ash (SF+BA), silica fume and steel slag aggregate (SF+SSA), bottom ash and steel slag aggregate (BA+SSA) and Ternary mixes involved combination of three materials such as silica fume, bottom ash and steel slag aggregate (SF+BA+SSA) in High performance concrete. The investigation revealed that the combined use of silica fume, bottom ash and steel slag aggregate improved the mechanical properties of HPC and thus there 3 materials may use as a partial replacement material in making HPC. The durability studies such as acid resistance, salt resistance, sulphate resistance & water absorption were conducted. From the experimental investigation, it was observed that mineral admixture of silica fume and industrial by-products of bottom ash & steel slag aggregate plays a vital role in improving the strength and durability parameter itself.

Keywords: *HPC, strength, durability, silica fume, bottom ash, steel slag aggregate.*

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I. INTRODUCTION

According to ACI definition, concrete which meets special performance and uniformity requirements that cannot always be achieved routinely by using only conventional materials. Use of chemical admixtures reduces the water content, thereby reducing the porosity within the hydrated cement paste. Mineral admixtures, also called as cement replacement materials, act as pozzolanic materials as well as fine fillers, thereby the microstructure of hardened cement matrix becomes denser and stronger. Industrial by-products such as silica fume, bottom ash and steel slag aggregate improve the engineering and performance properties of high performance concrete when they are used as a mineral additive or as partial raw material replacement. With the progress of research on by-products in recent years, the use of materials as such as silica fume as binders has been increasing, along with bottom ash. By using these by-products, we can improve cost and environmental effects depending on the characteristics of the by-products. Now a day a new generation HPC require along with improved compressive strengths, high tensile strength, reduced porosity and very high durability. In HPC, it is necessary to reduce the w/c ratio and which in general increases the cement content. To overcome these low workability problem, different kinds of mineral admixtures of industrial by-products like silica fume, bottom ash and steel slag aggregate can be used.

1.1 Materials & Admixtures used for HPC

In the experimental study, generally a good quality of cement like 43 grade cement is preferred but it may vary according to the grade of HPC needed. Natural sands crushed and rounded sands and manufactured sands are suitable for HPC. River sand of specific gravity 2.65 and conforming to zone II of IS 363 was used for the present study. The shape and particle size distribution of the aggregate is very important as it affects the packing and voids content. The moisture content, water absorption, grading and variations in fines content of all aggregate should be closely and continuously monitored and must be taken into account in order to produce HPC of constant quality. Coarse aggregate used in this study had a maximum size of 10mm. Specific gravity of coarse aggregate used was 2.75 as per IS 363. Ordinary potable water was used. Super plasticizers are high range water reducing admixtures an essential component of HPC. Conplast SP 430 was used as super plasticizer. Silica fume imparts very good improvement to rheological, mechanical and chemical properties. It improves the durability of the concrete by reinforcing the microstructure through filler effect and thus reduces segregation and bleeding. It is also helps in achieving high early strength. Silica fume is the by-product of producing silicon metal or ferrosilicon alloys. One of the most beneficial uses for silica fume is to help to produce high performance concrete. The silica fume is collected from ELKM INDIA (P) Ltd, Mumbai. Bottom ash obtained from thermal power plant, Neyveli Lignite Corporation Ltd, Neyveli, TamilNadu, India was used in this investigation. Steel slag is the by-product of metal smelting and hundreds of tons of it are produced every year all over the world in the process of refining metals and making alloys. When the metal is smelted to satisfaction, the slag is skimmed from the top and disposed of in a slag heap to age. In this experimental investigation an attempt is made to study the effect of partial replacement of cement by silica fume and partial replacement of fine aggregate and coarse aggregate by bottom ash and steel slag aggregate for making high performance concrete.

1.2 Experimental Investigation

Based on the laboratory test it has been observed that strength of concrete is increasing with addition of mineral and industrial by-products. The various tests that are conducted to test the strength and durability characteristics and their results correlate with the study and derive positive result and improvement.

1.3 Strength for Combination of Admixtures

1.3.1 Compressive strength of concrete

The compressive strength is tested for the nominal concrete for average 3 cubes on different curing periods. The specimen's 150mmx150mx150mm cubes of each mixture were cast for compressive strength test. After 28 days of continuous curing the specimens are taken out and they are exposed to atmosphere for six hours to 24 hours. Surface water and grit shall be wiped off the specimens and any projecting fins are removed. After visual confirming that the specimens are dry it is then taken for testing.

1.3.2 Split tensile test

The specimens remained in the steel mould for 24 hours and then it is de-moulded and then placed in curing tank. After 28 days specimen were taken out and exposed to atmospheric condition so as to obtain dry surface. The specimen is placed diagonally in the standard compression testing machine. The concrete cubes were placed in the machine in such a manner that the load was applied on the diagonally edge surface of the cube as cast.

Table 1: Results for combination of admixtures

Sl. No.	Name of the Mix	Compressive Strength *N/mm²*	Split tensile strength N/mm²	Flexural strength N/mm²
1	CC	30.16	2.77	7.11
2	SF+BA	31.99	3.37	7.8
3	SF+SSA	37.59	3.89	8.15
4	BA+SSA	36.68	3.88	7.9
5	SF+BA+SSA	28.48	3.72	7.49

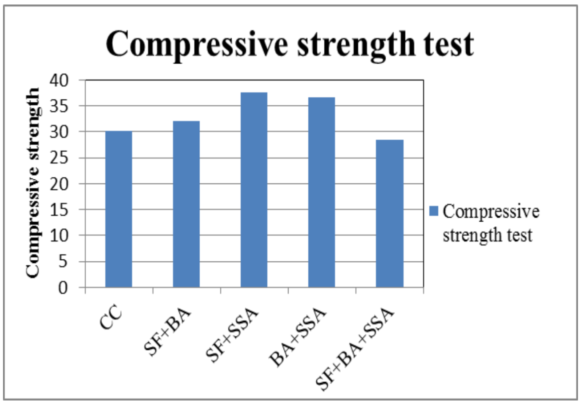

Figure 1: Compressive strength for combination of admixtures.

1.3.3 Flexural test

The Prism specimens of size (100* 100*500) were cast in steel mould. Casting was conducted in three layers with each layer compacted by using ramping rod up to sufficient levels. The specimens remained in the steel mould for 24 hours and then it is de-u and then placed in curing tank. After 28 days prisms were taken out and exposed to atmospheric condition so as to obtain dry surface. Two points loading was used to determine the flexural strength of the prism.

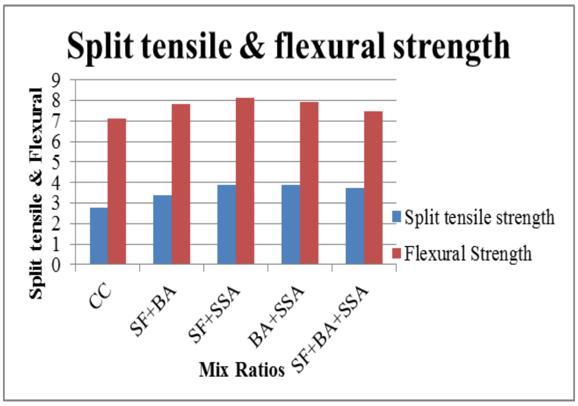

Figure 2: Split tensile & flexural strength for combination of admixtures

1.6 Modulus of Elasticity

For each mix two cylinder of size 150mm diameter and 300mm long were cast to determine the Modulus of Elasticity of concrete. The cylinder were placed inside the young's modulus testing apparatus called compressometer, providing equal clearance to top and bottom of specimen. Each cylinder was tested in 300T capacity compression testing machine (CTM). Loads were applied by means of 0.5T and the reading is noted in the deflectometer.

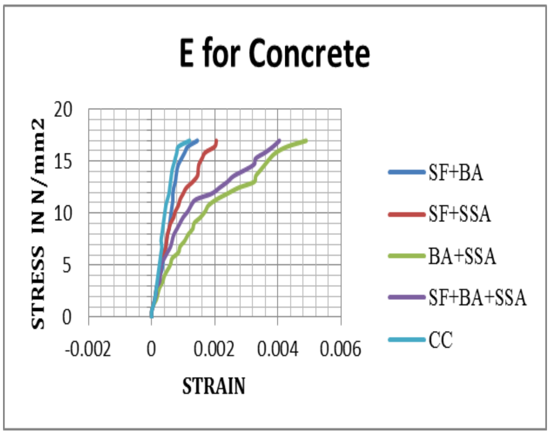

Figure 3: E for concrete for combination of materials

II. DURABILITY TESTS

2.1 Acid Resistance

The acid resistance tests were carried out on 150mm size cube specimens at the age of 28 days curing. The cube specimens were weighed and immersed in water diluted with one percent by weight of sulphuric acid for 30 days continuously. Then the specimens were taken out from the acid water and the surfaces of the cubes were cleaned. Next the weight and the compressive strengths of the specimens were found out and the average percentage of loss of weight and compressive strengths were calculated.

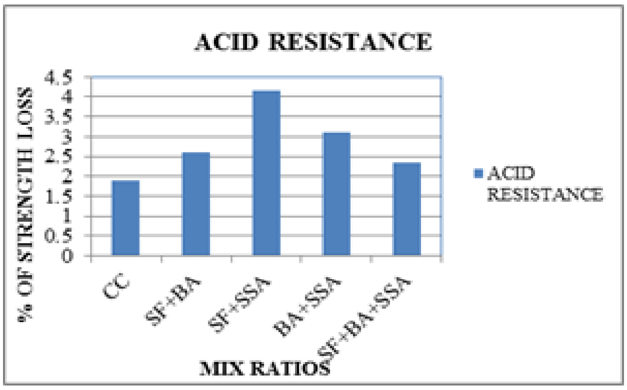

Figure 4: Percentage Mass loss of concrete

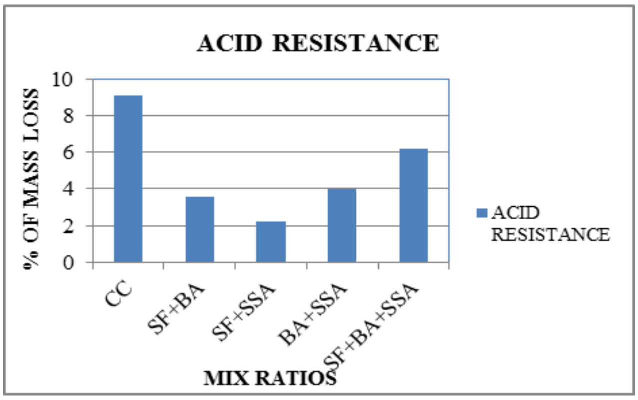

Figure 5: Percentage Strength loss of concrete

2.2 Salt Resistance

The salt water resistance tests were performed the resistance of concrete cubes subjected to salt water attack which might have resulted from the sea water. The concrete specimen cubes of 150mmx150mmx150mm size were cast for finding the weight loss and strength loss due to the salt water attack. The cubes were cured in water for 28 days. The specimens were taken out from the water were weighed and immersed in salt water with 3% diluted sodium chloride solutions. Then the specimens were taken out from the salt water and the surfaces of the cubes were cleaned.

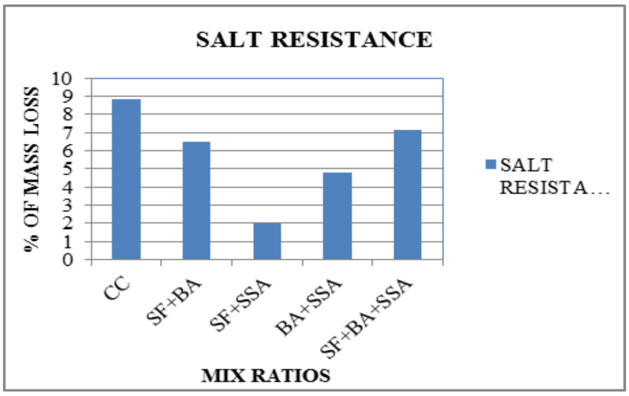

Figure 6: Percentage Mass loss of concrete

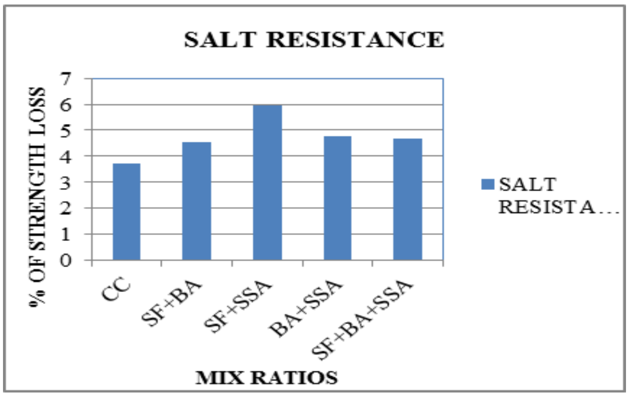

Figure 7: Percentage reduction in strength

2.3 Sulphate Resistance

The Sulphate resistance tests were performed to evaluate the resistance of concrete cubes subjected to sulphate attack. The cube specimens were weighed and immersed in water diluted with 5% by weight of sodium sulphate diluted solutions for 30 days continuously. Then the specimens were taken out from the acid water and the surfaces of the cubes were cleaned. Next the weight and the compressive strengths of the specimens were found out and the average percentage of loss of weight and compressive strengths were calculated.

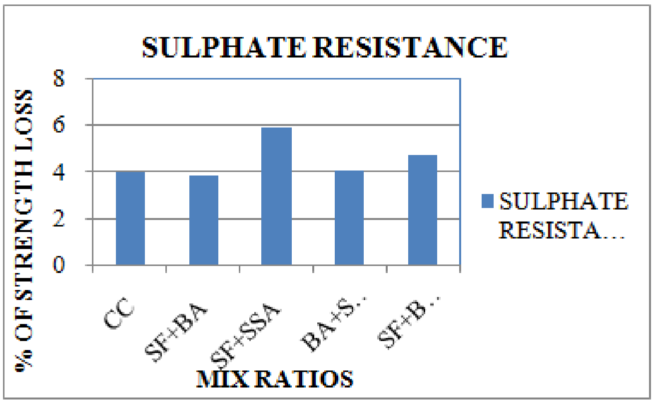

Figure 8: Percentage Mass loss of concrete

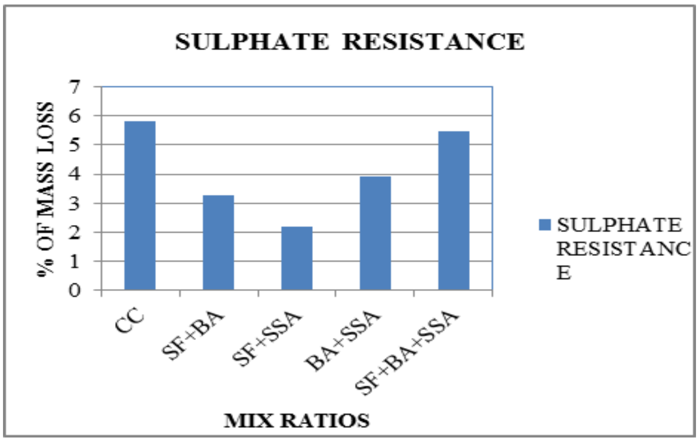

Figure 9: Percentage Mass loss of concrete

2.4 Saturated Water Absorption

The water absorption test were carried out by casting cubes of 150mm size specimens and cured for 28 days. At the end of 28 days, the specimens were taken out and kept out for 3 days dry position. After immersing specimens completely in water for 24 hours the measurement were taken and the difference in weight was found. The difference between the measured water saturated mass and oven dried mass expressed as % of oven dry mass gives the saturated water absorption.

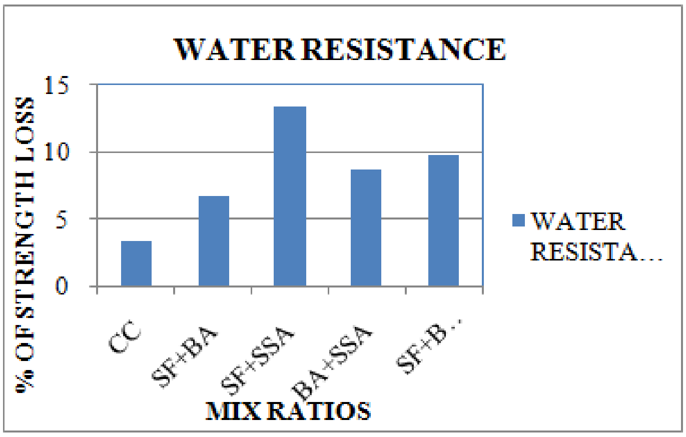

Figure 10: Percentage Mass loss of concrete

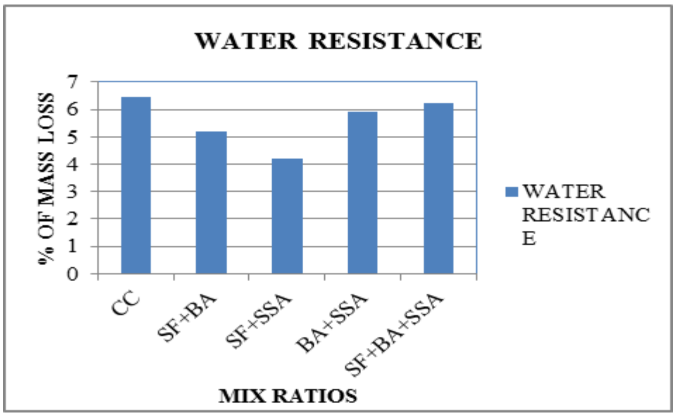

Figure 11: Percentage Strength loss of concrete

III. CONCLUSIONS

The durability of a material in a particular environment can only be established over time, so it is difficult to precisely predict the durability of high performance concrete because we do not have a track record for HPC exposed to very harsh environments. According to the test results, it can be conclude that high performance concrete of material combination can be produced successfully. The strength and durability characteristics of high performance concrete are increased by using admixtures & industrial by-products. The strength characteristics of HPC with different replacement levels of combination of three materials were studied at different ages of curing. All the three combination materials were very effective in improving the strength and durability characteristics of concrete. The conclusions from the different experimental studies are as follows:

- The weight loss and strength loss was found in acid immersion. The obtained values of the percentage mass loss were 3.4%, 2.61%, 1.38%, 2.79% & 4.2% for CC, SFBA, SFSSA, BASSA, SFBASSA mixes of concrete and the strength percentage loss were 4.8%, 2.76%, 4.35%, 3.23% & 2.4% respectively. The results showed that SFSSA mixes of concrete the mass loss were lower but strength losses were higher than the conventional concrete.
- The weight loss and strength loss was found in salt water immersion. The obtained values of the percentage mass loss were 2.42%, 3.5%, 2.15%, 0.8% & 3.64% for CC, SFBA, SFSSA, BASSA, SFBASSA mixes of concrete and the strength percentage loss were 6.3%, 6%, 4.7%, 5% & 5.02% respectively. The results showed that BASSA mixes of concrete the mass loss were lower but strength losses were higher than the conventional concrete.
- The weight loss and strength loss was found in sulphate resistance immersion. The obtained values of the percentage mass loss were 6.3%, 5.6%, 7.5%, 2.43% & 6.4% for CC, SFBA, SFSSA, BASSA, SFBASSA mixes of concrete and the strength percentage loss were 6.27%, 3.9%, 4.1%, 4.23% & 4.9% respectively. The results showed that BASSA mixes of concrete the mass loss were lower but strength losses were higher than the conventional concrete.
- This may due to the fact that the silica fume, bottom ash & steel slag aggregate which also acted as a filler material and increasing the density of the concrete by filling the voids. The addition of silica fume, bottom ash & steel slag aggregate significantly according to the results of mass loss and strength reduction.

All specimens including conventional concrete showed significant mechanical behaviour and durability properties, nevertheless the improvement of concrete properties was more considerable in the case of adding pozzolanic materials and industrial by-products.

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