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Experimental Investigation on the Impact of Sulphate and Chloride on High Volume Fly Ash Concrete

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Abstract. High weathering action in the corrosive and chemically active environment can significantly affect the strength characteristics of the concrete and also excessive utilization of sand as fine aggregates in building construction enhances degradation of the environment and urges the need for an alternative source in the scene of sustainable construction. Fly ash has generally used an alternative of cement, such as an admixture in concrete, and production of cement. As per the literature it has been found that concrete containing fly ash as partial to complete replacement of fine aggregate has been found to increase strength on a long-term basis. An experimental investigation was carried out to evaluate the strength and durability characteristics of concrete building blocks by replacing fine aggregates with fly ash at 10% to 100% by weight of fine aggregate and subjecting it to chloride attack and sulfate attack. Various tests were conducted for the properties of fresh concrete. Compressive strength and flexural strength were determined at 28 days. Test results indicate significant improvement in strength properties of plain concrete by the inclusion of fly ash as partial replacement of fine aggregate (sand), and increase in resistance to sulfate and Chloride attacks and can be effectively used in structural concrete.

Keywords. Chloride attack; Sulfate attack; Fly ash

1. Introduction

Fly ash is a waste product that is produced in thermal power plants. In India each year 250 million tons of fly ash is produced and its utilization percentage is well below 13%. Class F type fly ash is the most abundantly produced. Fine aggregates are a natural resource and to meet the growing demand for concrete in the construction field we are exploiting them gradually. In this project, we will be using concrete that is made by using fly ash as a replacement for sand. In this way, we can save the natural resource by reducing its usage by using an alternative product. The demand for building materials like cement, sand, and coarse aggregate is increasing in the country due to the increase in the growth of population, economy, and living standards of the people. It has been some time now that some cement companies have started utilizing fly ash in the production of cement, known as 'Pozzolana Portland cement', but the overall percentage of utilization remains very low, and the majority of the fly ash ends up in landfills. It has been noted that concrete containing fly ash as partial replacement of cement has problems of delayed early strength development and concrete containing fly ash as partial replacement of fine aggregate will have no delay in early strength development, but would rather improve its strength on a long-term basis. This project is designed to explore the possibility of replacing fine aggregate with fly ash and evaluate the characteristic strength when subjected to sulfate and chloride attack. The behavior of high-volume fly ash concrete in response to the various chemical attacks such as Sulfate attacks and Chloride attacks is studied in this paper. The sulfate attack happens when sulfates combine with calcium hydroxide generated during the hydration of cement and forms calcium sulfate (gypsum). The aluminate compounds from the Portland cement will further react and form ettringite, which is very harmful to concrete. Chloride enters the concrete and builds up massive corrosive products on the reinforcement which expands and cracks the surrounding concrete. Fly ash binds with the free lime radicals in cementitious compounds, making it unavailable for reacting with sulfates.

2. Methodology

In the experiment, Ordinary Portland (43 grade) cement was used and has been tested as per Indian Standard Specifications corresponding to IS: 8112-1989. Fine aggregates of natural sand with a 4.75-mm maximum size were used as a fine aggregate conforming to Indian Standard Specifications IS: 383-1970. Coarse aggregate used in the project was 20-mm nominal size and was also tested as per Indian Standard Specifications corresponding to IS 383:1970. Class F fly ash has been employed in the project. To control the demand for water in the field while mixing the concrete superplasticizer were used. Superplasticizers are also called High Range Water-reducing admixtures because of the ability to reduce 3-4 liters of mixing water in a given concrete mixture compared to normal water-reducing admixtures. Superplasticizer Fosroc Conplast SP430 DIS (Sulphonated Napthalene Formaldehyde) was used in the project. To ensure that the concretes are subjected to different weathering conditions, the concretes are cured in acidic water to simulate the condition that they are subjected to acid attacks. The main acid attacks are sulfate attacks and chloride attacks. The concretes are subjected to mild acid attack which is maintained at the pH of 5. A pH test is carried out to determine the amount of concentrated acids required to bring the pH of the water to 5. Mix design of concrete confirming to IS 456:2000 and IS 10262-2009 is prepared.

Eleven different mixes of M30 grade namely Conventional Aggregate Concrete (CAC), concrete made by successively replacing sand by 10%, 20%, 30%, 40%, 50%, 60%, 70%, 80%, 90%, 100% respectively by fly ash are to be prepared. Firstly, sand is placed on the ground, then Cement and fly Ash is poured onto them. Finally, the Coarse Aggregate layer is placed on the top. These are then mixed properly. After the dry mixing, the mix is then evenly spread through and water with superplasticizer mix is sprinkled onto them. These are then mixed within 5 minutes of pouring of water. The Slump Test and compaction factor test are carried out as soon as the mix is complete. After this, the concrete is placed in the molds. The cube molds are of dimensions 150 x 150 x 150 mm and the beam molds are of dimensions 700 x 150 x 150 mm. A total of six beams and six cubes are to be cast for each % replacement. The cubes and beams are demolded after 24 hours. Half of the molds (3 cube molds and 3 beam molds) are placed in the curing tank containing H_2SO_4 at a pH of 5. The other half is placed in the curing tank containing HCl at a pH of 5. They are placed in the curing tanks for 28 days and removed. After the end of 28 days of curing, the concrete cubes and beams are kept to dry for some time and then put to testing. The concrete cubes are subjected to testing for compressive strength while the concrete beams are subjected to a flexural strength test. The testing apparatus is started and the values in which the concrete gives in are noted down. All the test readings are noted and the values are analyzed.

3. Results and Discussions

The slump test and Compaction factor test are conducted after the mixing of concrete. The data

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obtained by this test are as shown in table 1. From the given table it has been found that compaction factor value increases with the increase in slump value of the concrete and gradually decreases with the decrease in slump value. The compaction factor value reaches the peak value of 0.84 with a slump value at 56mm at 30% replacement of fine aggregates by fly ash. Thus, there is the highest workability at 30% replacement of fine aggregates by fly ash.

The graph is plotted by observing the values obtained by conducting the compressive and flexural strength tests, as shown in Figure 1. In the figure, it can be observed that Compressive strength and Flexural strength continued to increase with the increase in fly ash percentages up to 30% replacement of fine aggregates. This is believed to be due to the large pozzolanic reaction and improved interfacial bond between paste and aggregates. Thus, showing more resistance to Sulphate and Chloride attack.

Table 1: Slump test value and Compaction factor value.

Percentage replacement of fine aggregates by fly ash	Slump value (mm)	Compaction factor
0	50	0.8
10	52	0.81
20	54	0.83
30	56	0.84
40	44	0.83
50	40	0.82
60	38	0.82
70	34	0.81
80	30	0.81
90	25	0.8
100	22	0.8

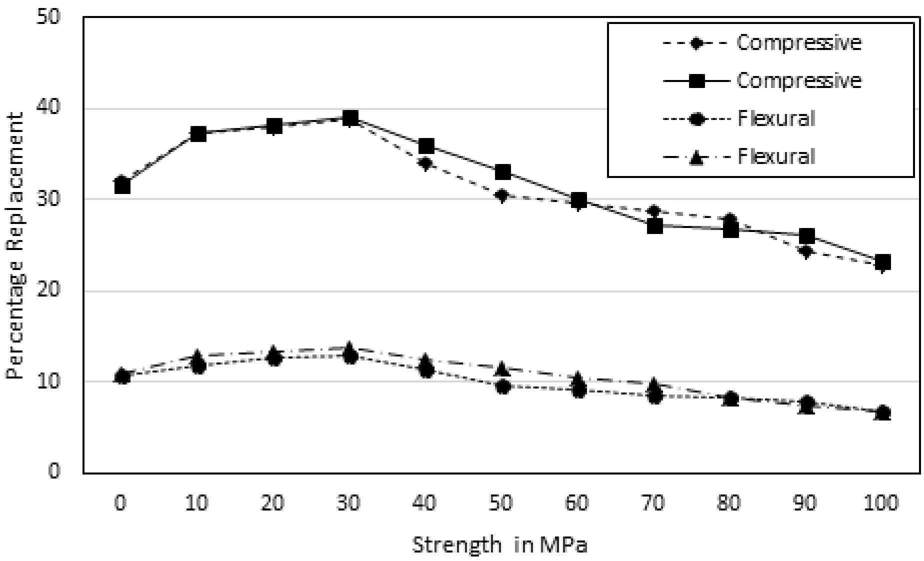

Figure 1. Percentage replacement of fine aggregates by fly ash vs. Characteristics compressive and flexural strength of concrete (MPa).

4. Conclusion

Compressive strength and flexural strength of fine aggregate (sand) replaced fly ash concrete continued to increase up to a certain extent and then decreases with a further increase in fly ash content. The characteristic strength is found to be maximum for both the cases (Sulphate attack and Chloride attack) at 30% fine aggregate replacement. The maximum compressive strength under chloride attack is at 30% replacement of fine aggregates with 38.83MPa. The maximum compressive strength under sulfate attack is at 30% replacement of fine aggregates with 39.01MPa. The maximum flexural strength under chloride attack is at 30% fine aggregate replacement with 13.03MPa. The maximum flexural strength under sulfate attack is at 30% fine aggregate replacement with 13.85MPa. It can be observed that High volume fly ash concrete with partial replacement of fine aggregates by fly ash has more resistance to sulfate attack than chloride attack. Results from this project suggest that fly ash can be used conveniently as partial replacement of fine aggregates up to 30% in structural concrete.

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Conflicts of Interest
The authors declare that there is no personal relationship or competing financial interests that could have influenced the work that has been reported in this paper.

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