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Investigation on the strength and corrosion resistive properties of fly ash blended quarry dust concrete

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Abstract: **-- Properly graded quarry sand can be effectively utilized as fine aggregate to meet the intensifying demand of river sand in construction industry. The use of Portland cement in concrete has significant greenhouse gas implications and this can be reduced by partial replacement of cement with supplementary cementing materials such as fly ash and GGBFS. This study focused on investigating the suitability of quarry dust as a replacing material(100%) for river sand and significance of fly ash as partial replacement for cement. The objective of this work is to study the strength and corrosion resistive properties of fly ash blended quarry dust concrete. The partial replacement of fly ash was done at the levels of 10% to 50% by weight of cement. The resistance to corrosion was evaluated by means of impressed voltage technique in saline medium, rapid chloride penetration test (RCPT), weight loss method and Scanning Electron Microscopic (SEM) analysis. The optimum percentage of replacement has been arrived from the test results.**

Index Terms—Quarry Dust, Flyash, Workability, Strength, Durability, Corrosion resistance

I. INTRODUCTION

The requirement for natural sand is increasing day by day since the available natural sand could meet the demand of construction sector. Under these circumstances, quarry dust, a byproduct from the crushing process of stones (Blue metal) is an economical alternative to the river sand. The usage of quarry dust as partial /hundred percent substitute for natural sand in concrete and the strength properties was studied by many authors [1-3]. The use of quarry dust as fine aggregate will also reduce environmental impact, if consumed by the construction industry in large quantity[4-7]. The use of quarry dust in concrete is generally limited due to the high cement paste volume needed to obtain an adequate workability of concrete. The increase of water demand of quarry dust concrete mixtures can be mitigated using high-range water reducing admixture or super plasticizer [8]. But these remedies increase the cost of construction. In such situations, use of mineral admixtures in concrete increases the workability, consistency and reduces the water demand[9].

One of the practical solutions to minimize the production of cement in order to reduce greenhouse gases is replacement of cement with supplementary cementations materials[10] Fly ash is a by-product of coal-fired electric generating plants and the spherical shape of fly ash particles alter the flocculation of cement resulting in lowering the quantity of water required[11,12]. However, fly ash causes a slight reduction in early strength. Therefore, the concurrent use of quarry dust and fly ash in concrete will lead to the benefits such as, the decrease in early strength by the addition of fly ash is reduced by the addition of quarry dust and the decrease in workability by the addition of quarry dust is reduced by the addition of fly ash[13,14]. Saraswathy and Song[15] investigated the effect of admixing fly ash on the corrosion resistance of concrete and found that it significantly improved the corrosion performance of concrete and also contributes to the environmental pollution control[16-20]. In the present study, the effect of partial replacement of cement with fly ash at 10% to 50% percentages in concrete containing quarry dust as fine aggregate has been investigated and the optimal percentage of fly ash was determined.

II. EXPERIMENTAL PROCEDURE

Materials used:

Ordinary Portland Cement (43 Grade) was used throughout the investigation. Locally available well-graded quarry dust, conforming to Zone-II having specific gravity 2.68 and fineness modulus 2.70 was used as fine aggregate. Class C fly ash obtained from nearby thermal power plant was used to replace cement. Natural granite aggregate having density of 2700kg/m3, specific gravity 2.7and fineness modulus 4.33 was used as coarse aggregate. High yield strength deformed bars of diameter 16mm was used for pullout and corrosion tests. To attain strength of 20 N/mm2, a mix proportion was designed based on IS 10262-1982 and SP23:1982(21). The mixture was 1:1.517:3.38 with water cement ratio 0.45.

Methodology:

Concrete cubes of size 150 x 150 x150mm, beams of size 500 x 100 x 100 mm, cylinders of size 150mm diameter and 300 mm long were cast for compressive, flexural and split tensile strength tests. Triplicate specimens were cast for each test. After 24 hours the specimens were demoulded and subjected to water curing. After 3, 7, 28, 56,90and 180days curing the specimens were tested as per IS: 516 – 1964. Cylinders of size150mm diameter and 300 mm long with rods of 70cm length kept at the centre were used for determination of bond strength. Water absorption of hardened concrete specimens was calculated based on ASTM C642-81. Concrete cylinders of size 75 mm diameter and 150 mm length with centrally embedded a high yield strength deformed(HYSD) steel bar of 16mm diameter were used to assess the corrosion protection efficiency under accelerated test conditions and weight loss measurement. After 28 days curing the specimens were subjected to acceleration corrosion process in order to accelerate reinforcement corrosion in the saline media (3% Sodium chloride) under a constant voltage of 6 volts from the D.C power pack. For weight loss measurement the cylinders were immersed in 3% NaCl solution under alternate wetting (3days) and drying (3days) conditions over a period of 90 days. At the end of 90days the cylinders were broke open and the final weight of the specimens was taken and the loss in weight was calculated. From the weight loss obtained corrosion rate is calculated. The RCPT is performed by monitoring the amount of electrical current that passes through concrete discs of 50mm thickness and 100mm diameter for a period of six hours. A voltage of 60 V DC is maintained across the ends of the specimen throughout the test. One lead is immersed in a sodium chloride(NaCl) solution(0.5N) and the other in a sodium hydroxide(NaOH) solution (0.3). The total charge passed through the cell in coulombs has been found in order to determine the resistance of the specimen to chloride ion penetration.

III. RESULTS AND DISCUSSION

Strength tests

The effect of fly ash on the strength and corrosion resistance of quarry dust concrete has been investigated by various strength and durability tests and the results are discussed below.The compressive, split tensile, flexural and bond strength results obtained after 7, 28, 56, 90,180 days are shown in figure 1to 4.

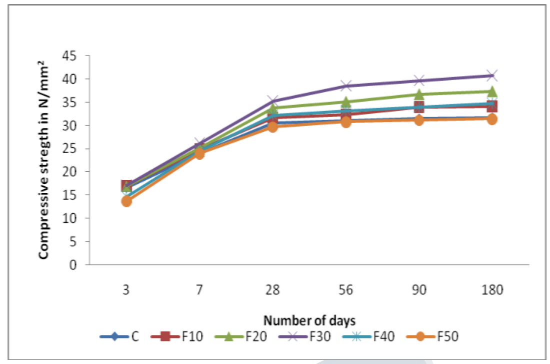

Figure.1 Compressive strength development

From the Figure1, it is evident that 10% addition of fly ash shows 8% increase in the compressive strength, 20% shows 14% improvement while the addition of 30% gives hike of 28.84% and this yields the maximum increase in the strength value. Further, addition of fly ash to 40% gives 9% increase and 50% yields a comparatively lower value than control specimen.

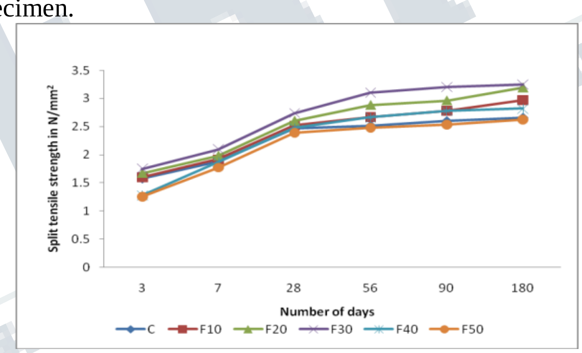

Figure.2 Split tensile strength development

Similarly, the addition of fly ash gives the maximum increase in split tensile strength value at 30% replacement (Figure 2) and the increase in strength value is 22. 52%.

In accordance with Figures 3, it is understood that addition of 30% of fly ash shows the maximum increase in the flexural strength value by 18.17%.

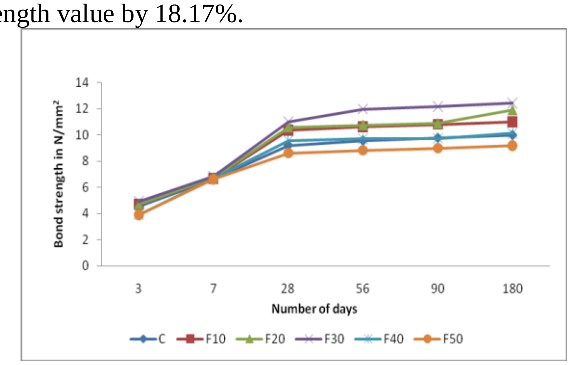

Figure.3 Flexural strength development

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Considering figure 4, it is observed that the maximum increase in the bond strength is observed as 24.36% in 30% addition of fly ash.

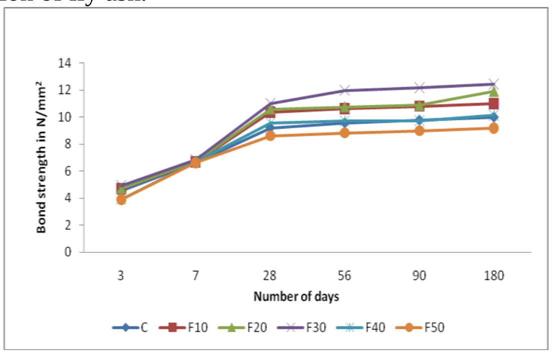

Figure.4 Bond strength development

From the results obtained, it can be seen that at the age of 7 days, the strength values of fly ash blended quarry dust concrete specimens are lower than the control specimen. This is because the rate of hydration is slow at early ages hence delay in setting time leading to increased loss of moisture which decreases the strength development for the concrete incorporating fly ash. But from 28 days onwards, the strength is increasing consistently with time and the magnitude of the strength is more than the control specimen for all percentages of fly ash. This is due to the formation of denser concrete matrix caused by the micro filling ability of the ultrafine particles of fly ash. Furthermore, the accelerated pozzolanic reaction of fly ash is enhancing the strength developed between the paste and aggregate strength.

The overall results of the mechanical strength properties indicate that the strength values are increasing gradually up to 30% but for 40% and 50% there is a reduction in strength values due to extension in initial and final set and quick loss of workability. The results proved that 30% replacement of cement by fly ash is the optimum percentage for getting maximum strength values.

MICRO STRUCTURAL PROPERTIES

The values obtained from the water absorption, permeability and bulk density tests performed on the quarry dust concrete and fly ash blended quarrydust concrete specimens are listed in Table 1.

Table 1 Micro structural properties of flyash blended quarrydust concrete

S. No.	Specimen	Water absorption (%)	Percentage of voids (%)	Bulk density kg/m^3
1	C	4.15	2.812	2410
2	F10	3.1	1.549	2480
3	F 20	2.5	0.933	2515
4	F 30	1.95	0.558	2540
5	F 40	1.96	0.560	2539
6	F50	1.98	0.563	2437

The test values obtained on the micro structural properties of fly ash blended and quarry dust concrete specimens reveal that, the increase in fly ash percentages, resulting in decrease in water absorption, percentage of voids and increase in bulk density. This is because, through pozzolanic activity, fly ash combines with water and calcium hydroxide - forming additional cementitious compounds which result in denser and impermeable concrete, thereby helping to maintain high density.

Durability tests

Impressed voltage test

The impressed voltage technique is an accelerated corrosion testing technique which indirectly gives information about the permeation characteristics of the concrete. The impressed voltage data for quarry dust concrete and various percentages of fly ash blended quarry dust concrete are shown in Figure 6 and 7.

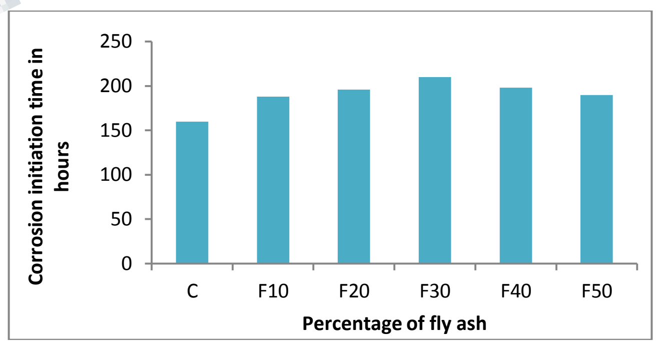

Figure 6. Corrosion initiation time

It is found from figure 6 that the time to initiate corrosion for quarry dust concrete was found to be 160 hours. Fly ash systems with 10%, 20% and 30% replacement of cement show better corrosion resistance when compared with quarry dust concrete without fly ash. On the other hand, beyond 30% there was earlier cracking of concrete indicating the inferior properties at this level. Results of the impressed

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voltage method show that the increase in the corrosion resistance for 10% to 50% replacement of cement by fly ash are found to be 17.97%, 22.14%, 30.69%, 24.68% and 19.19% respectively. Figure 7 shows the current intensity with respect to corrosion initiation time.

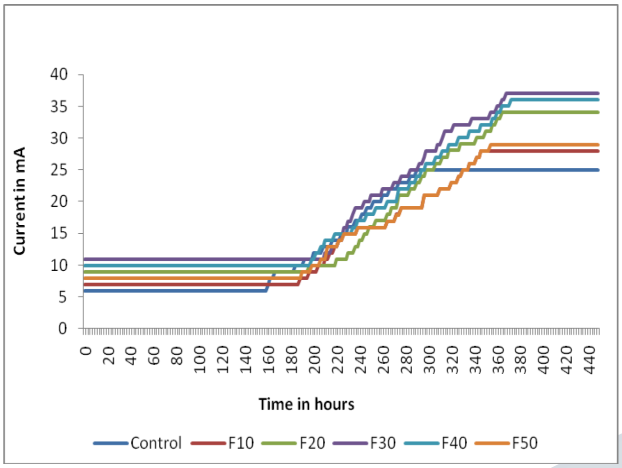

Figure 7. Corrosion initiation time Vs Current

Results herein proved that 30% replacement of cement by fly ash is the most efficient percentage to be added in concrete containing quarry dust as a complete replacement for river sand.

Rapid Chloride Penetration Test (RCPT)

Figure 8 shows the chloride diffusion results of the different percentages of fly ash. The chloride ion penetration in the form of charge passed in coulombs for different percentages of fly ash is shown in the figure 8. The performance of the quarry dust concrete with 10%, 20%, 30%, 40% and 50% replacement of cement by fly ash are observed to be 1.53, 1.87, 1.41 and 0.94 times greater than the control specimen. This is because the conversion of soluble calcium hydroxide to cementations compounds decreases bleeds channels, capillary channels and void spaces and thereby reduces permeability.

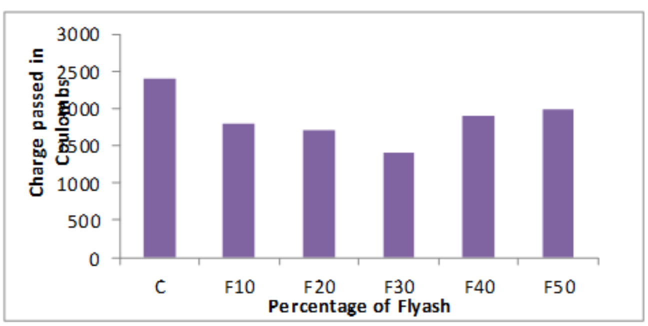

Figure.8 Rapid Chloride Penetration Test

The RCPT test results show that due to the addition of fly ash permeability of the quarry dust concrete was considerably reduced and the amount of chloride ion penetration which is the main cause for initiation of corrosion in concrete has been decreased significantly. From the figure it is observed that addition of 30% replacement shows lower coulomb values than the other mixes. These results are in agreement with impressed voltage test results.

Weight loss measurement

Figure 9 demonstrates average corrosion rate calculated in mmpy for various percentages of fly ash from weight – loss measurements.

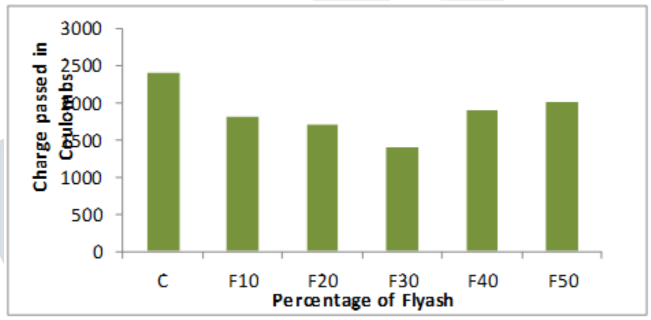

Figure.9.Corrosion rate in mmpy

The specimens with 10%, 20% and 30% fly ash have shown 19.55%, 22.37%, and 28.75% decrease in corrosion rate respectively which represent the tolerable limit of replacement with better corrosion resistive properties. From the figure it is inferred that 30% replacement of fly ash show the lowest corrosion rate values. The same trend was observed in impressed voltage test and RCPT test also. Because of the reduction in permeability, quarry dust concrete containing fly ash may require less depth of reinforcement cover than conventional concrete.

Scanning Electron Microscopic studies

The surface analysis of quarry dust concrete and fly ash blended quarry dust concrete has been done by scanning electron microscopic studies. SEM is a powerful tool for examining and interpreting microstructures of materials, and is widely used in the field of material science. Scanning Electron Microscopic studies have been carried on the concrete specimens for interpreting the microstructures. Figure 9 shows the SEM image of concrete specimens.

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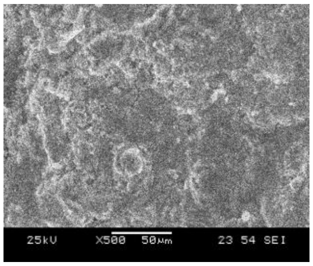
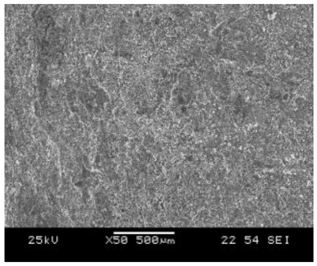
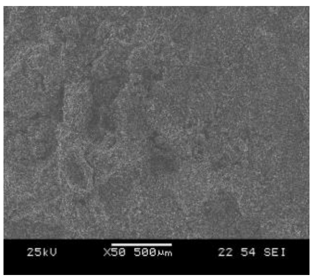


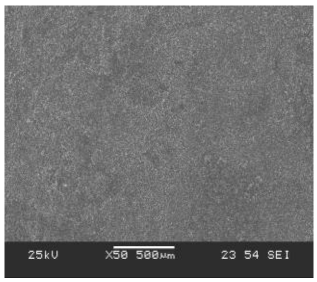
SEM -Control specimen



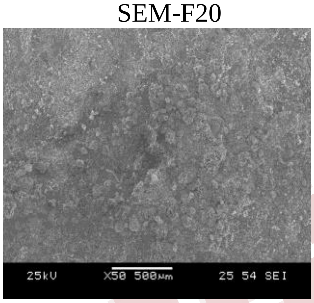
SEM-F10



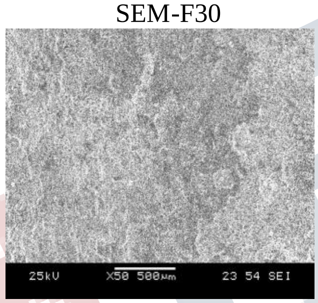
SEM-F20



SEM-F30



SEM-F40



SEM-F50

Figure 9 SEM photographs

From the above scanning electron microscopic images taken for fly ash blended qarry dust concrete it is obviously seen that the specimens with 30% of fly ash had formed compounds that reduced the permeability and porosity which protects the concrete from the attack of any external agents and thereby protecting the passive layer of the embedded steel. It could be concluded from the above result that, considering strength as well as durability criteria, the optimum percentage of replacement of fly ash by weight of cement in concrete containing quarry dust as fine aggregate is 30%.

CONCLUSION

• Concrete containing quarry dust as fine aggregate can be effectively utilized in the construction industry with fly ash, since it has higher proportion of the strength- enhancing Calcium Silicate Hydrates (CSH) than concrete made with Portland cement alone.

• Use of mineral admixtures in concrete increases the workability, consistency and reduces the water demand

• Chloride resistance of fly ash blended concrete is higher than the conventional concrete due to its lower permeability. Hence it offers very good resistance against rebar corrosion.

• From the results of strength and durability tests it has been arrived that 30% fly ash blended cement concrete containing quarry dust as fine aggregate can be effectively and economically utilized in the construction industry.

• The utilization of quarry dust and fly ash also contribute to a very satisfactory outlet of these industrial by-products which were earlier considered as waste materials and dumped on huge quantities on barren lands causing pollution problems to the surrounding localities.

• Conversion of these industrial by-products into effective construction material not only reduces the construction cost but also leads to a wide range of environmental benefits and places a significant role in producing eco friendly smart concrete.

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