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Properties of Green Concrete Mix by Concurrent use of Fly Ash and Quarry Dust

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Abstract: - Green Concrete is a concept of thinking environment into concrete considering every aspect from raw materials manufactures over mixture design to structural design, construction and service life. The raw materials of concrete consist of cement, sand and crushed aggregates. Partial or 100% replacement of these raw materials by waste products may decrease the cost, reduce the energy consumption and also reduce the environment pollution. Wastes can be used to produce new products or can be used as admixtures so that natural sources are used more efficiently and the environment is protected from waste deposits. Fly ash can be used as filler materials and helps to reduce the total voids content in concrete. However, the use of fly ash leads to a reduction in early strength of concrete. The use of quarry dust in concrete is desirable of benefits such as useful disposal of a byproduct, reducing of river sand consumption and increased strength. However, the use of quarry dust leads to a reduction in the workability of concrete. Therefore, concurrent use of fly ash and quarry dust in concrete will make the concrete by using their properties in a beneficial way. The decrease in early strength by the addition of fly ash is compensated by addition of quarry dust .The decrease in workability by the addition of quarry dust is reduced by the addition fly ash. This paper investigates the workability and strength characteristics of Quarry Dust Concrete (QDC) containing 0% to 30% of fly ash. Based on the test results, it can be concluded that combined use of quarry dust and fly ash can be shown improved strength in concrete and also preserve the environment.

Keywords: - *Fly Ash, Properties, Quarry Dust, Strength*

I. INTRODUCTION

Green concrete capable for sustainable development is characterized by application of industrial wastes to reduce consumption of natural resources and energy and pollution of the environment. River sand has been the most popular choice for the fine aggregate component of concrete in the past, but overuse of the material has led to environmental concerns, the depleting of securable river sand deposits and a concomitant price increase in the material. Therefore, it is desirable to obtain cheap, environmentally friendly substitutes for cement and river sand that are preferably by-products. Fly ash (pulverized fuel ash) is used extensively as a partial replacement of cement. However, though the inclusion of fly ash in concrete gives many benefits, such inclusion causes a significant reduction in early strength due to the relatively slow hydration of fly ash. Nevertheless, fly ash causes an increase in workability of concrete. Quarry dust has been proposed as an alternative to river sand that gives additional benefit to concrete. Quarry dust is known to increase the strength of concrete over concrete made with equal quantities of river sand, but it causes a reduction in the workability of concrete. When examining the above qualities of fly ash and quarry dust it becomes apparent that if both are used together, the loss in early strength due to one may be alleviated by the gain in strength due to the other, and the loss of workability due to the one may be partially negated by the improvement in workability caused by the inclusion of the other. This paper is generated from a research project designed to determine whether such benefits could be obtained by the use of these two materials together, and to quantify such benefits. Positive results will lead to the possibility of using the two by-products in large quantities, while reducing the dependency on chemical admixtures.

1.1 Quarry Dust

The most widely used fine aggregate for making of concrete is the natural sand mined from the riverbeds. However, the availability of river sand for the preparation of concrete is becoming scarce due to the excessive non-scientific methods of mining from the riverbeds, lowering of water table, sinking of bridge piers, etc. are becoming common problems. The present scenario demands identification of substitute materials for the river sand for making concrete. Quarry dust as a by product from crushing process during quarrying activities is one of those materials that have recently gained attention to be used as concreting aggregates, especially as fine aggregate. In concrete production it could be used as a partial or full replacement of natural sand. Besides, the utilization of quarry waste, which itself is a waste material, will reduce the cost of concrete production.

1.2 Fly Ash

Fly ash is one of the residues generated in the combustion of coal. Fly ash is generally captured from the chimneys of coal-fired power plants, and is one of two types of ash that jointly are known as coal ash; the other, bottom ash, is removed from the bottom of coal furnaces. Depending upon the source and makeup of the coal being burned, the components of fly ash vary considerably, but all fly ash includes substantial amounts of silicon dioxide (SiO2) (both amorphous and crystalline) and calcium oxide (CaO), both being endemic ingredients in many coal bearing rock strata.About 43 percent is recycled and often used to supplement Portland cement in concrete production.

II. LITERATURE REVIEW

Alireza Mokhtarzadeh and Catherine French studied the use of supplementary cementitious materials, such as fly ash and silica fume, does not necessarily translate into higher strengths. It was shown that benefits from inclusion of fly ash and / or silica fume in the production of HSC depended on the factors such as mixture proportions, type of aggregate in the mixture and the method of curing. When the strength of the HSC was limited by the failure of the aggregate, further reduction in the w-c ratio will not increase strength, and may cause problems by reducing workability of the mixture.

Charles Berryman et al. investigated the maximum compressive strength was found at a fly ash replacement percentage of 35% for concrete containing Class C fly ash. The mean value of compressive strength for 35% type C fly ash was slightly above 41.5 MPa. The maximum compressive strength for concrete where cement was replaced with Class F fly ash was at 25% replacement. Maximum compressive strength for concrete containing type F fly ash was approximately 36.0 MPa.

N. Bouzoubaa, et al. studied the type of the fly ash used, the concrete made with the HVFA blended cements developed higher compressive strength at all ages than that of the HVFA concrete in which unground fly ashes and laboratory - produced portland cements had been added separately at the concrete mixer. The increase in the compressive strength was more significant for the HVFA blended cement produced with the cement without a SP and made with coarse fly ash.

H. B. Mahmud, et al. had studied the experimental study on suitability of Quarry Dust as Partial Replacement Material for Sand in Concrete. Results obtained indicate that the incorporation of quarry dust into the concrete mix as partial replacement material to river sand resulted in lower 28th day compressive strength. The results of the study also indicates that quarry dust can be utilised as partial replacement material to sand, in the presence of silica fume or fly ash, to produce concretes with fair ranges of compressive strength.

According to Tarun R. et al. to develop structural grade concrete containing high-volume of high-calcium fly ash (ASTM Class C) concrete mixes were proportioned for four levels of cement replacements (40%, 50%, 60%, and 70%) by fly ash. Fly ash-to-cement ratio was maintained at 1-1.25 for all test conditions. Properties of concrete, namely, compressive strength, splitting tensile strength, and modulus of elasticity were determined as a function of fly ash amounts and age. Modulus of elasticity for fly ash concrete at 28 days was not determined. It was computed from the formula in the ACI code. The test results showed that the compressive strength of fly ash concrete was higher than the strength of the reference concrete at 28-day age within the experimental range.

III. MATERIAL USED AND THEIR PROPERTIES

Locally available quarry dust was the primary material used in this research work. Besides that, for concrete mixing purposes, Ordinary Portland Cement, crushed stone coarse aggregate, river sand, fly ash (Class C Fly ash obtained from Neyveli confirms to IS: 3812-1981) were used. Normal tap water was used for both concrete mixing and curing purposes. Sulphonated naphthalene formaldehyde (conplast sp 430) was used as Super plasticizer to improve the workability.

First category of the tests conducted to find the physical and chemical composition of the quarry sand. These properties are the particle size distribution based on IS 383: 1970, the specific gravity (IS 2386(part III) 1963) for assessing batch quantities; bulk density (IS: 2386 (Part III) 1963) which enables quantities of materials for concrete to be converted from quantities by weight to volume. The second category of the test examined the slump and the compressive strength of concrete using quarry dust as fine aggregate and crushed stone as the coarse aggregate. For this purpose, two different mixes of M40 grade 1: 1.39: 1.7 (cement: river sand: crushed stone aggregate) and 1: 1.37: 1.7 (cement: quarry dust: crushed stone aggregate) ratios were used. Each mix was carried out at water-cement ratio of 0.40.The various properties of materials used are given in Table 1, Table 2, and Table 3.Table 4 shows the various mix proportions of concrete used.

Table 1. Physical Properties of Cement and Fly Ash

Sl.no	Property	Cement	Fly Ash
1	Normal consistency	29%	40%
2	Initial setting time	63 min	150 min
3	Final setting time	240 min	-
4	Specific gravity	3.15	2.412
5	Fineness of cement by sieve	1.2%	2.26%

Table 2. Chemical Properties of Fly Ash

Properties	Percentage
Ca O	12.90
Si O2	44.5
Al2 o3	21.1
SO3	7.81
Na2o	6.25
K2O	0.80

Table 3. Physical Properties of Fine aggregate and Coarse Aggregate

S.No	Property	Fine Aggregate(Sand)	Fine Aggregate(QD)	Coarse Aggregate
1	Specific gravity	2.63	2.41	2.707
2	Fineness Modulus	2.46	3.77	5.914
3	Uniformity co-efficient	3.33	9.28	1.479
4	co-efficient of curvature	0.948	1.06	1.201

Table 4. Details of Mix Proportions of Concrete

Sl No	Materials Used	CC	QCC	$QCFA_1$	$QCFA_2$	$QCFA_3$
1.	Fly ash (F.A)%	0	0	10	15	20
2.	Superplasticer (S.P) %	0	2.0	2.0	2.0	2.0
2.	Cement (Kg/m^3)	530	530	477	450	424
3.	Fly ash (Kg/m^3)	0	0	53	80	106
4.	Sand (Kg/m^3)	740.25	0	0	0	0
5.	Quarry dust (Kg/m3)	0	725	725	725	725
6.	Coarse aggregate (Kg/m^3)	901.53	901.53	901.53	901.53	901.53
7.	water(lit/m^3)	212	212	212	212	212
8.	Superplasticer (lit/m^3)	0	10.6	10.6	10.6	10.6

CC = Control concrete without fly ash QCC = Quarry dust concrete without fly ash
$QCFA_1$ = Quarry dust concrete with fly ash 10% $QCFA_2$ =Quarry dust concrete with fly ash 15%
$QCFA_3$ =Quarry dust concrete with fly ash 20%

IV. AGE OF TESTING

The tests were conducted at 3, 7, 14, 28, 60 and 90 days. A total 228 specimens were casted for testing. (60 cube specimen for compression, 60 cylinder specimens for compression, 60 cylinder specimens for split tensile, 48 specimens for flexural strength)

V. SPECIMEN DETAILS

The compressive strength of concrete was tested as per IS 516 -1959 cube size of 100x100x100 mm .The concrete prisms size of 100x100x500 mm was caste for obtain the flexural strength as per IS 516 -1959. The concrete cylinders diameter of 100mm and length of 200 mm were caste for obtain the splitting tensile strength of concrete as per IS 5816. Three specimens were tested for the required age and the average value was taken.

Figure 1. Casting of Specimen

VI. RESULTS AND DISCUSSIONS

To study and compare the behavior of concrete using quarry dust as fully replacement of sand, experimental investigations as mentioned were carried out on concrete samples for their strength and properties. The concrete samples were cast with mix 1: 1.39: 1.7 and 1:1.37:1:7. The tests were carried out after 3, 7, 14, 28, 60, 90 days of the casting of concrete specimen. Summary of the test result for concrete mixes with fully replacement of fine aggregate using quarry dust as recorded. The percentage variation in properties of concrete using quarry dust, with respect to that using sand is also illustrated in the figures for comparative study.

6.1 Workability Tests

The concrete mix used for the test are of low to medium workability hence Slump cone and compaction factor tests are carried out since it is relevant for the study. The workability was improved by adding Super plasticizer to the concrete. Slump value decreases with the increase in amount of quarry dust. At first it decreases rapidly and then it decreases gradually. This is because of water absorption capacity of quarry dust is more. The reasons for the reduction in workability of concrete are attributable to the properties of fine aggregates.

Table 5. Results of Workability Tests on Concrete

Type of concrete	Slump value Mm	Compaction Factor	Flow %
CC	85	0.88	42
QCC	94	0.90	35
$QCFA_1$	80	0.8	41
$QCFA_2$	78	0.77	44
$QCFA_3$	76	0.74	51

6.2 Compressive Strength of Concrete

Of the various strength of concrete the determination of compressive strength has received a large amount of attention because the concrete is primarily meant to withstand compressive stresses. Cubes, cylinders and prisms are the three types of compression test specimens used to determine compressive strength. The cubes are usually of 100 mm or 150 mm side, the cylinders are 100 mm diameter by 200 mm height; the prisms used are 100 mm × 100 mm × 500 mm. The specimens are cast, curved and tested as per standards prescribed. The results are shown in fig.2.

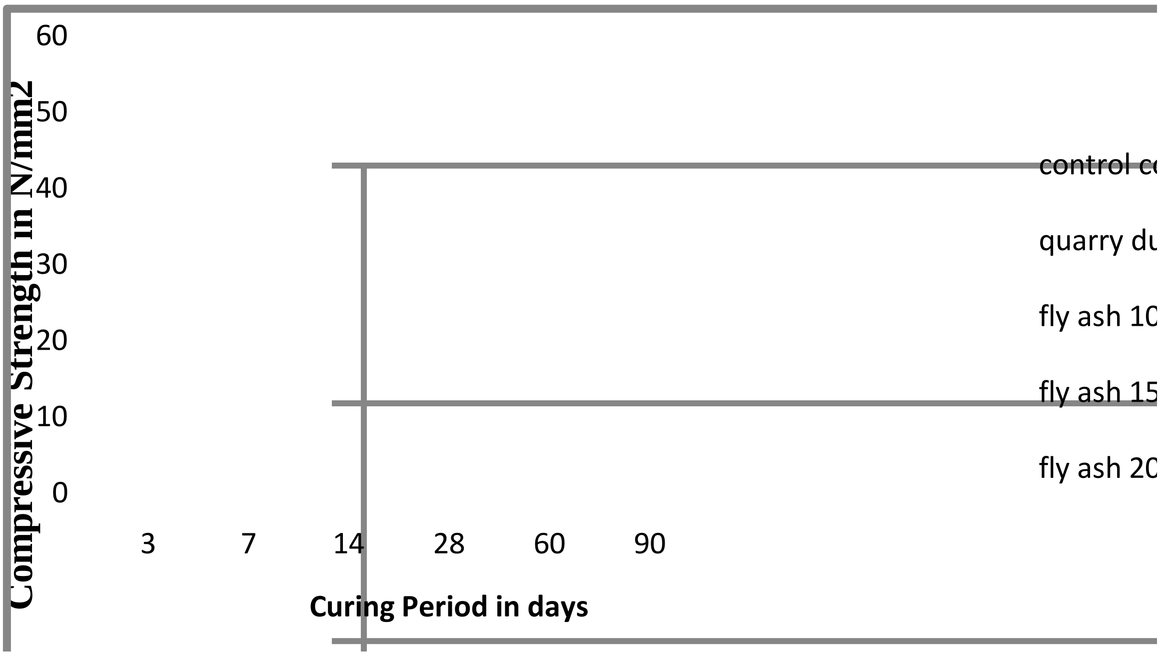

Figure 2. Comparison of Compressive Strength of Cube

The compressive strength of cubes of Quarry Dust concrete is slightly less than the Sand concrete. This is due to the poor grading of particles in Quarry Dust. The test results of cylinder compressive strength of various concrete specimens are shown in fig. 3. Here also the same pattern reflected in the test results.

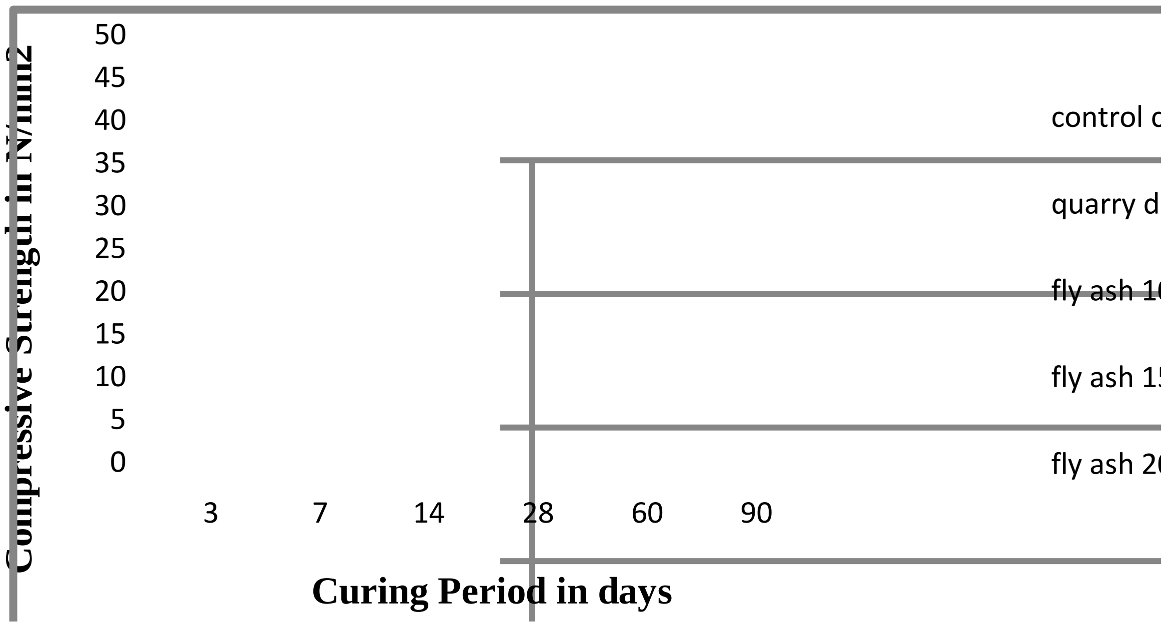

Figure 3. Comparison of Compressive Strength of Cylinder

6.3 Split Tensile Strength for Cylinder

The cylinder specimens were tested for split tensile strength at an age of 3, 7, 14, 28, 60 and 90 days. According to IS-5816-1999 Split Tensile Strength of Concrete method of Test, the tensile strength was determined. The test results are shown in the fig. 4. It indicates that the values of QDC with fly ash more or less same as Sand concrete.

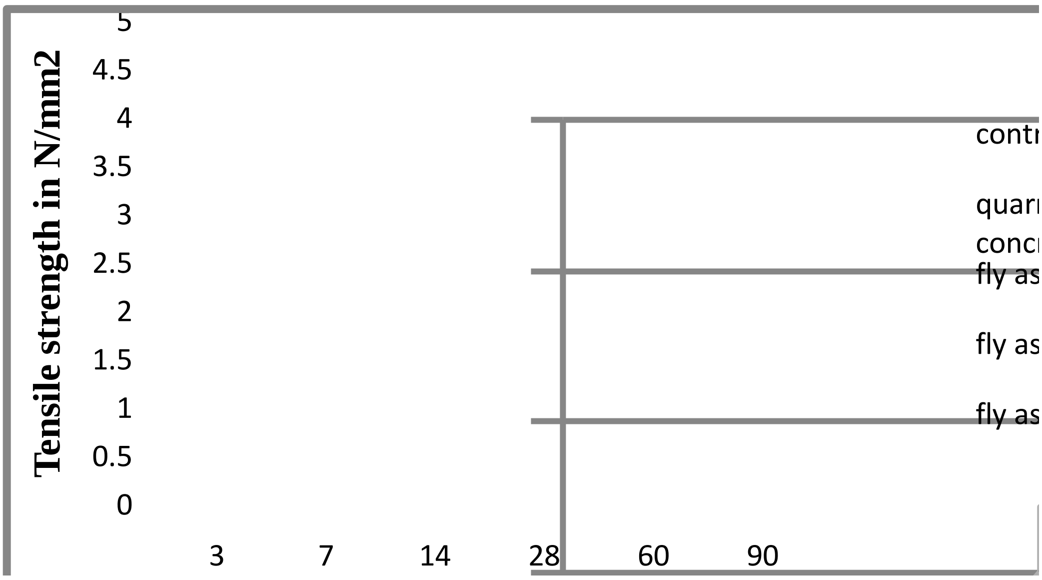

Fig. 4 Comparison of Split Tensile Strength of Cylinder

6.4 Flexural Strength Of Concrete

The concrete prisms of 100x100x500 mm^3 size were tested under a third-point loading system to obtain the flexural strength. Test results and development of flexural strength at various percentage of replacement of cement are shown in fig. 5.

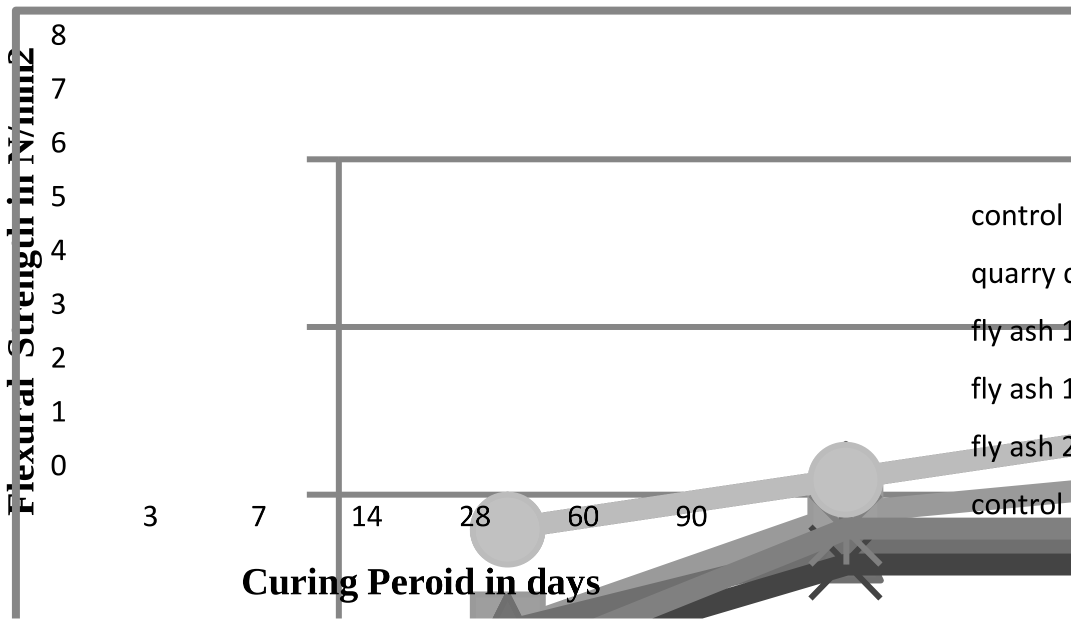

Figure 5. Development of Flexural Strength of Beams

VII. CONCLUSION

In the experimental investigation, compare the conventional concrete with green concrete quarry dust as fine aggregate and replacement of fly ash 10%, 15% & 20% by cement have been studied and the results were presented and analyzed in the previous chapter.

- ✓ Natural river sand, if replaced by hundred percent Quarry Rock Dust from quarries, may sometimes give equal or better result than the concrete made with Natural Sand, in terms of compressive and flexural strength studies.
- ✓ Fly ash is a byproduct that can be used in concrete to obtain durability, cost, and environmental benefits.
- ✓ The concurrent use of the above two by products, with the expectation that the decrease in early strength by the addition of fly ash is ameliorated by the addition of quarry dust.
- ✓ The decrease in workability by the addition of quarry dust is reduced by the addition of fly ash
- ✓ Quarry waste fine aggregate decreased the compressive strength of concrete due to deficient grading and excessive flakiness
- ✓ Split tensile strength of quarry dust concrete is more or less equal to conventional concrete.
- ✓ Flexural strength of quarry dust concrete is more or less equal to conventional concrete
- ✓ Green concrete improves the fresh concrete behavior and can be used in architectural concrete mixtures containing white cement.
- ✓ Thus, it concluded that the replacement of natural sand with quarry rock dust, as full replacement in concrete and also partial replacement of cement with fly ash is possible. However, more research studies are being made on quarry rock dust concrete necessary for the practical application of quarry rock dust as fine aggregate with fly ash.

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