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Study on the Effect of Replacement of Cement with Silica Fume Along With Recycled Aggregate

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Abstract— Construction industry is witnessing a tremendous growth year by year. The increase in demand of the construction is causing many environmental impacts. To spot an example, 1 ton of cement production releases 1 ton of CO_2 to the atmosphere. Apart from cement aggregate is an important constituent of concrete and extensive mining of the sources of aggregate is causing an ecological imbalance. Ecological sustainability and sustainable construction has to be given prior importance. This paper deals with the partial replacement of cement with silica fume and using a percentage of recycled aggregates as coarse aggregates. Experimental program includes two stages. In the first stage cement is replaced with 5%,7.5%,10%,15% silica fume and its percentage is optimised and in the second stage, with that optimised percentage of silica fume recycled aggregate is varied with 20%, 30% and 40%. Strength parameters studied includes compressive strength, flexural strength, split tensile strength.
Keywords— cement, aggregates, silica fume, recycled aggregates

I. INTRODUCTION

Concrete is widely used in construction industry due to its structural stability and strength. A main constituent in concrete includes ordinary Portland cement (OPC), fine aggregates, coarse aggregates and water. Unfortunately production of cement releases large amount of CO_2 to the atmosphere and extensive mining of rocks for aggregates causes ecological imbalance. Industrial by-products can be effectively used for replacing cement in concrete and it is gaining importance and acceptance nowadays. Fly ash, silica fume, GGBS, metakaolin etc are some of the examples. Most of them have pozzolanic property, so can be effectively used in concrete as partial replacement of cement. Addition of silica fume has many advantages like improved strength and durability. Large quantities of construction waste are dumping as landfills. Effective uses of these construction wastes in concrete reduce the problem of shortage of dumping place and helps in the preservation of sources of natural aggregates. Objective of this study the effectiveness in using silica fume and recycled aggregates in concrete industry.

II. SILICA FUME RECYCLED AGGREGATE CONCRETE

Silica fume is a by product of silicon industry. It is formed by the reduction of high purity quartz in an electric arc furnace. The fumes that arises are condensed and this condensed silica fume consist of 90% of SiO_2. This silica fume is purified and is used. Silica fume has got different names such as micro silica, silica dust, and condensed silica fume. Silica fume posses both pozzolanic property as well as cementitious property. It is obvious that using recycled aggregate in concrete reduces the strength of concrete. The main reason for reduced strength is due to the presence of residual mortar. Residual mortar is to be considered while designing the mix. The decrease in strength due to recycled aggregate is compensated by the addition of silica fume. So the combination of both these materials can be done effectively without compromising the strength of concrete.

A. Mechanism

Strength gaining of silica incorporated concrete is mainly due to pozzolanic action of silica fume. The silica present in silica fume combines with the calcium hydroxide which is a product of hydration to from C-S-H gel which posses cementitious property. This imparts strength to the concrete. Second reason is the fineness of silica fume. Due to larger surface area silica fume will get densely packed in the cement paste and in aggregates and reduces the wall effect in transition zone.

III. EXPERIMENTAL PROGRAM

A. Materials and Properties

Different materials selected for this experimental study includes OPC cement, natural and recycled coarse aggregate, manufactured fine aggregate, super plasticizer. All the materials are tested since the properties of each component greatly affects the properties of

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concrete.

1) Cement: Ordinary Portland cement 53 grade was used for the experimental study and it was purchased from St. Mary's hollow bricks company, Kothamangalam and it conforms to IS specifications. Properties of the cement are listed in Table 1

TABLE 1 PHYSICAL PROPERTIES OF CEMENT

Name of test	Result
Specific gravity	3.14
Standard consistency	32%
Initial setting time	40 minutes
Final setting time	540 minutes

2) Fine Aggregate: It should pass through IS sieve 4.75mm. fine aggregate used for the study was M sand and it was graded properly to give the minimum void ratio. Fine aggregate selected was free from clay, silt, and chloride contamination. Specific gravity was found to be 2.62

3) Natural Coarse Aggregate: It is the strongest and least porous component of concrete. Angular aggregates are preferred. Flaky and elongated aggregates should be avoided as far as possible. Both 20 mm and 12 mm aggregates were used. Aggregate crushing value was obtained as 30 % and specific gravity as 2.67

4) Recycled Aggregate: Manually crushed RCA was prepared by crushing the concrete blocks with a hammer and sieving it to get the required size. Aggregates passing through 25mm sieve and retained on 4.75 mm sieves were taken for the investigation. Specific gravity was found to be 2.50

5) Silica Fume: Silica fume required for the study was purchased from BSS suppliers, kakkanad. The specific gravity of silica fume was found to be 2.4.

Fig 1Silica fume

B. Experimental Work: The mix design was done as per IS: 10262(2009). M30 Grade was adopted for the work. Fine aggregate selected for the study falls under zone II. Water cement ratio was fixed at 0 .43. the mix proportion was carried out to get a sump of 150 mm. The quantity of materials required per m^3 of concrete is listed in table 2.

TABLE 2 QUANTITIES OF MATERIALS

Material	Quantity
	388
Cement (kg/m3)	670
Fine aggregate (kg/m3)	1200
Coarse aggregate(kg/m3)	167
Water(*l*/m3)	1.373
Super plasticizer(*l*/m3)	

IV. TESTS AND RESULTS

A. Compressive Strength

Cubes of size 150mm x 150mm x 150 mm were casted. Both 7 and 28 day compressive strength tests were done. The results are tabulated in table 3.

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TABLE 3 COMPRESSIVE STRENGTH

Mix	7 day compressive strength (MPa)	28 day compressive strength (MPa)
CM	28	39.8
S5	32.5	43.6
S7.5	34.6	45.8
S10	30.6	41.2
S15	30.2	40.8

B. Split Tensile Strength

Cylinders of size 150mm x 300 mm were casted .both 7 and 28 days split tensile strength were tested. The results are tabulated in Table 4

TABLE 4 SPLIT TENSILE STRENGTH

Mix	7 day tensile strength (MPa)	28 day tensile strength (MPa)
CM	1.88	2.83
S5	2.56	3.38
S7.5	3.02	3.65
S10	3.15	3.82
S15	2.88	3.15

C. Flexural Strength

Beams of size 100mm x 100mm x 500 mm were casted. Both 7 and 28 day flexural strength test were done. Results are tabulated in table 5

TABLE 5 FLEXURAL STRENGTH

Mix	7 day flexural strength (MPa)	28 day flexural strength (MPa)
CM	4.13	5.3
S5	4.29	5.4
S7.5	4.93	6.1
S10	4.62	5.88
S15	4.12	5.33

From the above results 7.5 % of silica fume shows max strength in compression and flexure and in tensile strength also it showed very good result. In split tensile strength also. So 7.5 % silica fume is optimised for the IInd stage of experiment by varying the recycled aggregate percentage.

D. Compressive Strength (RAC)

Strength of specimens with recycled aggregate showed lesser strength than that of silica fume concrete. 28 day strength test was conducted. The results obtained are tabulated in table 6

TABLE 6 28 DAY COMPRESSIVE STRENGTH OF RAC

Mix	28 day compressive strength (MPa)
CM	39.8
R20S7.5	42.3
R30S7.5	40.6
R40S7.5	37

E. Split Tensile Strength (RAC)

28 day split tensile strength was tested. The test results showed that up to 30 % replacement of recycled aggregate showed good results without much compromise in strength. The results obtained are tabulated in Table 7

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TABLE 7 28 DAY TENSILE STRENGTH OF RAC

Mix	28 day tensile strength (MPa)
CM	2.83
R20S7.5	3.52
R30S7.5	2.9
R40S7.5	2.76

F. Flexural Strength (RAC)

100mm x 100mm x 500 mm beams were tested for determining the 28 day flexural strength test. The results are tabulated in Table 8.

TABLE 8 28 DAY FLEXURAL STRENGTH OF RAC

Mix	28 day Flexural strength (MPa)
CM	5.3
R20S7.5	5.9
R30S7.5	5.76
R40S7.5	5.4

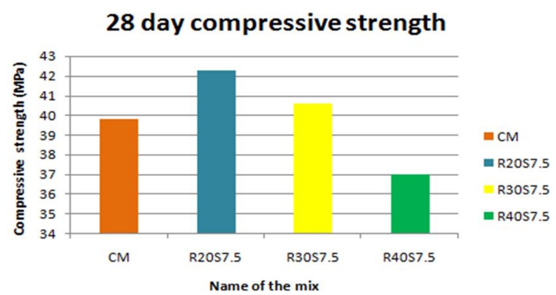

Fig 3 Compressive strength of RCA at 28 day

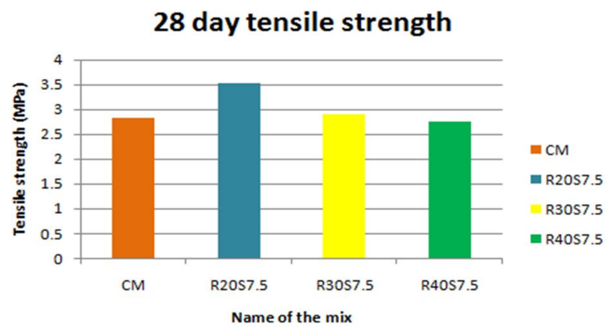

Fig 4 Tensile strength of RCA at 28 day

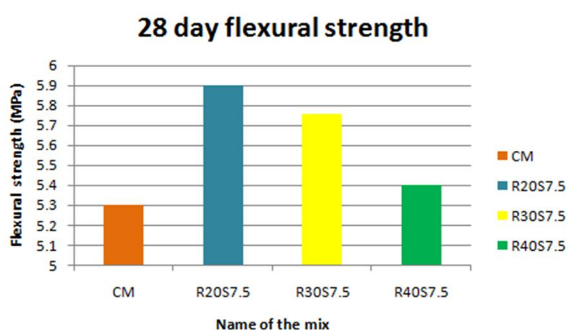

Fig 5 Flexural strength of RCA at 28 day

From the test results of compressive strength, tensile strength and flexural strength, it can be seen that, up to 30 % of recycled aggregate can be incorporated in concrete along with silica fume without compromising strength of concrete. The decrease in strength due to recycled aggregate is compensated by the addition of silica fume.

V. CONCLUSION

These are the main findings of this works and are listed below

The compressive strength of silica fume concrete is found to be more than normal concrete. Compressive strength increase in 7 day is due to the void filling ability of silica fume and compressive strength increase in 28 day is due to the pozzolanic activity of silica fume. 7.5 % replacement of silica fume shows higher strength.

10 % replacement of silica fume is found to give higher flexural strength. This is due to the fact that increased percentage of silica fume increases the bonding.

7.5% of silica fume is found to give higher flexural strength in both 7 and 28 day tensile strength.

It is obvious that addition of recycled aggregate shows decrease in strength. But up to 30 % replacement of recycled aggregates shows higher strength than control mix.

So by combining silica fume and recycled aggregate we can effectively reduce content of cement and natural aggregate in concrete and thereby reducing environmental impact.

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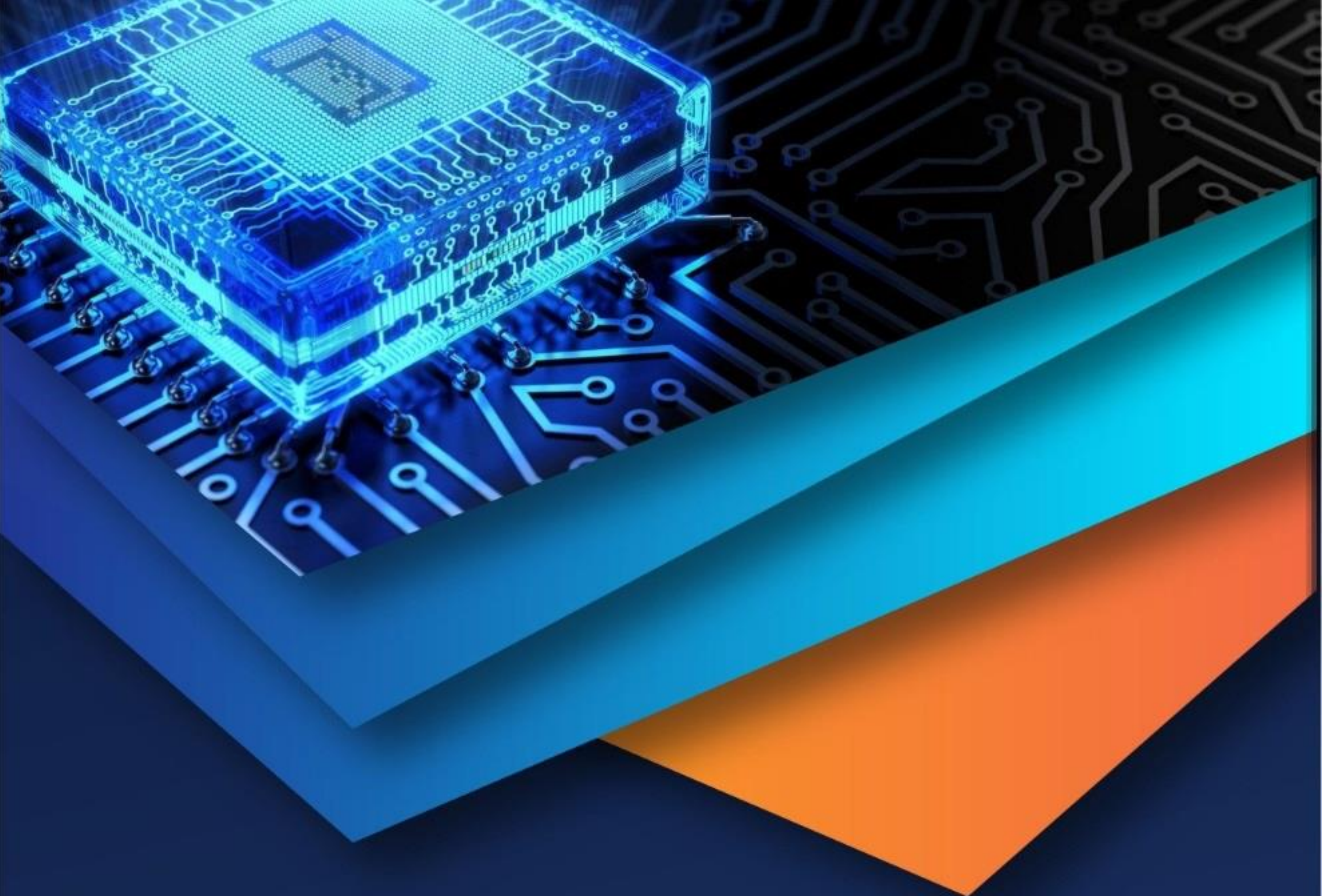

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