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INVESTIGATIVE STUDIES ON USE OF SILICAFUME AS A MINERAL ADMIXTURE IN THE CONCRETE

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ABSTRACT

Aggregate is one of the main ingredients in producing concrete. It covers 75% of the total for any concrete mix. The strength of the concrete produced is dependent on the properties of aggregates used. The aim for this project was to determine the strength and durability characteristics of high strength concrete by using recycled coarse aggregates with supplementary cementitious material (Silica fume), which will give a better understanding on the properties of concrete with recycled aggregates. This paper deals with the use of Silica fume which is having good pozzolanic activity and recycled aggregate for the production high strength concrete which is getting popularity because of its positive effect on various properties of concrete.

Keywords: *Concrete, Strength, Silica fume, Recycled aggregate*

I. INTRODUCTION

Concrete is generally classified as Normal Strength Concrete (NSC), High Strength Concrete (HSC) and Ultra High Strength Concrete (UHSC). There is no clear cut boundary for the above classification. Indian Standard Recommended Methods of Mix Design denotes the boundary of 35 MPa between NSC and HSC. They did not talk about UHSC. But elsewhere in the international forum, about thirty years ago, the high strength label was applied to concrete having strength above 40 MPa. More recently, the threshold rose to 55 MPa as per IS 456- 2000.

Research on the usage of waste construction materials is very important since the materials waste is gradually increasing with the increase of population and increasing of urban development. The reasons that many investigations and analysis had been made on recycled aggregate are because recycled aggregate is easy to obtain and the cost is cheaper than virgin aggregate. Use of Silica fume in construction industry as partial replacement of cement started in the 1960's and the interest in this material has considerably increased in recent years. Silica fume has pozzolanic properties bringing positive effects on resulting properties of concrete. Pozzolanic properties cause chemical reaction of active components with calcium hydroxide (portlandite), which is formed as a product of cement hydration. This reaction leads to formation of binding phases of following types: secondary C-S-H gel, C_4AH_{13}, C_3AH_6, and C_2ASH_8 thereby increasing strength. Hence this paper mainly focuses on development of high strength concrete using recycled aggregate and Silica fume. Ganesh Babu and Saradhi Babu (2003) investigated strength and durability properties of concrete containing silica fume (3%, 5% and 9%) as partial replacement of cement and Expanded Polystyrene (EPS) beads as partial replacement of aggregates. From the experiments, the densities of EPS concrete ranging from 1500 to 2000 kg/cum and the compressive strengths ranging from 10 to 21 MPa achieved correspondingly. The durability properties like chloride permeability and corrosion resistance of EPS concrete are observed to be good. Patil (2012), Aiswarya (2013), Katrina (2013), yong (2009), Sivakumar (2014), Rushabh (2013) and Ramesh (2013) worked on the usage of different supplementary materials in the concrete. The present investigation is mainly focused on the use of silica fume with recycled aggregate concrete.

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II. MATERIAL PROPERTIES

A. Silica fume

Silica fume (SF), also called condensed silica fume (CSF), is a mineral admixture, mostly composed of submicron particles of amorphous silicon dioxide. The term "silica fume" is adopted by the American Concrete Institute. The SF (Table 1) used in concrete is a byproduct of the smelting process in the production of silicon metal and ferrosilicon alloys, containing more than 75% silicon.

The important characteristics that make SF an effective pozzolanic material are (a) fineness (15,000–25,000 m2/kg, N_2 adsorption method), with an average particle diameter 100 times smaller than that of Portland cement, (b) spherical shaped articles that improve the rheology of concrete, and (c) glassy structure and high amorphous silica that enhances reactivity with cement.

A) Physical Properties

Table 1. Physical and chemical properties of silica fume

Specific Gravity	2.2
Physical Form	Powder
Color	Gray to Buff
Specific Surface	8– 15 m^2 /g.

B) Chemical Composition

SiO2	97.5	MgO	0.10
Al2O3	0.29	Na2O	0.10
Fe2O3	0.03	K2O	0.20
SO3	0.10	L.O.I.	0.7
CaO	0.20		

B. Cement

The cement (Table 2) used is SANGHI OPC 53 grade cement. Tests were conducted on cement like Specific gravity, consistency tests, setting tests.

Table 2. Properties of cement

S.No.	Properties	Result
1	Specific gravity	3.15
2	Standard Consistency (%)	30%
3	Initial setting time (hours, min)	2.5hours
4	Final setting time (hours, min)	10hours

C. Fine Aggregate

Fine aggregate (Table 3) are material passing through an IS sieve that is less than 4.75mm gauge beyond which they are known as coarse aggregate. The fine aggregate also helps the cement paste to hold the coarse aggregate particle in suspension. According to IS 383:1970 the fine aggregate is being classified in to four different zone, that is Zone-I, Zone-II, Zone-III, Zone-IV. The river sand is used as fine aggregate conforming to the requirements of IS: 383. The river sand is washed and screened, to eliminate deleterious materials and over size particles. The fine aggregate used here is confining to Zone-II.

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Table 3. Properties of sand

Property	**Fine Aggregate**
Fineness modulus	3.1
Specific gravity	2.767
Water absorption (%)	1.2
Bulk Density (gm/cc)	1.78

D. Coarse aggregate

In case of coarse aggregate maximum 20 mm coarse aggregate is suitable for concrete work. But in this study coarse natural aggregate used is around 75% and 25% of recycled aggregate.

E. Recycled aggregate

The usage of natural aggregate is getting more and more intense with the advanced development in constructional area. In order to reduce the usage of natural aggregate, recycled aggregate (Table 4) can be used as the replacement materials in coarse aggregate in various proportions. Recycled aggregate are comprised of crushed, graded inorganic particles processed from the materials that have been used in the constructions and demolition debris. These materials are generally from Buildings, roads, bridges, and sometimes even from catastrophes, such as wars and earthquakes.

Table 4. Properties of coarse aggregate and recycled aggregate

Property	Coarse aggregate	Recycled aggregate
Specific gravity	2.5	2.65
Water absorption	0.15	3.8
Aggregate crushing value	29.9	34.73

F. Super plasticizer

The excellent dispersion properties of VARAPLAST PC 432 make it the ideal admixture for ready mixed concrete where low water cement ratios are required. This property allows the production of very high ultimate strength concrete with minimal voids and therefore optimum density. VARAPLAST PC 432 (fig. 1) is recommended for concrete grades M 40 and above. The use of VARAPLAST PC 432 gives a combination of excellent initial workability and workability retention over a long period in cementitious rich compositions like M-100 concrete.

Fig.1. Varaplast P C 432

Properties of superplasticzer

Calcium chloride content: Nil

Specific gravity: 1.10 at 20 °C

Air entrainment: Less than 1% additional air is entrained.

Setting time: 1 - 4 hours retardation depending on dosage and climatic conditions.

Chloride content: Nil to BS 5075

III. DESIGN MIX METHODOLOGY

a) Design Mix

A design mix of grade M60 (Table 5) was designed as per IS: 10262 method and the proportions were used to prepare the test samples. The below given table has mix proportions by volume and weight for 1 m3 of M60 grade concrete.

Table 5. mix design proportions

Materials	By Weight(kgs)	By Volume
Cement	51.79	1
Fine aggregate	37.5	1.7
Coarse aggregate	56.3(10mm) 56.3(20mm)	2.17
Water	15.5liters	0.3

Description of samples

Trial mixtures (Table 6) were prepared to obtain target strength of more than 60 MPa for the control mixture at 28 days and the water/binder ratio for all the mixtures were kept constant at 0.30 with 0.8% of super plasticizer. Six cubes of cross-section area of 22.5 were casted and three cubes of cross-section area of 100 were casted and well compacted, so that there are no voids within it and finally left overnight to set.

Table 6. mix ingradients

Sample	Description
C1	Cement+Fine aggregate + Coarse aggregate(75%) + Recycled aggregate(25%) + superplastizer(0.8%)
M1	Silicafume (5%) + Cement + Fine aggregate + coarse aggregate (75%) + Recycled aggregate (25%) + Super plasticizer (0.8%)
M2	Silica fume (10%) + Cement+ Fine aggregate + coarse aggregate (75%) + Recycled aggregate (25%) +Super plasticizer (0.8%)
M3	Silica fume (15%) +Cement+ Fine aggregate+coarse aggregate+Recycled aggregate (25%) +Super plasticizer (0.8%)

All the six samples of cubes are tested using standard compression testing machine (STM). The cubes are tested in the period of 7 and 28 days. The mean compressive strength of the cubes is calculated for each sample of mix proportion. Similarly, the other three samples are used to calculate sorpitivity coefficient, porosity, and the impact resistance is calculated by the drop weight impact test.

IV. RESULTS AND DISCUSSIONS

Effect of SF on consistency of cement:

Silica fume having greater fineness than cement and greater surface area so the consistency increases greatly, when Silica fume percentage increases compare to plain cement. It was observed that normal consistency (Table 7) increases about 36% when Silica fume percentage increases from 0% to 15%.

Table 7. Consistancy

Percentage of SF	Consistency
0	28
5	30
10	34
15	36

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Compression Test:

The six samples of dimensions 150 x 150mm are subjected to compression strength test. The cubes are tested for the period of 7 and 28 days. The table 8 and fig 2 provides the average value of compression test obtained after three trails.

Table 8. Compressive strength of concrete

Description	7 Days	28 Days
Sample C1	31	58
Sample M1	44	60
Sample M2	46	65
Sample M3	42	58

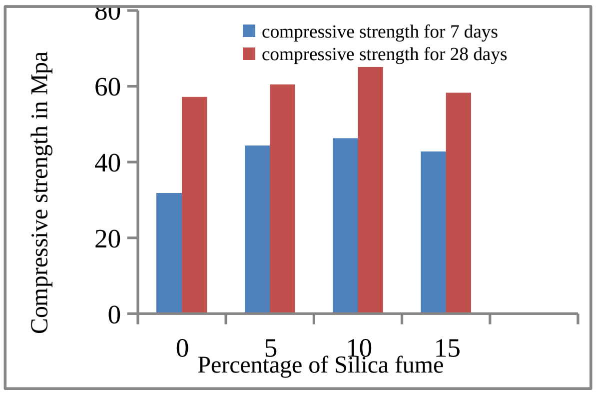

Fig.2. Compressive strength

Capillary Absorption Test:

The capillary absorption (Table 9 and Fig. 4) test can be determined by capillary absorption rate on a specimen or homogeneous material. The capillary absorption test is also known as sorpitivity test. The cubes of dimension 100x100mm where casted and cured for 28 days. The specimen where dried in an oven over 106°C for 24 hours. After it has dried then it is drowned in water bath with water level for not more than 5mm and in order to prevent the flow from horizontal surface a non-absorbent coat such as paraffin is applied so that the water absorption is under capillary suction. . The weight of the specimen was measured at regular 30 minutes interval up to 2hr 30 min to get the little absorption variation of water as shown in the experimental set up in figure 3.

Fig.3. Sorpitivity test

Sorpitivity is mainly calculated by

$I=S.t^{½}$ therefore **$S=I/ t^{½}$]**

Where;

ISSN 2348 – 8034
Impact Factor- 5.070

S= sorpitivity in mm,
t= elapsed time in sec.
I=Δw/Ad
Δw= change in weight = W2-W1
W1 = Oven dry weight of cylinder in grams
W2 = Weight of cylinder after 30 minutes capillary suction of water in grams.
A= surface area of the specimen through which water penetrated.
d= density of water

Table 9. capillary absorption coefficient

Silica fume (%)	**Capillary absorption coefficient (k)**
5	3.92×10^{-4}
10	7.85×10^{-4}
15	2.16×10^{-3}

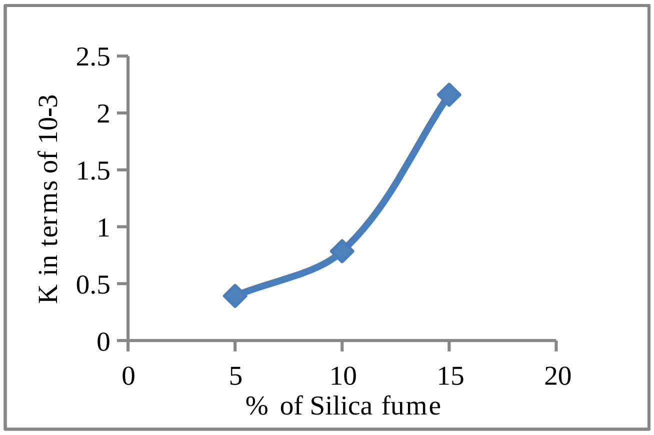

Fig.4. Capillary absorption coefficient

Porosity test: This test was conducted to evaluate the percentage of voids present in the specimens prepared. First of all saturated weights Wsat of the specimens cured for 28 days were obtained. Then specimens were dried in oven at about 105°C until constant mass Wdry was obtained. Then weight of water absorbed Ww was calculated in grams, which was converted to cc. this signifies the volume of voids present within the specimen. The test was conducted on a cube of cross sectional area of 100 sq.cm. of different mixes of ordinary Portland cement with replacement of different mixes of Silica fume. Finally porosity (Table 10) was calculated using the formula given below,

$$\text{Porosity } \eta = \frac{Vv}{V} = \frac{Wsat\text{-}Wdry}{V} = \frac{Ww}{V}$$

Where, Vv = volume of voids in cc
V = total volume of specimen in cc

Table 10. Porosity

Silica fume (%)	Porosity η (%)
5	1
10	1.5
15	1.8

ISSN 2348 – 8034
Impact Factor- 5.070

Drop Weight Impact Test: Drop weight impact test is a method to find out the impact resistance of a specimen by allowing a specific weight to drop with a rails to guide. In this experiment, concrete specimen were casted with different Silica fume percentages (5%, 10%, and 15%) and recycled aggregate (25%) is used. The weight of hammer is 5.4 Kg with a drop of 1.7m having a diameter of 80mm. The impact energy delivered to the specimen (Table 11) are calculated by each impact is calculated as follows:

EI = (N)(mgh)

Where EI is impact energy (Nm),
N is the number of blows,
m is mass of the drop hammer (kg),
g is gravity acceleration (N/kg), and
h is height of drop hammer (m).

Table. 11 Impact test

Silica fume (%)	5	10	15
Curing period	28	28	28
No. of drops at first crack	40	44	30
No. of drops at failure	46	52	37
Impact energy at first crack	3535	3889	2651
Impact energy at failure	4065	4596	3270

Fig. 5. Specimens after failure due to impact

V. CONCLUSIONS

This project is to determine the strength characteristics of recycled aggregate with Silica fume for potential application in the high strength structural concrete. It was found that cement can be replaced effectively with Supplementary Cementitious Materials (SCM's) like Silica fume. In the case of strength and durability, the SCM's shows better results than normal mixes. With regard to workability and setting time, Silica fume generally required more super plasticizer and it reduces the setting time of pastes as compared to control mixtures. Thereby I can conclude that:

- With replacement of cement with Silica fume the consistency of cement increases due to the fineness of the Silica fume.
- With partial replacement of cement with Silica fume (10%) and coarse aggregate with recycled aggregate (25%) the strength obtained is the maximum.
- With the use of super plasticizer it possible to get a mix with low water to cement ratio to get the desired strength.

As the sorpitivity of concrete increases the strength decreases

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