Effect of Varying Size of Aggregate on High Strength Concrete

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Abstract - *In the present experimental investigation, an attempt has been made to determine the effect of varying size of aggregate on high strength concrete using silica fume with and without fly ash and with different dosage of super plasticizer. In this investigation high strength concrete was cast using usual ingredients such as cement, fine aggregate, coarse aggregate, water and mineral admixtures such as silica fume and fly ash or combination of both and the super plasticizer (CONSFLO –HP). The used plasticizer is based on polycaboxylate ester. Three sizes of coarse aggregates i.e. 10mm, 12.5mm and 16mm, two types of fine aggregates with Fineness Modulus (FM) = 2.65 and 2.88 and two dosage of super plasticizer (SP) i.e. 2% and 3% by weight of binder were used in the concrete specimen. The percentage of silica fume and Fly Ash that replaced cement by weight was 7.5% and 10% respectively.*

***Key Words*:** Compressive strength, Fly Ash, High Strength Concrete, Silica fume, Super plasticizer.

1. INTRODUCTION

Now a days high strength and high performance concrete are being widely used all over the world. Most applications of high strength concrete have been in high rise buildings, long span bridges and in some special applications in structures. In developed countries, using high strength concrete in structures today would result in both technical and economical advantage. In high strength concrete, it is necessary to reduce the water/cement ratio and which in general increases the cement content. To overcome low workability problem, different kinds of pozzolanic mineral admixtures such as fly ash and silica fume etc. and chemical admixtures are used to achieve the required workability. Using identical materials and similar mix proportions, the diabase and limestone aggregates were found to produce concretes with significantly higher strength and elastic modulus than did the granite and river gravel[1]. It is also believed that in high strength concrete tensile strength is controlled by mortar strength whereas compressive strength is significantly influenced by strength and surface characteristics of coarse aggregate[2].

1.1 Effect of aggregate on HSC

Blick *et al*. concluded that fine aggregates with a rounded particle shape and smooth texture have been found to require less mixing water in concrete and for this reason are preferable in high-strength concrete[3].Mechanical properties of high strength concrete are affected by the properties of aggregate[4]. Wu *et al*. suggested that high-strength concrete with lower brittleness can be made by selecting high-strength aggregate with low brittleness[5]. use of smaller maximum aggregate size would give a higher strength and the mineralogy of the coarse aggregate would affect the strength of concrete[6].

1.2 Effect of admixture on HSC

The strength and durability related tests have demonstrated superior strength and durability characteristics of HPC mixes containing Silica Fume. This is due to the improvement in the microstructure due to pozzolanic action and filler effects of Silica Fume, resulting in fine and discontinuous pore structure[7]. Addition of chemical admixtures do considerably improve the compressive strength of concrete in cubes[8]. Portland cement-fly ash-silica fume concrete was found to increase the compressive strength of concrete on all age when compared to concrete made with fly ash and silica fume alone[9]. Baroninsh *et al.* studied on the influence of the dosage of super plasticizer on properties of high performance concrete and found that increasing dosage of SP to 2.5% by weight of cement improved the performance of concrete and contributed more to the improvement of its transportability properties as well as mechanical properties, but at the same time has considerably reduced water/cement (W/C) ratio[10].

2. Experimental Program

The aim of this study is to evaluate the effect of varying types of aggregate on high strength concrete using silica fume with and without fly ash and with different dosage of super plasticizer. High strength concrete is made by partial replacement of cement by fly ash and silica fume. Replacement of cement by weight with fly ash and silica fume were 10 % and 7.5 % respectively. Super plasticizer was added to all the mix. Dosage of super plasticizer in all the mix was 2 % and 3 % (percent by weight of binder).

2.1 Silica Fume

The commercially available micro silica of grade 920 U (silica content of more than 92 percent) was used in the present study. The silica fume bags were covered with airtight polythene sheets to prevent seepage of moisture into them. The physical properties and chemical properties are given in the Table 1. The properties of silica fume were found to conform to the recommendations of IS 15388: (2003).

Table -1: Properties of Silica fume

Characteristics	Observed values
Blaine's fineness (cm^2/g)	22000
Specific Gravity	2.20
Silicon dioxide, SiO_2 (percent by mass)	92.13
$SiO_2 + Al_2O_3 + Fe_2O_3$, (percent by mass)	95.10
Loss on ignition, percent by mass	1.75

2.2 Fly Ash

Fly ash has been collected from Harduaganj thermal power station, which is located 15.5 km, north of Aligarh by side of upper Ganga canal generates 440 MW of electricity. It uses pulverized coal of high ash content (40%) and produces bottom ash and fly ash. The portion of the ash which is classified as fly ash and constitutes about 30-60% of total ash, is not collected and escapes with flue gases. Since coal is supplied from twenty two different coal mines of Jharkhand.

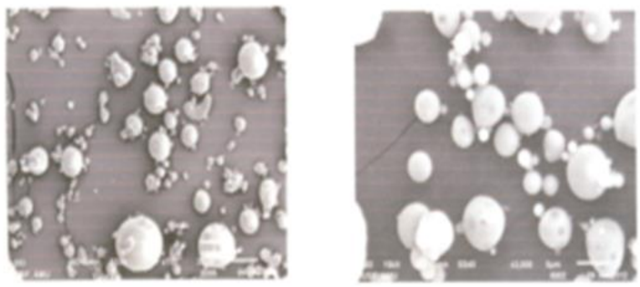
The morphology and chemical composition of fly ash have been examined using optical microscopes, scanning electron microscope (SEM) equipped with energy dispersive X-ray spectroscopy (EDS) as shown in Fig. 1 and Fig. 2 respectively.. The chemical and physical properties also vary to a great extent as shown in Table 2 and Table 3 respectively.

Table -2: Physical properties of fly ash

Characteristics	Observed values
Specific Gravity	2.12
Unit weight, (KN/m^2)	14.39
Liquid limit (%)	24
Loss on ignition, percent by mass	0.40

Table -3: Chemical properties of fly ash

Characteristics	Observed values (%)	Range specified for Class C Fly Ash (as per ASTM C-618)
Silicon dioxide (SiO_2)	59.00	46-60
Alumina (Al_2O_3)	27.00	21-28
Iron oxide (Fe_2O_3)	4.50	5-9
Calcium oxide (CaO)	1.80	0.5-6
Magnesium oxide (MgO)	0.70	0.2-4
Sulphur trioxide (SO_3)	0.10	0-0.4
Sodium oxide (Na_2O)	0.28	0-0.3
Potassium oxide (K_2O)	1.44	0-0.2



(a) (b)

Fig -1: Scanning electron microscope (SEM) Photomicrograph (a) Fly Ash particles at 700 x magnification (b) Fly Ash particles at 3000 x magnification

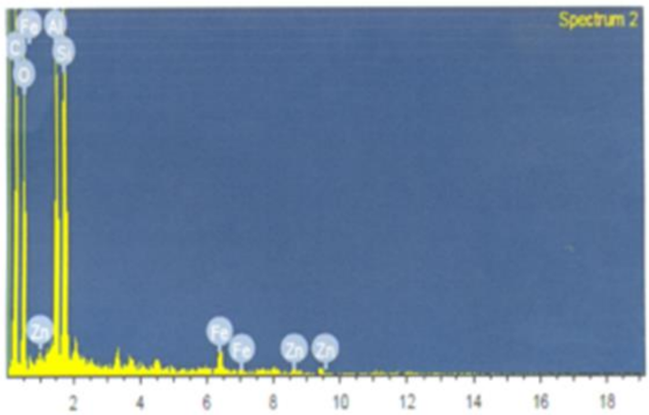


Fig -2: Energy- dispersive X ray spectroscopy (EDX) spectrum of plain Fly Ash

2.3 Super Plasticizers

A commercially available super plasticizer (SP) namely CONSFLO HP conforming to ASTM C 494 type G & F and IS 9103:1999 was used throughout the experiment for achieving adequate workability. The properties of super plasticizers are shown in Table 4.

Table -4: Properties of super plasticizer

Characteristics	Observed values	Specification (as per IS 9103:1999)
Physical State	Light Brown Liquid	Light Brown Liquid
Chemical name of active ingredient	Polycarboxlate polymer	Polycarboxlate polymer
Specific Gravity	1.105	1.15 + 0.015 at 27°C
Chloride Content	Nil	Nil

2.3 Concrete Mix

As per the guidelines of IS 10262 (1982)&ACI 211.4R-08, and with the help of different trial mix, high strength concrete mix of compressive strength of 60 MPa at 28thdays was achieved for coarse aggregate size 12.5 mm and sand whose fineness modulus is 2.88. The detailed constitution of the mix is given in the Table 5. For the assessment of compressive strength of concrete at room temperature, cubes of size 150 mm x 150 mm x 150 mm were cast. Cube specimens were taken as Cube A (cement + fly ash + silica fume)and Cube B (cement + silica fume).

Table -4: Concrete mix proportions

Mix (HSC)	Cement (Kg/m³)	Coarse Aggregate (Kg/m³)	Sand (Kg/m³)	Silica Fume (Kg/m³)	Fly Ash (Kg/m³)	Water Binder Ratio	Super plasticizer (% by weight of Binder)
Cube -A	472.8	1061	588.5	42.9	57.3	0.30	2
Cube -B	530.1	1061	588.5	42.9	-	0.30	2

3. Results and Discussion

Comparison of slump value and compressive strength of all the samples has been shown in chart 1 and chart 2 respectively. From Chart 1 it can be shown that slump value increases as the size of coarse aggregate increases for cube specimen B with super plasticizer is 3% by weight of binder. The average compressive strength decreases as the size of coarse aggregate increases for sample cube B with super plasticizer is 2% by weight of binder.

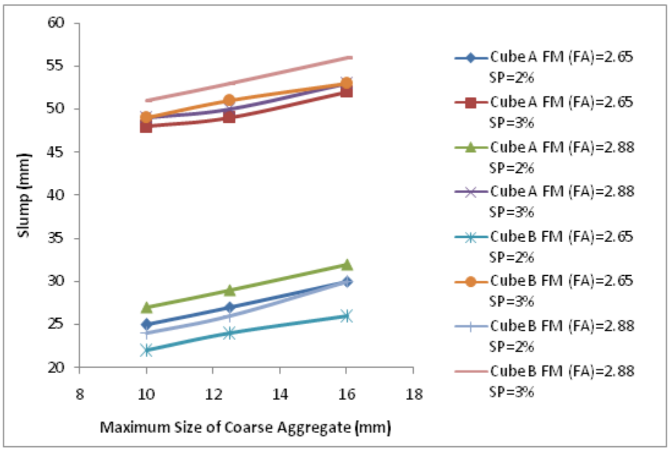


Chart -1: Comparison of Slump of all the Samples

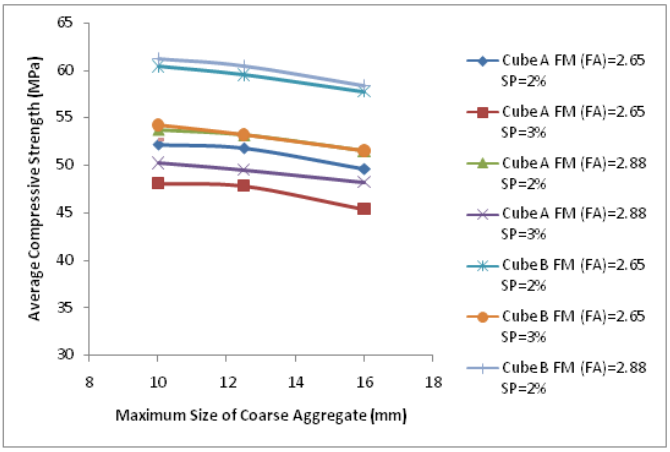


Chart -2: Comparison of Average Compressive Strength of all the Samples

4. CONCLUSIONS

On the basis of experimental results, the following conclusions have been drawn.

1. Concrete made with silica fume shows higher compressive strength than that made with combination of both silica fume and fly ash. From the test result it is found that the compressive strength of the concrete made with silica fume of 10 mm coarse aggregate, sand (FM = 2.88) and super plasticizer of 2% was 13.75 % higher than that made with combination of both silica fume and fly ash.

2. Concrete made with silica fume shows lower workability than that made with combination of

both silica fume and fly ash. From the test result it is found that the workability of the concrete made with silica fume was 11.11 % lower than that made with combination of both silica fume and fly ash.

3. Concrete made with 10mm maximum coarse aggregate size shows higher compressive strength than that made with 12.5mm and 16mm maximum coarse aggregate size for all the replacement of silica fume with and without fly ash and with different dosage of super plasticizer.

4. Concrete made with sand whose fineness modulus is 2.88 shows higher compressive strength than that made with sand whose fineness modulus is 2.65 for all the replacement of silica fume with and without fly ash and with different dosage of super plasticizer.

5. Concrete made with sand whose fineness modulus is 2.88 shows lower workability than that made with sand whose fineness modulus is 2.65 for all the replacement of silica fume with and without fly ash and with different dosage of super plasticizer.

6. Concrete made with super plasticizer 2% shows lower workability than that made with super plasticizer 3% for all the replacement of cement by silica fume with and without fly ash.

7. Concrete made with super plasticizer 2% shows higher compressive strength than that made with super plasticizer 3%for all the replacement of silica fume with and without fly ash.

8. Concrete made with the replacement of 10 % fly ash and 7.5% silica fume showslower compressive strength than concrete made with 7.5% silica fume at 28 days. This is because of slow pozzolanic reaction.

9. Replacement by weight of cement with 10 percent fly ash and 7.5 percent microsilica has almost the same compressive strength as the microsilica content of 7.5 percent by weight of cement through 56 days.

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