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Effect of Size and Dosage of Microsilica on Compressive Strength Along With Microstructural Analysis of Concrete

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Abstract: The present study investigates the effect of microsilica as partial replacement for cement in concrete with different range of particles at different dosages. The grade of concrete used in the study is M20.The compressive strength is obtained for the particles ranging from 0-20 µm, 20-45µm, 45-90 µm, 90-125 µm and 125-250 µm, and the replacement is from 10% to 40% at an increment of 10%. The microstructural study is carried out using scanning electron microscopy (SEM) and energy dispersive spectrometer (EDS).The two main compounds observed in the study are Silica and Calcium, their consumptions before and after the pozzolonic reactions are studied. The optimum compressive strength is observed for 0-20 µm size particles at 20% replacement level and it is also observed that the consumption of calcium is more for the above said replacement.

Key words: Microsilica, scanning electron microscopy (SEM), energy dispersive spectrometer (EDS).

I. INTRODUCTION

Microsilica is a by-product obtained by the smelting process in the silicon and ferrosilicon industry. The reduction of high purity of quartz material to silica at temperatures reaching 2000^0C generates silica vapours which oxidizes and condense in the low temperature zone to low particles containing non-crystalline silica. .Microsilica is also identified as silica fume, condensed silica fume, volatilized silica or silica dust. Microsilica has been recognized as a pozzolanic admixture that is effective in improving the mechanical properties to a great extent. By using microsilica along with super-plasticizers, it is comparatively easier to obtain higher compressive strength. Concrete has a highly heterogeneous and complex microstructure, it is difficult to predict actual models of its microstructure from which the action of the contents can be properly predicted. The acquaintance of the microstructure, the properties and influences of the individual components of concrete and their inter-relationship are useful for working out control on the properties of concrete. The term microstructure indicates the structure which develops in concrete at a micro level, when water is added to cement and aggregates. To understand the cause, extent and mechanism of deterioration, or how to improve some of the properties of concrete, a thorough awareness of the basic microstructure of hardened concrete is required .Mechanical properties of concrete more often depend on its intrinsic microstructure. The high resolution capability of SEM coupled with EDS/EDXA has opened a world of opportunities in the field of concrete technology. The microstructure of concrete is described as an integrated system consisting of (i) hydrated cement paste (ii) coarse and fine aggregates and (iii) the interface between aggregate and hydrated cement paste, also known as interfacial transition zone (ITZ). Reference as in [1] investigated the strength of silica fume concrete at a constant water binder ratio (w/b) of 0.34 and replacement percentages varies from 0 to 25. The maximum 28 day compressive strength was obtained at 15% replacement level. They also studied the silica fume effect with different water binder ratios. In their study it is observed that the maximum strength was obtained at 25% replacement of cement by silica fume. [2] studied the workability and the compressive strength of silica fume concretes for low water-cementations materials ratios with super plasticizer. They observed optimum compressive strength at 20% replacements and the strength gain is less than 15%. [3] have investigated, effect on strength and chemical resistance of concrete for M25 grade by using microsilica 920-D. The percentage of microsilica used in the investigation is ranging from 0% to 40%. The optimum strength is obtained at 10% replacement. [4] reported that the strength of silica fume concrete is greater than that of silica fume paste which they attributed to the change in the role of the aggregate in concrete.[5] investigated the influence of silica fume on the compressive strength of high performance concrete.[6] stated the difference in strength development in OPC concrete and silica fume concrete. [7] studied the compressive strength of high performance concrete. [8] studied the compressive strength of concrete containing silica fume and w/c ratio kept as variable factor. [9] designed the concrete mixtures to evaluate the effect of silica fume on the compressive strength. [10] investigated the compressive strength of hooked ends steel fiber concrete with silica fume. [15] investigated nanosilica in powder and colloidal form and their effect were investigated with specific surface area of particles varying from $80m^2/gm$ to $380m^2/gm$, on the mechanical properties including workability on cement paste and mortar. However, by increasing the specific surface area more than $90m^2/gm$, the compressive strength of specimens decreased. It is observed from the earlier research, there are no investigations were performed with the range of particles with various replacements. In this paper the effect of size and dosage of microsilica on compressive strength along with microstructure using SEM and EDS are presented in detail, with the evidence of experimental study.

II. EXPERIMENTAL PROGRAMME

Microsilica used the experimental study is with particle sizes retained in the sieves, in the range of 0-20 µm, 20-45µm, 45-90 µm, 90-125 µm and 125-250 µm. The percentage of partial replacement of cement with microsilica is varied from 0% to40% with an increment of 10%.The M20 grade concrete mix was designed as per IS10262-2009 and mix adopted is 1:2.65:4.55 and water cement ratio as 0.5.The superplasticizer CONPLAST-SP430 was used in the experimental programme to obtain desirable workability.

III. MATERIALS

A. The following materials were used in the experimental investigations

1) *Cement:* The cement used in the investigations is ordinary Portland cement (OPC) of 53 grade. Physical and chemical properties are presented in table 1 and 2.

TABLE 1 Physical Properties of Cement

Specific gravity	Bulk density (kg/m^3)	Surface area(m^2/kg)
3.09	1865	340

TABLE 2
Chemical Properties of Cement

Cao	Sio_2	Al_2o_3	Fe_2o_3	Mgo	So_3	P_2o_5	K_2o	Na_2o	Tio_2
60.84	16.34	6.95	5.38	2.32	1.99	1.67	2.73	1.50	0.28

2) *Fine aggregate:* River sand is used as fine aggregate, which is of grade II, based on particle size distribution. The properties are tabulated in table 3.

TABLE 3
Physical Properties of River Sand

Sl no	Description	River sand
1	Specific gravity	2.64
2	Bulk density(loose)kg/m^3	1480
3	Bulk density(compacted)kg/m^3	1695
4	Fineness modulus	2.45
5	Grading zone	II

3) *Coarse aggregate:* Crushed granite stone is used as coarse aggregate in the investigation.
4) *Super Plasticizer:* The super plasticizer used in the present work is CONPLAST-SP430 in the form of Sulphonated Naphthalene polymers complies with IS: 9103-1999, to improve the workability of concrete.
5) *Water:* Locally available portable water is used for mixing and curing of the specimens.
6) *Microsilica:* Microsilica 920-D is used in this experimental programme is supplied by ELKEM INDUSTRIES, MUMBAI and the properties are tabulated in table 4 and 5.

TABLE 4
Physical Properties of Microsilica

Particulars	Microsilica
Specific gravity	2.27
Surface area m^2/kg	20000
Particle size (micrometer)	<1
Bulk density kg/m^3	187.91
Loss on ignition (%)	1.92
PH	7.90

TABLE 5
Chemical Properties of Microsilica

Sl no	Chemical component	%by weight
1	Sio2 (%)	85-95
2	Sio3 (%)	0.18
3	Cl (%)	0.12
4	Total alkali (%)	0.66
5	Moisture content (%)	0.16
6	Loss of ignition (%)	1.92
7	PH	7.90

IV. RESULTS AND DISCUSSIONS

The compressive strength for 10%, 20%, 30% and 40% replacement of cement by microsilica are investigated and the results is presented in the table no7 to 10. . From the table, it is observed that the compressive strength increases as the particle size decreases which are observed at 7, 14, 21 and 28 days of testing of samples. From the graph, it is observed that, the compressive strength is higher for 0-20µm particle size and for other sizes, the values are lower and the lowest is observed for 125-250µm particle size. At 28 days of testing, the percentage increase at 10%, 20%, 30% and 40% replacements for 0-20µm, when compared with 125-250µm particle size, it is equal to 28%, 28%, 26% and 19% respectively. The increase in compressive strength is observed at 10% and 20% replacement of cement by microsilica and it decreases at 30% and 40% replacements. The optimum strength is obtained at 20% replacement level, the percentage increase in strength, when compared with control mix for 0-20µm particle size is 42%. For example the SEM image for cement(figure 1) shows the particles are spherical and non-spherical in morphology at 20 kv,2000 magnification , at working distance of 6.8 mm .The EDS/EDXA for cement(figure 2) shows the various elements and oxides present as percentage weight or atomic percentage weight. In the table 6, silica present is 17.62% and calcium is 53.60% by weight. By considering these two elements as reference, the investigations is carried out to know the physical mechanism and chemical mechanism involved in the pore structures of concrete and pozzolanic reactions that take place after addition of mineral admixtures. Figure 3 and 4 shows the SEM and EDS diagram for microsilica. When mineral admixtures are added as percentage replacement for cement, the percentage weight of silica and calcium consumed and remained unreacted can be calculated. The percentage weight of silica and calcium present in cement and microsilica are shown in the SEM and EDS/EDXA. In the SEM micrograph the following compounds can be identified

A. ETTRINGITE---pipe like structures without branches of size 4-5µm in length.
B. CALCIUM HYDROXIDE OR PORTLANDITE----hexagonal structures.
C. C-S-H ---fibrous type to irregular grains forming a reticular network (cotton shaped like structures).

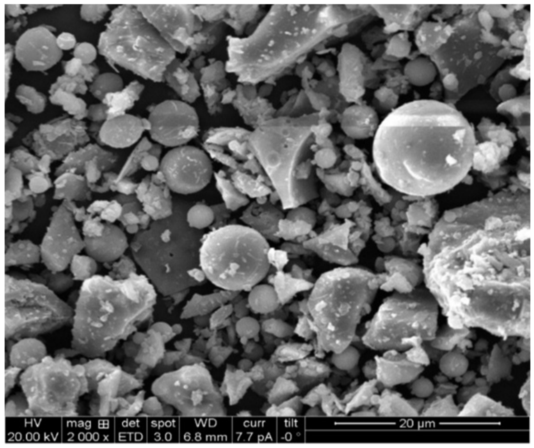

Fig.1 SEM Diagram for Cement

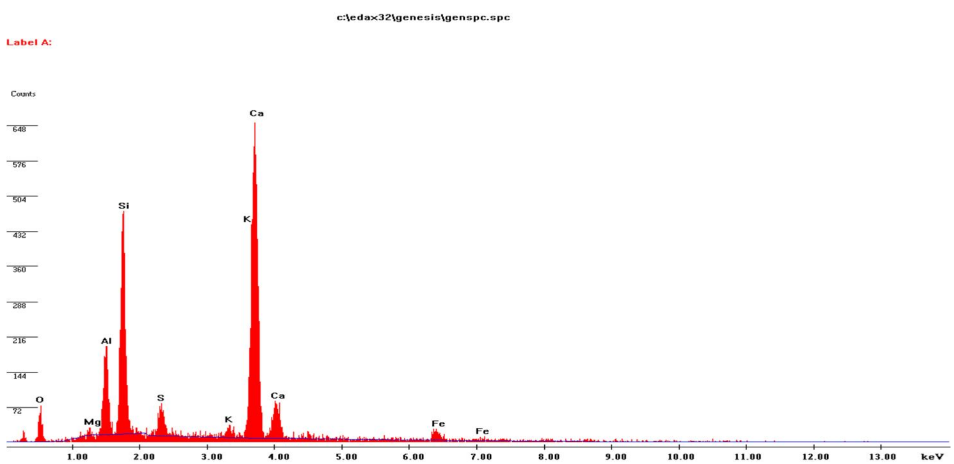

Fig. 2 EDS for CEMENT

TABLE 6

Elem	Wt%	At %	K-Ratio	Z	A	F
O K	9.99	19.98	0.0152	1.0716	0.1421	1.0003
MgK	0.47	0.61	0.0029	1.0231	0.5939	1.0055
AlK	6.86	8.13	0.0497	0.9948	0.7218	1.0084
SiK	17.62	20.08	0.1408	1.0251	0.7749	------
S K	3.40	3.39	0.0290	1.0108	0.8301	1.0155
K K	1.55	1.26	0.0151	0.9681	0.9432	1.0736
CaK	53.60	42.79	0.5095	0.9891	0.9596	1.0016
FeK	6.52	3.74	0.0564	0.8942	0.9669	1.0000
Total 100.00 100.00						

Where Z, A and F are corrections applied
Z- Atomic number
A- Absorption number
F- Fluorescence

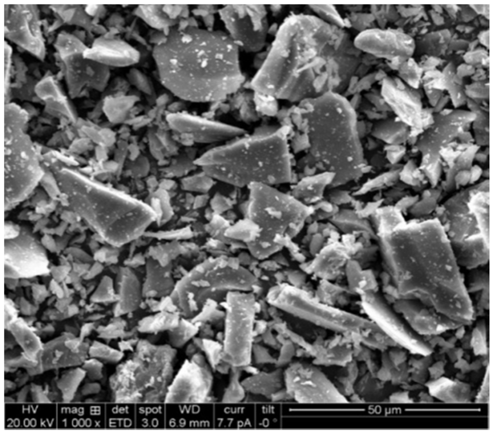

Fig 3 SEM Diagram for Microsilica

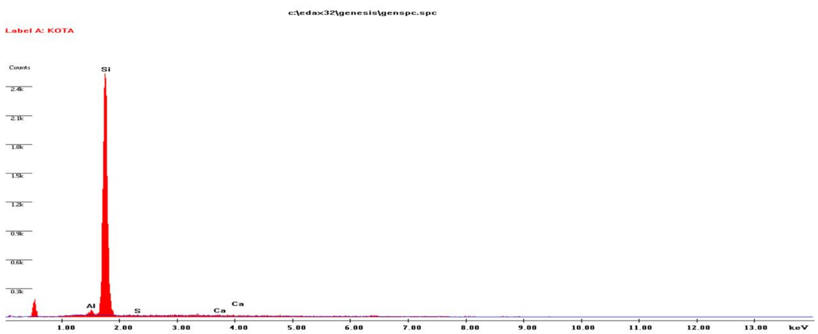

Fig 4 EDS for Microsilica Silica present as per EDS is 83.89% by weight

Table 7

Compressive strength at 10% replacement of cement by micro silica

Sl.No	Particle Size(µm)	Compressive Strength(Mpa)			
		7 days	14 days	21 days	28 days
Compressive strength for control mix		14.65	18.40	21.75	25.90
1	0-20	17.80	22.20	31.20	34.50
2	20-45	16.50	20.40	28.70	32.50
3	45-90	15.60	19.20	27.10	30.60
4	90-125	15.10	18.60	25.90	29.30
5	125-250	14.70	17.70	23.80	26.90

Table 8

Compressive strength at 20% replacement of cement by micro silica

Sl.No	Particle Size(µm)	Compressive Strength(Mpa)			
		7 days	14 days	21 days	28 days
Compressive strength for control mix		14.65	18.40	21.75	25.90
1	0-20	20.1	23.6	35	36.9
2	20-45	17.8	21.5	31.5	34.4
3	45-90	16.5	19.8	29.1	31.6
4	90-125	15.8	19.4	27.4	30.3
5	125-250	15.3	18.2	26.1	28.7

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Table 9
Compressive strength at 30% replacement of cement by micro silica

Sl.No	Particle Size(μm)	Compressive Strength(Mpa)			
		7 days	14 days	21 days	28 days
Compressive strength for control mix		14.65	18.40	21.75	25.90
1	0-20	19.80	23.10	34.60	36.70
2	20-45	17.20	21.10	31.20	34.10
3	45-90	16.10	19.40	28.40	31.20
4	90-125	15.40	18.90	27.10	29.80
5	125-250	15.10	17.70	25.60	28.30

Table 10
Compressive strength at 40% replacement of cement by micro silica

Sl.No	Particle Size(μm)	Compressive Strength(Mpa)			
		7 days	14 days	21 days	28 days
Compressive strength for control mix		14.65	18.40	21.75	25.90
1	0-20	17.00	21.30	26.80	28.90
2	20-45	16.40	19.80	25.40	27.20
3	45-90	15.40	18.60	23.90	25.70
4	90-125	15.10	17.90	23.30	25.20
5	125-250	14.10	17.30	22.40	24.20

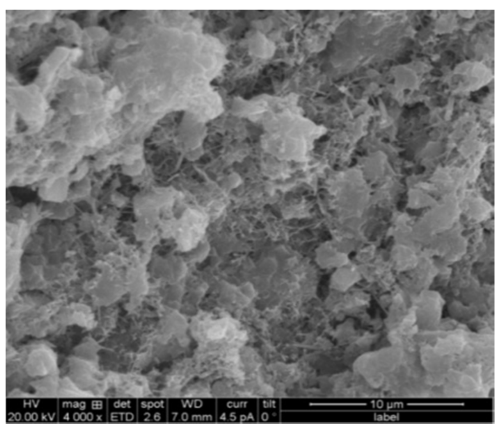

Fig 5 SEM Image At 20% Replacement

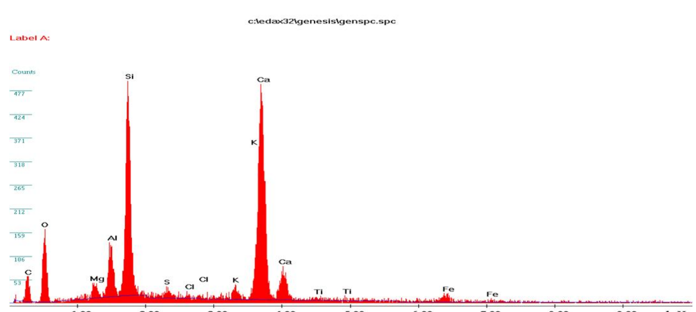

Fig 6 EDS At 20% Replacement of Cement

The percentage weight of silica and calcium after reactions found to be equal to 17.22% and 37.38% from the EDS table. The SEM micrography and EDS tables are obtained for other replacements levels also, and the following conclusions were drawn (the SEM and EDS are shown here for 20% replacement only).

V. CONCLUSIONS

From the experimental investigations conducted on microsilica, the following conclusions were drawn

A. As the particle size decreases, the strength increases .The strength depends upon the specific surface area of the mineral admixtures used in the investigations.
B. Addition of microsilica gives more strength because of its higher specific surface area, when compared to cement, hence more space available for the pozzolanic reactions to take place.
C. The optimum compressive strength is obtained at 20% replacement of cement by microsilica. For 0-20 µm particle size, strength is maximum, the reason could be smaller size particles, more specific surface area available for pozzolanic reaction to take place and hence more strength. It is observed that for 0-20 µm particle size, the compressive strength is 36.9 MPa, the percentage increase when compared with control mix is 43%, whereas for 125- 250 µm particle size the increase is 10%.
D. The SEM micrograph for 20% replacement clearly shows the formation of C-S-H gel, portlandite with ettringite also in the concrete matrix. The SEM image is dense and compact when compared with other replacements. From EDXA table, the quantity of silica and calcium consumed in the pozzolanic reaction is equal to 13.65gm and 5.5gm, since more quantity of silica is consumed in the pozzolanic reaction, hence more strength.

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