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Effect of Micro Silica on the properties of hardened concrete

Vikash Kumar[1*], Ashhad Imam[2], Vikas Srivastava[3], Atul[4], Y Kushwaha[5]

[1]PG Student, Department of Civil Engineering, Sam Higginbottom University of Agriculture, Technology and Sciences, Allahabad, India.
[2]Assistant Professor, Department of Civil Engineering, Sam Higginbottom University of Agriculture, Technology and Sciences, Allahabad, India.
[3]Associate Professor, Department of Civil Engineering, Sam Higginbottom University of Agriculture, Technology and Sciences, Allahabad, India.
[4]Assistant Professor, Department of Civil Engineering, Sam Higginbottom University of Agriculture, Technology and Sciences, Allahabad, India.
[5]Assistant Professor, Department of Civil Engineering, Sam Higginbottom University of Agriculture, Technology and Sciences, Allahabad, India.
Corresponding Author: Vikash Kumar

ABSTRACT:- This paper presents the use of Micro Silica (MS) as a mineral admixture in the concrete. Several researches have been performed towards investigating the fresh as well as hardened properties of concrete when blended with Silica Fume or Micro Silica (MS). The present study has been designed to investigate the strength properties of concrete formed with partial replacement of cement by Micro Silica and the percentage variation was 6%, 7% & 8% for M25 grade of concrete with a fixed W/C ratio 0.40 as a result of which the desired workability in the range of 75 - 100 mm was maintained by adding 0.7 % (by weight of cement) super plasticizer. The results produced for blended concrete demonstrated a substantive quality enhancement towards mechanical properties of concrete as compared to normal concrete prepared with Ordinary Portland Cement (OPC) only. It can be concluded that the optimum percentage of replacement with MS lies at 8% for compressive strength. Nevertheless, the variation of blending goes up to 8% in case of flexure strength as well and the percentage goes down up to 7% in case of split tensile strength.

Keywords:- Silica Fume, Compressive strength, Split tensile strength, Flexure strength.

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I. INTRODUCTION

Concrete is a widely used construction material for various types of structures due to its structural stability and strength. In the production of concrete Ordinary Portland Cement (OPC) is one of the main ingredients and has no alternative in the construction industry but in the production of cement involves large amount of carbon-dioxide gas emission into the atmosphere as well as a major contributor for green house effect and also the global warming, hence it is inevitable either to search another material or partially replaced by some other material [**1**]. The search for any other material, which can be used as an alternative for cement, should lead to lowest possible environmental impact. When industrial by products are used as a partial replacement of cement as a result of cost saving and substantial energy. Some of the pozzolanic material which can be used as partially replacement of cement such are Ground Granulated Blast furnace Slag, Silica Fume or Micro Silica, Fly ash, Metakaolin, Rice husk ash, etc **[2].**

In India as well as abroad a large number of studies are going on the impact of these pozzolanic materials as a partial replacement with cement. Addition of Micro Silica to concrete produces high strength, durability and reduction in production of cement. When these pozzolanic materials are mixed in concrete then the silica present in these materials react with the calcium hydroxide released during the hydration of cement and forms additional calcium silicate hydrate (C – S – H), as a result improve the mechanical properties and durability parameters of concrete **[3].** Silica Fume was firstly obtained in Norway (Oslo) in 1947, during filtration of the exhaust gases from furnaces as fumes. The large portion of these fumes contained very fine powder of high percentage of silicon dioxide. Since the 1970s, filtration of gases has started at large scale and, in 1976, first standard NS 3050 was granted to use silica fume in factory-produced cement **[4].** Silica Fume is very reactive pozzolanic material. It's very reactive pozzolanic property, while it is used in concrete because of its fine particles, large surface area and high SiO_2 content. Silica fume is much fined separated silica obtained as a by-product in industry. It is used as an admixture in the concrete mix and it has significant effects on the properties of the resulting material **[5].** It is extremely fine with particles size less than 1 micron and with an average diameter of about 0.1 microns, about 100 times smaller than average cement particles. Its behaviour is related to the high content of amorphous silica (> 90%). The reduction of high-purity quartz to silicon at temperatures up to 2,000º C produces SiO_2 vapours, which oxidizes and condense in the low temperature zone to tiny particles consisting of non-crystalline silica **[6].**

Silica fume has been recognized as a pozzolanic admixture that is effective in enhancing the mechanical properties to a great extent. The physical composition of silica fume Diameter is about 0.1 micron to 0.2 microns; Surface area about 30,000 m^2/kg and Density varies from 150 to 700 kg/m^3. Fig. 1 shows the schematic diagram of silica fume production. The silica fume is collected in very large filters in the bag house and then made available for use in concrete **[7].** It is a high quality material used in the cement and concrete industry. It has been reported that if a typical dosage of silica fume of 8–10% by weight of cement is added in concrete, concrete mix will be denser and cohesive due to fine particles of silica fume **[8].**

Silica Fume can be utilised as material for supplementary cementations to increase the strength and durability conforming to AASHTO M 307 or ASTM C 1240. According to the Florida Department of Transportation (2004), the quantity of cement replacement with silica fume should be between 7% and 9% by mass of cementation materials **[9].** In this paper Micro Silica is replaced with cement at varying percentage and mechanical properties were compared with conventional concrete.

II. MATERIALS AND METHODS

A. Cement

In present study, Ordinary Portland Cement (OPC) of Birla Samrat brand of 43 grade confirming to IS: 269-2015 was used. The properties of cement found are shown in Table I:

Table I: Properties of Cement

Properties	Observed value
Fineness	2.73%
Normal Consistency	28%
Specific Gravity	3.14
Initial Setting Time	95 minutes
Final Setting Time	225 nutes

B. Aggregate

Natural River sand from Yamuna as Fine Aggregate (FA) and Crushed stone obtained from Banda, U.P. of different sizes i.e. 20 mm and 12.5 mm were used as Coarse Aggregate (CA) for carrying out the experimental study. Testing of aggregate as per the specification given by IS: 383 – 1970. The properties details for Fine Aggregate and Coarse Aggregate are depicted in the Table II:

Table II: Properties of Aggregate

Properties	Fine Aggregate	Coarse Aggregate	
		12.5 mm	20 mm
Fineness Modulus	2.78%	6.80%	8.36%
Specific Gravity	2.74	2.74	2.61
Water Absorption	1.4%	0.40%	0.56%

C. Micro Silica

Micro Silica (MS) purchased from Astrra Chemicals, Chennai. The details of the physical and chemical properties for Micro Silica have been provided by the manufacturer itself and are illustrated in Tables III & IV:

Table III: Physical properties of Micro Silica

Physical Properties	Results
Physical State	Micronized Powder
Odour	Odourless
Appearance	White Colour Powder
Colour	White
Pack Density	0.76 gm/cc
PH of 5% Solution	6.90
Specific Gravity	2.63
Moisture	0.058%
Oil Absorption	55 ml/100 gms

Table IV: Chemical properties of Micro Silica

Chemical Properties	Results
Silica (SiO_2)	99.886%
Alumina (Al_2O_3)	0.043%
Ferric Oxide (Fe_2O_3)	0.040%
Titanium Oxide (TiO_2)	0.001%

Calcium Oxide (CaO)	0.001%
Magnesium Oxide (MgO)	0.000%
Pottasium Oxide (K_2O)	0.001%
Sodium Oxide (Na_2O)	0.003%
Loss on Ignition	0.015%

D. Super plasticizer

Super plasticizer (SP) with specification Auramix 400 was used to maintain the slump value in an acceptable range of 75 - 100 mm. The SP grade compiles with the recommendations of IS: 9103-1999(2007) and ASTM C 494 Type G from Fosroc chemicals was adopted at a constant dose of 0.7% (by weight of cement).

E. Experimental Methodology

In the present study, Concrete mix proportioning was calculated for unit volume of concrete as per the recommendations given by IS 10262: 2009 for M 25 grade of concrete. The quantities for unit volume were taken as given in Table V:

Table V: Quantities per unit volume of concrete

Cement (kg/m^3)	Fine Aggregate (kg/m^3)	Coarse Aggregate (kg/m^3)	
		12.5 mm	20 mm
370	765	482	688

The final mix proportion was calculated as 1:2.07:3.16 keeping the water cement ratio of 0.40 as fixed entity. The samples casted were tested for mechanical properties of concrete (compressive, flexural and split tensile strength) in hardened state after 28 days of wet curing. For compressive strength, 12 cubes of size 150 mm × 150 mm × 150 mm, for flexure strength 4 beams of size 100 mm × 100 mm × 500 mm and for split tensile strength, 12 cylinders of size 75 mm × 150 mm were casted. A total of 3 cubes, 3 cylinders and 1 beam have been kept under one mix, for which the volume with 18% wastage of material was calculated as 0.02019 m^3. Finally the quantities of each mixes for different ingredients are illustrated in Table VI. Different mixes were designated as M0 with no blending of Micro Silica (control mix), M1 with 6% blending, M2 with 7% blending and M3 with 8% blending of Micro Silica have been used in this study in order to get rid of any experimental mishap.

Table VI: Quantities of different ingredients for different mixes

Mix No.	OPC (kg)	MS (kg)	F.A. (kg)	C. A. (kg)		Water (kg)	S.P. (kg)
				(12.5 mm)	(20mm)		
M0 (0% MS)	7.47	0	15.64	9.75	13.96	3.32	0.052
M1 (6% MS)	7.03	0.45	15.60	9.73	13.93	3.32	0.052
M2 (7% MS)	6.95	0.52	15.60	9.73	13.93	3.32	0.052
M3 (8% MS)	6.86	0.61	15.60	9.73	13.92	3.32	0.052

III. Results And Discussion

A. Effect of Micro Silica on Compressive Strength of Concrete

The test for compressive strength was carried out conforming to IS 516-1959 after 28 days of wet curing. The cubes were tested using Compression Testing Machine (CTM) of capacity 2000 kN. From Fig. 1, the compressive strength for control mix was found as 33.39 N/mm^2 and keeps on rising as the replacement level is increased. Almost 25 % of increment in strength values (i.e. 41.63 N/mm^2) has been observed for replacement cement with 8 % Micro Silica. Slight increase in strength (i.e. 36.29 N/mm^2 to 37.18 N/mm^2) has been seen when the replacement level goes from 6 % to 7 %. A significant improvement in the compressive strength of concrete has been noted by the use of Micro Silica owing to its high pozzolanic activity and void filling ability [10].

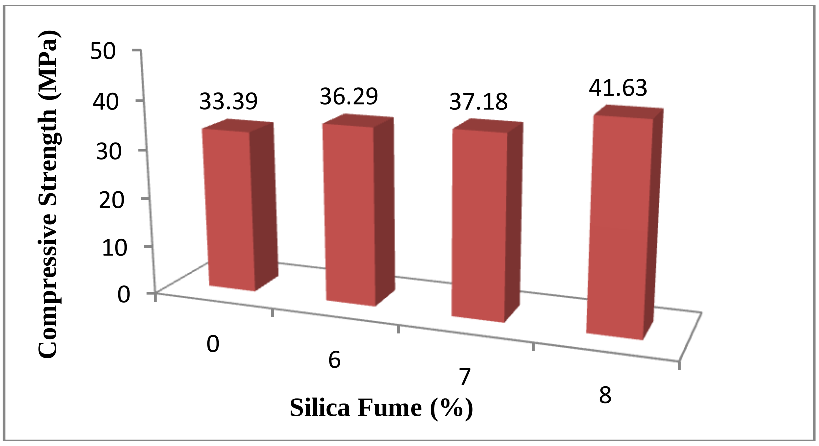

Fig. 1: Variation of Compressive Strength at different replacement level of MS

B. Effect of Micro Silica on Flexure Strength and Split Tensile Strength of Concrete

The test for flexure as well as split tensile strength was carried out conforming to IS 516-1959 after 28 days of wet curing. The beam specimen for flexure strength was tested using Universal Testing Machine (UTM) of 100 KN capacities. Fig. 2 shows the variation of flexure values with different degrees of blending with MS. The flexure strength for control mix is noted as 13.75 N/mm^2. It is clear that the blending of MS shows a little impact on flexure strength. Similar results have been obtained for flexure strength at various replacement levels. The flexure value slightly falls up to 17 % (i.e. from 13.75 N/mm^2 to 11.5 N/mm^2) at 6 % blending of MS.

Similarly, cylindrical samples for split tensile strength was tested using Compression Testing Machine (CTM) of 2000 KN capacity. Fig. 3 shows the variation of split tensile values with different degrees of blending with MS. The split tensile strength for control mix is noted as 2.17 N/mm^2. From Fig. 3, the maximum tensile strength is observed as 2.92 N/mm^2 at 28 days of curing. The optimum value of replacement of micro silica by cement is observed at 7%. Indeed it can be said that split tensile values will shows an increasing trend from control mix value, when blended with different degrees of replacement level of MS.

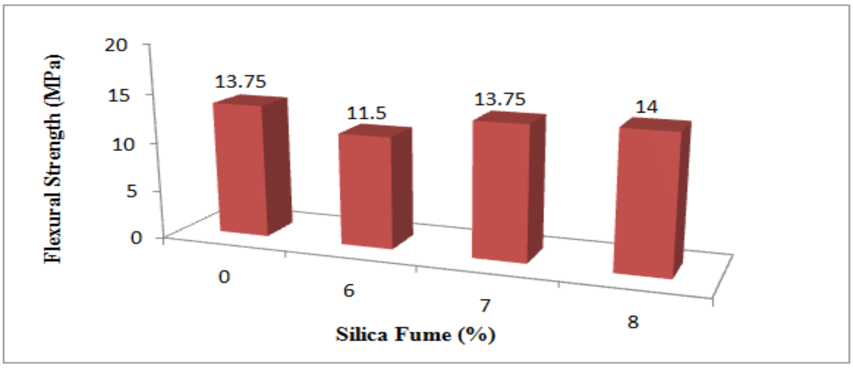

Fig 2: Variation of Flexure Strength at different replacement level of MS

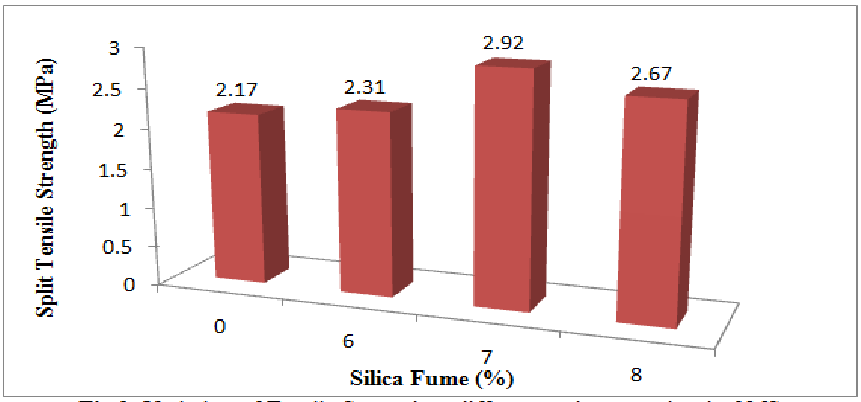

Fig 3: Variation of Tensile Strength at different replacement level of MS

IV. CONCLUSION

Based on the investigation, it is quite clear that mineral admixture like Silica Fume has proved to be the most promising blending material to provide a good quality concrete. The following generalized conclusions can be drawn on the mechanical properties of concrete.

- Micro Silica is considered as a highly reactive pozzolanic material which provides an increased cohesiveness in concrete due to its high fineness modulus. However, the requirement of water may be offset by adding super plasticizer.
- The compressive strength of concrete increases with increase in replacement level of micro silica. The optimum value of replacement of micro silica is found at 8%.
- The flexure strength of concrete also increases in increasing replacement level of micro silica. The optimum value of replacement of micro silica is also found at 8%.
- The optimum value for split tensile strength is obtained at 7% replacement level of micro silica. Although the split tensile values shows an increasing trend from control mix value, when blended with different degrees of replacement level of MS.

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