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Research Article

EXPERIMENTAL INVESTIGATION ON EFFECT OF MICRO SILICA ON HIGH-STRENGTH CONCRETE

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A R T I C L E I N F O

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A B S T R A C T

Concrete is the most widely used building material in construction industry. Now-a-days various types of admixture are used to improve different properties of concrete. These admixtures are waste products of different manufacturing industries, which also helps to decrease material cost. Along with mechanical properties, environmental properties of concrete can be improved with efficient use of mineral and chemical admixture. The following research investigates effect of microsilica on high-strength concrete. The cement content in the concrete was replaced by Microsilica in varying percentages. Different specimens of standard sizes were tested to check compressive, tensile and flexural strength of concrete. To check environmental property of high-strength concrete, water permeability test was carried on cube specimens. It was concluded that, use of micro silica increases strength of concrete for small amount of replacements to cement. With more increase in content of microsilica, the strength of concrete decreases. Along with strength permeability of concrete was also improved.

INTRODUCTION

Concrete is a strong and tough material. Reinforced concrete structures resist cyclones, earthquakes, blasts and fires much better than timber and steel if designed efficiently. Compared to many other Engineering materials such as steel, rubber, etc. concrete requires less energy input for its manufacture. Now-a-days a large number of mineral admixtures, which are waste products of other industries, are beneficially used in making quality concrete. Thus, from the consideration of energy and resource conservation and sustainability of the environment, concrete is the most preferred building material. The increasing demand of infrastructure due to continuous rise in population and high rate of urban drift, concrete has more consumed because of industrialization and urbanization. Concrete is the most widely consumed resource in construction industry. The continuous global demand for concrete implies that, more aggregate and cement would be required in the production of concrete, thereby leading to more extraction and depletion of deposits of natural gravel, and increased CO2 emission from quarrying activities. Also the continuous use of conventional concrete, (that is concrete produced with virgin aggregates and ordinary Portland cement) has proved to be very unfriendly to the environment.Concrete is generally classified as Normal Strength Concrete (NSC), High Strength Concrete (HSC) and Ultra High Strength Concrete (UHSC).

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There is no boundary for the above classification. Indian Standards recommended methods of Mix Design denote the boundary at 50 MPa between NSC and HSC. No recommendations are given about UHSC. As per IS 456:2000, the high strength category is applied to concrete having strength above 50 MPa. The development in admixtures, mixing and placing methods has made it possible to produce concretes with much higher strengths (70-100 MPa). High-strength concrete (HSC) has compressive strengths of up to 100 MPa as against NSC which has compressive strength of less than 50 MPa. The ingredients of high-strength concrete are same as those used in NSC with the addition of one or two admixtures, both chemical and mineral. The mix requires high paste volume, which often leads to shrinkage and high evolution of heat of hydration, besides increasing cost. The substitution of cement by supplementary cementitious materials such as mineral admixtures partially introduces favourable behavior with respect to the above mentioned defects and incidentally reduces the cost. The materials that are commonly used are fly ash, ground granulated blast-furnace slag, silica fume, rice husk ash and metakaolin.

The use of such materials not only improves the properties of fresh concrete but also enhances the long-term durability characteristics. High-strength concrete essentially has a low water-cement ratio. A value of 0.3 is the boundary between normal-strength concrete and high-strength concrete.

Ali Alsalman *et al*. (2017) studied effect of various sand particles of different sizes, different binding materials and different curing conditions on compressive strength of concrete. The binding materials like Portland cement (Type I), silica fume and class C fly ash were used. Use of finer sand particles supported to fill all the voids of concrete which led to increase in compressive strength of concrete. Use of artificial sand with different fine sizes gives higher compressive strength than natural sand. Increase in content of fly ash above 20% decreases compressive strength at early ages. Highest compressive strength of 155 MPa was obtained for 5% silica fume after 90 days of curing [1]. K. E. Hassan *et al*., presented a laboratory study on the influence of two mineral admixtures, silica fume (SF) and fly ash (FA), on the properties of super plasticised high-performance concrete. The concrete mixes were assessed based on short-term and long-term testing techniques used for the purpose of designing and controlling the quality of high-performance concrete. SF enhances the early ages as well as the long-term properties of concrete. It reduces the permeability when compared to OPC concrete. FA concrete has relatively poorer characteristics at early ages, but achieves similar strength and transport characteristics to SF concrete in the long term [2]. Horia Constantinescu *et al*., investigated high-strength concrete which was cast from commercially available materials that require no special investments to procure. Mean strength of sample cured at standard conditions and at laboratory conditions are 107.60 MPa and 118.61 MPa respectively. The development of tensile strength being greatly affected by curing conditions means that any structural elements that require crack control need to be designed. [3]. Sukhoon Pyo *et al*., studied mechanical properties and shrinkage of ultra-high performance concrete (UHPC) by adding coarser fine aggregates with maximum particle size of 5 mm. The replacement of silica powder with coal bottom ash powder resulted in comparable compressive strength and cracking patterns compared to the UHPC with silica powder, the replacement was not effective at improving the tensile capacities. It was found that the usage of basalt as a coarser fine aggregate in UHPC was not favorable for achieving exceptional mechanical properties [4]. Mohamadreza Shafieifar *et al*., determined the tensile and compressive behavior of UHPC. Ductal is a commercial product, the compressive strength of commercial UHPC was three to four times greater than NSC. The strong mechanical interlocking force between steel fibers and concrete matrix cylinders and cubes remained intact even after failure loading, whereas the control sample of normal strength concrete after failure split into large concrete pieces [7]. Tiefeng Chen *et al*., studied compressive strength, flexural strength and fracture toughness of ultra-high performance concretes (UHPC) containing silica fume and different dosage of fly ash (0%, 10%, 20% and 30%). The microstructure of UHPC samples was measured by using MIP, XRD and SEM. The incorporation of fly ash increases compressive strength and different fly ash dosage can lead to different effect. The autoclave curing effectively improves the compressive and flexural strength of UHPC, with the maximum increase of 37.5% and 30.3% respectively. The incorporation of fly ash and the increasing autoclave duration reduces porosity of UHPC samples [8].

MATERIAL

Ordinary Portland cement. (OPC) of 53 grade, coarse and fine aggregates conforming which were available locally. The micro silica complies with specific gravity of 2.20 was used to replace cement. Concrete loses its workability when less amount of water is used, to increase the workability water reducing admixtures (WRA) or high range water reducing admixtures (HRWRA) was used. Locally available SPRMC APC 1000 super plasticizer was added 1 % by weight of cement. M55 grade of concrete mix proportions 1: 1.06: 2 was designed as per guidelines of IS 10262-2009 [12].

Table I Chemical Properties of Micro Silica

Sr. No.	Chemical property	By Mass (%)
1	Silicon Dioxide(SiO_2)	92.0
2	Elemental Silicon	0.12
3	Free Calcium Oxide	0.34
4	Sulphate (SO_2)	0.14
5	Total Alkali (Na_2O_{eq})	0.40
6	Chloride (Cl_2)	0.03

Experimental Work

High-strength concrete mix of M55 grade with water-cement ratio of 0.22 was designed as per guidelines of IS 10262:2009. As water-cement ratio of the high-strength mix is less than 0.45, the superplasticizer was used to obtain workable concrete. The concrete mix for replacement of cement with 0%, 5% and 10% micro silica by weight of cement were cast and checked for compressive strength, water permeability, split tensile strength and flexure strength.

Table II Concrete Mix Design of M55 Grade

Sr. No.	Material	Quantity per m^3
1	Cement (kg)	550
2	Fine Aggregate (kg)	586
3	Coarse Aggregate (kg)	1368
4	Water (liter)	121

RESULTS

The fresh and mechanical properties of concrete were tested by carrying out slump test, compression test, split tensile test, flexure test and water permeability test.

Workability

The workability of concrete was determined by Slump test as per IS 1199-1959. Table III represents workability of concrete for replacement of cement with microsilica by 0%, 5%, 10% and 15% (by weight of cement).

Table III Workability

Sr. No	Replacement of cement with micro silica (%)	Slump (mm)
1	0%	75
2	5%	87
3	10%	92
4	15%	98

Compressive Strength

The compression test was carried on 12 cube specimens of standard size after 28 days of curing as per guidelines of IS 516-2013. The results are shown in Table IV, where CC stands for control cube and MC5 stands for cube with addition of micro silica followed by percentage.

Table IV Compressive Strength

Sr. No.	Specimen Designation	Compressive Strength (N/mm^2)
1	CC	65.93
2	MC5	64.74
3	MC10	52.00
4	MC15	44.89

Water Permeability Test

The results of water permeability test obtained for 12 standard cube specimens for replacement of cement with micro silica are shown in Table V, where CC stands for control cube and MC5 stands for cube with addition of micro silica followed by percentage.

Table V Water Permeability Test

Sr. No.	Specimen Designation	Penetration of water (mm)
1	CC	1.33
2	MC5	1.00
3	MC10	0.67
4	MC15	0.67

Split Tensile Strength

The indirect tensile strength of concrete was tested using Split Tensile test as per IS 5816-1999. Total 12-cylinder specimen of standard size were tested after 28 days of curing. The results are shown in Table VI, where Cy stands for control cylinder and MCy5 stands for cylinder with addition of micro silica followed by percentage.

Table VI Split Tensile Strength

Sr. No.	Specimen Designation	Split tensile strength (N/mm^2)
1	Cy	4.07
2	MCy5	4.60
3	MCy10	4.36
4	MCy15	4.31

Flexure Strength

The flexure test of concrete was carried on 12 beam specimens of standard size after 28 days of curing as per IS 516-2013. The results are shown in Table VII, where CB stands for control beam and MB5 stands for beam with addition of micro silica followed by percentage.

Table VII Flexural Strength

Sr. No.	Specimen Designation	Flexure strength (N/mm^2)
1	CB	6.24
2	MB5	7.28
3	MB10	6.39
4	MB15	4.98

DISCUSSION

Workability

The increase in percentage of micro silica increased workability of concrete. Adsorption of superplasticizer on the surface of micro silica retains water to come in contact and increase free water content in the mix. This increases free water with increase in content of micro silica ultimately increases workability of concrete

Compressive Strength

Maximum compressive strength was obtained for replacement of cement with 5% micro silica. SiO_2, a constituent of micro silica reacts faster than cement with calcium hydroxide present in hydration of cement to form calcium-silicate-hydrate (C-S-H) and increased rate of hydration led to increase in compressive strength for 5% addition of micro silica. With higher amount of micro silica process of hydration is slowed down which decreases rate of hydration. The increase in amount of micro silica decreases rate of hydration which led to decrease in compressive strength of concrete.

Water Permeability Test

The fine particles of micro silica increases packing of solid by filling voids between cement grains as cement fills voids between fine aggregate. Micro silica reduces voids in the concrete which makes micro-structure of paste more homogenous and dense. As content of micro silica increased, it decreased number of voids which led to decrease in permeability of concrete. The permeability of concrete decreased by 25% and 50% for 5%, and 10% replacement of cement with micro silica respectively compared to control specimen.

Split Tensile Strength

Maximum tensile strength was obtained for replacement of cement with 5% micro silica and later decrease with increase in content of micro silica. All specimens with content of micro silica obtained higher tensile strength than control specimen. The tensile strength increased by 13.02%, 7.10% and 5.90% for 5%, 10% and 15% replacement of cement with micro silica respectively compared to control specimen.

Flexure Strength

The flexure strength of concrete increased by 16.67% and 2.40% for 5% and 10% replacement of cement with micro silica respectively than control specimen. All beam specimens showed flexure failure pattern with evolution of vertical cracks on gradual application of load. The maximum deflection of 0.91 mm was obtained for control beam specimen.

CONCLUSION

The research comprises of replacement of cement with micro silica (0%, 5% 10% and 15% by weight of cement) to check the effect of micro silica on concrete. From above discussion, it can be concluded that –

1. As the percentage of micro silica increases, workability of concrete increases.
2. Increase in content of micro silica decreased compressive strength of concrete due to pozzolanic reaction of admixture.
3. The increase in workability decreased tensile strength of concrete with increase in content of micro silica.
4. Water permeability of concrete decreases with addition of micro silica which will be helpful to reduce corrosion of reinforcement.
5. Replacement of cement with 5% micro silica (by weight of cement) showed higher results than 10% and 15% replacement, it can be recommended to obtain high-strength concrete of M55 grade and more.

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