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RESEARCH ARTICLE

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EFFECT OF SUPPLEMENTARY CEMENTITIOUS MATERIAL (MICROSILICA / SILICA FUME) ON COMPRESSIVE STRENGTH OF CONCRETE

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ABSTRACT

In present era vast development occurred in the field of concrete technology. Many scientists and researcher have been developed numerous techniques to improve strength and durability parameters of the concrete. A number of studies have been carried out to investigate the possibility of utilizing a broad range of materials as partial replacement material for cement in the production of concrete. The use of supplementary cementitious material in production of concrete can result in major saving of energy and cost. It also helps to improve strength, durability, impermeability and chemical resistance of concrete.

The present study investigates the effects of mineral admixture (microsilica) & chemical admixture (Super plasticizer) on strength properties of M-30 grade concrete. The experimental program is designed to investigate microsilica (silica fume) as partial cement replacement in concrete. The replacement levels of cement by microsilica are selected as 4%, 8%, 12%, 16% and 20% for constant water-cementitious material ratio of 0.45. For all mixes compressive strength is determined at 3, 7, 28 days for 150 X 150 X 150 mm size cubes. Current experimental study shows that 12% replacement of cement by microsilica gives higher strength.

Keywords: Concrete, supplementary cementitious material, microsilica, super plasticizer, compressive strength.

I. INTRODUCTION

The Ordinary Portland Cement (OPC) is one of the main ingredients used for the production of concrete and has no alternative in the civil construction industry. Unfortunately, production of cement involves emission of large amounts of carbon-dioxide gas into the atmosphere, a major contributor for greenhouse effect and the global warming, hence it is inevitable either to search for another material or partly replace it by some other material. The search for any such material, which can be used as an alternative or as a supplementary for cement should lead to global sustainable development and lowest possible environmental impact.

To achieve the quest of high strength, high performance concrete we should accentuate on the replacement of OPC with some supplementary cementitious material (SCM). Supplementary Cementitious Materials (SCMs) are generally by products from various industrial processes or natural materials. Microsilica, Fly ash, High Reactive

Metakaolin, Ground Granulated Blast furnace Slag, Rice husk ash etc. are some of the Supplementary Cementitious Materials (SCMs) which can be used in concrete as partial replacement of cement. A number of studies are going on in India as well as abroad to study the impact of use of these SCMs as cement replacements and the results are encouraging. Out of above Supplementary Cementitious Materials (SCMs) we use Microsilica / silica fume as partial replacement of cement and experimental investigation is carried out.

The advantages like high strength, durability and reduction in cement production are obtained due to the incorporation of microsilica in concrete and the optimum percentage replacement of microsilica ranging from 8 to 12% to obtain maximum 28-days compressive strength of concrete. Durability and the other mechanical properties of concrete are improved when pozzolanic materials are incorporated in concrete because of the reaction between silica present in pozzolana and the free calcium hydroxide during the hydration of cement and consequently forms extra calcium silicate hydrate (C-S-H). Consequently, the use of microsilica (silica fume) concrete in civil structures is wide spreading. Incorporation of microsilica in concrete has an adverse effect on workability. Therefore, super plasticizer is needed for higher percentage of cement replacement by microsilica. In this paper our attempt has been made to study the effect of microsilica / silica fume on strength properties of concrete considering a constant water-cementitious material ratio of 0.45 for M-30 grade concrete mix.

II. EXPERIMENTAL PROGRAM

A. Materials Used: The following materials were used for experiment confirming to various standards.

1. *Cement:*

Ordinary portland cement of 53 grade (Coromandal King) available in the local market is used in the investigation. The cement used has been tested for various properties as per IS 4031-1988 and found to be conforming to various specifications of IS 12269-1987. The specific gravity is 3.06 and fineness is 2600 cm^2/gram.

2. *Fine aggregate:*

Locally available crushed sand was used as fine aggregate which confirms to zone II of IS 383-1983. Coarser sand were preferred, as finer sand increases the water demand of concrete and very fine sand may not be essential in silica fume concrete as it usually has larger content of fine particles in the form of cement and mineral admixtures such as microsilica etc. The specific gravity of fine aggregate is 2.63 and fineness modulus is 3.515.

3. *Coarse aggregate:*

Crushed angular granite metal from a local source was used as coarse aggregate having size ranging from 10mm to 20mm. The specific gravity of coarse aggregate is 2.77, fineness modulus is 7.4 and water absorption is 0.6%.

4. *Micro silica:*

Commercially available Microsilica from Elkem Metallurgy, India Ltd. Mumbai, having the properties as shown in Table 1 is used.

TABLE 1:PHYSICAL AND CHEMICAL PROPERTIES OF MICROSILICA

Sr. No.	Microsilica Characteristics	Specification Requirement
1	Form / Appearance	White colored very fine powder
2	SiO_2	89.64%
3	Bulk Density	645 kg/m^3
	Specific gravity	2.21
4	Particle size	< 1µm
5	Specific surface area (NAM)	23000 m^2/kg
6	Loss of ignition at 800°C:	2.9%

5. *Water:*

The water used for the study was free of acids, organic matter, suspended solids, alkalis and impurities which when present may have adverse effect on the strength of concrete.

6. *Super plasticizer:*

Super plasticizers used in the experimental work conforming to IS 9103-1999, was supplied by a private agency and it is a Sodium Naphthalene Sulphonate based retarder type Super plasticizers EB-821/R with a dosage of 0.8 to 1.2% by volume to weight of total binder contentof concrete. Necessary properties, given by supplier are given in Table 2.

TABLE 2: PROPERTIES OF SUPER PLASTICIZERS

Sr. No.	Properties	Description
1.	Chemical admixture	Masterplast SPL – 9
2.	Color	Brown
3.	Type	Sulphonated Naphthalene formaldehyde polymer
4.	Specific Gravity	1.26 at 30°C
5.	pH Value	9
6.	Chloride content	Nil
7.	Air Entrainment	Nil
8.	Nitrate content	Nil
9.	Viscosity	Medium Viscous

B. Mix Proportion:

Concrete mix design in this experiment was designed as per the guidelines specified in I.S. 10262-1982. Mix Proportioning by weight was used and the cement/ dried total aggregates ratio was 1:2:3.62. Micro silica were used to replace OPC at dosage levels of 4%, 8%, 12%, 16% and 20% by weight of the binder. The mix proportions were calculated and presented in Table 3.

TABLE 3: QUANTITIES OF MATERIALS PER 1m^{3}OF CONCRETE

Composition of the concrete mixtures (Kg/m^3) per m^3 of concrete							
Mix	**w/c**	**OPC (kg)**	**Micro -silica (kg)**	**Fine Agg. (kg)**	**Coarse Agg. (kg)**	**Super plasticizer (kg)**	**Water (kg)**
NC	0.45	350	0	706.28	1266.6	7.00	157.60
NC + 4% M-S	0.45	336	14	706.28	1266.6	7.00	157.60
NC + 8% M-S	0.45	322	28	706.28	1266.6	7.00	157.60
NC + 12% M-S	0.45	308	42	706.28	1266.6	7.00	157.60
NC + 16% M-S	0.45	294	56	706.28	1266.6	7.00	157.60
NC + 20% M-S	0.45	280	70	706.28	1266.6	7.00	157.60

C. Preparation of Test Specimen:

In this study, a total number of 54 cubes for the control and cement replacement levels of 4%, 8%, 12%, 16% and 20% were produced respectively. All the mixes were cast using 1:2:3.62 mix proportion with constant w/c ratio of 0.45. For the compressive strength, 150mm x 150mm x 150mm cube moulds were used to cast the cubes. During moulding the cubes were mechanically vibrated. All freshly cast specimens were left in the moulds for 24 hours before being de-moulded and then submerged in water for curing until the time of testing 3 specimens were tested for each age in a particular mix (i.e. the cubes were tested at 3, 7 and 28 days respectively). The specimens were tested for compressive strength using a compression testing machine.

D. Testing Of Specimen:

Compressive strength test were carried out at specified ages on the cubes. For the compression test, the cubes are placed in machine in such a manner that the load is applied on the forces perpendicular to the direction of cast. In Compression Testing Machine, the top surface of machine is fixed and load is applied on the bottom surface of specimen. The rate of loading is gradual and failure (crushing) load is noted. Also the failure pattern is observed precisely. Figure 1 shows compressive strength test setup.

FIGURE 1: COMPRESSIVE STRENGTH TEST SETUP

III. RESULTS AND DISCUSSION

A. Results of compressive strength of concrete:

The test was carried out conforming to IS 516:1959 to obtain compressive strength of M-30 grade of concrete. For compressive strength testing total 54 concrete cubes are casted. Six concrete mix samples are used. The compressive strength of high strength concrete with OPC, microsilica and super plasticizer concrete at the age of 3, 7 and 28 days are presented in table 4. There is a significant improvement in the strength of concrete because of the high pozzolanic nature, fineness of the microsilica and its void filling ability. The compressive strength of the mix M-30 at 3, 7 and 28 days age, with replacement of cement by microsilica was increased gradually up to an optimum replacement level of 12% andbeyond 12% to 20% there is decrease in compressive strength. The compressive strength of M-30 grade concrete with partial replacement of 12% cement by silica fume shows 20.52% greater than the controlled concrete. The maximum compressive strength of concrete with microsilica depends on three parameters, namely the replacement level, water cement ratio and chemical admixture. The maximum 3, 7 and 28 days cube compressive strength of M-30 grade with 12% of silica fume was 23.16, 31.38 and 50.56 Mpa respectively.

TABLE 4: COMPRESSIVE STRENGTH FOR VARIOUS MIX PROPORTIONS

Type of concrete	Compressive Strength (N/mm^2) 3 Days	7 Days	28 Days
Normal Concrete	15.10	23.60	41.95
Normal Concrete + 4 % Microsilica	17.67	25.27	43.73
Normal Concrete + 8 % Microsilica	20.33	29.53	46.33
Normal Concrete + 12 % Microsilica	23.16	31.36	50.56
Normal Concrete + 16 % Microsilica	20.79	28.69	45.64
Normal Concrete + 20 % Microsilica	18.83	24.20	44.00

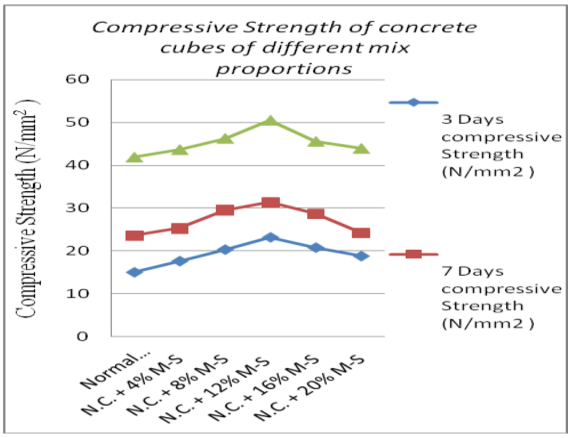

CHART NO.1: COMPRESSIVE STRENGTH OF CONCRETE CUBES FOR DIFFERENT TRIAL MIXES FOR 3, 7 & 28 DAYS CURING PERIOD

B. *Discussion:*

As expected the compressive strength increases with increase in content of microsilica. As the total water/binder ratio is kept constant, the variation of strength with respect to constant water/cement ratio remains open to discussion. The compressive strength of silica fume / microsilica concrete increases with increase in microsilica content upto 12% and further increment of microsilica will result in strength reduction. The graph plotted denotes that the highest compressive strength of M-30 grade silica fume concrete at optimum dose of 12 % is 50.56 MPa.

IV. CONCLUSION

- Cement replacement up to 12% with microsilica leads to increase in compressive strength for M-30 grade of concrete. From 16% there is decrease in compressive strength for 3, 7 and 28 days of curing period.
- The optimum dose of microsilica for achieving higher compressive strength is 12%.
- Microsilica increases the compressive strength of concrete more than 20%.
- Super plasticizer with dosage range of 0.75 to 1.80% by weight of cementations materials (Cm = OPC + Microsilica) has been used to maintain the adequate workability of silica fume concrete.
- The gain of strength of microsilica / silica fume concrete with age is much more compared to that of normal concrete.
- By effective usage of this industrial waste (Micro silica) in optimum percentage in concrete may make concrete economic and environmental friendly.

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