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AN EXPERIMENTAL STUDY ON STRENGTH AND PERMEABILITY PROPERTIES OF HIGH STRENGTH CONCRETE

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ABSTRACT

Concrete is the most important engineering material and the addition of some other materials may change the properties of concrete. Mineral additions which are also known as mineral admixtures have been used with cements for many years. There are two types of materials crystalline and non crystalline. High performance concrete (HPC) exceeds the properties and constructability of normal concrete. Micro silica or silica fume is very fine non crystalline material. Silica fume is produced in electric arc furnace as a byproduct of the production of elemental silicon**'**s or alloys containing silicon. IT is usually a grey colored powder somewhat similar to Portland or some fly ashes silica fume is generally categorized as a supplementary cementious material In our experiment we are using micro silica as an artificial pozzolans. We are adding 0%, 5%, 10%, 15% and 20% by wt of cement in concrete. HPC are made with carefully selected high quality ingredients and optimized mixture designs. Super Plasticizers are usually used to make these concretes fluid and workable. HPC almost always has a higher strength than normal concrete

KEYWORDS: Micro silica, hydration, Work ability, Compressive Strength.

I. INTRODUCTION

I.I General:

Concrete is widely used for making architectural structures, foundations, brick walls, pavements, bridges/over passes, motorways/roads, runway sparking structures, dams and pools/reservoirs of all the above purposes it can be widely used for construction purposes. Due to the advancement in the technology the usage of the concrete along with their partial replacements have done a new revolution. Scientists, engineers and technologies, are continuously on the look-out for the materials that can act as substitute for conventional materials and which can be used along with the concrete, so that the structure can be built economically

I.2 Concrete:

Concrete *IS* a mixture of four materials which are Portland cement, water, fine aggregate (sand) and coarse aggregate (gravel or crushed stone). Concrete hardening is not caused by evaporation or drying but as results from a chemical reaction which is hydration between Portland cement and water. sometimes admixtures in required proportions. Fresh concrete or plastic concrete is freshly mixed material which can be moulded into any shape hardens into a rock-like mass known as concrete

I.3 Silica Fume:

Very fine non crystalline silica produced in electric arc furnaces as a by-product of the production of elemental silicon or alloys containing silicon; also known as condensed silica fume or micro silica**.** Smoke by-product from furnaces used in the production of ferrosilicon and silicon metals amorphous silica with high SiO2 content, extremely small particle size, and large surface area highly reactive pozzolanic used to improve mortar and concrete. The American Concrete Institute (ACI) defines silica fume as **"**very fine non-crystalline silica produced in electric arc furnaces as a by-product of the productions of elemental silicon or alloys containing silicon**"**. It is usually a gray recolored powder, somewhat similar to Portland cement or some fly ashes. Silica fume is usually categorized as a supplementary cementations material. It is usually a grey coloured powder, somewhat similar to Portland cement or some fly ashes. It can exhibit both pozzolanic and cementations properties. Silica fume has been recognized as a pozzolanic admixture that is effective in enhancing the mechanical properties to a great extent. Addition of silica fume to concrete improves the durability of concrete, compressive strength of concrete, abrasion resistance, reduces permeability and also in protecting the embedded steel from corrosion. Fixed silica fume content of 7.5% to 8.5%

II. LITERATURE REVIEW

2.1 GENERAL:

Extensive research works both at National and International level has been done on the use of various admixtures in mortars and concrete's with a common goal. In India, only government educational and research institutions and construction departments are responsible for research while in advanced countries, the most remarkable breakthrough have been achieved by the building material industries and their R&D laboratories. An accepted fact is that these encouraging results on the use of admixtures are not penetrating into the user community and the entire research work is getting flocked at their organization. With the result the very purpose of research work is questioned along with R&D units. The policy maker and consultants should take more interest in handling these issues directly keeping not only the techno economics in view but also national obligations.

2.2 REVIEW:

Advance concrete technology can reduce the consumption of natural resources and energy sources thereby lessen the burden of pollutants on environment. We describe the feasibility of using the electric furnace waste in concrete production as partial replacement of cement with silica fume. Silica fume is sold in powder form but is more commonly available in a liquid. Silica fume is used in amounts between 10% and 100% by mass of the total cementious material. The specimen shall be made for each sample for testing at 28 days. Additional samples may be required for various purposes such as to determine the strength of concrete at 3 days & 7 days

Yogendran et al. (1987) made an attempt to modify the properties of concrete with respect to its strength and other properties by using silica fume and chemical admixtures. They concluded that optimum replacementof cement by silica fume for high strength is found to be 15% for a water cementious ratio of 0.34 at all age.

Brooks et.al. (2000) after studying the effect of silica fume, Metakaolin, fly ash and ground granulated blast furnace slag on setting times of high strength concrete, they concluded that there was increase in the retarding effect up to 10% replacement of cement by Metakaolin and as the percentage replacement is increased, the retarding effect is reduced

Uchikawa (2012)mentioned that use of excessivesuper plasticizer may cause substantial delays in setting times of cement paste containing silica fume.

Meland observed that cumulative heat evolved is lower when paste containing silica fume and lingo sulfonate. In addition, the higher the amount of silica fume, the smaller the amount of heat evolved. In the presence of lingo sulfonate, the hydration reaction was retarded and less heat was evolved from paste containing silica fume.

III. MATERIALS AND METHODS

3.1 CEMENT

In the most general sense of the word, cement is a binder, a substance that sets and hardens independently, and can bind other materials together. The word "cement" traces to the Romans, who used the term opus caementicium to describe masonry resembling modern concrete was made from crushed rock with burnt lime as binder. The volcanic ash and pulverized brick additives that were added to the burnt lime to obtain a hydraulic binder were later referred to as cementer, cimentum, cament, and cement. The chemical reaction that results when the anhydrous cement powder is mixed with water produces hydrates that are not water soluble. Non-hydraulic cements (e.g. gypsum plaster) must be kept dry in order to retain their strength. The most important use of cement is the production of mortar and concrete,

PORTLAND CEMENT

Cement is made by heating limestone (calcium carbonate) with small quantities of other materials (such as clay) to 1450 °C in a kiln, in a process known as calcinations, whereby a molecule of carbon dioxide is liberated from the calcium carbonate to form calcium oxide, or quicklime, which is then blended with the other materials that have been induced in the mix

PORTLAND SILICA FUME CEMENT

Addition of silica fume can yield exceptionally high strengths, and cements containing 5–20% silica fume are occasionally produced. However, silica fume is more usually added to Portland cement at the concrete mixer. Masonry-cements are USED for bricklaying mortars and stuccos, and must not be used in concrete. They are usually complex proprietary formulations containing Portland clinker and a number of other ingredients that may include limestone, hydrated lime, air entertainers, retarders, water proofers and colouring agents. Even with intensive grinding they can use up to 50% less energy to fabricate than ordinary Portland cements.

3.2 AGGREGATES

Aggregate properties greatly influence the behavior of concrete, since they occupy about 80% of the total volume of concrete. The aggregates are classified as **1.Coarse aggregate 2.Fine aggregate**

Fine aggregate are material passing through an IS sieve that is less than 4.75mm gauge beyond which they are known as coarse aggregate. Coarse aggregate from the main matrix of the concrete. Whereas fine aggregate from the filler matrix between the coarse aggregate. The most important function of the aggregate is to provide workability and uniformity in the mixture. The fine aggregate also helps the cement paste to hold the coarse aggregate particle in suspension

Table 3.1 Sizes of Coarse Aggregate for Mass Concrete:

Class And Size	Is Sieve Designation	Percentage Passing
Very large, 150 to 80mm	160mm 80mm	90 to 100 0 to 10
Large , 80 t0 40mm	80mm 40mm	90 to 100 0 to 10
Medium ,40 to 20mm	40mm 20mm	90 to 100 0 to 10
Small, 20 to 4.75mm	20mm 4.75mm 2.36mm	90 to 100 0 to 10 0 to 2

Table 3.2 sizes of Fine aggregates for mass of concrete:

Is Sieve Designation	Percentage Passing For			
	Grading zone-I	Grading zone-II	Grading zone-III	Grading zone-IV
10mm	100	100	100	100
4.75mm	90-100	90-100	90-100	95-100
2.36mm	60-95	75-100	85-100	95-100
1.18mm	30-70	55-90	75-100	90-100
600 micron	15-34	35-59	60-79	80-100
300 micron	5-20	8-30	12-40	15-50
150 micron	0-10	0-10	0-10	0-15

3.3 Silica Fume

Silica fume, also referred to as micro silica or condensed silica fume, is a by product material that is used as a pozzolan. This by product is a result of the reduction of high-purity quartz with coal in an electric arc furnace in the manufacture of silicon or ferrosilicon alloy. The condensed silica fume is then processed to remove impurities and to control particle size.

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Fig 3.3: Silica Fume Colors- Premium White and Standard Grey

PHYSICAL PROPERTIES OF SILICA FUME

The bulk density of silica fume depends on the degree of densification in the silo and varies from 130 (unidentified) to 600 kg/m3. The specific gravity of silica fume is generally in the range of 2.2 to 2.3. The specific surface area of silica fume can be measured with the BET method or nitrogen adsorption method. It typically ranges from 15,000 to 30,000m2/kg.

CHEMICAL PROPERTIES OF SILICA FUME

Silicon (% of SiO_2> 85),Aluminium (%of Al_2O_3< 2),Iron (% of Fe_2O_3<1),Calcium (% of CaO<1),Magnesium (% of MgO<1),Sodium (% of Na_2O <1) ,Potassium (% of K_2O <1),Chloride (% of Cl< 0.3),Loss of Ignition (% <4) ,Sulfate (% of SO_4<0.3),Free Calcium Oxide (% < 1)

INFLUENCE OF SILICA FUME IN CONCRETE

The American concrete institute (ACI) defines silica fume as very fine non crystalline silica produced in electric arc furnaces as a by-product of production of elemental silicon or alloys containing silicon. Silica fume is also known as micro silica, condensed silica fume, volatized silica or silica dust. It is usually a grey coloured powder, somewhat similar to Portland cement or some fly ashes. It can exhibit both pozzolanic and cementations properties. Silica fume has been recognized as a pozzolanic admixture that is effective in enhancing the mechanical properties to a great extent. Addition of silica fume to concrete improves the durability of concrete, compressive strength of concrete, abrasion resistance, reduces permeability and also in protecting the embedded steel from corrosion

WORKABILITY

With the addition of silica fume, the slump loss with time is directly proportional to increase in the silica fume content due to the introduction of large surface area in the concrete mix by its addition. Although the slump decreases, the mix remains highly cohesive.

SEGREGATION AND BLEEDING

Silica fume reduces bleeding significantly because the free water is consumed in wetting of the large surface area of the silica fume and hence the free water left in the mix for bleeding also decreases. Silica fume also blocks the pores in the fresh concrete so water within the concrete is not allowed to come to the surface.

3.4 SUPERPLASTICIZER

It is a substance which imparts very high workability with a large decrease in water content (at least 20%), for a given workability. A high range water reducing admixture (HRWRA) is also referred asSuper plasticizer, which is capable of reducing water content by about 20 to 40 percent has been developed. These can be added to concrete mix having a low to-normal slump and water cement ratio to produce high slump flowing concrete. The effect of Super plasticizers lasts only for 30to 60 minutes, depending on composition and dosage and is followed by rapid loss in workability. One of the important factors that govern the issue water–cement ratio during the manufacture of concrete, lower the water-cement ratio lower will be the capillary pores and hence lower permeability and enhanced durability. To achieve the uniform workability, the admixture dosage was adjusted without changing the unit water content. This ensured the identical W/C ratio for a particular cementious content and the effect of pozzolanic material replacement can directly be studied on the various properties of concrete.

3.4 EXPERIMENTAL SETUP

In this stage collection of materials required and the data required for mix design are obtained by specific gravity test. Specific gravity tests are carried out for fine and coarse aggregate. The various materials used were tested as per Indian standard specifications.

Materials

Raw materials required for the concreting operations of the present work are

Cement
Silica Fume
Coarse aggregate
Fine aggregate

Table 4.1 Physical Properties of ordinary Portland cement of ANJANI-53 Grade

S.NO.	PROPERTY.	TEST RESULTS.
1	Normal consistency	32%
2	Specific gravity	3.13
3	Initial setting time	105 minutes.
	Final setting time.	520 minutes.
4	Soundness (Expansion) Lechatlier method	2 mm
5	Fineness of cement (Dry sieving method)	98%
6	Compressive strength cement at 7 days - 28 days.	31.6 N/mm2
		22.9 N/mm 2

WATER

Water to be used in the concrete work should have following properties:

It should be free from injurious amount of oil, acids, alkalis or other organic or inorganic impurities.
It should be free from iron, vegetable matter or other any type of substances,
which likely to have adverse affect on concrete or reinforcement.
It should be quite satisfactory for drinking purpose which is used in mixing of concrete.

3.5 PROCESS OF MANUFACTURE OF CONCRETE

Aggregates

The coarse aggregate was kept completely immersed in clean water for 24 hours for water absorption. After 24 hours, the aggregate was gently surface dried with dry cloth. It was then spread out and exposed to the atmosphere until it appears to be completely surface dry. For fineaggregate, considering the huge time to be taken to become surface dry from wet condition, it was not immersed in water. Instead the water was sprinkled then it was spread out and exposed to the atmosphere until it appears to be completely surface dry.

Batching

The quantities of cement, fly ash, fine aggregate, coarse aggregate and water for each batch were measured by a weighing balance of an accuracy of 1 gm

Mixing:

The object of mixing is to coat the surface of all aggregate particles with cement paste and to blend all the ingredients of concrete in to a uniform mass. Thorough mixing of the materials is essential for the production of uniform concrete. The mixing should ensure that the mass becomes homogeneous, uniform in colour and consistency. Two methods are adopted for mixing concrete, Hand mixing and Machine mixing. In this study the process of mixing the materials has been done by hand mixing. ***Casting of Concrete Cubes***

The test moulds are kept ready before preparing the mix. Moulds are cleaned and oiled on all contact surfaces then fixed on vibrating table firmly. The concrete is filled into moulds in layers and then vibrated. The top surface of concrete is struck off level with a trowel. The number and date of casting are put on the top surface of the cubes

Compaction

When compacting by hand, the standard tamping bar is used and the strokes of the bar are distributed in a uniform manner over the cross section of the mould. The number of strokes per layer required to produce the specified conditions vary according to the type of concrete. In no case should the concrete be subject to less than 35 strokes per layer for 15cm or 25 strokes per layer for 10 cm cubes. For cylindrical specimens, the numbers of strokes are not less than thirty per layer. Fly ash replacement material (FA) of design mixes compaction of cubes, cylinders, beams and all regular mix for beams was hand compacted.

CURING

The test specimens were stored in a place free from vibration and covered with wet gunny bags for 24 hours from the time of addition of water to the dry ingredients. After this period, specimens are removed from the moulds and immediately submerged in curing tank and kept there until taken out just period to rest. The water of curing tank was renewed or every seven days and maintained at a temperature of 27± 2 /^{0}C.

3.6 MIX DESIGN

ACI, 234R-96, **"**guide for the use of silica fume in concrete,**"** recommended a set of procedure for design of concrete mix mainly based on the work done in national laboratories. This method can be applied for high strength concrete. The following mixes are designed are based on American concrete institution.

STIPULATIONS FOR MIX PROPORTIONING

Characteristic Compressive Strength: 60 N/mm2
Maximum size of aggregate: 20 mm
Degree of workability (slump): 50-100 mm
Degree of quality control: Good
Type of exposure: Severe

TEST DATA OF THE MATERIAL

Cement OPC – 53 G
Specific Gravity of Cement: 3.13
Specific Gravity of C A: 2.64
Specific Gravity of F A: 2.62

Target mean strength for mix design:

$$F_{ck} = f_{ck} + (t * s)$$

Where
Fck=characteristic compressive strength at 28 days.
fck= Characteristic Compressive Strength at 28 days
S=standard deviatio
t = a statistical value depending on the risk factor

fck= 60 + 1.65 x 5 = 68.25N/mm2.

From ACI 211.4R Assuming slump as 50 to 75 mm and for C.A size 20 mm the Mixing water is = 174 lit.
Take w/c ratio = 0.35
Cement Content is calculated by
Weight of Cement = 174/0.35 = 497.14 Kg/cum Say 500Kg/cum.
From ACI 211.4R Dry rodded volume of coarse aggregate is 0.68 of volume of concrete.
Wt. of CA = 0.68 x 1535= 1043.80 Kg/cum, Say 1044 Kg/cum.
Calculated quantities of materials per cum of concrete are

- Cement = 500 Kg
- Fine Aggregate = 720 Kg

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- Coarse Aggregate = 1044 Kg
- Water = 169 lit
- Super plasticizer = 5lit.
- W/C = 0.35.

Silica replacement in %	w/c	Cement (kg)	Fine aggregate (Kg)	Coarse aggregate (kg)	Water (lit)	Super plasticizer(lit)	Silica (kg)
0	0.35	500	720	1044	169	5	0
5	0.35	475	720	1044	169	5	25
10	0.35	450	720	1044	169	5	50
15	0.35	425	720	1044	169	5	75
20	0.35	400	720	1044	169	5	100

IV. RESULTS AND DISCUSSION

COMPRESSIVE STRENGTH VALUES FORREPLACEMENT OF CEMENT BY SILICA FUME

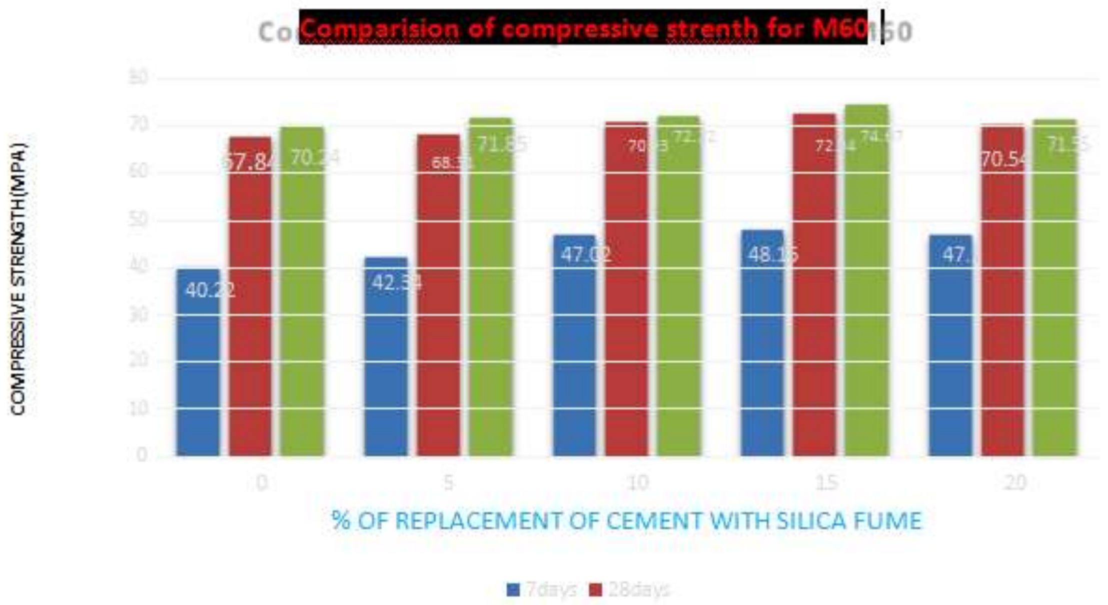
Table 6.4 Compressive Strength Results for Replacement of Cement by Silica Fume

S.No	Total Replacement By silica fume Only(Mix)	7 days	28 days	56 days
1	0	40.22	67.84	70.24
2	5	42.34	68.31	71.85
3	10	47.02	70.93	72.22
4	15	48.16	72.84	74.67
5	20	47.1	70.54	71.55

ACCELERATED CURING TEST RESULTS

Table 6.5 Compressive Strength Results for Replacement of Cement by Silica Fume

S.No	Total Replacement By silica fume Only(Mix)	Compressive strength(Mpa)
1	0	68.8
2	5	71.1
3	10	77.26
4	15	78.14
5	20	75.24



V. CONCLUSION

- As the silica fume content increases the compressive strength increases up to 15% [HPC4] and then decreases. Hence the optimum replacement is 15%.
- Silica fume is much cheaper than cement therefore it is very important from economical point of view.
- Silica fume is a material which may be a reason of air pollution this is a byproduct of some industries.
- Use of micro silica with concrete reduces the air pollution.
- Silica fume also decreases the voids in concrete.
- Addition of silica fume reduces capillary

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