Study of Silica Fume by using Natural Adhesive in Concrete

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Abstract— Portland cement has been widely used as a binding material in concrete production, but its demand increases along with rapid growth of infrastructure development. The problem developed in Portland cement production because it releases much of carbon dioxide (CO2) into the atmosphere and it causes harm to the environment. To reduce carbon dioxide emissions due to the Portland cement production, it is necessary to find other materials as Portland cement replacement materials are Silica Fume with Natural adhesive GUM ARABIC and Lime. The study shows that good results of compressive strength concrete and workability of concrete were obtained when using the gum Arabic liquid the aim of this research is to evaluating the performance of silica-fume as a replacement material by conducting some tests and determining the quantity silica-fume of that can be used successfully in manufacturing of concrete.

Key words: Cement, Sand, Aggregate, Silica fume. Lime, Gum Arabic

I. Introduction

Traditionally, Ordinary Portland cement is used for making the civil structures. Portland cement can be partially replaced by silica fume. Silica fume is nonmetallic and nonhazardous waste of industries. It is suitable for concrete mix and improves properties of concrete i.e. compressive strength etc. The main objective of this research work is to determine the optimum replacement percentages which can be suitably used under the Indian conditions. To fulfill the objective various properties of concrete using silica fume have been evaluated. Further to determine the optimum replacement percentage comparison between the regular concrete and concrete containing silica fume is done. The effect of Silica fume on various other properties of Concrete has also been evaluated.

Portland cement has been widely used as a binding material in concrete production, where its demand increases along with rapid growth of infrastructure development. The problem emerges in Portland cement production because it releases much of carbon dioxide (CO_2) into the atmosphere and it could harm the environment. To reduce carbon dioxide emissions due to the Portland cement production, it is necessary to find other materials as Portland cement replacement materials.

II. Objectives

1) Checking the availability of Silica fume in the country.
2) Evaluating. the performance of silica-fume as a replacement material by conducting some tests and determining the quantity silica-fume of that can be used successfully in manufacturing of concrete
3) Investigating the economic and environmental issues of using silica fume for cement replacement.
4) To investigate, effect of natural adhesive on the binding properties with cement and composition.
5) To know the strength variation of and study their property.
6) To know the correct Percentage of silica fume with natural adhesive and lime.
7) To find compressive strength, and flexure test after 7days 14 days, and 28 days, and check as per I.S code.

III. Experimental Study

A. Material & Methods:

1) Cement

Cement is considered as the best binding material and is being commonly used as a binding material in the construction of various engineering structures these days. Portland cement is referred as ordinary Portland cement is the most important type of cement and is a fine powder produced by grinding Portland cement clinker. Concrete is made by Portland cement, water and aggregates. Cement constitutes about 20 % of the total volume of concrete. Portland cement is hydraulic cement that hardens in water to form a water-resistant compound. The hydration products act as binder to hold the aggregates together to form concrete. The name Portland cement comes from the fact that the color and quality of the resulting concrete are similar to Portland stone, a kind of limestone found in England.

a) Classification of OPC:-

Depending upon the strength of the cement at 28 days when tested as per IS 4031-1988. Cement is classified as

- 33 grade cement
- 43 grade cement
- 53 grade cement

If 28 days strength is not less than 33N/mm^2, it is called 33 grade of cement, if the strength is not less than 43N/mm^2, it is called 43 grade of cement, and if the strength is not less than 53N/mm^2, it is called 53 grade of cement. But actual strength obtained by these cements at the factory is much higher than the BIS specifications. Ordinary Portland Cement 43 grade (OPC-43) confirming to IS 8112:1989. The cement used was of Ultratech Cement. Following table 1 gives the properties of cement tested.

Sr. No.	Characteristics	Values obtained experimentally	Values specified by IS
1	Specific gravity	3.156	3.15
2.	Standard consistency (%)	33	30
3.	Initial setting time	45(minutes)	30(Minutes)
4.	Final setting time	325(minutes)	600(Minutes)
5.	Compressive strength 3 days 7 days 28 days.	25.2 N/mm^2 37.9 N/mm^2 47.8 N/mm^2	23 N/mm^2 (Min.) 33 N/mm^2 (Min)

			43N/mm^2 (Min)

Table 1: Chemical Composition of O.P.C Cement

2) Fine Aggregates (FA)

The aggregates most of which pass through 4.75 mm IS sieve are termed as fine aggregates. The fine aggregate may be of following types:

1) Natural sand, i.e. fine aggregate resulting from natural disintegration of rocks.
2) Crushed stone sand, i.e. fine aggregate produced by crushing hard stone.
3) Crushed gravel sand, i.e. fine aggregate produced by crushing natural gravel.

Fine aggregate (natural sand) confirming to IS 383:1970 used in this study was locally procured. Physical properties of this sand are given in table 2 below.

Sr.No.	Characteristics	Value
1.	Specific gravity	2.34
2.	Bulk density(kg/m3)	1.3
3.	Fineness modulus	2.62
4.	Water absorption	0.88

Table 2: Properties of fine aggregate

3) Coarse Aggregates (CA)

The aggregate which is retained over IS Sieve 4.75 mm is termed as coarse aggregate. The coarse aggregates may be of following types:-

1) Crushed graves or stone obtained by crushing of gravel or hard stone.
2) Uncrushed gravel or stone resulting from the natural disintegration of rock
3) Partially crushed gravel obtained as product of blending of above two types.

The normal maximum size is gradually 10-20 mm; however particle sizes up to 40 mm or more have been used in Self Compacting Concrete. Locally available coarse aggregate having the maximum size of 20 mm was used in this work. The aggregates were washed to remove dust and dirt and were dried to surface dry condition. The aggregates were tested as per IS: 383-1970. Specific gravity and other properties of coarse aggregates are given in Table 2. The sieve analysis of coarse aggregate was done. Table 2 the result of sieve analysis. Proportioning of coarse aggregates was done and fineness modulus was obtained.

Sr.No.	Characteristics	Value
1.	Color	Grey
2.	Size	20mm
3.	Shape	Angular
4.	Specific gravity	2.74

Table 3: Properties of coarse aggregate

4) Silica fume

It is waste by product in the manufacturing of elemental silica. Also referred as micro silica or condensed silica it is a pozzolanic material. Having size less than 1µm and spherical shape, this is an ultrafine material. The specific surface is approximately 20,000 m^2/kg. It is of light to dark grey color and generally acts as filler material in fine aggregates, thus improves the various properties of concrete. Due to its high surface area, high pozzolanic action and its chemical properties it has both engineering as well as economic benefits. The various physical properties of silica fume are given in table 4 below.

Sr.No.	Property	Value
1.	Color	Grey
2.	Particle size	< 1 µm
3.	Specific surface	20000 m^2/kg
4.	Specific gravity	2.2

Table 4: Properties of Silica Fume

5) Lime

Limestone is calcareous sedimentary rocks formed at the bottom of lakes and seas with the accumulation of shells, bones and other calcium rich goods. It is composed of calcite (CaCO3). The organic matter upon which it settles in lakes or seas are preserved as fossils. The limestone used acts as a basic binding material. Lime can be used as a cement replacement in concrete. There are, as there have always been, two critical issues with this type of cement replacement: the change in physical properties with respect to compressive strength and the cost analysis of the alternatives. Hydraulic limes gain strength over time hence providing flexibility and avoiding the need for expansion joints. Considered to be more environmentally friendly than cement as they are burnt at a lower temperature and uniquely re-absorb some of the carbon dioxide given off during burning as they cure/carbonate in/on the wall. Enable building components to be reclaimed and reused as they are 'softer' than cement. Set under water hence making them ideal for applications in contact with the sea, canals, rivers etc.

6) Gum Arabic (Natural adhesives)

An adhesive, also known as glue, cement, mucilage, or paste, is any nonmetallic substance applied to one surface, or both surfaces, of two separate items that binds them together and resists their separation.

In this research, Gum Arabic, extracted from (Hashab) trees (in western Sudan) the purest kind of gum, is used in concrete mixes after crushing to be in a form of powder which was dissolved in water to get the liquid of this additive. In this study, Gum Arabic powder and liquid was added to concrete mixes at ratios 0.1%, 0.2%, 0.4%, 0.6%, 0.8%, 1.0 % and 1.2 % of cement.

The study showed that the addition of Gum Arabic to the concrete mixes has a clear effect when equal to 0.4% of cement content. The compressive strength was measured at ages of 7, 21, and 28 days and it was found that it decreases slightly with increase in the proportion of Gum Arabic in concrete mixes.

The study shows that good results of compressive strength concrete and workability of concrete were obtained when using the gum Arabic liquid. The concrete mixes prepared using modified gum Arabic in its liquid state by reducing (w/c) and adding gum Arabic as a percentage of cement content showed a clear change in the properties of concrete. These ratios resulted in high compressive strength concrete with good workability.

IV. CONCRETE MIXES

Mix design for M30 grade of concrete was carried out using the guidelines prescribed by IS: 10262- 1982. The designed concrete mix for M30 served as basic control mix (CM). Silica fume concrete mixes were obtained by adding silica fume to basic control mix in percentages varying from 0 to 15% at an increment of 5% by weight of cement. (SFC0, SFC5, SFC10, SFC15).

A. Batching, Mixing, & Curing:

The concrete ingredients viz. cement, sand and coarse aggregate were weighed according to M30 and are dry mixed on a platform. To this the calculated quantity of silica fume was added and dry mixed thoroughly. The required quantity of water was added to the dry mix and homogenously mixed. The homogeneous concrete mix was placed layer by layer in moulds kept on the vibrating table. The specimens are given the required compaction both manually and through table vibrator. After through compaction the specimens were finished smooth. After 24 hours of casting, the specimen were demoded and transferred to curing tank wherein they were immersed in water for the desired period of curing.

B. Mix Design (M30):

1) Specific gravity of cement 3.14
2) Specific gravity of coarse aggregates 2.74
3) Specific gravity of fine aggregates 2.34
4) Zone of fine aggregates II
5) Water absorption of coarse aggregates 0.43%
6) Water absorption of fine aggregates 0.88%

V. DATA ANALYSIS PROCEDURE

A. Result & Discussion:

The presentation of results obtained from various tests conducted on concrete specimens cast with and without silica fume are shown here.

The experimental program was planned to investigate the effect of silica fume on compressive strength and split tensile strength concrete. The experimental program consist of casting, curing and testing of controlled and silica fume concrete specimen at different ages.

The experimental program included the following:

- Testing of properties of materials used for making concrete.
- Design mix (M30).
- Casting and curing of specimens.
- Tests to determine the compressive strength and split tensile strength of concrete.

B. Compressive Strength

1) General:

In most structural applications, concrete is employed primarily to resist compressive stresses. When a plain concrete member is subjected to compression, the failure of the member takes place, in its vertical plane along the diagonal. The vertical crack occurs due to lateral tensile strains. A flow in the concrete, which is in the form of micro crack along the vertical axis of the member will take place on the application of axial compression load and propagate further due to the lateral tensile strains.

2) Test Procedure and Results:

Test specimens of size 150 *150* 150 mm were prepared for testing the compressive strength concrete. The concrete mixes with varying percentages (0%, 5%, 10% and 15%) of silica fume as partial replacement of cement were cast into cubes and cylinders for subsequent testing. In this study, to make concrete, cement and fine aggregate were first mixed dry to uniform colour and then coarse aggregate was added and mixed with the mixture of cement and fine aggregates. Water was then added and the whole mass mixed. The interior surface of the moulds and the base plate were oiled before concrete was placed. After 24 hours the specimens were removed from the moulds and placed in clean fresh water at a temperature of 27^0 C. The specimens so cast were tested after 7, 14 and 28 days of curing measured from the time water is added to the dry mix. For testing in compression, no cushioning material was placed between the specimen and the plates of the machine. The load was applied axially without shock till the specimen was crushed. Results of the compressive strength test on concrete with varying proportions of silica fume replacement at the age of 7, 14 and 28 days are given in the Table 5, 6 and 7.

Mix (%)	Compressive strength(N/mm^2) after 7 days			Average compressive strength after 7 days
	Specimen 1	Specimen 2	Specimen 3	
0	17.94	18.04	18.35	18.11
5	19.46	19.21	19.35	19.34
10	21.17	21.55	20.28	21.0
15	18.27	18.24	18.39	18.3

Table 5: Compressive strength of cube for 7 days.

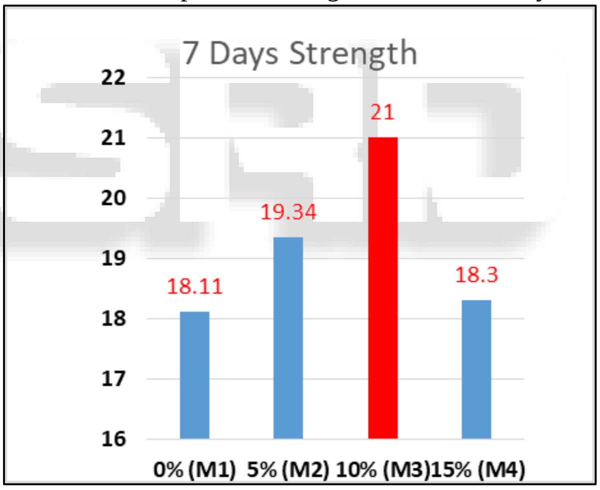

Fig. 1: Graph representation of cube for 7 days.

Mix (%)	Compressive strength(N/mm^2) after 14 days			Average compressive strength after 14 days
	Specimen 1	Specimen 2	Specimen 3	
0	22.36	23.32	22.93	22.87
5	23.32	23.45	23.43	23.40
10	29.76	9.63	29.56	29.65
15	26.43	26.78	26.83	26.68

Table 6: Compressive strength of cube for 14 days.

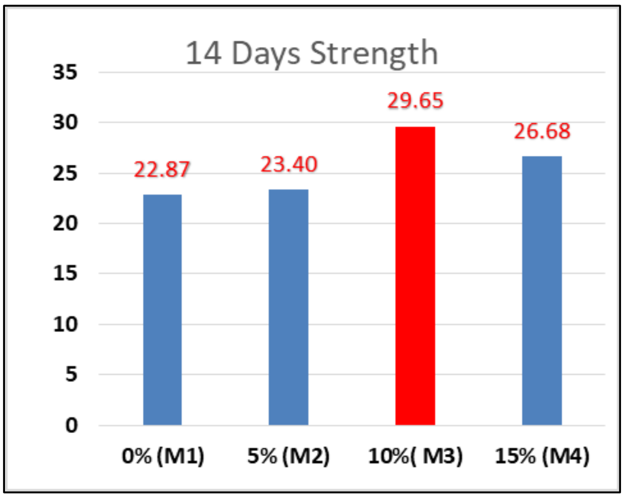

Fig. 2: Compressive strength graph after 14 Days

Mix (%)	Compressive strength(N/mm^2) after 28 days			Average compressive strength after 28 days
	Specimen 1	Specimen 2	Specimen 3	
0	25.86	26.34	26.40	26.20
5	31.46	31.33	31.53	31.44
10	34.86	34.81	35.15	34.93
15	30.18	30.48	29.94	30.20

Table 7:- Compressive strength of cube for 28 days.

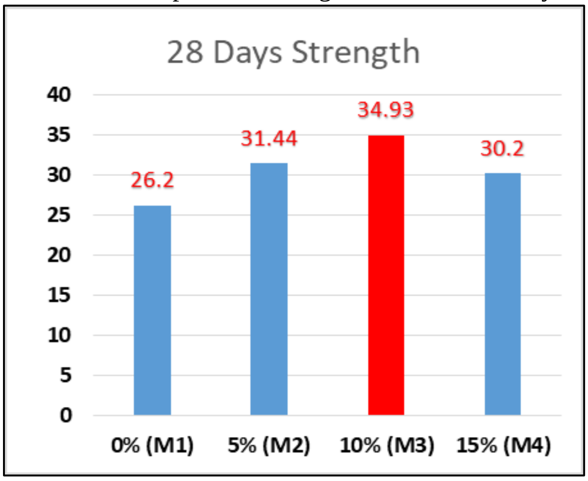

Fig. 3: Compressive strength graph after 28 Days

VI. CONCLUSION

- The compressive strength has increased with increase in silica fume content, his increase is due to the pozzolanic action and binder formation of silica fume with cement.
- The optimum strength of cube is gain at 10% replacement for all 7,14 and 28 days respectively.
- The compressive strength has increased with increase in silica fume content, his increase is due to the pozzolanic action and binder formation of silica fume with cement.
- The permeability of ions through go on decreasing with addition of silica fume as it acts as a void filler in concrete
- With the increase in w/c ratio the compressive strength decreases and vice versa. Addition of silica fume in proper proportion improves durability attack by acidic waters and improving concrete conditions.
- Silica fume having high fineness leads to high normal consistency. Silica fume gives a higher strength of compressive strength as compared to any other material such as fly ash, GGBS
- As we observed that hydration of cementitious material performs in two types of hydration, primary hydration- by cement content and secondary hydration by lime content.

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