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Effect of Silica Fumes on the Compressive Strength of Concrete

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***Abstract*—** The necessity of high strength concrete is increasing because of the increasing demand of the construction materials in the construction industry. Efforts for improving the performance of concrete over the past few years suggest that cement replacement materials along with Mineral & chemical admixtures can improve the strength and durability characteristics of concrete. Silica fume is one of the materials that can be utilized to produce highly durable and economical concrete composites. This study is focused on the utilization of Silica Fume as partial replacement of cement for the design of high strength concrete M30. After lot of trials the combination of 1:1.3:2.6 of cement, fine Aggregates and Coarse Aggregates with 10% of Silica Fume the desired results i.e. 14 Days Compressive strength of the Concrete cubes was found to be nearly 37.53 MPa. Hence the study proves the future generation Silica Fume as a substitute for partial replacement of normal cements (Binding Materials).
From the last millennium concrete had demanding requirements both in terms of technical performance and economy. The necessity of high strength concrete is increasing because of demands in the construction industry. Efforts for improving the performance of concrete over the past few years suggest that cement replacement materials along with Mineral & chemical admixtures can improve the strength and durability characteristics of concrete. Silica fume can be utilized to produce highly durable and economical concrete composites. This study is focused on the utilization of Silica fume as partial replacement of cement

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Index Terms— high strength concrete, Silica Fume, fine Aggregates and Coarse Aggregates
Sub Area :Concrete Technology
Broad Area :Civil Engineering

OBJECTIVES OF THE MINOR PROJECT PROGRAM:

The purpose of the minor project is to expose students to real work of environment experience and at the same time to gain knowledge through hands on observation and job execution. From the minor project the students will also develop skills in work ethics, communication, management, others. Moreover this minor project program allows students to relate theoretical knowledge with its application in the field. The objectives of the minor project are:

1. To provide student the opportunity to test their interest in a particular career before permanent commitments are made.
2. To develop skills in the application of theory of practical work situations.
3. To develop skills and technique directly applicable to their careers.
4. To learn proper behavior of corporate life in industrial sector.
5. To instilled with good moral values such as responsibility, commitment and trustworthy during their minor project.

IMPORTANCE OF MINOR PROJECT PROGRAM:

As we know minor project is part of syllabus for all engineering students. The main importance of minor project is to expose student to the working environment. So it will enable students to understand the theories studied with more detailed and hands on practice within a real job situation. At the same time minor project can also nurture a student's leadership ability and responsibility to perform or execute the give task.

Beside of that, the student will be more disciplined to follow rule and regulations when conducting minor project. They would be trained for proper schedule planning and time management. This situation will be fostered responsible and independent to students. Finally through this minor project student can take this as a challenge and test their preservance and thinking abilities when facing a decision making situation. Minor project is a great and invaluable experience for students.

BENEFITS DERIVED FROM THE MINOR PROJECT:

The main reason engineering students need to do minor project is so they are well prepared for graduate job in their chosen field. It is a chance for you to put what you have learned at university to work in the kind of real life situation you will come up against when you start your career. Minor project gives you great experience during your Bachelor of Engineering Degree. If you can demonstrate the ability to take responsibility, make sound decisions and apply technical skills you will stand out as someone that might be great for their organization.

INTRODUCTION

For many years, high-strength, high-performance concrete has been used in the columns of high-rise buildings. However, in recent years, there has been increased use of high-performance concrete (HSC) in bridges where both strength and durability are important considerations. The primary reasons for selecting HSC are to produce a more economical product, provide a feasible technical solution, or a combination of both.

At the present time, a cubic yard of HSC generally costs more than a cubic yard of conventional concrete. HSC requires addition-al quantities of materials such as cement, fly ash, silica fume, high-range water-reducers and retarders to ensure that the concrete meets the specified performance. However, concrete is only one component in construction, and the total cost of the finished product is more important than the cost of an individual material. On the other hand, HSC should not be specified if there are no economical or technical advantages to be gained from its use. Here, we explain why HSC is used in buildings.

The economic advantages of using high-strength, high-performance concrete in the columns of high-rise buildings have been known for many years. In simple terms, high-strength concrete provides the most economical way to carry a vertical load to the building foundation. The three major components contributing to the cost of a column are concrete, steel reinforcement and form-work. By utilizing high-strength concrete, the column size is reduced. Consequently, less concrete and less formwork is needed. At the same time, the amount of vertical reinforcement can be reduced to the minimum amount allowed by the code. The net result is that the least expensive column is achieved with the smallest size column, the least amount of reinforcement and the highest readily available concrete strength.
In addition to the reduction in initial cost, a smaller column size results in less intrusion in the lower stories of commercial space and, thereby, more rentable floor space. Yet the use of high-strength concrete in columns has not been limited to tall buildings: Parking garages have also used the material to reduce column sizes. Since columns intrude into the layout for parking spaces, a small column is advantageous.

In addition to specifying concrete compressive strength, modulus of elasticity has been specified for the concrete in several high-rise buildings.

REVIEWS OF ARTICLES

- Amudhavalli & Mathew (2012) studied the Effect of silica fume on the strength and durability characteristics of concrete. The main parameter investigated in this study is M35 grade concrete with partial replacement of cement by silica fume by 0, 5, 10,15and by 20%. A detailed experimental study in Compressive strength, split tensile strength, flexural strength at age of 7 and28 day was carried out. Results Shows that Silica fume in concrete has improved the performance of concrete in strength as well as in durability aspect.
- Perumal& Sundararajan (2004) observe the Effect of partial replacement of cement with silica fume on the strength and durability properties of high grade concrete. Strength and durability properties for M60, M70 and M11 0 grades of HSC trial mixes and to arrive at the maximum levels of replacement of cement with Silica fume, investigations were taken. The strength and durability characteristics of these mixes are compared with the mixes without SF. Compressive strengths of 60 N/mm^2, 70 N/mm^2 and 110 N/mm^2 at 28days were obtained by using 10 percent replacement of cement with SF. The results also show that the SF concretes possess superior durability properties.
- Kumar & Dhaka (2016) write a Review paper on partial replacement of cement with silica fume and its effects on concrete properties. The main parameter investigated in this study M-35 concrete mix with partial replacement by silica fume with varying 0, 5, 9, 12 and 15% by weight of cement the paper presents a detailed experimental study on compressive strength, flexural strength and split tensile strength for 7 days and 28 days respectively. The results of experimental investigation indicate that the use of silica fume in concrete has increased the strength and durability at all ages when compared to normal concrete.

REACTION MECHANISM

Because of its extreme fineness and very high amorphous silicon dioxide content, silica fume is a very reactive pozzolanic material. As the Portland cement in concrete begins to react chemically, it releases calcium hydroxide. The silica fume reacts with this calcium hydroxide to form additional binder material called calcium silicate hydrate which is very similar to the calcium silicate hydrate formed from Portland cement. It is an additional binder that gives silica-fume concrete its improved properties. Mechanism of silica fume in concrete can be studied basic allyunder three roles:

I. Pore-size Refinement and Matrix Densification: The presence of silica fume in the Portland cement concrete mixes causes considerable reduction in the volume of large pores at all ages. It basically acts as filler due to its fineness and because of which it fits into spaces between grains in the same way that sand fills the spaces between particles of coarse aggregates and cement grains fill the spaces between fine aggregates grains.

II. Reaction with Free-Lime: (From Hydration of Cement) CH crystals in Portland cement pastes are a source of weakness because crack scan easily propagate through or within these crystals without any significant resistance affecting the strength, durability and other properties of concrete. Silica fume which is siliceous and aluminous material reacts with CH resulting reduction in CH content in addition to forming strength contributing cementitious products which in other words can be termed as Pozzolanic Reaction''.

III. Cement Paste: Aggregate Interfacial Refinement In concrete the characteristics of the transition zone between the aggregate particles and cement paste plays a significant role in the cement-aggregate bond. Silica fume addition influences the thickness of transition phase in mortars and the degree of the orientation of the CH crystals in it. The thickness compared with mortar containing only ordinary Portland cement decreases and reduction in degree of orientation of CH crystals in transition phase with the addition of silica fume. Hence mechanical properties and durability is improved because of the enhancement in interfacial or bond strength. Mechanism behind is not only connected to chemical formation of C–S–H (i.e. pozzolanic reaction) at interface, but also to the microstructure modification (i.e. CH) orientation, porosity and transition zone thickness) as well.

SILICA FUME EFFICIENCY

Silica fume efficiency in concrete is not constant at all percentages of replacement. The overall efficiency factor of silica fume can be assessed in two separate parts; general efficiency which is constant at all percentages of replacement and the percentage efficiency factor which varies with the replacement percentage. The activity of silica fume in concrete is obtained in terms of the amount of cement replaced through its cementing efficiency factor (K).

Efficiency factor for silica fume in concrete can be defined as the number of parts of cement that may be replaced by one part of the silica fume, without changing the property being investigated generally the compressive strength.

K = (Ke) X Kp

K = Overall Efficiency Factor

Kp = Percentage Efficiency Factor

Ke = General Efficiency Factor (Ke). It is taken as 3, usually kept constant for all
the percentages of replacement.

pr = the percentage of silica fume in the total cementitious materials

ADVANTAGES OF USING SILICA FUME

- High early compressive strength
- High tensile, flexural strength, and modulus of elasticity
- Very low permeability to chloride and water intrusion
- Enhanced durability
- Increased toughness
- Increased abrasion resistance on decks, floors, overlays and marine structures
- Superior resistance to chemical attack from chlorides, acids, nitrates and sulphates and life-cycle cost efficiency.
- Higher bond strength
- High electrical resistivity and low permeability

EFFECT OF SILICA FUME ON FRESH PROPERTIES OF CEMENT/ MORTAR/ CONCRETE

Rheological properties of a fresh cement paste play an important role in determining the workability of concrete. The water requirement for flow, hydration behavior, and properties of the hardened state largely depends upon the degree of dispersion of cement in water. Properties such as fineness, particle size distribution, and mixing intensity are important in determining the rheological properties of cement paste. Due to the charges that develop on the surface, cement particles tend to agglomerate in the paste and form floc that trap some of the mixing water. Factors such as water content, early hydration, water reducing admixtures and mineral admixtures like silica fume determine the degree of flocculation in a cement paste. Fresh concrete containing silica fume is more cohesive and less prone to segregation than concrete without silica fume. Concrete containing silica fume shows substantial reduced bleeding. Additionally silica fume reduces bleeding by physically blocking the pores in the fresh concrete. Use of silica fume does not significantly change the unit weight of concrete.

Setting Times

The addition of silica fume to concrete in the absence of water-reducer or super plasticizer causes delay in setting time, compared to non-silica fume concrete of equal strength, especially when the silica fume content was high. Specific gravity and specific surface of the silica fume were 2.05 and 16000 m2/kg, respectively. Following Figure No.-1 shows the variation of setting times with the addition of silica fume in cement pastes. It was observed that initial setting time decreased with the increase in silica fume content. At smaller contents, the setting time of cement paste did not affect much. However, at higher silica fume contents, the initial setting time was significantly decreased. It was observed that the setting of fresh pastes (sample A-series) was slightly accelerated but the difference between initial and final setting time decreased with increase in NS content.

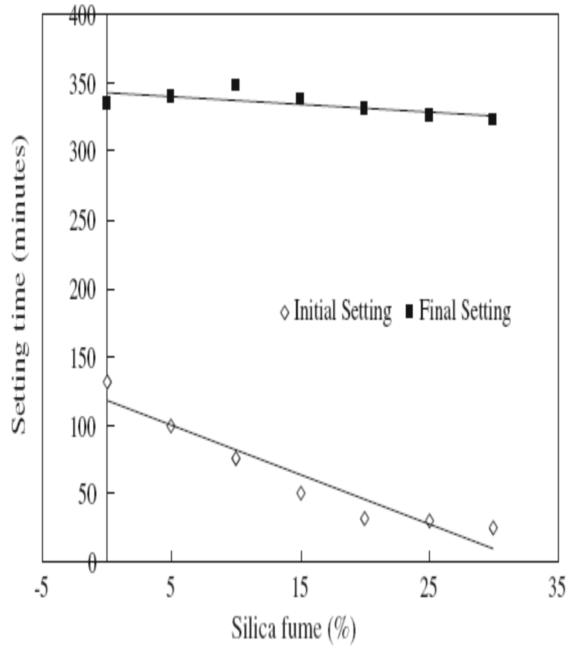

Fig. No.-1 Variation of setting time with different % of silica fume addition

EFFECT OF SILICA FUME ON THE HARDENED PROPERTIES OF CEMENT/ MORTAR/ CONCRETE

Compressive Strength

When silica fume is added to concrete, it results in a significant change in the compressive strength of the mix. This is mainly due to the aggregate-paste bond improvement and enhanced microstructure.

Compressive Strength of Cement Paste/Mortar

Mortar without silica fume has lower strength than cement paste with the same water cement ratio, while mortar with 30% of cement replaced with silica fume has a higher strength than cement silica fume paste with the same water cementitious ratio. The addition of silica fume to mortar resulted in an improved bond between the hydrated cement matrix and sand in the mix, hence increasing strength. This improved bond is due to the conversion of the calcium hydroxide, which tends to form on the surface of aggregate particles, into calcium silicate hydrate due to the presence of reactive silica. The replacement of cement by silica fume (up to18%) and the addition of super-plasticizer increased the strength of cement paste. Concrete containing silica fume as a partial replacement of cement exhibited an increased compressive strength largely because of the improved strength of cement paste matrix. But, changes in paste aggregate interface caused by the incorporation of silica fume had little effect on the compressive strength of concrete. Compressive strength of silica fume mortar having proportion 1:1:6(Cement + silica fume: lime: sand). In Portland cement mortars with silica fume, lime is better suited in the paste and there is no evidence of concentration of silica fume at the interface paste aggregate.

Compressive Strength of Normal Strength/High-Performance Concrete

The strength of silica fume concrete is greater than that of silica fume paste which they attributed to the change in the role of the aggregate in concrete. In cement concrete, the aggregate functions as inert filler but due to the presence of weak interfacial zone, composite concrete is weaker then cement paste. But, in silica fume concrete, the presence of silica fume eliminates this weak link by strengthening the cement paste aggregate bond and forming a less porous and more homogenous microstructure in the interfacial region. Thus, silica fume concrete is stronger than silica fume cement paste, taking into account that the strength of aggregate exceeds the strength of cement paste.

Table-1:Development of compressive strength with age (MPa)

%SILICA FUME REPLACEMENTS	7 days strength N/mm2	14 days strength N/mm2
0% (PCC)	19.87	26.33
10%	27.51	37.53
15%	25.89	38.63

Concrete containing silica fume had significantly higher strength than that of OPC concrete at room temperature. After exposure to 1008C, significant reductions occurred in the compressive strength of concrete with and without silica fume. In the range 300–6008C, severe strength losses occurred in all three concretes, which were 68.8, 70.9 and 73.2% of the initial values for W30OPC, W30SF6 and W30SF10 concretes respectively. This was because during exposure to high temperatures, cement paste contracts, whereas aggregates expand. Thus, the transition zone and bonding between aggregates and paste are weakened. As a result, this process as well as chemical decomposition of hydration products causes severe deteriorations and strength loses in concrete after subjecting to high temperatures and after heating to 6008C, the residual compressive strength of all three concretes were approximately same, whereas the relative residual compressive strengths of concretes containing 6 and 10% silica fume were 6.7 and 14.1% lower than those of the OPC concretes, respectively, after exposure to 600'C. Therefore, the rate of strength loss was significantly of silica fume in concretes that produced very dense transition zone between aggregate and paste due to ultrafine particles as filler.

DESIGN MIX OF CONCRETE (M30)

RESULTS:

SPECIFIC GRAVITY OF FINE AGGREGATE (BY PYCNOMETER METHOD)

Weight of fine aggregate = 500 g
Mass of pycnometer with lid, M1 = 796 g
Mass of pycnometer with dry soil, M2 = 1296
Mass of pycnometer and soil and water, M3 = 1962 g
Mass of pycnometer filled with water only, M4 = 1655 g
Therefore, specific gravity of fine aggregate, G = (M2- M1)/((M2-M1)-(M3-M4))

G = (1296 -796)/((1296-796)-(1962-1655))

G = 2.59

SPECIFIC GRAVITY OF COARSE AGGREGATE

Weight of oven dry sample, M1 = 982 g
Weight of saturated surface dry sample, M2 = 990g
Weight of sample + vessel + water, M3 = 3372 g
Weight of vessel + water, M4 =2754 g
Therefore weight of saturated aggregate, C = M3 – M4 = 618 g
Bulk specific gravity = M1/ (M2-C) = 982/ (990-618) = 2.64
Water absorption (%) = (M2-M1)/M1 = 0.8147%

FINENESS MODULUS OF SAND

Table 5.1:

SEIVE SIZE	WEIGHT OF FINE AGGREGATE RETAINED				PERCENTAGE RETAINED	COMMUTATIVE PRCENTAGE RETAINED	PERCENTAGE PASSING
	1	2	3	AVG.			

10mm	0	0	6	2	0.2	0.2	99.8
4.75mm	10	12	14	12	1.2	1.4	98.6
2.36mm	38	30	22	30	3.0	4.4	95.6
1.18mm	314	322	330	322	32.2	36.6	63.4
600u	212	188	224	208	20.8	57.4	42.6
300u	272	290	266	276	27.6	85.0	15.0
150u	110	102	109	107	10.7	95.7	4.3
75u	20	26	17	21	2.1	97.8	2.2
PAN	24	30	12	22	2.2	100	0

RESULT: Sand corresponds to Grading Zone 2.

CONCLUSIONS

There is a need for concerted effort to promote the technically sound, environmental safe and economically justified utilization of silica fume. A number of researches and projects on high levels utilization of silica fume have been carried out in many parts of the world. Because of the extreme fineness and high silica content, silica fume is a very effective pozzolanic material. Silica fume is added to Portland cement concrete to improve its properties, in particular its compressive strength, bond strength and abrasion resistance. These improvements stem from both the mechanical improvements resulting from addition of a very fine powder to the cement paste mix as well as from the pozzolanic reactions between the silica fume and free calcium hydroxide in the paste.

Addition of silica fume also reduces the permeability of concrete to chloride ions, which protects the reinforcing steel of concrete from corrosion, especially in chloride-rich environments such as coastal regions and those of humid continental roadways and runways and saltwater bridges.

The normal consistency of cement concrete increases about 40% when silica fume percentage increases from 0% to 20%. The optimum 7 and 28-day compressive strength and flexural strength have been obtained in the range of 10-15% silica fume replacement level. When compared to other mix the loss in weight and compressive strength percentage was found to be reduced by 2.23 and 7.69 when the cement was replaced by 10% of silica fume.

Silica fume should be considered as an essential ingredient of concrete and not merely for replacement of cement or reduction in cost.

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APPENDIX

MIX WITHOUT SILICA FUME.

CUBIC MOULD.

CUBES OF CONCRETE WITHOUT SILICA FUME.

CURING OF CUBES.

UTM(UNIVERSAL TESTING MACHINE).

TEST ON UTM.

CONCRETE CUBE UNDER THE LOAD.


SILICA FUME. MIX WITH SILICA FUME.


CUBES OF CONCRETE WITH SILICA FUME.
CONCRETE CUBE WITH SILICA UNDER THE LOAD.

REFRENCES

1. Ramasamy, V.; Biswas, S. "Mechanical properties and durability of silica fume concrete"(Report), International Journal Of Applied Engineering Research December 1, 2008.
2. Bayasi, Zing, Zhou, Jing, (1993) "Properties of silica fume concrete and mortar", ACI materials Journal 90 (4) 349-356.
3. Venkatesh Babu DL, Nateshan SC. Investigations on silica fume concrete, The Indian Concrete Journal, September 2004, pp.57-60.
4. S, Bhanja, B. Sengupta, "Influence of silica fume on the tensile strength of concrete", Cement and Cocrete Research, Vol. 35, 743-747.
5. Debabrata Pradhan, D. Dutta, "Influence of Silica Fume on Normal Concrete", Int. Journal of Engineering Research and Applications Vol. 3, Issue 5, Sep-Oct 2013, pp.79-82.
6. Vikas Srivastava, V.C. Agarwal and Rakesh Kumar," Effect of Silica fume on mechanical properties of Concrete", J. Acad. Indus. Res. Vol. 1(4) September 2012 ,pp.176-179.
7. Sabir B.B., "High-Strength Condensed Silica Fume Concrete", Magazine of Concrete Research, Vol- 47, Issue-172, (1995),pp. 219–226.
8. O.E. Gjorv, P.J.M. Monteiro, P.K. Mehta. "Effect of Condensed Silica Fume on the Steel-Concrete Bond", ACI Materials Journal, Vol.87, Nov.-Dec 1990, pp. 573–580.
9. https://theconstructor.org/concrete/silica-fume-concrete/1038/. & http://www.norchem.com/silica-fume-concrete.html