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A NEW APPROACH IN INDUSTRIAL HSC- HIGH STRENGTH CONCRETE USING SILICA FUME

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ABSTRACT:

In this paper, A few years ago, concrete having the compressive strength at 28 days of 50 N/mm^2 or more made with normal weight aggregate At (28 d**a**ys) is defined as 100 N/mm^2; concrete exceeding this limit is considered to fall in to the category of ultra-high strength concrete.

High strength Concrete now a day's used widely in the construction industry worldwide. To produce High strength Concrete with normal ingredients we use mineral admixtures like Silica fume, fly ash and workable agents like Super plasticizers are also used. The usage of mineral admixtures in the concrete not only enhances its strength properties and also durability. The compressive strength are investigating finding the optimum use of mineral admixture(Silica fume of levels 0, 5, 10,15, 20 and 25% at 7 days and 28 days of curing).

The main parameter investigated in this study is M60 grade concrete with partial replacement of cement by silica fume by 0, 5, 10,15and by 20%. This project presents a detailed experimental study on Compressive strength, split tensile strength, flexural strength at age of 7 and 28 day and also studied the percentage of weight loss is compared with normal concrete. Test results indicate that use of Silica fume in concrete has improved the performance of concrete in strength as well as in durability aspect.

KEYWORDS: ultra-high strength concrete, Silica fume in concrete.

1.INTRODUCTION

Ordinary Portland cement is the most important Ingredient of concrete and is versatile and relatively high cost material. Large scale production of cement is causing environmental problems on one hand and depletion of natural resources on other hand. This threat to ecology has led to use industrial by products as supplementary cementations material in making concrete. In recent years, the terminology "High-

Performance Concrete" has been introduced into the construction industry. The American Concrete Institute (ACI) defines high-performance concrete as concrete meeting special combinations of performance and uniformity requirements that cannot always be achieved routinely when using conventional constituents and normal mixing, placing and curing practices. A commentary to the definition states that a high-performance concrete is one in which certain characteristics are developed for a particular application and environment.

Examples of characteristics that may be considered critical for an application are:

- Ease of placement
- Compaction without segregation
- Early age strength
- Long-term mechanical properties
- Permeability
- Density
- Heat of hydration
- Toughness
- Volume stability
- Long life in severe environments

Because many characteristics of high-performance concrete are interrelated, a change in one usually results in changes in one or more of the other characteristics. A high-performance concrete is something more than is achieved on a routine basis and involves a specification that often requires the concrete to meet several criteria.

For example, on the Lacey V. Murrow floating bridge in Washington State, the concrete was specified to meet compressive strength, shrinkage and permeability requirements. The latter two requirements controlled the mix proportions so that the actual strength was well in excess of the specified strength. This occurred because of the interrelation between the three characteristics.

FIBRE MECHANISM:

Fibre work with concrete utilizing two mechanisms: the spacing mechanism and the crack bridging mechanism. The spacing mechanism requires a large number of

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fibres well distributed within the concrete matrix to arrest any existing micro crack that could potentially expand create a sound crack. For typical volume of fractions of fibres utilizing small diameter of fibres or micro fibres can ensure the required no of fibres for micro crack arrest. The second mechanism termed crack bridging requires larger straight fibres with adequate bond to concrete. Steel fibres are considered a prime example of this fibre type that is commonly referred as large diameter fibres or micro fibres.

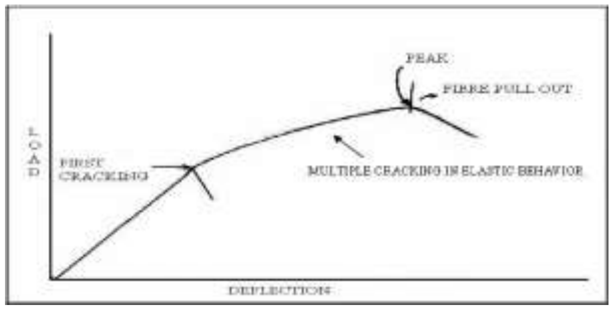

Fig 1.1 Fibre Mechanism

FIBRE - MATRIX INTERACTION:

The tensile cracking strain of cement matrix is much lower than the yield or ultimate strain of fibres. As a result when a fibre reinforced composite is loaded the matrix will crack long before the fibres can be fractured. Once the matrix is cracked composite continues to carry increasing tensile stress. The peak stress and strain of the concrete composite are greater than those of the matrix alone during the inelastic range between first cracking and the peak. Multiple cracking of matrix occurs as indicated in fig.1.1.

RIDGING ACTION:

Pull-out resistance of fibres (dowel action) is important for efficiency. Pullout strength of fibres significantly improves the post-cracking tensile strength of concrete. As an FRC beam or other structural element is loaded, fibres bridge the cracks. Such bridging action provides the FRC specimen with greater ultimate tensile strength and, more importantly, larger toughness and better energy absorption.

An important benefit of this fibre behaviour is material damage tolerance. Bayasi and Kaiser (2001) performed a study where damage tolerance factor is defined as the ratio

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of flexural resistance at 2-mm maximum crack width to ultimate flexural capacity. At 2% steel fibre volume, damage tolerance factor according to Bayasi and Kaiser was determined as 93%.

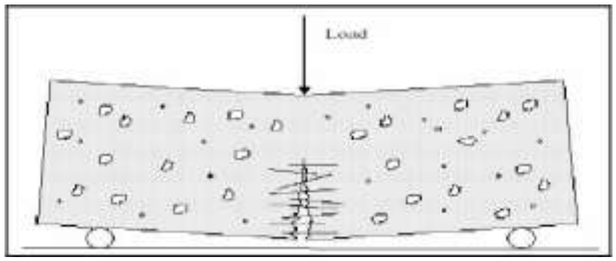

Fig 1.2 Pullout Mechanism.

1.4.4 WORKABILITY:

Workability is defined as the properties of freshly mixed concrete or mortar which determines the ease and homogeneity with which it can be mixed, placed, consolidated and finished. The workability was measured by conducting slump cone test and compaction factor test in accordance with IS: 1199- 1959. The strength of both cement paste and concrete can be affected by the dosage of super plasticizers. Thus, if the dosage of SP is varied with the silica fume replacement percentage, then the variations in the concrete strength will occur not only due to variations in the silica fume contents but also due to change in the dosage of super plasticizer. Since the SP content of all the mixes was kept constant, to minimize variations in workability, the compaction energy was varied for obtaining proper compaction.

1.4.5 STEEL FIBRE REINFORCED CONCRETE

According to Exodus Egyptians used straw to reinforce mud bricks. There is evidence that asbestos fibre was used to reinforce clay posts about 5000 years ago. Prof.Alberto Fava of the University of La Plata in Argentina points out that the hornero is a tiny bird native to Argentina, Chile, Bolivia and other South American countries; the bird had been painstakingly building straw reinforced clay nests on tree tops since the advent of man. However, N.V.Bekaert is been regarded as the father of "Fibre Reinforced Concrete".

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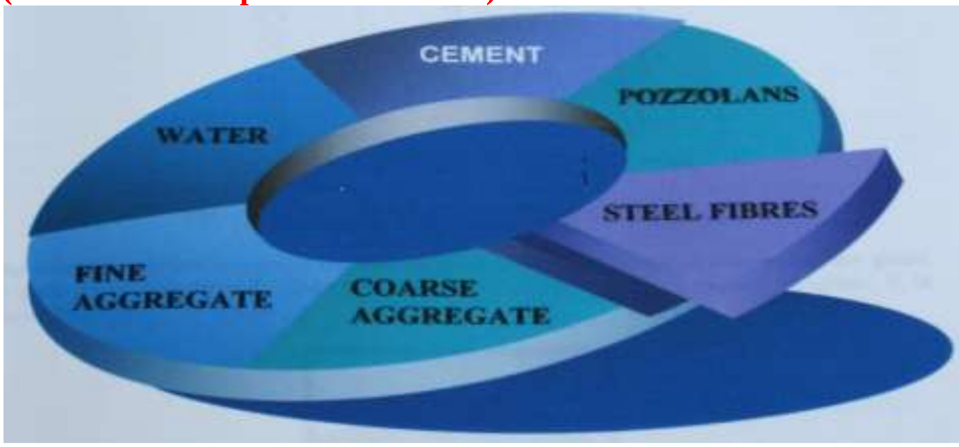

Fig 1.3 Composition of Steel Fibre Reinforced Concret

2.LITERATURE SURVEY

Khedr and Abou-Zeid (1994) have conducted experimental studies using six levels of silica fume contents (0%, 5%, 10%, 15%, 20%, and 25%) as partial replacement of cement with and without superplasticizer. They concluded that for maximum 28-day strength and above, SF is in the range of 10% to 20%. They also observed that elastic modulus, toughness, steel-concrete bond, and durability properties increased at the optimum silica fume content in the concrete. Significant gain in compressive and flexural tensile strengths at the optimum dosage of silica fume in the range of 10 to 20% has also been reported.

Babu and Prakash (1995) proposed two parameters namely, a general efficiency factor (k_e) and the percentage efficiency factor (k_p) corresponding to the percentage replacement and then considered overall efficiency factor ($k=k_ek_p$) for equivalent cement replacement to give equivalent strength. They showed that w/c ratio of the control concrete and the effective w/b ratio of the silica fume concrete [w/(c+k.s)] would be the same for any particular strength at all percentage of replacement and finally evaluated the overall efficiency factor for any particular concrete at any particular replacement.

Duval and Kadri (1998) have reported that SF at replacement contents up to 20% produces higher compressive strength than control concrete. A mathematical model was developed to evaluate the compressive strength of SF concrete at any time 't' and is valid for w/cm ratio <0.4. It was observed that the optimum SF replacement is around 10-15% for w/cm ratios ranging from 0.25 to 0.45 with varying dosages of HRWRA. Taking into account the % efficiency factor, k_p which is based on the equation developed by Babu and Prakash (1995) for evaluating the efficiency of silica fume concrete, the equation was suggested to assess the compressive strength at a given time for silica fume concrete

Bharatkumar et al (2001) have developed a modified mix design procedure, utilizing optimum water content and efficiency factor of a mineral admixture. Using the efficiency factor for a cement replacement material (CRM), the strength of the CRM mixes has been determined by modifying the Bolomey equation. They observed that cement required per unit strength reduces, as CRM content increases. Extensive experimentation was performed to determine the isolated effect of silica fume on the properties of concrete over w/cm ratios ranging from 0.3 to 0.42 and SF replacement from 0 to 30%. Based on the compressive strength results, a statistical model was developed for predictingthe 28-day compressive strength of SF concrete over the wide range of w/cm ratios, involving non-dimensional variables, and concluded that the model is independent of the specimen parameters (Banja and Sengupta 2002).

Abdul Razak and Wang (2005) have proposed a mathematical model (linear equation) for estimating the compressive strength of high-strength concrete mixtures incorporating metakaolin an SF (up to 15% replacement) with w/cm ranging from 0.27 to 0.33, based on the control OPC concrete. In this equation two factors were related to pozzolanic and dilution effect of the particular pozzolan and these factors are dependent on the pozzolan content. The strength of the pozzolanic mixture was related to the strength of its equivalent control concrete by the linear function. They observed that the accuracy of the model increases with increasing the age from 28 and above.

Banja and Sengupta (2005) have carried over extensive experimental work over water-binder (w/b) ratios ranging from 0.26-0.42 and SF/b ratios from 0.0 to 0.3. For all mixes compressive, flexural and splitting tensile strengths were determined at 28 days. Results indicated that optimum replacement percentage is not a constant one but depends on the w/b ratio of the mix. Incorporation of SF in concrete results in significant improvement in the tensile strength of concrete along with compressive strength. Optimum 28-day split tensile strength has been obtained in the range of 5 to 15% silica fume replacements, whereas for flexural strength, it ranged from 15 to 25%. However, increase in splitting tensile strength beyond 15% SF content was almost insignificant. Optimum silica fume replacement percentages for tensile strengths have been found to be a function of w/b ratio of the mix.

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3. TESTS ON HARDENED CONCRETE

COMPRESSIVE STRENGTH TEST

This test was conducted as per IS 516-1959. The cubes of standard size 150x150x150mm were used to find the compressive strength of concrete. Specimens were placed on the bearing surface of UTM, of capacity 2000KN .The maximum load was noted and the compressive strength was calculated. Cube compressive strength (f_{ck}) in MPa = P/A

Where,

P= cube compression load

A= area of the cube on which load is applied (= 150 x 150= 22500 mm^{2})

FLEXURAL TEST

Beams of size 150x150x700mm are tested using a flexure testing machine. The specimen is simply supported on the two rollers of the machine which are 600mm apart, with a bearing of 50mm from each support. The load shall be applied on the beam from two rollers which are placed above the beam with a spacing of 200mm. The load is applied at a uniform rate such that the extreme fibers stress increases at 0.7N/mm2/min i.e., the rate of loading shall be 4 KN/min. The load is increased till the specimen fails. The maximum value of the load applied is noted down. The appearance of the fracture faces of concrete and any unique features are noted.

The modulus of rupture is calculated using the formula.

$\sigma_s = Pl/bd^2$, where,

P = load in N applied to the specimen

l = length in mm of the span on which the specimen is supported (600)

b = measured width in mm of the specimen

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d = measured depth in mm of the specimen at point of failure.

SPLIT TENSILE TEST

cylinders of size 150mm (dia) x 300mm (height) are casted. The test is carried out by placing a cylindrical specimen horizontally between the loading surface of a compression testing machine and the load is applied until the failure of the cylinder, along the vertical diameter. When the load is applied along the generatrix, an element on the vertical diameter of the cylinder is subjected to a horizontal stress of $2P/\pi ld$.

The main advantage of this method is that the same type of specimen and the same testing machine as used for the compression test can be employed for this test. This is why this test is gaining popularity. The splitting test is simple to perform and gives more uniform results than the other tension tests. Strength determined in the splitting test is believed to be closer to the true tensile strength of concrete, than the modulus of rupture. Splitting strength gives about 5 to 10% higher value than the direct tensile strength.

Fig : Initial Mixing of Constituents of Concrete

4. PROPOSED APPROACH

The results of compressive strength for conventional concrete are shown in Table 4.1 7 days and at 28 days. **4.1.** Show the relation between compressive strength and percentage of silica

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fume.

Table 4.1. Compressive Strength of concrete at the age of 7 and 28 Days

S.No	Specimen	Silica fume(%)	Compressive strength in N/mm^2	
			7 Days	28 Days
1	B00	0%	20.77	54.93
2	B10	5%	37.58	62.58
3	B11	10%	39.19	65.48
4	B12	15%	28.34	59.23
5	B13	20%	26.82	51.93
6	B14	25%	25.12	48.26
7	B15	30%	22.05	45.72

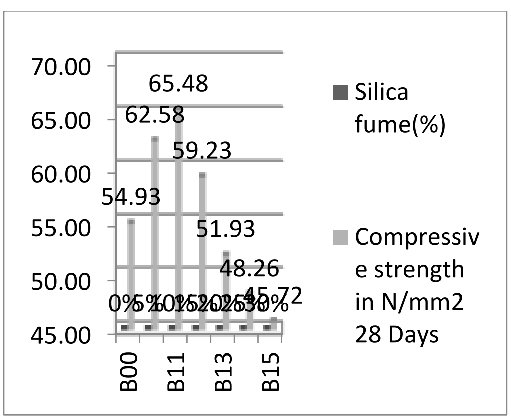

Chart 4.1 Compressive Strength of concrete at the age of 28 Days

DISCUSSION:

➢ We take 7 specimens in order to test, by increasing the percentage of adding silica fume for each specimen, we can observe the variation of compressive strength i.e increases up to 10% of silica fume after 10% even though we add silica fume of more percentage there

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will be decrease in compressive strength.

- We can observe the compressive strength values in table 4.1 that there is variation between 7 days of curing and also 28 days of curing.
- For the conventional concrete for M60 grade is 60 MPa, when we are adding silica fume percentage the compressive strength will be increases.

4. 2 Split Tensile Strength

Table 4.2 Split Tensile Strength of concrete at the age of 28 Days

S.No	**Specimen**	**Silica fume**	**Split Tensile strength In N/mm^2**
1	B00	0%	2.97
2	B10	5%	3.68
3	B11	10%	4.0
4	B12	15%	3.71
5	B13	20%	3.52
6	B14	25%	2.02
7	B15	30%	1.98

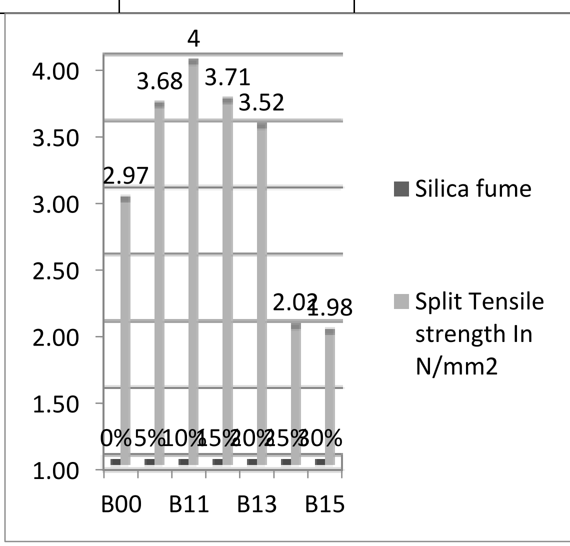

Chart 4.2 Split Tensile Strength of concrete at the age of 28 Days

4.3. Flexural Strength

Tabel 4.3 Flexural Strength of concrete at the age of 28 Days

S.No	Specimen	Silica fume	Flexural Strength in N/mm^2
1	B00	0%	7.66
2	B10	5%	13.720
3	B11	10%	13.86
4	B12	15%	12.40
5	B13	20%	11.23
6	B14	25%	10.52
7	B15	30%	10.07

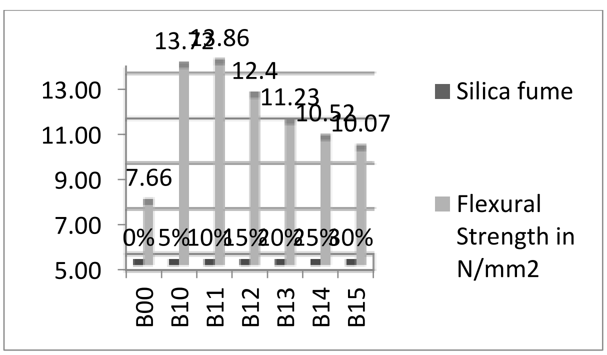

Chart 4.3 Flexural Strength of concrete at the age of 28 Days

DISCUSSION:

- Table 4.2 and 4.3 shows the split tensile strength and flexural strengths of modified concrete (with silica) and conventional concrete. By adding silica fume up to 10%

flexural strength & split tensile strength is increases beyond that strength will be decreases.

- In Table 4.2 when we take different specimens with different silica fume percentages, there is gradual increase in bar chart up to 10% of silica fume added beyond that gradual decrease will occurs
- In Table 4.3 when we take different specimens with different silica fume percentages, there is sudden increase of graph from when we add silica fume of 0% to silica fume of 5% respectively. Up to 10% of silica fume added Graph will increases beyond that it will decreases.
- Silica fume on reinforced concrete is showed little effective in resisting flexural tensile stresses as compared to compressive stresses

CONCLUSION

- Silica fume can be used as the supplementary material for cement.
- The strength of concrete is increases up to certain point after it reaches maximum value it will again start decreases.
- Cement replacement up to 10% with silica fume leads to increase in compressive strength, splitting tensile strength and flexural strength.
- Beyond 10% there is a decrease in compressive strength, tensile strength and flexural strength for 28 days curing period.
- There is a decrease in workability as the replacement level increases, and hence water Consumption will be more for higher replacements.
- Use of silica fume gives significant result on properties of concrete as compared to normal concrete. when we adding silica fume as it is very fine powder fill the space between fine aggregate in concrete paste and as a result decreasing the voids in concrete blocks and that lead to increase the compressive strength

- As per the Practical Experience, Consistency of cement depends upon its fineness. Silica fume is having greater fineness than cement and greater surface area so the consistency increases greatly, when silica fume percentage increases.

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