Pragmatic studies on automated properties of High Efficiency Concrete

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Abstract: The term high efficiency concrete is similar to high performance (HPC) is vividly used in the concrete industry since it has definite rheological properties in comparison with traditional concrete. Current research specifies the outcome of silica fume (SF) inclusion to M60 grade concrete by cumulative percentage replacements of SF with respect to cement, from 0-15 varying 5 and steel fiber of 1 percent is added by weight of cementitious binder. A super plasticizer of 1% is added to enhance workability of concrete. Water-binder ratio (w/b) is maintained at a ratio of 0.33. Mechanical properties of HPC are studied and results were tabulated.

Key Words: High Efficiency Concrete, Automated Properties, Silica Fume (SF), Super Plasticizer.

1. Introduction

Infrastructure is an index to showcase the economical development of the country; enormous research is going on to understand the nature of high performance concrete. The low permeability characteristics, high strength concrete behaves far better than conventional concrete under harsh climatic conditions, high strength concrete’s are frail in nature; hence the use of this is limited. In recent times, demand has been amplified for high strength concrete for use in infrastructure construction. This composite material is used in high-rise structures to evade the use of unacceptably oversized columns on lower floors, to tolerate large column spacing and more serviceable floor space, or to increase the total height of the structure without detracting from the architectural view and the functioning of the lower floors. Moreover, because of the low permeability individuality, high strength concrete operates much smarter under intense climate conditions and marine environments, therefore plummeting the maintenance and repair expenses. However, high performance concrete is likely to be fragile than normal concrete and for this reason; utilization of high performance concrete is seriously restricted.

Furthermore it is well tacit that SF, due to high Pozzolanic activity, is an obligatory material when producing high performance concrete; however it also affects the concrete to have a more frail nature. Therefore upgrading of ductility is an important challenge in concrete science and IS taken into account by researchers. It is commonly established that the ductility of high performance concrete can be enhanced by bring in various types of fibers, especially steel fibers, into concrete mixes.

Fiber reinforcement permit for crack bridging mixtures, taking advantage of mechanism that control crack opening and boost the energy absorption of the concrete composites.
By inserting steel fibers in concrete, mortar & cement paste can improve many of the engineering properties, such as flexural strength, fracture toughness, thermal shock strength and resistance under impact and fatigue loadings.

2. Literature Survey
Handong Yan and Wei Sunet al. 1999[1] stated in his study “The effect of silica fume and steel fiber on the dynamic mechanical performance of high-strength concrete”. Silica fume competently enhanced the structural interface, reduced the limitation of the interfacial transition region, reduced the size and quantity of cracks, and improved the capability of crack arresting and restrain damage. Therefore, incorporation of steel fibers and SF can enhance the performance of high strength concrete subjected to impact and fatigue.

Shannag et al 2000 [2] studied numerous combinations of a local natural pozzolana and silica fume(SF) were employed to manufacture high workable to super high strength mortars, concretes as well with a compressive strength ranging around 69-110 MPa. The incorporation of silica fume by 15% of weight of cement can yield relatively greater strength.

Khaled Marar, Ozgur Eren et al. 2001[3] examined the influence of HSC and compression tests were performed on concrete cylinders are prepared by enforcing hooked-end type of steel fibre for three dissimilar aspect ratios i.e.,60, 75, and 80 and percentage variation of steel fibers is of 0.5%, with 0.5 increment by volume of concrete. By introducing steel fibers, concrete achieved impact resistance and compression toughness as well.

Aetcin 2004[4] comprehensible studied about the HSC in “The durability characteristics of high performance concrete” High-performance concrete have w/b usually around 0.3 to 0.4.In High-Performance Concrete (HPC), the incursion of reactive agents is rather difficult and artificial. However, self-aridity can be detrimental if it is not treated in the early phase of hydration process, for that reason, curing process for HPC is definitely varied for ordinary concrete. Concrete, remains as a safe material, from fire resistance, in comparison with other building materials.

Mazloom, Ramezanianpouret al.2004 [5] analyzed on concrete mixes of constant w/b ratio of 0.35 and fixed binder content of 500kg/m3.SF is replaced at different percentage levels of 0-15 with a variation of 5. the outcomes of this research has shown that as SF content augmented fresh properties like workability decreased but 28-day strength got improved. It does not show any major influence on the total shrinkage; however, the internal shrinkage is proportional to the amount of SF levels. Further tests on swelling are conducted after shrinkage & creep. It is observed that as the fraction of silica fume (SF) augmented amount of expansion got decreased. Existing models have shown inaccurate readings in creep and shrinkage since HSC contains silica fume, hence substitute models are presented.

Balaguru,Najm et al. 2005 [6] presented a paper on “High performance fiber reinforced concrete mixture properties with high fiber volume fractions”. With the inclusion of silica fume and steel fibers in concrete flexural toughness is achieved of mixtures is 2 to 3 times more than conventional concrete.

Hanja, Senguptaet al.2005 [7] studied extensively on w/b ratios ranging from 0.26-0.42 and SF/b from 0.0 to 0.3. Mechanical properties were found out for all mixes. The compressive, tensile strengths increased with incorporation of silica fume and the result explicitly shows that the finest replacement percentage cannot be identified; but it mostly dependent on w/c fraction. In Comparison with split tensile strengths, flexural strengths have revealed greater progress.

Poon, Shruiet al.2006 [8] examined the behaviour study of the concrete mixes prepared with silica fume and metakaolin with and without steel fibre and polypropylene fibres. At elevated temperatures of 8000C temperatures. The result has shown that steel fibre reinforced concrete exhibited the highest energy absorption capacity.

KatrinHabel, Marco Vivianiet al.2006 [9] presented a paper on“Development of the mechanical properties of an Ultra-High Performance Fiber Reinforced Concrete (UHPFRC)” It was pragmatic that for the UHPFRC, the scale of development of mechanical properties was premier for secant modulus, followed by compressive and tensile strengths.
3. Methodology

| S.No | Design Mix | Cement (Kg/m³) | Coarse Aggregate (Kg/m³) | Fine Aggregate (Kg/m³) | Steel Fibers (Kg/m³) | Super Plasticizer (Kg/m³) | Water Cement ratio |
|------|------------|----------------|--------------------------|------------------------|----------------------|--------------------------|-------------------|
| 1    | M 60 (with steel fibers) | 450 | 1273 | 679 | 4.5 | 4.5 | 0.33 |
| 2    | M 60 (without steel fibers) | 450 | 1273 | 679 | 0  | 4.5 | 0.33 |

4. Tests performed

Five different mixes are prepared with different percentage replacements of steel fibers from 0 to 15. Tests were conducted on the fresh concrete.

4.1. Slump cone test

Slump test is the most often adopted to measure the consistency of concrete which can be done either in the laboratory or at the site. It is not appropriate method for extremely damp or dry concrete. Neither does it not quantify all factors connecting to workability. IS 7320:1972 specifies the slump cone test, according to this; test is conducted to assess the workability of concrete. However, it is used duly as a check test and gives a sign of the evenness of concrete from batch to batch. The slump details are given in following table

| S.No | Mix | Silica fume % | Slump (mm) |
|------|-----|---------------|------------|
| 1    | M1  | 0             | 56         |
| 2    | M2  | 5             | 48         |
| 3    | M3  | 10            | 37         |
| 4    | M4  | 15            | 18         |

4.2. Compaction factor test

It is one of the most efficient tests for estimating the workability. This test mechanism works on the principle of evaluating the quantity of compaction attained by a standard extent of work done by permitting the concrete to plunge through a typical height. The degree of compaction called the compaction factor which is calculated by the density ratio. IS 5515-1983 specifies the CF apparatus

\[
CF = \frac{\text{Weight of partially compacted concrete}}{\text{Weight of fully compacted concrete}}
\]

| S.No | Mix | Silica fume % | Compaction factor |
|------|-----|---------------|-------------------|
| 1    | M1  | 0             | 0.95              |
| 2    | M2  | 5             | 0.92              |
| 3    | M3  | 10            | 0.85              |
| 4    | M4  | 15            | 0.79              |
4.3. Tests on hardened concrete
For hardened concrete, compressive strengths tests are made on cubes at of 7 and 28 day curing regime. Also, compression strength and split tensile strength tests on 150mm $\times$ 300 mm cylinders and flexural tests on beams have to carry after 28 days curing specimens as per IS specifications.

![Figure1 Casted specimens](image)

5. Experimental results
Compressive strength of concrete on test specimens were conducted. The concrete mixes of various proportions (0%, 5%, 10% and 15%) of silica fume as fractional replacement of binder, 1% of super plasticizer and 1% of steel fibers by weight of cement were casted. The mix was prepared. The inner face of the moulds and bottom plate were greased for initial set, after the concrete was allowed to cure in potable water at a temperature of $27^\circ \pm 20^\circ$C.

| Mix | Silica Fume (%) | W/B Ratio | Cement (Kg) | Silica Fume (Kg) | F.A (Kg) | C.A (Kg) | Super Plasticizer (Lit) | Steel Fiber (Kg) | Water (Lit) |
|-----|----------------|-----------|-------------|----------------|----------|----------|-------------------------|-----------------|-------------|
| M1  | 0              | 0.32      | 450.0       | 0.00           | 678      | 1272     | 4.50                    | 4.50            | 143.5       |
| M2  | 5              | 0.32      | 427.5       | 22.5           | 678      | 1272     | 4.50                    | 4.50            | 143.5       |
| M3  | 10             | 0.32      | 405.0       | 45.0           | 678      | 1272     | 4.50                    | 4.50            | 143.5       |
| M4  | 15             | 0.32      | 382.5       | 67.5           | 678      | 1272     | 4.50                    | 4.50            | 143.5       |

5.1. Compressive strength
The specimens 150mm $\times$ 150mm $\times$ 150mm casted were tested after 7 and 28 days of curing calculated from the time. By proper mixing the concrete specimens are prepared. The load was applied in the mid way without any impact till the specimen was crushed and peak value is observed. Results of this test on concrete with diverse proportions of silica fume (SF) replacement at 7 and 28 days curing regime are given below.

| Mix | Silica fume % | 7 days compressive strength (MPa) | 28 days compressive strength (MPa) |
|-----|---------------|----------------------------------|-----------------------------------|
| M1  | 0             | 44.43                            | 59.04                             |
| M2  | 5             | 48.63                            | 62.81                             |
| M3  | 10            | 53.62                            | 68.44                             |
| M4  | 15            | 50.64                            | 58.32                             |
From the table it is observed that, when silica fume is replaced at 10% maximum strength is achieved since silica fume acts as pore filler since it is having spherical structure.

**Fig 2** Compressive strength of cubes at 7 days

![Fig 2 Compressive strength of cubes at 7 days](image)

**Fig 3** Compressive Strength of cubes at 28 days

![Fig 3 Compressive Strength of cubes at 28 days](image)

5.2. *Split tensile strength*

The specimens of 150 mm diameter and 300 mm height are cast and tested after 28 days of curing measured from the time. For testing in split tensile, no cushioning material was placed between the specimens and the plates of the machine. The load was applied along its generator without shock till the specimen was crushed. Results of this strength test of concrete with varying proportions of silica fume(SF) replacement at the age of 28 day are given below.
### Table 6 Split tensile strength

| Mix | Silica fume % | Split tensile strength (MPa) |
|-----|---------------|-----------------------------|
| M1  | 0             | 4.10                        |
| M2  | 5             | 4.16                        |
| M3  | 10            | 5.23                        |
| M4  | 15            | 3.82                        |

Fig 4 shows Split Tensile Strength

From the above results of compressive strength and split tensile strengths the mix M3 is having maximum higher strengths when replaced with 10% silica fume, for increasing the ductile property of this mix, steel fibers are introduced in order to overcome the brittle nature.

**Comparing the mechanical properties of HPC at 10% silica fume with fibers and without fibers**

The compressive strength, Split tensile strength and Flexural strength of HPC containing 10% silica fume along with steel fibers and without steel fibers are tabulated below.

### Table 7 Comparison of compressive strength of HPC containing 10% of silica fume with steel fibers and without steel fibers

| Days | Silica fume % | Compressive strength (MPa) with steel fibers | Compressive strength (MPa) without steel fibers |
|------|---------------|---------------------------------------------|-------------------------------------------------|
| 7    | 10            | 53.62                                       | 40.25                                           |
| 28   | 10            | 68.44                                       | 51.39                                           |

It was observed that the compressive strength of concrete with inclusion of 10% silica fume (SF) along with steel fibers is 33% higher when compared to concrete without steel fibers.
Fig 5 Split tensile strength test setup and cylinder at failure

Table 8 Comparison of Split tensile strength of HPC containing 10% silica fume with steel fibers and without steel fibers

| Silica fume % | Split tensile strength (MPa) with steel fibers | Split tensile strength (MPa) without steel fibers |
|---------------|-----------------------------------------------|-----------------------------------------------|
| 10            | 5.23                                          | 3.77                                          |

Similarly the split tensile strength of concrete containing steel fibers at 10% of silica fume is 39% additional when compared the concrete without steel fibers.

Table 9 Comparison of flexural strength of HPC containing 10% silica fume with steel fibers and without steel fibers

| Silica fume % | Flexural strength (MPa) with steel fibers | Flexural strength (MPa) without steel fibers |
|---------------|------------------------------------------|---------------------------------------------|
| 10            | 5.23                                     | 3.77                                        |

The flexural strength of concrete including steel fibers is 48% auxiliary when judge against the concrete exclusive of steel fibers.

Fig 6 Test set up of beam for flexure
6. Conclusions
The outcome of cube compressive strength, split tensile strength and flexural strength are
tested. The best possible proportion of cement replacement by silica fume is 0%, 5%, 10%
and 15%, steel fibers with aspect ratio 40 is 1% by weight of cement and 1% of super
plasticizer for the mentioned tests for M60 grade of concrete. In fact the strength gain is due
to the pozzolanic reaction and filler effects of Silica Fume and steel fiber. Increasing the silica
fume and steel fiber content in concrete enhances the compressive strength spectacularly.

1. Workability of silica fume and steel fiber concrete is inversely proportional to the
silica fume content. Hence forth fractional replacement of cement by silica fume (SF)
and steel fiber tends to reduce workability of concrete.

2. Steel fiber reinforced concrete mixes required extensive mixing and placing stretch
than those of non-fiber concrete.

3. Addition of super plasticizer appreciably improved the workability of concrete with
and without fiber

4. When compared with the non-fiber concrete; the stringy concrete showed higher
compressive, split tensile and flexural strengths for different curing regimes at all
ages.

5. It was pragmatic that toting up of 10% silica fume as fractional replacement of
cements directs to the maximum gain in compressive strength, split tensile strength,
flexural strength.

6. By critical observation it is found that the compressive strength of concrete with
addition of 10% silica fume and steel fibers is 33% more when judge against to
concrete without steel fibers.

7. Correspondingly, the split tensile strength of concrete enclosing the steel fibers at 10%
of silica fume is 39% additional when compared the concrete without steel fibers.

8. Tested for flexural strength of concrete containing steel fibers is 48% higher than
concrete without steel fibers.

Once silica fume is added to acquire high performance concrete mundane plasticizers may not
be effective in such a case use super plasticizer is vastly recommended.

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