# A Study on Effect of Steel Fibers on Impact Resistance of High Strength Steel Fiber Reinforced Concrete (HSFRC) Subjected To Drop Weight Test

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*Abstract*— Impact resistance of M60 grade high strength concrete (HSC) and high strength steel fiber reinforced concrete (HSFRC) with fiber volume fraction ($V_f$) of 0.5, 1, 1.5, 2 % is investigated by using drop weight test method as recommended by ACI Committee 544. Due to non-availability of standard drop weight test equipment in India. Fabricated drop weight equipment is used. The obtained results from drop weight test suggest that addition of steel fibers in concrete at 0.5% $V_f$ shows decrease in first crack impact resistance in comparison to HSC of same strength. While it shows some increase for first crack impact resistance than HSC at steel fiber $V_f$ of 1.5% followed by 2 and 1 %. HSFRC showed good increase in ultimate failure impact resistance for various steel fibers $V_f$. It continuously improved as steel fiber $V_f$ in concrete increases.

***Key words:*** Drop Weight Test, HSFRC

## I. INTRODUCTION

In modern times, structure such as high rise building, industrial floors, airport and highway pavement, industrial floors, bridge decks, thin-shell structures etc. may be subjected to impact loads in their lifetime. It may be in planned or unplanned manner. For example high rise building may be subjected to impact by aircraft crash or earthquake loads, industrial floor may be subjected to drop of high weight instrument etc. Thus there is need of a construction material for their construction which is capable to absorb more impact loads than normal construction material. Use of HSFRC can fulfill demand of energy absorption before failure, as it made by using water, cement, sand, coarse aggregate, fly ash, superplasticizer and hooked end steel fibers. Steel fibers are used to reinforce concrete, they are defined as short, discrete lengths of steel having an aspect ratio varying from 20 to 100 and that are sufficiently small that can be easily dispersed in fresh concrete mixture using normal mixing procedures [12]. Steel fibers in HSFRC act as energy absorber thus when specimen subjected to impact loads it absorbs impact loads even after formation of crack on concrete specimen and delays ultimate failure of specimen which leads to ultimately increase impact resistance of concrete. The resistance to impact i.e. suddenly applied loads and the capacity to absorb large amounts of energy after first crack are therefore recognized to be important characteristics of fiber reinforced concrete [4]. Many investigators have shown that addition of fibers greatly improves the energy absorption and cracking resistance of concrete. This energy absorption of SFRC is termed as toughness under impact [4].

Numbers of test are available to evaluate impact resistance of concrete. The various tests suggested by ACI committee 544 are drop weight test, charpy impact test, projectile impact test, constant strain rate test, explosive test and split Hopkinson bar test [11]. Out of these tests, drop weight test it is used to carry experimental work as it is simplest to carry out. Standard equipment for drop weight test is not available in India. So it caused to fabricate drop weight test equipment in laboratory. In the test, number of blows to form the first visible crack (N1) and the number of blows to cause ultimate failure of the concrete specimen (N2). For this test concrete specimen of size 150 mm diameter and 63.5 mm height is casted. Greater deviation in impact results may occur. This may be due to following reasons [1].

1) First crack on specimen can identified visually, which may occur in any direction.
2) Impact loads acts on single point on specimen, it may happen that impact is applied on a hard particle of coarse aggregate or soft area of mortar or on the higher concentration of steel fibers.
3) As concrete is heterogeneous material. The variation of mix design may cause the change in impact resistance, including aggregate type and shape, geometry of the fibre, fibers distribution, etc.
4) It is difficult to maintain exact height of fall as it handmade process.

This experimental work is carried to investigate effect of steel fibers $V_f$ on improving the impact resistance of HSFRC and to study behavior of concrete under impact loads. This study helpful to extend the use of HSFRC in construction of modern structures and will clarify behavior of HPC under impact loading.

## II. SYSTEM DEVELOPMENT

### A. Materials

In this experimental investigation, Ordinary Portland cement (53 grade) was used throughout the program. The specific gravity of cement was found to be 3.15. Fly ash named Pozzocrete 100 which had 90% of particles less than 10 microns and it had high silica contents. Hooked end type steel fibers were used. Fig. 2.1 shows hooked end steel fibers while its properties are given in Table 2.1.

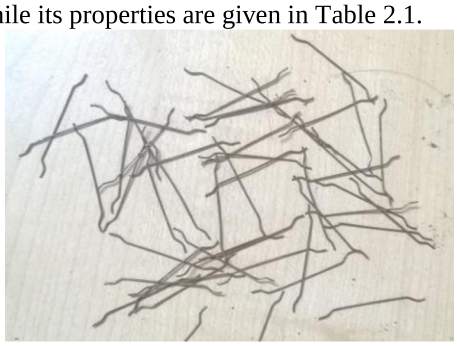

Fig. 2.1 Hooked end steel fibers.

 

| Sr. no. | Properties | |
|---|---|---|
| 1 | Material | Low Carbon Drawn Wire |
| 2 | Aspect ratio | 65 |
| 3 | Length (mm) | 35 |
| 4 | Diameter (mm) | 0.55 |
| 5 | Tensile strength | >1100 MPa |
| 6 | Appearance | Loose Unglued with Hook End Anchorage |

Table 2.1: Properties Of Hooked End Steel Fiber.

Basalt of maximum size 10 mm was used as coarse aggregate. It has specific gravity of 2.72. Natural sand is used as fine aggregate with maximum size of 4.74 mm and specific gravity of 2.6. Addition of steel fibers into concrete showed bad effect on workability so superplasticizer named Conplast SP 430 was added into mix to improve workability of concrete. Five types of concrete samples with different dosage of steel fibers were tested. The concrete mix is designed according to DOE method of concrete mix design. The mix proportion of concrete is given in table no. 2.2. Steel fibers were added to concrete mix at volume fraction ($V_f$) of 0, 0.5, 1, 1.5 and 2%.

| Material name | Quantity of material in kg/m$^3$ |
|---|---|
| Water | 160. |
| Cement | 500 |
| Fly ash | 56 |
| Fine aggregate | 736 |
| Coarse aggregate | 998 |
| SP | 6.68 |

Table 2.2: Mix Proportion of M60 Concrete

### B. *Testing Methods*

Mixing of concrete has effect on impact resistance of concrete. Thus uniform mixing of concrete is ensured by well dispersion of steel fibers into fresh concrete mix and then allowed to mix in mechanical concrete mixer for additionally 2 min after formation of fresh concrete mix. 3 cubical specimens for compressive strength of size 150 × 150 × 150 mm were casted. 3 disc specimens of size 150 mm diameter × 63.5 mm height were casted for each type of concrete. Thus total 15 disc specimens were casted. After casting, specimens were demoulded after 24 hours and cured in water tank for 28 days. Fig. 2.2 shows both types of specimens casted.

Fig. 2.2: Disc specimens for drop weight test and cubical specimens for compressive strength test.

Drop weight test was used to determine impact resistance of concrete. Fabricated drop weight test equipment is used. The impact test was carried according to recommendations of ACI Committee 544. The test was carried out by dropping a hammer weighing 5.1 kg from a height of 384 mm repeatedly on a 63.5 mm diameter hardened steel ball, which is placed on the top of the centre of the cylindrical disc, as shown in Fig. 2.3. In fabricated instrument drop hammer weight is increased while drop height is reduced to maintain same energy production as in standard drop weight test. Impact energy produced by this equipment is same as produced by standard drop weight test equipment. The number of blows to form first visible crack on the disc was recorded as the first-crack impact strength (N1). After formation of first crack, hammer is allowed to continuously dropped on specimen until it break the cracked disc into pieces touching three of the lugs. The number of blows to cause ultimate failure by touching action was recorded as the failure impact strength (N2). Thus, N1 represents first crack impact resistance while N2 represents failure impact resistance of concrete.

Fig. 2.3: Fabricated drop weight test equipment.

## III. RESULTS AND DISCUSSION

### A. *Compressive strength test results of HSC:*

All specimen exceeded compressive strength of 60 MPa. The average of load carried by three cubical specimens is found to be above 60 MPa. Therefore design mix of concrete produced concrete which satisfactory meets strength requirements of high strength concrete (HSC).

| Grade of concrete | Average load carried (KN) | Average compressive strength (MPa) |
|---|---|---|
| M 60 | 1400 | 62.22 |

Table 3.1: Compressive Strength Test Results

Compressive strength was determined to check quality control. The results for compressive strength showed small variation thus it indicated good quality control over concrete production.

### B. *Comparison of impact resistance of high strength concrete (HSC) and high strength steel fiber reinforced concrete (HSFRC):*

Table 3.2 represents average of impact test results obtained. Average of impact values (N1 and N2) are obtained from impact values of 3 specimens of each type of concrete. First column represents serial number of concrete type. Second column represents concrete with various $V_f$ of steel fibers. Third column represents average number of blows required to form first crack (N1) on the specimen. For certain type of concrete, average of N1 values is determined by dividing sum of all values by number of values. Fourth column represents average of N2 values calculated similarly as average of N1. Fifth column represents average difference between N1 and N2. It is calculated by formula N2 - N1. Sixth column represents average energy required for N1, it is determined by multiplying energy produced by each blow by average N1 values. While seventh column represents energy required for average N2, it is determined by multiplying energy produced by each blow by average N2 values. Eighth columns shows values for average energy absorbed after average N1, which is calculated by multiplying energy produced by each blow by average N2 – N1 values.

In order to check effect of addition of steel fibers on impact resistance of concrete. Average N1 and N2 values of concrete with various steel fibers $V_f$ are Compared with concrete of steel fiber $V_f$ 0%. From Table 3.2, Ratios of average N1 values of HSFRC with HSC were 0.77, 1.02, 1.08, 1.06 times at steel fiber $V_f$ of 0.5, 1, 1.5 and 2%. Average number of blows for N1 of HSFRC at steel fiber $V_f$ of 0.5 are lower than HSC but shows slighter increase at steel fiber $V_f$ of 1, 1.5 and 2% than HSC. Maximum increase in average N1 values for various steel fibers $V_f$ was 0.08 times. Thus addition of steel fiber does show considerable effect on improvement of first crack impact resistance (N1) of concrete. When average N2 values of HSFRC compared with HSC, it showed increased of 1.183, 1.91, 2.81 and 3.75 times at steel fiber $V_f$ of 0.5, 1, 1.5 and 2%. Thus improvement in N2 occurred with increase in steel fiber $V_f$. Thus maximum increase in failure impact resistance (N2) is obtained at steel fiber $V_f$ 2% followed by 1.5, 1 and 0.5 %. From results for both N1 and N2 it can be observed that, steels fibers do not show considerable effect on improvement of first crack impact strength. But after formation of first crack steel fibers enables concrete to absorb large number of blows, thus shows great effect of steel fibers on improvement of failure impact resistance of concrete. This increase may be due bridging and load transfer action of steel fiber, which acts as bridge between two cracks and transfers load from one part to another part of specimen. Steel fibers also controls crack propagation and crack width, thus keeps specimen in to integrity which enables it to absorbs more number of blows after first crack, which lead to improve failure impact resistance of concrete. Finally specimen fails after large number of blows by pull out of steel fibers from integrity. This increase of N2 value increases with increase in steel fiber $V_f$. thus steel fiber $V_f$ have effect on improvement of ultimate failure impact resistance.

| Sr. no. | Steel fiber $V_f$ (%) | Average N1 values | Average N2 values | Average N2 – N1 | Average energy required for N1 (kN mm) | Average energy required for N2 (kN mm) | Average energy absorbed after N1 (kN mm) |
|---|---|---|---|---|---|---|---|
| 1 | 0 | 508.3333 | 513.3333 | 5 | 10342.04 | 10443.77 | 101.725 |
| 2 | 0.5 | 395 | 609 | 214 | 8036.275 | 12390.11 | 4353.83 |
| 3 | 1 | 521.6667 | 980.6667 | 459 | 10613.31 | 19951.66 | 9338.355 |
| 4 | 1.5 | 552 | 1446.667 | 894.6667 | 11230.44 | 29432.43 | 18201.99 |
| 5 | 2 | 540.6667 | 1928.333 | 1387.667 | 10999.86 | 39231.94 | 28232.08 |

Table 3.2: Impact Strength Results for M 60 Concrete With Different $V_f$ Of Steel Fibers

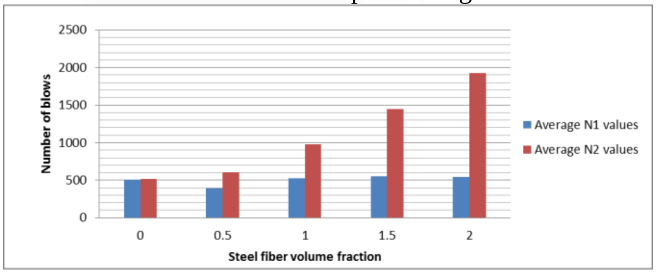


Fig. 3.1 Average values of N1 and N2 for M60 concrete with various dosage of steel fiber.

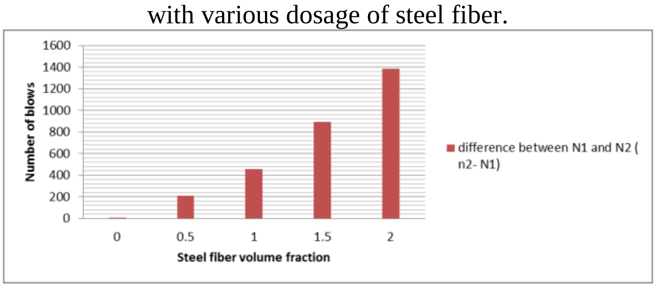


Fig. 3.2 Difference in N1 and N2 values for various Vf of steel fibers.

### *C. Difference in N1 and N2 values:*

In Table 3.2, N2 - N1 values represent difference in N1 and N2 values. From Table 3.2 and Fig. 3.2 we can see difference in N1 and N2 values for various $V_f$ of steel fibers. In HSC concrete which has 0% steel fiber $V_f$ shows negligible difference between N1 and N2. Thus it shows brittle behavior of HSC by failing immediately after formation of first crack (N1). While, HSFRC shows increase of difference between N1 and N2 values. From results it is observed that average difference in N1 and N2 values are 5, 214, 459, 894.6 and 1387.6 for concrete with steel fiber $V_f$ of 0, 0.5, 1, 1.5 and 2%. Thus difference between N1 and N2 values increased with increase of steel fibers $V_f$ in concrete. Thus shows ductile behavior of HSFRC as it absorbs large number of blows after formation of first crack. Increasing $V_f$ of steel fiber improves energy absorption capacity of concrete. This increase in energy absorption may be due to stress distribution by steel fiber over its contact area. Thus increase in steel fiber dosage increases contact area thus stresses are distributed over larger contact area which lead to improve energy absorption of concrete.

## IV. CONCLUSIONS

1) Under impact loading, HSC shows brittle behavior while HSFRC shows ductile behavior
2) Addition of steel fibers into concrete shows negligible improvement for first crack impact

 

resistance (N1) at 1, 1.5, 2% $V_f$ of steel fiber while at 0.5 % $V_f$ it shows reduction of N1 in comparison to HSC.

3) Failure impact resistance (N2) of concrete is greatly improved by addition of steel fibers. It increases with increase in steel fiber $V_f$. Maximum increase of 3.75 times occurred at $V_f$ of 2% in comparison to HSC.
4) Difference between N1 and N2 values increases with increase in steel fiber $V_f$ up to 2%. Thus energy absorption increases with increase in steel fiber $V_f$.

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