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Effect of Hybrid Fiber Reinforced Concrete on Strength of Concrete

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Abstract

The major chunk of construction is covered by concrete construction. Concrete is a mixture of cement, sand, crush and water in appropriate ratio. It is good in compression but weak in tension. In order to improve these strengths of concrete, this research was conducted to evaluate the effect of Hybrid Fiber Reinforced Concrete (HFRC) on strength of concrete. Steel reinforced fibers were used to improve the compressive and tensile strength of concrete and also to control the progress of cracks in concrete. Steel reinforced fibers concrete (SFRC) was produced having 5000 Psi as target strength. Two types of steel wires having 25mm and 18mm fibers were used. 1.25% of concrete volume was replaced with steel fiber having aspect ratio for 25mm fiber was 60 and for 18mm fiber it was 40. Different proportions of steel fibers from 25% to 100% for both types of fibers were used to evaluate their effect on strength of concrete. The main purpose of introducing fiber steel concrete is to eliminate the traditional shears stirrups in concrete members. Cubes and prisms were casted to test for compressive strength and tensile strength on concrete. It was observed that there is no significance effect of steel fibers on compressive strength of concrete while around 58.33% of tensile strength was improved because short length steel fibers controlled the propagation of cracks in concrete. The maximum results were achieved at 100% replacement of 18mm fibers. The results are helpful for building stakeholders to improve strength of concrete by using steel fibers in concrete. Further studies can be carried out to find out other properties of steel fiber reinforced concrete.

Key words: Hybrid steel fibers, compressive strength, flexural strength, Mechanical properties, Aspect ratio

1. INTRODUCTION

A stone like material is known as concrete which is attained by a warily balanced mixture of cement, sand, gravel and water. While in fresh state, concrete is a plastic which can be molded into any desired shape but with time it becomes hardened. Concrete develops micro cracks during curing. Cracks propagate in the fibers that are right under the load and these hybrid steel fibers block crack propagation. Due to dry shrinkage problem in concrete, formation of cracks also occurs and by elapsing of time increase in size and magnitude of cracks take place resulting in failure of concrete. (Maruthachalam et al, 2013). To minimize this phenomenon fibers are introduced as a new technique which helps to increase the tensile strength of concrete.

Concrete which contain fibrous material is known as Fiber Reinforced Concrete (FRC) which improves its structural strength. It incorporates quick isolated fibers which are equally allotted and haphazardly oriented. Fiber reinforced concrete consisting of, cement, water, fine and coarse aggregate, along with discontinuous fibers. The small Piece of reinforcing material which own certain properties and minimize the propagation of cracks are called Fibers which are equivalently disseminated and arbitrarily arranged. This concrete is named as fibers reinforced concrete. (Grijaet al, 2016). The addition of fibers greatly reduced the post cracking behavior in concrete which improves structural integrity and cohesiveness of material.(Vandewalle, 2007)

Typical aspect ratio of fibers ranges from 20 to 100 while length dimensions ranges from 6.4 to 76mm (ACI 544.1R-96). The volume fraction (V_f) is a term, used to represent the amount of fibers added in the concrete mix as a total volume of concrete. The steel fiber volume fraction used in concrete typically ranges from 0.1% to 3.0% (Global Research Analysis). More than 1.0% of volume fraction generally decreases workability and fiber dispersion and need a special mix design or concrete placement techniques (Portland Cement Association).

Figure 1 shows the effect of long and short fibers on concrete. Short length fibers bridges micro cracks, control the growth of cracks and also delay the coalescence in fiber reinforced concrete. Long length fibers prevent the propagation of micro cracks, control the macro cracks also and then improve the fracture toughness of composites.

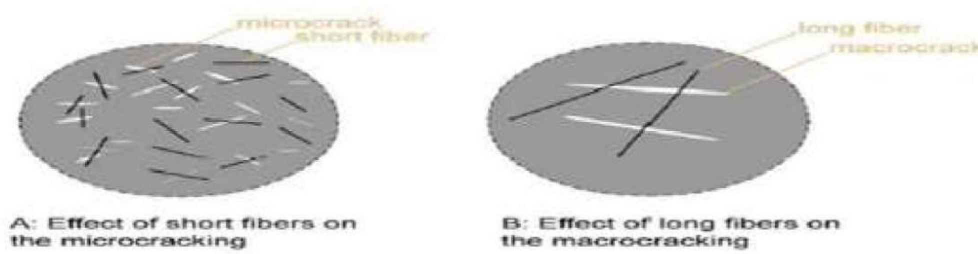

Figure 1: Effects of short and long fibers

An attempt was made to find out the effect of steel fibers in concrete. Steel fibers of length 18mm and 25mm was used in this research at different percentages to evaluate their effects on mechanical properties of concrete like compressive strength, flexural strength, ultimate load carrying capacity and ductility. Some positive effects were observed in concrete after adding hybrid steel fiber in concrete as compare to Plain concrete. The results of this study will helpful in selection of concrete with improved compressive and flexural strength and also with improved ductility. The greater compressive and flexural strength co concrete will help the design engineer to make their design more economical and safer.

2. MATERIALS USED

Ordinary Portland cement having Type-I manufactured by DG cement with fairly high CS content for good early strength development was used. Usually include natural aggregate with passing through a 9.5mm sieve. Source of Fine Aggregates was Lawrencepur having Specific gravity 4.81, Fineness Modulus 3.37 and 0.80% water absorption capacity. Similarly, source of Coarse Aggregates was Margalla having Specific gravity 2.53, aggregate size 12mm and 1.37% water absorption capacity.

Hybrid mild steel fibers having diameter 0.43mm were used in concrete having length 25mm and 18mm with 60 and 40 aspect ratios respectively. Portable water was used for this research and Chemrite 520 BA was used as water reducing and set retarding concrete admixture at the rate of 0.5 lit/50 kg cement. These fibers were added in concrete at a volume fraction of 1.25% whereas no fibers were added in control mix (CM) specimen.

Table 1: Different Ratios of Fibers used

Mix specimens	***Steel fibers by volume of concrete (%)***
CM	Normal Concrete
Sample-I	100% (25mm)
Sample-II	100% (18mm)
Sample-III	50% (25mm), 50% (18mm)
Sample-IV	75% (25mm), 25% (18mm)
Sample-V	*25% (25mm), 75% (18mm)*

The concrete mixture design was carried out to find out values of ingredients. Trial mixture design was carried out first to find out the mixture ratios for required strength of concrete. For this research concrete mix 1:1.6:1.8 was used with 0.4 water to cement ratio.

Deformed high strength steel of 13mm & 16mm bars were used to provide longitudinal reinforcement in beams. 16mm bars provided at bottom of beams and 13mm bars provided at top of beams. For stirrups used 10mm bars for all the beams. In plain reinforced concrete beams stirrups are provided throughout the beam but in fiber reinforced concrete beams two stirrups are provided at its one end two stirrups are provided at its other end. Stirrups are provided to hold the top and bottom bar (Singh et al, 2016).

3. EXPERIMENTAL METHODOLOGY

3.1 Compressive strength test

This test was performed according to ASTM C39. To find out compressive strength of concrete the cylinder of size 300x150mm were used. Specimen were placed on bearing surface of UTM, of capacity 100 tones deprived of eccentricity and uniform rate of loading of 0.25 MPa per second was applied till the failure of cylinder. Machine gives compressive strength direct in MPa so no need to convert the compressive strength value (Ohitha et al, 2016).

3.2 Flexure strength test

Plain and SFRC beams of size 100x150x1200mm were tested using a universal testing machine. The loading scheme was two point. The beam was simply supported over a span of 970mm and a two-point loading system was adopted having an end bearing of 115mm from each support. A load was applied to stiff steel beam that distributed into two points and then from the two points load is transferred to beam specimen. The rate of loading applied on beam was 0.5 MPa per second. The load is applied till the failure of specimen. The first crack load and ultimate load are noted and deflection was measured using the dial gauge (Cho et al, 2009).

4. EXPERIMENTAL RESULTS

After the preliminary tests, various samples were casted included cylinders and beams to evaluate the properties of concrete with and without use of steel fiber in concrete. Cylinders were casted for the compressive strength test and beams were casted for the flexural strength test. These samples have various percentages of steel fiber in concrete.

The below figure-2 indicates the comparison of plain concrete and steel fiber reinforced concrete with all described percentages. It is clear from figure-2 that there is a significant improvement in compressive strength of concrete by adding steel reinforced fiber in concrete as compare to plain concrete. The addition of 25%, 75% and 100% steel fiber of 18mm and 25mm lengths have not produced large difference at 28 days. While among the steel fiber reinforced concrete, the addition of 25mm and 18mm long steel fibers at 50% yielded the maximum results as compare to all other options. Therefore, it is clear that this is the optimum percentage of steel fiber reinforced in concrete for the improvement of compressive strength.

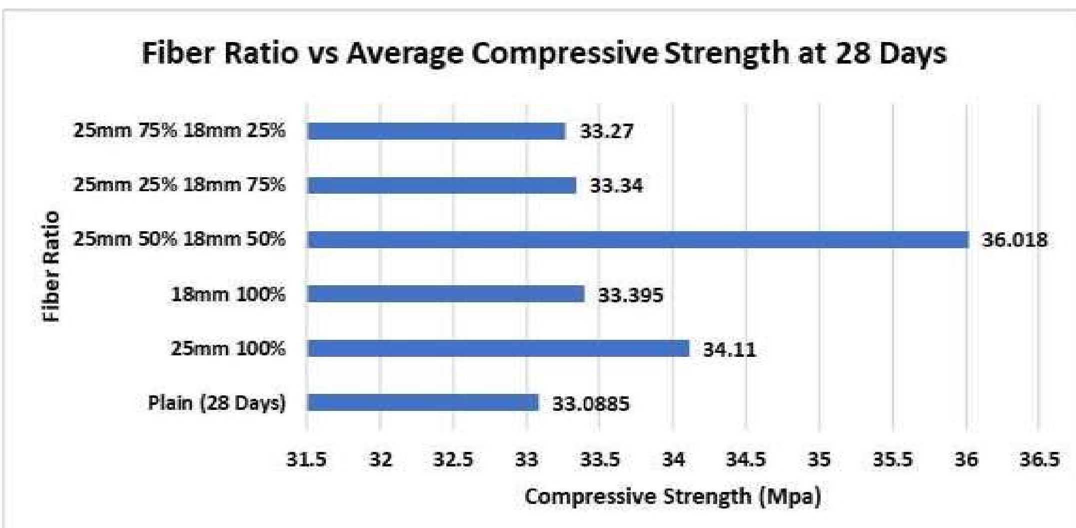

Figure 2: comparison of compressive strength for plain and fibrous cylinders

Similar trend was also found in concrete at age of 14 days. Where the addition of 25mm and 18mm long steel fibers at 50% yielded the maximum results as compare to all other options.

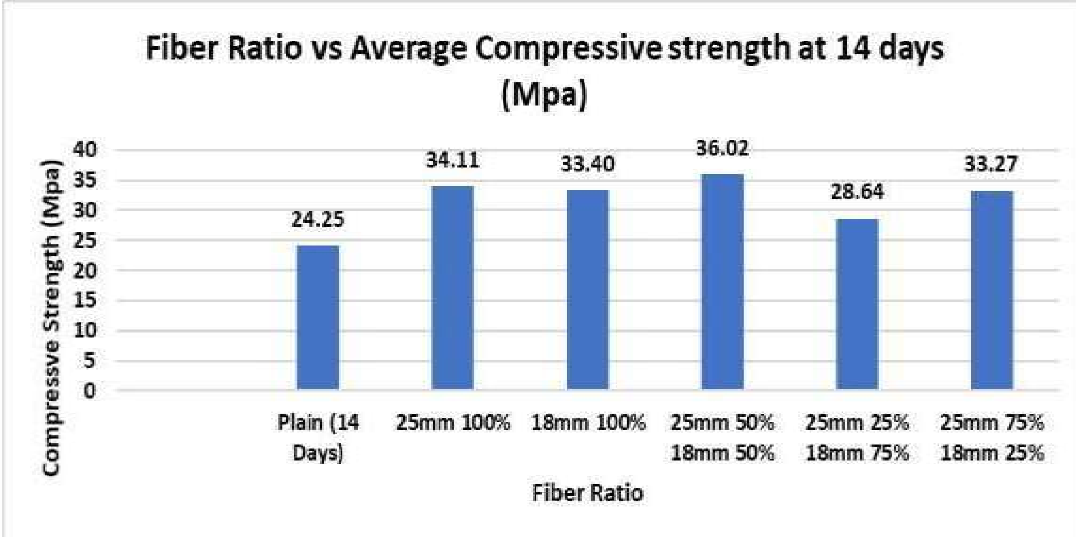

Figure 3: Compressive strength at 14 days

Similar trend was also found in concrete at age of 7 days. Where among the steel fiber reinforced concrete, the addition of 25mm and 18mm long steel fibers at 50% yielded the maximum results as compare to all other options. But the rate of gain of compressive with rest to time was not found here in steel fiber reinforced concrete. The compressive strength of steel fiber reinforced concrete remains constant at around 36.02 Mpa in different ages.

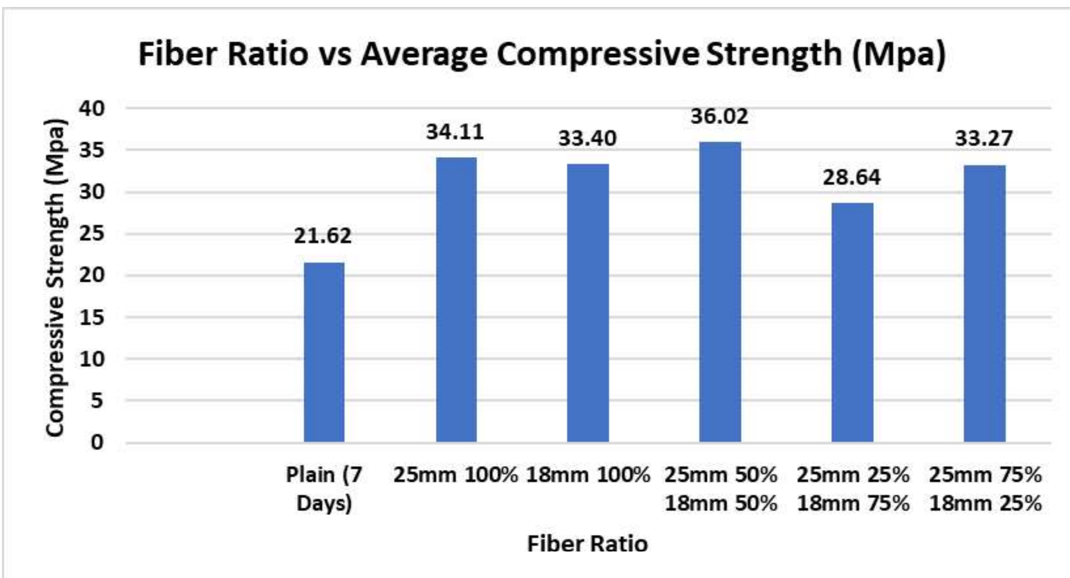

Figure 4: Compressive strength at 7 days

Deflection tests were performed on beams to find out the ductility of steel fiber reinforced concrete. It is clear from below graph that steel fiber reinforced concrete with 25mm long steel fiber with 100% replacement yielded maximum deflection as compare to other samples. It is also clear that there is significant improvement in deflection of steel fiber reinforced concrete as compare to plain concrete which shows that addition of steel fiber reinforcement improves the ductility of concrete and hence improve the warning before failure of steel fiber reinforced concrete structures.

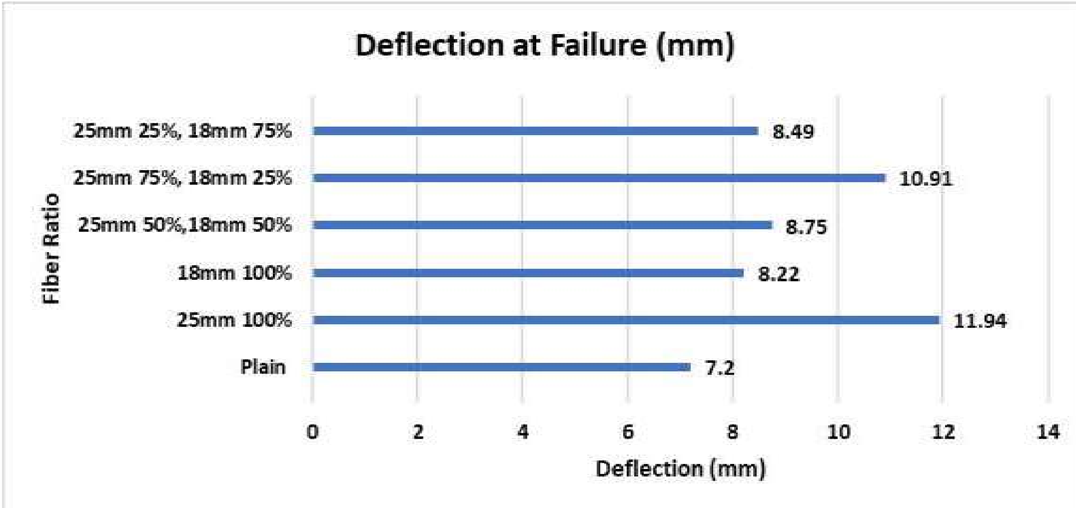

Figure 5: comparison of deflection at failure for plain and fibrous beams

5. CONCLUSION

Concrete is a good building material and widely used in construction all over the world. It has good compressive strength but it is very weak in tension which make it lesser durable against tension loading. In order to improve the tensile strength of concrete steel fibers used in this research has significant effects on all properties of concrete when compared to conventional concrete. Following are the major findings of this study.

a. Compressive strength of plain cylinder is 33.09 MPa. There is 8.13% improvement in compressive strength of concrete by adding steel fiber ratio (25mm 50% +18mm 50%) in concrete. Because long fibers have greater pull out resistance which improves the post cracking tensile strength of concrete and short fibers provides micro crack control at early stage so both long and short fibers combined to achieve the maximum compressive strength.

b. Flexural strength at first crack load in plain beam is 7.5 KN. As compare to plain concrete, around 58.33% flexural strength of concrete was improved by adding steel fiber ratio (18mm 100%). It is because short length fibers control the micro cracks in early stage of loading which leads to higher tensile strength of concrete so the first crack appear later on 18mm 100% beam sample.

c. Flexural strength at ultimate load in plain beam is 85 KN (Average of two samples). Around 8.11% improvement was found by adding steel fiber ratio (25mm 50%+18mm 50%) because when the beam was subjected to flexural loading the long fibers bridge the micro cracks and prevent the expansion of cracks and when long fibers fail than short fiber bridging cracks until its fail so combination of both long and short length fibers combine to achieve maximum flexural strength at ultimate load.

d. The variation in results of Load Deflection Curve is due to hand compaction of concrete and there is no use of vibrator for compaction concrete, due to this deflection is more in 18mm fibers rather than 25mm fiber but according to previous studies deflection should be more in long fibers as compared to short fibers.

e. The energy absorption in plain beam is 445 KN-mm. Around 36.49% improvement was found by adding steel fiber ratio 18mm 100% because deflection in case of this ratio also maximum so energy absorption also maximum. More the deflection more is energy absorbed by the beam sample.

6. RECOMMENDATIONS

1. Improvement in tensile strength and also in ductility of concrete is helpful in choosing steel fiber reinforced concrete structures specially in earthquake areas where tension and ductility is the basic requirement of structures.
2. This improvement inf tensile strength and ductility due to steel fiber reinforced concrete also helpful for the designers to reduce the member size and make the structure more economical as compare to traditional concrete.
3. Future research can be carried out by changing the aspect ratios and volume of fractions of fibers (such as 1.5% and 1.75%) and check the compressive and flexural behavior.
4. Analytical modeling of fiber reinforced concrete beam can be done.
5. Stress strain curve can be plotted and their behavior can be studied.

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