Experimental Investigation on Hybrid Fibre Reinforced Concrete Beams

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Abstract – The normal conventional concrete has less compressive and tensile strength so to enhance the performance of the concrete some kinds of fibres are added to the concrete gain required strength. This research work presents the effect of fibres on high strength reinforced concrete beams with and without fibres. The study parameters for the investigation included ultimate load, ultimate deflection and flexural strength. The fibres used in the investigation are steel fibres and polyolefin fibers. Fibers are added to the concrete not only to increase tensile strength but also to control the crack and to change the behavior of cracked material by bridging across the cracks.

Keywords – Flexural Strength, Hybrid Fiber Reinforced Concrete, Mechanical Properties, Polyolefin Fibres, Steel Fibres.

I. INTRODUCTION

Concrete is relatively a brittle material and has serious short-coming of poor toughness. Plain concrete possesses a very low tensile strength, limited ductility and little resistance of cracking. Internal micro cracks are inherently present in the concrete and its poor tensile strength is due to propagation of such micro cracks, eventually leading to brittle fracture of the concrete.

In plain concrete and brittle materials, structural cracks (micro cracks) develop even before loading, particularly due to drying shrinkage or other causes of volume changes. The width of these initial cracks seldom exceeds a few microns.

It has been recognized that the addition of small, closely spaced and uniformly dispersed fibres to concrete would act as crack arrester and would substantially improve its dynamic properties. This type of concrete is known as fiber reinforced concrete.

Addition of randomly distributed fibers improves concrete structural characteristics flexural strength, ductility and flexural toughness etc. which depend upon fibre type, size, aspect ratio and volume fractions of the fibres used. Recent years have seen considerable interest in the fibre hybridization – particularly combinations of metallic and non-metallic fibres. For optimal behaviour, different types of metallic and non-metallic fibres have been combined. The mechanical properties such as compressive strength, flexural strength and flexural toughness etc was improved.

Fibre reinforced concrete may be defined as a composite materials made with Portland cement, aggregate and incorporating discrete discontinuous fibres. Plain, unrestrained concrete is brittle material with a low tensile strength and a low strain capacity. The role of randomly distributed discontinuous fibres is to bridge across the crack that develops in future.

The development of such micro cracks is the main cause of in elastic deformation in concrete. It has been recognized that the addition of small closely spaced and uniformly dispersed fibers to concrete would act as crack arrester and would substantially improve its static and dynamic properties. Several forms of fibre such as steel and polypropylene have been tried and these are available in variety of shapes, sizes and thickness. These fibres are used either jointly called as hybrid fibre. The addition of fibers reduces immediate deflection, long-term deflection and crack width of beam two kinds of fibers have been used in concrete mix that is steel and polyolefin fibers since the now no single fiber reinforced Concrete could exhibit perfect mechanical properties.

Fibre reinforced cement and concrete materials (FRC) have been developed progressively since the early work by Romualdi and Batson in the 1960s. By the 1990s, a wide range of fibre composites and FRC products were commercially available and novel manufacturing techniques were developed for use with high fibre content. In parallel with the commercial development of FRC materials and products, an extensive research programme was undertaken to quantify the enhanced properties of FRC materials and more specifically to allow comparisons to be made between various types of fibres. Fibre reinforced concrete (FRC) is a composite material consisting of cement, sand, coarse aggregate, water and fibres. In this composite material, short discrete fibres are randomly distributed throughout the concrete mass. The behavioral efficiency of this composite material is far superior to that of plain concrete and many other construction materials of equal cost. Due to this benefit, the use of FRC has steadily increased during the last two decades and its current field of application includes: airport and highway pavements, earthquake-resistant and explosive-resistant structures, mine and tunnel linings, bridge deck overlays, hydraulic structures, rock-slope
stabilization, etc. Concrete is relatively a brittle material and has serious short-coming of poor toughness. The term high strength concrete is generally used for concrete with compressive strength higher than 41MPa (6000psi). The addition of randomly distributed fibres improves concrete structural characteristics. Fiber reinforced concrete (FRC) is a composite material consisting of cement, sand, coarse aggregate, water and fibres. The main purpose of steel and synthetic fibers is used to resist cracks forming in the concrete structures.

II. PRODUCTION OF HIGH STRENGTH CONCRETE

The manufacture of high strength concrete is to more compressive strength lesser cracks but the water absorption will be more to reduce the water absorption will added some materials will grow to find its due to place in concrete construction for all the obvious benefits in the modern batching plants. High strength concrete is produced in a mechanical manner of course one has been taken care about mix proportioning shape of aggregates, use of supplementary cementations materials, silica fume we are adding these materials to reduce the voids between the aggregates will be reduce but one of the defect is water absorption will be more to reduce the water absorption will be adding HRWR (high range water reduces). With the modern equipment’s understanding the role of the constituent materials, production of high strength concrete has become a routine matter.

III. PRODUCTION OF HYBRID FIBRE REINFORCED CONCRETE BEAMS

Fibre reinforced concrete is a type of concrete that includes fibrous substance that increases its structural strength and cohesion. Fibre reinforced concrete has small distinct fibres that are homogeneously dispersed and oriented haphazardly. Fibres are natural fibres and artificial fibres, namely steel fibres and polyethylene fibres. The characteristics of fibre reinforced concrete are changed by the alteration of quantities of fibres, plain Portland cement concrete is a brittle material the strength concrete in tension is much lower than the compression. Growing crack in plain concrete can very soon lead to failure. In the presence of reinforcement the tensile load is transfer to the steel. An alternative to increasing the load carrying capacity of concrete in tension is the addition of fibres. Well-dispersed fibres in the concrete act to bridge the cracks developed in concrete. The incorporation of fibres in a cement matrix leads to an increase in the toughness and tensile strength, and an improvement in the cracking and deformation characteristics of the resultant concrete.

Fibres are usually in concrete to control plastic shrinkage cracking and drying shrinkage cracking. They also lower the permeability of concrete and thus reduce bleeding of water. Some types of fibers produce greater impact, abrasion and shatter resistance in concrete. Generally fibers do not increase the flexural strength of concrete, so it cannot replace moment resisting or structural steel reinforcement. The amount of fibres added to a concrete mix is measured as a percentage of the total volume of the composite (concrete and fibres) termed volume fraction typically ranges from 0.5 to 1%.

Some recent research indicated that using fiber in concrete has limited effect on the impact resistance of concrete materials. This finding is very important since traditionally people think the ductility increases when concrete reinforced with fibers. The results also pointed out that the micro fibers is better in impact resistance compared with the longer fiber.

IV. PROPERTIES OF FIBRES ARE USED

<table>
<thead>
<tr>
<th>Fiber Properties</th>
<th>Fiber Details</th>
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<tbody>
<tr>
<td></td>
<td>Polyolefin</td>
</tr>
<tr>
<td>Length (mm)</td>
<td>48</td>
</tr>
<tr>
<td>Shape</td>
<td>straight</td>
</tr>
<tr>
<td>Size / Diameter (mm)</td>
<td>1.22x0.732mm</td>
</tr>
<tr>
<td>Aspect Ratio</td>
<td>39.34</td>
</tr>
<tr>
<td>Density (kg / m3)</td>
<td>920</td>
</tr>
<tr>
<td>Young’s Modulus (GPa)</td>
<td>6</td>
</tr>
<tr>
<td>Tensile strength (MPa)</td>
<td>550</td>
</tr>
<tr>
<td>Tensile strength (MPa)</td>
<td>530</td>
</tr>
</tbody>
</table>

V. TESTS CONDUCTED AND RESULTS

An experimental program was carried out to study the performance of HFRC beams with and without fibres, by Two-point loading. The beams of 150 mm x 250 mm in cross section and overall length of 3000mm provided with 3 nos. 1 beam was control beam without another 2 beams are hybrid fibre reinforced concrete beams 0.5% and 1% of steel and polyolefin fibres 70%(steel fibres)-30%(polyolefin fibres) in total volume of concrete in that beam 2 bars of 8mm φ on tension zone and 2 bars 12mm φ in compression zone and as the 6mm stripes were used.

Fig.1. specimen details
Table 2: Specification of beam

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length of beam</td>
<td>3000 mm</td>
</tr>
<tr>
<td>Depth of beam</td>
<td>250 mm</td>
</tr>
<tr>
<td>Width of beam</td>
<td>150 mm</td>
</tr>
<tr>
<td>Steel bars</td>
<td>12mm, 8mm</td>
</tr>
<tr>
<td>Stirrups</td>
<td>6mm dia @ 200 mm</td>
</tr>
<tr>
<td>Clear cover</td>
<td>25mm</td>
</tr>
</tbody>
</table>

1. Loading setup

The beams are testing after 28 days proper curing. The loading setup of the beam, was shown in the below figure. The pallets are arranged on beam with constant spacing, totally 28 pallets are arranged on compression side and tension side. These pallets arranged with a clear cover of 25mm on all sides (top and bottom both sides).

2. Testing Procedure

All the beams were tested, under two-point loading as per ASTM C 78, in a loading frame of 500 KN capacity and 100mm bearing was given on both ends, resulting in an effective test span of 2800mm as shown in (fig.2). The deflections were measured at mid span and load points using mechanical dial gauges of 0.01mm accuracy. Three dial gauges were setup on the tension side of the specimen under load points and center of the beam to measure slope at the ends. The strains at extreme fibres were measured using demountable mechanical strain gauge. The crack widths were measured using a demo gauge with a least count of 0.02mm. The pallets are placed at constant distance.

For the applying of loading proving ring is used with a capacity of 500KN and to measure displacement dial gauges are used with an accurate of 0.2mm, the diagram of proving ring and dial gauges was shown below. The strain and crack width can be measured by using the democ gauge the first crack and end crack can be measured. The deflections can be measured at different load levels the crack development and propagation was measured during the process of testing.

A total of 3 beams were casted and tested in this investigation to study the strength and load deflection behavior of the hybrid fiber reinforced concrete beams. The test results of the ultimate load, yield load, deflection and crack width as shown in figure below. Concrete mix for all beams are taken from the mix design as per the ACI codal provision, respectively.

Table 3: Ultimate Load Yield Load Data of the Beam

<table>
<thead>
<tr>
<th>Specimen Name</th>
<th>Control</th>
<th>0.5% Beam</th>
<th>1% Beam</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volume fraction</td>
<td>Steel</td>
<td>0.35</td>
<td>0.7</td>
</tr>
<tr>
<td></td>
<td>polyolefin</td>
<td>0.15</td>
<td>0.3</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>0.5%</td>
<td>1%</td>
</tr>
<tr>
<td>Yield load</td>
<td>37</td>
<td>43</td>
<td>40</td>
</tr>
<tr>
<td>Yield deflection</td>
<td>26.045</td>
<td>24.075</td>
<td>23.0</td>
</tr>
<tr>
<td>Ultimate load</td>
<td>56.19</td>
<td>71.43</td>
<td>61.43</td>
</tr>
<tr>
<td>Ultimate deflection</td>
<td>73</td>
<td>78</td>
<td>75</td>
</tr>
</tbody>
</table>
VI. CONCLUSION

The hybrid fibre volume fraction of 0.5% with 70% - 30% steel polyolefin combine significantly improves the overall performance of high-strength reinforced concrete beams.

The increase in ultimate load was found to be 15.24% when compared to reference beam. The increase in ultimate deflection was found to be 22.03% when compared to reference beam.

APPENDIX

MIX DESIGN

Step 1
Select slump and required strength
Fcr = (8702.34+1400)/0.9=11224.8psi

Step 2
Max size of aggregate = 1/2 in
Bulk specific gravity of aggregate = 2.806
Water absorption = 0.39%
Dry Bulk density = 95.50lb/ft³

Step 3
Vol of Coarse aggregate = 0.68 (As per code provision)
Dry wt/yd³ of concrete = (0.68X95.50X27) = 1753.38lb

Step 4
Slump = 1 to 2
C.A size = 1/2 in
For this condition water content = 295 lb/yd³
(As per code provision)

Step 5
Finding W/c +p

Step 6
Wt of cementations material = (317.08/0.283)=1120.42lb

Step 7
Cement content/yd³ of concrete =1120.42 lb
Volumes/yd³ of all materials expect sand
Cement = [(1120)/(3.15X62.4)] =5.69ft³
Coarse Aggregate = [1753.38/(2.806X62.4)] =10.01ft³

Material content:
Cement =1120.42 lb
Coarse Aggregate =1753.38 lb
Sand =974.68 lb
Water =317.08 lb

Adjustments:
Cement =1120.42 lb
Coarse Aggregate = (1753.38 X [(1) + (0.39/100)]) =1760.22 lb
Fine Aggregate = (974.68 X [(1) + (1.21/100)]) =986.47 lb
Water = (317.08-[(974.68) X (0.0638-0.0121)])-(1753.38 X (0.0033-0.0039))=264.77 lb

As Per Indian Units:
Cement =661.04Kg/Cum
Coarse Aggregate =1038.52Kg/Cum
Fine Aggregate =582.01Kg/Cum
Water =184Kg/Cum

Mix for silica fume:

Mix 1 Cement Silica Fume
8% 608.15 52.88

Mix 2 Cement Silica Fume
9% 601.55 59.49

Mix for HRWR:

Mix 1 Water HRWR
1.25% 175.74 8.26
Mix 2 Water HRWR
1.5% 174.08 9.92

Compaction Mix:

Mix Cement F.A C.A Water S.F HRWR
#1 608.1 582.0 1038.5 175.7 52.8 826
#2 601.5 582.0 1038.5 174.0 59.4 9.92

ACKNOWLEDGMENT

First and foremost, I would express my sincere gratitude to our beloved Sponsor K.Kartheek Babu Match and also thank to financial support Mr.K.Rushi Kesava Reddy M.Tech. for providing me the necessary facilities for the completion of my article for her constant support.

I also express my sincere thanks to my guide Mr. A. Annadurai (Ph.D.) and my counsellors for their constant guidance and supervision during the period of my project work.
Last but not least, I would like to thank my beloved parents for their encouragement and

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