A Study of Flexural and Bending Strength of Steel, Polypropylene and Hybrid Fibre Reinforced Concrete without Adding Admixture

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Abstract

The present study has been taken up for evaluating the different types of concrete. Emphasis has been given to the strength and deformation properties of reinforced concrete beams. This paper presents the results of an experimental investigation carried out on four different types reinforced concrete beams, 150 mm × 150 mm × 700 mm in size. The beams were tested under one-third point loading. The results exhibited that the flexural strength of concrete are meaningfully improved by adding steel, polypropylene and hybrid fibers. Out of the three different types of fibers used in this study, the fibers with steel and hybrid showed better efficiency in improving the flexural response.

Keywords: Fiber Reinforced Concrete, Steel, Polypropylene and Hybrid Flexural Properties.

1. Introduction

Concrete is currently the most widely used building material. Although many structures are built of concrete, there are still some limitations related to the use of conventional concrete, such as low tensile strength and almost no ductility. Fibers such as polypropylene when added to concrete reduce the compressive strength, but increases both split tensile strength and flexural strength [3].

They are more porous compared to the plain concrete. Steel fiber reinforced concrete (SFRC) offers good tensile strength, ultimate strength, flexural strength, shock resistance, fatigue resistance, ductility and crack arrest [7, 8, 9, 10]. Some researches shows that SFRC shows a slight tendency to reduce the young’s modulus as the fiber content decreases [4].

Some of the experimental results show that the beams reinforced with steel fibers shows a similar or even better post cracking behavior than beams with minimum amount of transverse reinforcement [5]. Researches shows that when the fibers are used in the hybrid form-steel and polypropylene, increases ductility [11]. Steel fiber bridging across cracks in concrete mix will increase joint shear strength. It is the concrete characteristics that influence the time to initiation of corrosion initially and later the cracking of concrete due to corrosion of steel is of importance.

The reinforcement is generally in a passive state up to initiation of corrosion and after initiation it is influenced by the environment in concrete up to cracking and later by the environment itself. The relationships between these have a lot of bearing on the performance of structures. In the last few years, many researchers [6,7] have begun to realize that strain localization also occurs for concrete specimens loaded in compression; however, the compressive failure mechanism is more complex than the tensile failure mechanism.
fibers. Hybrids consisting of two percent steel and two percent polypropylene fibers, respectively, to calculate their strength at 7 days and 28 days. Also, addition of more fibres reduces cracking and improves corrosion resistance. Moreover, fibre reinforcement also serves to improve the shear resistance of concrete.

2. Experimental Programme

To determine the strength properties of fibre reinforced concrete the following tests were planned and conducted.

2.1 Materials used

In this experimental study, Portland Pozzolanicement, fine aggregate, coarse aggregate, water and steel, polypropylene fibers were used. Types of fibres are shown in Fig. 1. Cement conforming to IS: 12269 (1987) was used in the experimental investigation. Also locally available 20mm and down coarse aggregates with specific gravity 2.70 were used. Locally available sand conforming to zone III as per IS: 383 (1970) with specific gravity 2.65, water absorption 2 per cent and fineness modulus 2.8, was used. Potable water was used for the experimentation. In this experimentation, crimped steel fiber and Polypropylene fiber consisting of Endura - 600 Macro synthetic were used. Properties of the steel fibre and polypropylene fibres are shown in Table 1.

2.2 Concrete Mix Design

Concrete mix of grade M30 was designed as per the recommendation of IS: 383 (1970) and IS: 10262 (2009). The proportions and quantities of various materials for the concrete mix are presented in Table 2.

3. Experimental Programme

3.1 Compressive strength

The compression test, samples were cast using M30 grade of concrete with four percent of steel fibre, four percent of Polypropylene fiber, and four percent of hybrid fibers. Shaking was given by vibrating equipments. The surface of the samples were smoothly finished. After 24 hours, the samples are remove from the mould and immersed to the curing tank for 7, 14, 21, 28 days. These cubes were tested on digital compression testing machine as per IS: 516 (1959) as shown in Fig. 2. The collapse load was noted. Three cubes were tested in each type, and their standard load was reported.

The compressive strength was considered as follows:

<table>
<thead>
<tr>
<th>Sl. No</th>
<th>Material</th>
<th>Traditional Concrete</th>
<th>Steel fiber reinforced concrete</th>
<th>Polypropylene fiber reinforced concrete</th>
<th>Hybrid fiber reinforced concrete</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Cement</td>
<td>420 kg/m³</td>
<td>420 kg/m³</td>
<td>420 kg/m³</td>
<td>420 kg/m³</td>
</tr>
<tr>
<td>2</td>
<td>Fine aggregate</td>
<td>420 kg/m³</td>
<td>420 kg/m³</td>
<td>420 kg/m³</td>
<td>420 kg/m³</td>
</tr>
<tr>
<td>3</td>
<td>Coarse aggregate</td>
<td>840 kg/m³</td>
<td>840 kg/m³</td>
<td>840 kg/m³</td>
<td>840 kg/m³</td>
</tr>
<tr>
<td>4</td>
<td>W/C ratio</td>
<td>0.45 %</td>
<td>0.45 %</td>
<td>0.45 %</td>
<td>0.45 %</td>
</tr>
<tr>
<td>5</td>
<td>Steel fiber</td>
<td>16.8 kg</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Polypropylene fiber</td>
<td>8.4 kg</td>
<td>8.4 kg</td>
<td>Total = 16.8 kg</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Hybrid fiber</td>
<td>8.4 kg</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Compressive strength (MPa) = Collapse load / C.S.A
Outcome of compressive strength for M30 grade of concrete on cube samples are exposed in Table 5.

<table>
<thead>
<tr>
<th>S no</th>
<th>Nature of concrete</th>
<th>Compressive strength Days (N/mm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>C₁</td>
<td>18.0</td>
</tr>
<tr>
<td>2</td>
<td>C₂</td>
<td>25.4</td>
</tr>
<tr>
<td>3</td>
<td>C₃</td>
<td>20.0</td>
</tr>
<tr>
<td>4</td>
<td>C₄</td>
<td>18.0</td>
</tr>
</tbody>
</table>
3.2 Flexural test of plain concrete

Standard plain concrete prisms of size 150mm×150mm×700mm were used for standard flexural strength tests. These prisms are tested on digital UTM was shown in the report (Bureau of Indian standards, IS:516:1959) and it was shown in Fig.3. The flexural strength of the specimen shall be expressed as the modulus of rupture $f_b$.

$$f_b = \frac{P \times l}{b \times d^2}$$

$b$ = Measured width in cm of the specimen;
$d$ = Measured depth in cm of the specimen at the point of failure;
$l$ = Length in cm of the span on which the specimen was supported, and
$P$ = Maximum load in kg applied to the specimen.

The flexural test results for M30 grade of concrete are given in Table 6.

### Table 6: Flexure test at 28 days

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Nature of Concrete</th>
<th>Flexural Strength (N/mm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>C₁</td>
<td>3.8</td>
</tr>
<tr>
<td>2.</td>
<td>C₂</td>
<td>4.7</td>
</tr>
<tr>
<td>3.</td>
<td>C₃</td>
<td>4.4</td>
</tr>
<tr>
<td>4.</td>
<td>C₄</td>
<td>2.8</td>
</tr>
</tbody>
</table>

Fig. 2: Cube testing in CTM

Fig. 3: Showing testing Arrangements

3.3 Design details of prisms

The details are furnished below. Cross-sectional dimension of the prism: 150 mm×150mm and length of the prism: 700mm. Prisms were cast with and without longitudinal reinforcement and with fibre reinforcement in all cases.

- Plain cement concrete beam: Here, no longitudinal reinforcement bar.
- Singly reinforced: 2 numbers of 12mm diameter main reinforcement bars with Fe415 steel on the tension side with nominal stirrups of 6 mm.
- Doubly reinforced: Main reinforcement bars: 2Nos.12mm dia with Fe415 steel on the tension side; 2Nos.8mm dia with Fe415 steel on the compression side; stirrups of 6mm dia at 75mm c/c. The Design details of the Prisms are shown in Figs 4 and 5.

Fig. 4: Singly reinforced R.C.C. beam
3.4 Bending Strength of Beam with Reinforcement

Singly reinforced and doubly reinforced concrete beams of size 150 mm × 150 mm × 700 mm were cast. For singly reinforced beams, 10 mm diameter bars at bottom side with nominal stirrups were provided as shown in Fig. 4 and doubly reinforced concrete beams were provided with stirrups and with 12 mm diameter bar on bottom side and 10 mm diameter bars at top as shown in Fig. 5. Three specimens were tested in flexure after 28 days.

Results of tested beams with singly and doubly reinforced sections for M30 grade of concrete are exposed in Table 7. The specimen used in standard mould and the size of 150 mm × 150 mm and 750 mm long. Thus the paper forms a part of a larger investigation being conducted to investigate the flexural characteristics of concrete containing steel, polypropylene and hybrids of steel and polypropylene fibers. Singly reinforced and doubly reinforced concrete beams were casted.

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Nature of concrete</th>
<th>Ultimate load (kN)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Without reinforcement</td>
<td>Singly reinforced</td>
</tr>
<tr>
<td>1.</td>
<td>C1</td>
<td>60</td>
</tr>
<tr>
<td>2.</td>
<td>C2</td>
<td>65</td>
</tr>
<tr>
<td>3.</td>
<td>C3</td>
<td>60</td>
</tr>
<tr>
<td>4.</td>
<td>C4</td>
<td>60</td>
</tr>
</tbody>
</table>

4. Results and Discussion

4.1 Compressive strength

The relative results for compressive strength of concrete between normal concrete, steel fiber reinforced concrete, polypropylene fiber reinforced concrete, and hybrid fiber specimens are shown in Fig. 6.

An assessment of the 7and to 28 days compressive strength outcomes are given. C3 at 7 days there is 41% increase in compressive strength, 60% increase at 14days, 3% decrease at 21 days and 3% increase at 28 days when compared to C1

4.2 Flexural Strength in plain concrete

The relative results for flexural strength of plain concrete beams of normal concrete, steel fiber reinforced concrete, polypropylene fiber reinforced concrete, and hybrid fibers samples are given in Fig. 7.
The assessment of the 7 to 28 days flexural strength of plain concrete outcomes shows,
1. In the concrete C2, 23% and 58% increase in flexural strength after compared to C1.
2. In the concrete C3 16% and 29% increase in flexural strength after compared to C1.
3. In the concrete C4 26% decrease and 17% increase in flexural strength after compared to C1.

4.3 Bending strength with reinforcement bars

Bending strength of concrete beams without reinforcement, singly reinforced and doubly reinforced was listed for reference and comparison. Results of tested beams, with singly and doubly reinforced sections for M30 grade of concrete are given in Fig. 8.

5.2 Flexural Strength of Plain concrete

Flexural strength of plain concrete prisms of C2, 23% and 58% increase, C3, 16% and 29% increase and C4 26% decrease and 17% increase at 7 and 28 days after compared to C1.

The value in bending strength for C2, was 8% more for the plain cement concrete, 41% higher for singly reinforced case and 22% increased, for doubly reinforced concrete beam, C3 was on plain cement concrete, 9% higher for singly reinforced case and 2% decreased, for doubly reinforced concrete beam and C4 was equal to the plain cement concrete, 17% higher for singly reinforced case and 49% increased, for doubly reinforced concrete beam than C1.

References

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