SHPB Experimental Study of Steel Fiber Reinforced Concrete in Low-temperature

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ABSTRACT: Three different content steel fiber reinforced concrete specimen (volume fractions were, 1%, 1.5%, 2.0%) were carried out impact test at -40°C by 74mm split Hopkinson pressure bar (SHPB) test device. The influence of strain rate on steel fiber reinforced concrete in a low temperature environment was analyzed, and affect law of steel fiber content on dynamic strength was probed. The results show that steel fiber addition on the dynamic mechanical properties of concrete has greatly improved and ideal steel fiber content of 1.5%.

1 INTRODUCTION

Steel fiber reinforced concrete, refers to a new type of composite concrete of the diameter of 0.3 ~ 0.6mm, length 20 ~ 40mm short steel fibers, according to a particular direction, or in random directions uniformly mixed concrete. The steel fiber reinforced concrete not only significantly improved tensile, compressive, shear and flexural properties, but also significantly increase the fracture toughness and impact resistance and other properties. It can be predicted steel fiber reinforced concrete will remain an important engineering material. Therefore, the dynamic performance of its low-temperature experimental study is necessary.

2 EXPERIMENTAL MATERIALS AND EQUIPMENTS

2.1 Experimental materials:

Steel fiber is milling steel fiber made in Shandong Lubang Fiber Technology Company, the fiber diameter d = 0.2mm, length l = 10 ~ 15mm.

The PC325 composite portland cement made in Xuzhou Zhonglian Cement Plant is used in the experiment.

Fine aggregate is washed river sand, by measuring its fineness modulus of about 2.6.

Coarse aggregate is washed continuous grain gravel, the maximum size of about 12mm.

Superplasticizer is used with the polycarboxylate superplasticizer made in Shandong Tongsheng Building Materials Co., Ltd.
2.2 Experimental equipments:

Homemade cryostat system. The original SHPB test device has been improved in order to study the temperature effect. Homemade cryostat system can maintain specimens temperature during the test, to achieve the matching with SHPB experimental system, as shown in Figure 1.

![Homemade cryostat device](image1.png)  
**Figure 1. Specimen cooling devices and the SHPB refrigeration system.**

74mm split Hopkinson pressure bar (SHPB) test device, as shown in Figure 2.

![SHPB experimental system](image2.png)  
**Figure 2. The SHPB experimental system.**

Alternating high and low temperature test chamber of model: XT5402TC series is used in the experiment.

Cryostat liquid bath tank of model XT5201 series is used in the experiment.

3 MIX DESIGN AND TEST PROGRAM

3.1 Mix design

In this paper, steel fiber concrete specimen is the use of secondary synthesis method to design. Reference to the relevant data specification. Every increase of 0.5% steel fiber, 1m³ concrete to
increase the water 8 kg, sand rate increased by 3%, and other materials in the same water-cement ratio condition to make a corresponding change. Preparation of steel fiber reinforced concrete has been adjusted combined with the above method. Concrete processed into standard Φ74mm × 34mm cylindrical test pieces, and maintain 28 days in standard curing chamber after specimen pouring molding. The experiments were made three kinds of steel fiber content of concrete specimens, ratio of the specific conditions shown in Table 1.

<table>
<thead>
<tr>
<th>Specimen grouping</th>
<th>Test temperature</th>
<th>Fiber volume fraction</th>
<th>Cement</th>
<th>Fine aggregate</th>
<th>Coarse aggregate</th>
<th>Water</th>
<th>Water Cement ratio</th>
<th>Superplasticizer</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>-40</td>
<td>1.0%</td>
<td>398.04</td>
<td>704.90</td>
<td>1142.10</td>
<td>203</td>
<td>0.51</td>
<td>3.6</td>
</tr>
<tr>
<td>2</td>
<td>-40</td>
<td>1.5%</td>
<td>413.73</td>
<td>726.05</td>
<td>1120.95</td>
<td>211</td>
<td>0.51</td>
<td>3.6</td>
</tr>
<tr>
<td>3</td>
<td>-40</td>
<td>2.0%</td>
<td>429.41</td>
<td>747.83</td>
<td>1099.17</td>
<td>219</td>
<td>0.51</td>
<td>3.6</td>
</tr>
</tbody>
</table>

3.2 Test program

In order to know the influence of strain rate on steel concrete specimens at low temperatures, this experiment has produced steel fiber concrete specimens of three different content (volume fractions were, 1%, 1.5%, 2.0%). For steel fiber specimens of different content, this thesis mainly consider dynamic performance changes in the case of -40 °C.

4 RESULTS AND DISCUSSION

Influence of strain rate on steel fiber reinforced concrete in a low temperature environment. By collating and analyzing data, found the affect law of strain rate on steel fiber reinforced concrete, the stress - strain curve shown in Figure 3.

As can be seen from Figure 3, for steel fiber specimen of different dosage, its dynamic elastic modulus and peak stress increased with strain rate increasing. When the steel fiber content of 1%, the peak stress increased from 62.68MPa to 90.04MPa with strain rate increasing. When the steel fiber content of 1.5%, the peak stress increased from 68.08MPa to 97.98MPa. When the steel fiber content of 2%, the peak stress increased from
73.24 MPa to 101.58 MPa. It reflects its strain rate sensitivity. The variation curve of peak stress with strain rate is shown in Figure 4.

As can be seen from Figure 4, when the strain from 65.05 s\(^{-1}\) to 84.01 s\(^{-1}\), peak stress of steel fiber reinforced concrete occurred the biggest change. It indicates that this range is the most sensitive range of strain rate at -40 °C. Influence of steel fiber content on concrete specimen in a low temperature environment. The peak stress changed with different contents is shown in Figure 5.
As can be seen from Figure 5, with the content of steel fibers increases, the peak stress of steel fiber reinforced concrete and dynamic elastic modulus showed increasing trend. When the steel fiber content from 0% to 1%, the peak stress has been significantly increased and dynamic strength increased by about 20%. This phenomenon indicates that the addition of steel fibers on the dynamic mechanical properties of concrete has greatly improved. When the steel fiber dosage increased to 1.5%, the peak stress at different strain rates were increased to 67.80MPa, 78.43MPa, 85.91MPa, 87.36MPa, 90.37MPa, 96.82MPa, at this time, adding steel fibers, respectively, dynamic strength of concrete increased 20.70%, 19.52%, 18.96%, 17.04%, 22.01%, 30.59%. Continue to improve the steel fiber dosage to 2.0%, the dynamic strength of steel fiber reinforced concrete has been enhanced though, but it did not increase greatly. It indicates the enhancement in addition to dep-ending on fiber volume fraction, but also depends on interfacial adhesion coefficient between steel fiber and concrete matrix. Therefore, for general engineering,
combined with economic considerations, 1.5% dosage of steel fiber reinforced concrete can be choose as the best content.

5 CONCLUSION

Steel fiber reinforced concrete is a kind of strain rate sensitive material at -40 °C. For steel fiber specimen of each dosage, its dynamic elastic modulus and peak stress are increasing with strain rates increase. When the strain from 65.05 s\(^{-1}\) ~ 84.01 s\(^{-1}\), peak stress of steel fiber reinforced concrete occur the biggest change. This range is the most sensitive range of strain rate at -40 °C.

With the increase of steel fiber, its peak stress and dynamic elastic modulus of steel fiber reinforced concrete increased. The dynamic mechanical properties of concrete has greatly improved with adding steel fiber. However, excessive increased of steel fiber content, not reinforced concrete obviously, the ideal content of steel fiber as 1.5%.

REFERENCES

