A Study on Properties of SBR Latex Modified Polypropylene Fibre Reinforced Concrete

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Abstract

This paper investigates the effect of latex modified systems and combination of latex and polypropylene fibre on the performance of concrete. In this study, the polypropylene fibre volume fraction and the amount of added latex, are varied and compressive strength, splitting tensile strength, flexural strength, impact resistance, abrasion resistance, and water absorption are measured. Increasing the volume fraction of the fibre and amount of added latex increases the flexural strength, splitting tensile strength, impact resistance, and abrasion resistance. As an application of this work, paving blocks of size 200 × 100 × 60 mm were casted and tested.

Keywords: Abrasion Resistance, Compressive Strength, Flexural Strength, Impact Resistance, Paving Blocks, Polypropylene Fibre, SBR Latex, Split Tensile Strength

I. INTRODUCTION

Concrete has high compressive strength but is relatively weak in tension and adhesion, and its porosity can lead to physical and chemical deterioration. Polymers, on the other hand, are weaker in compression but can have higher tensile capacities, and provide good adhesion to other materials as well as resistance to physical (i.e., abrasion, erosion, impact) and chemical attack. Combinations of these two materials can exploit the useful properties of both and yield composites with excellent strength and durability properties. Polymer-modified concrete (PMC) has been a popular construction material due to its excellent properties in comparison with ordinary concrete. Polymers are used in producing PMC in order to improve its workability, strength, and durability and reduces drying shrinkage. Polymeric admixtures are defined as polymers used as a main ingredient effective at modifying or improving cement-based material properties [7].

Latex addition to the concrete mix has been explored as a way to use high early-strength concrete in pavement formulations because of the ability of latex to improve the concrete’s permeability resistance [6]. Fiber reinforced concrete (FRC) is concrete that contains or is reinforced with dispersed, randomly oriented, unconnected fibers. Concrete is intrinsically brittle, but such brittleness is rectified if it is reinforced with fibers within its structure; its ductility is improved by the suppression of crack growth by the reinforcing fibers. Pavement made from fiber-reinforced precast concrete has a high resistance to cracking and to fracturing that can occur during transportation and installation. Adding latex improves the fluidity of the concrete mix, even at low water-to-cement ratios. This is because of interactions of cement materials with the surfactant present in the latex [8].

II. EXPERIMENTAL PROGRAMME

A. Materials Used

The materials used in the preparation of latex modified fibre reinforced concrete mixes are:

1) Cement: 53 Grade Ordinary Portland cement conforming to IS 12269 was used in this study.
2) Fine Aggregate: Manufacturer's sand has been used for the present investigation. It conforms to Zone II with a specific gravity of 2.75.
3) Coarse Aggregates: Coarse aggregates of 20 mm and 12 mm sizes were used in 60: 40 ratio. The specific gravity was 2.77.
4) Water: Potable clean drinking water available in the water supply system conforming to the requirements of water for concreting and curing as per IS : 456-2009 was used.
5) Superplasticizer: The superplasticizer used in this work was Master Glenium Sky 8233.
6) SBR Latex: Escobond SBR 651 is used as a polymer containing 52 % solids and 48 % water. Milky white pourable liquid. The specific gravity was 1.023.
7) Polypropylene Fibre: Fibres of length 12 mm and of specific gravity 0.92 was used.

### B. Mix Proportions

Concrete mix of strength M 30 has been designed and modified with varying percentages of latex (5, 10, and 15%) and fibre (0.2, 0.25 and 0.3%) by weight of cement. There were two basic mixes; latex modified concrete (LMC) and latex modified fibre reinforced concrete (LMPFC). The control mix in this research is designated as 'CM'. Mix proportioning specifications are detailed in Table 1.

<table>
<thead>
<tr>
<th>Mix Designation</th>
<th>SBR latex (%)</th>
<th>PP Fibre (%)</th>
<th>Cement (kg)</th>
<th>Fine Aggregate (kg)</th>
<th>Coarse Aggregate (kg)</th>
<th>Water (l)</th>
<th>Super plasticizer (ml)</th>
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<tbody>
<tr>
<td>CM</td>
<td>0</td>
<td>0</td>
<td>407</td>
<td>661</td>
<td>1214</td>
<td>154</td>
<td>1476</td>
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<tr>
<td>LMC 5</td>
<td>5</td>
<td>0</td>
<td>407</td>
<td>661</td>
<td>1198</td>
<td>154</td>
<td>1476</td>
</tr>
<tr>
<td>LMPFC 5</td>
<td>5</td>
<td>0.2</td>
<td>407</td>
<td>661</td>
<td>1198</td>
<td>154</td>
<td>1476</td>
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<tr>
<td>LMC 10</td>
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<td>0</td>
<td>407</td>
<td>671</td>
<td>1215</td>
<td>135</td>
<td>1476</td>
</tr>
<tr>
<td>LMPFC 10</td>
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<td>671</td>
<td>1215</td>
<td>135</td>
<td>1476</td>
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<tr>
<td>LMC 15</td>
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<td>0</td>
<td>407</td>
<td>707</td>
<td>1212</td>
<td>116</td>
<td>1476</td>
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<tr>
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<td>0.3</td>
<td>407</td>
<td>707</td>
<td>1212</td>
<td>116</td>
<td>1476</td>
</tr>
</tbody>
</table>

### C. Testing Program

In this experimental study, following properties of concrete were tested as per relevant standards.

1) Compressive Strength Test: This test was conducted on cube of 150 mm as per IS 516:1959.
2) Split Tensile Strength Test: It was conducted on cylinders of 150 mm diameter and 300 mm height. The test was done as per IS 5816: 1999.
3) Flexural Strength Test: Flexural test was conducted as per IS 516:1959. The test was conducted on beams of size 100 mm×100 mm×500 mm.
4) Abrasion Resistance: This test was conducted as per IS 1237: 2012. The test specimens shall be square in shape and size 7.06 cm×7.06 cm.
5) Impact Resistance: As the work previously conducted by Ahmed Tareq Noaman, the fabricated rig, Fig.1, was used to conduct the Impact test. In this test, beams of 100 mm×100 mm×500 mm size and were casted with a centre to centre span of 400 mm. A hammer of 5.1 kg was dropped from a height of 0.17 m. The impact energy IE can be determined at any number of blows (N) by using (1).

\[ IE = NMgH \]  

Where,

- N - Number of blows until failure
- M - Mass of hammer (5.1 kg)
- H - Height from which the hammer falls (0.17 m)
- g - Acceleration due to gravity (9.81 m/sec²)

### III. RESULTS AND DISCUSSIONS

#### A. Compressive Strength

The results obtained for cube compressive strengths for the different mixes at 28 day are shown in Fig.2. Fig. 2 shows the compressive strength test results for LMPFC containing varying amounts of added latex and polypropylene fibre. For plain
concrete, as the latex content increased from 5 to 10 and 15% the compressive strength steadily decreased from 43.3 to 39.2 and 36.2 MPa. At a polypropylene fraction increased from 5 to 10 and 15% compressive strength decreased from 38.6 to 36.2 and 32.1 MPa. The compressive strength of control mix at the age of 28 day obtained as 39.8 MPa.

B. Split Tensile Strength

Results obtained are reported in Fig.3. The results showed a considerable increase in the split tensile strength with the increase in the latex content and fibre content. This may be due to the latex film interfering with the hydration reaction. The split tensile strength of control specimen obtained is 2.85 MPa. The mix containing 15% latex content and 0.3% PP fibre content together contributes the highest value of splitting tensile strength.

C. Flexural Strength

The effects of varying latex percentage and fibre content are illustrated in Fig.4. The flexural strength of control mix is obtained as 5.3 MPa. For plain concrete, as the latex level increased from 0 to 5, 10, and 15% the flexural strength steadily increased from 5.3 to 5.4, 5.8, and 6.8. As the fibre content increased from 0.2 to 0.25, and 0.3% along with increase in latex content from 5 to 10 and 15% the flexural strength increased from 5.6 to 6.4 and 7.4. The latex film enhances the bond strength between materials when concrete is subjected to flexural or tensile loading. The flexural strength increased as more latex is added, and flexural strength also increased as polypropylene fibre fraction is increased. Fibre reinforced concrete has improved flexural strength because the generation and growth of cracks are suppressed during flexural loading. All of the mixes with co-addition of latex and fibre exceeded the target flexural strength 3.83 MPa.
D. Abrasion Resistance

Fig. 5 shows the abrasion resistance test results for LMPFC. The depth of abrasion was 3.18 mm for the control mix. And for the mix with 15% latex and 0.3% polypropylene fibre the wear was only 1.31 mm. This property is improved with the amount of added latex. This behaviour is due to coating of the concrete surface by the latex film, thereby strengthening the abrasion resistance of the surface. The test results also indicate that the abrasion resistance increased with the polypropylene fibre volume fraction. Latex addition improves fibre dispersion and can suppress surface wear by improving the bridging action of the reinforcing fibre through the formation of a latex film. Co-addition of latex and polypropylene was more effective at improving the wear resistance than using latex or polypropylene fibre alone.

E. Impact Resistance

Fig. 6 summarizes the impact resistance test results of the LMC and LMPFC mixes. The number of impacts required for ultimate failure increased with the amount of added latex. This is because the latex film improved the bond strengths between the materials and limited the crack formation and propagation resulting from impacts. The number of impacts required for the final breaking also increased with the polypropylene fibre fraction. Mixes containing both latex and polypropylene required more impacts to generate the fracture than the mixes made with only latex or polypropylene fibre.
IV. CONCLUSIONS

In this study, the PP fibre volume fraction (0.2, 0.25 and 0.3%) and the amount of added latex (0, 5, 10 and 15%) were varied for LMPFC. Based on the experimental results, the following conclusions can be drawn:

- Compressive strength decreased with increasing latex content and fibre content. The addition of PP fibre does not have effect on compressive strength.
- The splitting tensile strength increased with increasing latex content and fibre content.
- Flexural strength increased with the latex content and amount of polypropylene fibre content. Concurrent addition of latex and fibre was more effective at improving the flexural strength than the addition of either material individually. This is because the addition of latex improved the bonding between materials through the formation of a latex film.
- Abrasion resistance increased with increasing latex content and fibre content. LMPFC showed a minimum loss in thickness of the specimen.
- The impact energy increases with increase in latex content and fibre content.
- Latex Modified Polypropylene Fibre Reinforced Concrete with latex content of 15% and fibre content of 0.3% showed improved abrasion and impact resistance combined with adequate compressive strength, split tensile strength and flexural strength.

From the results, paving blocks were casted for the optimum percentage of latex and PP fibre. Optimum percentage of latex was 15% and of fibre was 0.35. Paving blocks of size 200 x 100 x 60 mm were casted as per IS 15658: 2006. As per IS 15658, blocks of grade M 30 are under non-traffic category and it can be used in building premises, monument premises, paths and patios and embankment slopes etc.

The 28 day compressive strength obtained for paving blocks is given in Table 2 which satisfies the specified compressive strength of paving blocks as per IS 15658.
Table 2

<table>
<thead>
<tr>
<th>Specimen Designation</th>
<th>28th day Compressive strength (MPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CM</td>
<td>31.5</td>
</tr>
<tr>
<td>LMC</td>
<td>33</td>
</tr>
<tr>
<td>LMPFC</td>
<td>30.25</td>
</tr>
</tbody>
</table>

ACKNOWLEDGEMENT

It is my privilege to express sincere thanks to my project guide, Prof. Shibi Varghese, Department of Civil Engineering, MACE for his valuable guidance and encouragement throughout my humble endeavour. Finally, I would like to express my gratitude to all my friends and classmates for their help.

REFERENCES