Effect of Glass Fibers In Rigid Pavement

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ABSTRACT
The present work shows the influence of glass fibers on the mechanical properties of the M20 grade concrete. Glass fibers of 0.1%, 0.2%, and 0.3% by weight of cement are added to the mix. From the results it is observed that the addition of alkaline resistant fibers improved the tensile and flexural strengths significantly. Compressive strength is marginally improved compared to the tensile and flexural strengths. It is found that 0.2% fibers by weight of cement is the optimum dosage. Using the flexural strength values at 0.2% fiber content, pavement thickness is evaluated as per IRC : 58, it is observed that there is a reduction in the pavement thickness by 25.8%.

Keywords- Alkali resistant glass fiber, compressive strength, tensile strength, flexural strength, pavement thickness.

INTRODUCTION
Road transportation is undoubtedly the life line of the nation and its development is a crucial concern. The traditional bituminous pavements and their needs for continuous maintenance and rehabilitation operations points towards the scope for cement concrete pavements. There are several advantages of cement concrete pavements over bituminous pavements. The present study emphasizes on Fiber Reinforced Concrete Pavements, which is a recent advancement in the field of reinforced concrete pavement design.

More recently micro fibers, such as those used in traditional composite materials have been introduced into the concrete mixture to increase its toughness, or ability to resist crack growth. FRC is Portland cement concrete reinforced with more or less randomly distributed fibers. In FRC, thousands of small fibers are dispersed and distributed randomly in the concrete during mixing, and thus improve concrete properties in all directions. The plain concrete structure cracks into two pieces when the structure is subjected to the peak tensile load and cannot withstand further load or deformation. Different types of fibres are available in the market for reinforcing concrete and they are: steel, glass, acrylic, aramid, carbon, nylon, polyester,
polyethylene, polypropylene, etc. Besides, natural fibres like sisal, wood cellulose, banana, jute, etc., have also been used. From the above mentioned fibres, glass fibre is more advantageous on the basis of strength and crack resisting characteristics.

Alkali resistant (AR) glass fibers are having higher tensile strength three times higher than steel and high young’s modulus over 10 times that of polypropylene and three times that of cured concrete. These properties combine to provide effective control of cracking caused by plastic shrinkage and restrained drying shrinkage. AR glass fibers will either prevent cracks from forming or will alter the cracking pattern from a few large, wide cracks to many smaller, fine cracks. Both these effects will improve concrete durability by reducing water permeability and absorption and reducing the depth of carbonation. Glass fibres improve the toughness as force required for deformation will be higher and more energy is needed for propagation of cracks. Previous researchers used glass fibers for improving mechanical properties of the concrete as well as for improving the fire resistance of the concrete. Pshtiwan N Shakor, et.al; [1] studied use of glass fiber reinforced concrete in construction. In this study trail test for concrete with glass fiber and without glass fiber are conducted to indicate differences in compressive strength and flexural strength by using cubes of varying sizes. The experimental test results indicate that the GFRC is a tremendous alternative construction material. Yogesh Iyer Murthy, et.al; [2] studied performance of glass fiber reinforced concrete. In his investigation the compressive strength, flexural strength and workability of concrete containing varying proportions of glass fiber as replacement of fine aggregate is studied. The increase in compressive strength is nominal while the flexural strength increased significantly as expected with the increase in percentage of glass fiber. Also significant reduction in slump value is observed with increase in glass fiber content. C.Selin ravi kumar, et.al; [3] investigated strength and fire resistant properties of glass fiber reinforced concrete. Glass fiber has higher the advantage of having higher tensile strength and fire resisting properties, thus reducing the loss of damage during fire accident of concrete structures. In this investigation glass fibers of 450mm length are added to the concrete by volume fraction of up to 1% to determine its strength and fire resistant characteristics. Experiment studies shows increase in compressive split tensile and flexural strength of concrete by increasing percentage of fiber. Avinash Gornale, et.al;[4] investigated strength aspects of glass fiber reinforced concrete. In his investigation he used glass fibers of 0.03% in M_{20}, M_{30} and M_{40} Grade concrete. It has been also observed that there is gradual increase in early strength for compression and flexural strength of glass fiber reinforced concrete as compared to plain concrete. There is sudden increase in ultimate strength for Split tensile strength of Glass Fiber Reinforced Concrete as compared to Plain Concrete. V.M. Southranjan, et.al; [5] studied reinforcing efficiency of glass fibers in low volume class F fly ash concrete. This study reports the reinforcing efficiency of glass fiber addition in the low volume fly ash concrete up to 25% cement replacement level. The experimental test results showed that 25% fly ash with 0.3% glass fibers addition in concrete provided highest compressive strength up to 51.45MPa at 28 days and a flexural strength of 5.15 MPa. Further tests on ultrasonic pulse velocity exhibited the quality of
various concrete mixes and conform to the standard requirement for a high quality concrete. K.Vijai, et.al; [6] studied the properties of glass fiber reinforced geopolymer concrete composites. He studied the effect of inclusion of glass fibers on the density, compressive strength, split tensile strength and flexural strength. Glass fibers were added to the mix in volume fractions of 0.01%, 0.02% and 0.03% by volume of concrete. Based on the test results, empirical expressions were developed to predict split tensile strength and flexural strength of glass fiber reinforced GPCC in terms of its compressive strength. Chandra mouli. K, et.al; [7] studied the rapid chloride permeability test for durability studies on glass fibre reinforced concrete. In his investigation cylinders of 100mm x 150mm of M20 grade concrete were casted with varying percentage of addition of 0.03%, 0.06% and 0.1% of glass fibre. The rapid chloride permeability tests were conducted for a period of 90, 180, 365 and 720 days. The test results show that the addition of glass fibres exhibit better performance. Huijan wu, et.al; [8] carried out a Study on Micro-Structure and Durability of Fiber Concrete. By this study author validated that glass fibers improve the strength of the concrete and impermeability of the concrete increases as the fiber content increases.

2. MATERIAL AND MIX PROPORTION

2.1 Materials

Ordinary Portland Cement (OPC) of grade 53 conforming to IS:12269 was used for the studies. Locally available quartzite aggregate with a maximum size of aggregate of 20mm down size, and sand were used as coarse aggregate and fine aggregate respectively. The polyester fibers of 8 mm length and diameter of 0.045 mm which was produced from Reliance industries Ltd., Mumbai are used in the present study. A water reducing admixture, Rheobuild 920kk is used in concrete. Its density and pH are 1.19 and >6 respectively.

2.2 Mix Proportion

All the mixes prepared are corresponds to M-20 grade. For the design of mix IS: 10262-2009 recommendations are adopted. Design mix proportions of M-20 grade are given in the following table.

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>Weight (kg/m³)</th>
<th>Water (lit)</th>
<th>Fine aggregate (kg/m³)</th>
<th>Coarse aggregate (kg/m³)</th>
<th>Chemical admixture (kg/m³)</th>
<th>Water cement Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cement</td>
<td>300</td>
<td>150</td>
<td>737.23</td>
<td>1248</td>
<td>2.17</td>
<td>0.55</td>
</tr>
</tbody>
</table>

EXPERIMENTAL PROCEDURES AND TESTS CONDUCTED

3.1 Test specimen and testing procedures

For compressive strength test, cube specimens of dimensions 150 x 150 x 150 mm were casted. The moulds were prepared with 0%, 0.1%, 0.2%, and 0.3% and glass fibers. The samples were tested for their
compressive strength at 3, 7 and 28 days. Cubes were tested on compression testing machine as per I.S. 516-1959. In each category three cubes were tested and their average value is reported. To determine the Split tensile strength, cylinder specimens of dimension 150 mm diameter and 300 mm length were casted. These specimens were tested under compression testing machine as per I.S. 5816:1999. For flexural strength test beam specimens of dimension 100x100x500 mm were casted. These flexural strength specimens were tested under four point loading as per I.S. 516-1959, using universal testing machine.

FIG-1: Compressive strength test  FIG-2: Split tensile strength

FIG-3: Flexural strength test

4. EXPERIMENTAL RESULTS

4.1 Workability: Slump cone test was performed to determine the slump of the mixes. The slump values for various mixes are shown in figure.4. It is evident from the figure.4 that as the percentage of fiber content increases slump values are decreasing. The reduction in the slump with the increase in the fiber will be attributed to presence of fibers which causes obstruction to the free flow of concrete.

FIG-4: Workability of mixes
Compressive strength

The compressive strength values of the cube specimens at the age of 3, 7 and 28 days are as shown in figure.5.

![Compressive strength values of C.C and GFRC at 3, 7 and 28 days](image)

From the above fig. it is observed that the compressive strength of concrete is increasing with the increase in fiber content compared to conventional concrete at 3, 7 and 28 days. It is observed that at 0.2% of fiber in the weight of cement, maximum strength was attained and later with increase in fiber content strengths are falling down. The increment in the compressive strength at 0.2% fiber content is 28.78%, 28.27% and 20.4% at the age of 3, 7 and 28 days respectively.

4.3 Split tensile strength

The test cylinders were tested for their tensile strength values at the age of 3, 7 and 28 days as shown in figure.6.

![Split Tensile strength values of C.C and PFRC at 3, 7 and 28 days](image)
From the above graph it is observed that tensile strength of P.F.R.C mixes is increasing significantly when it is compared with conventional concrete at 3, 7 and 28 days. It is found that 0.3% addition of glass fibers in the weight of cement is the optimum dosage. For this optimum dosage the increment in the tensile strength of the fiber concrete is 88.29%, 45.63% and 43.77% at the age of 3, 7 and 28 days respectively.

4.4 Flexural strength

The prism specimens were tested for their flexural strength using UTM, the results were shown in fig.7

![Fig-7: Flexural Strength values of C.C and GFRC at 3, 7 and 28 days](image)

From the above fig. it is observed that the flexural strength of concrete is increasing drastically with the increase in fiber content compared to conventional concrete at 3, 7 and 28 days. It is observed that at 0.3% of fiber dosage in the weight of cement, maximum strength is obtained and later strengths are reduced, although the fiber content is increased. This is evident from the figure.7 at 0.3% fiber content. The increment in the flexural strength at 0.2% fiber content is 93.71%, 68.99% and 53.96% at the age of 3, 7 and 28 days respectively.

**DESIGN OF SLAB THICKNESS**

Pavement slab is designed as per IRC 58:2002. The flexural strength is directly taken from the beam flexural test. The axial load spectrum is taken from IRC: 58-2002 and other data used in this design is given below. A cement concrete pavement is to be designed for a two lane two-way National Highway. The total two-way traffic is 3000 commercial vehicles per day at the end of the construction period. The design parameters are:
Effective modulus of subgrade reaction of the DLC sub-base = 8 kg/cm³
Elastic modulus of concrete = 3×10⁵ kg/cm²
Poisson’s ratio = 0.15
Coefficient of thermal expansion of concrete = 10×10⁻⁶/°C
Tyre pressure = 8 kg/cm²
Rate of traffic increase = 0.075
Spacing of contraction joints = 4.5 m
Width of slab = 3.5 m
Design life = 20 years
Present traffic = 3000 cvpd

By considering the above parameters the thickness of the pavement is calculated by taking flexural strength of conventional concrete and as well as glass fiber reinforced concrete at 0.2% fiber content. From the results slab thickness, fatigue life consumed and corner stresses are given in following table.

<table>
<thead>
<tr>
<th>Grade of concrete (M20)</th>
<th>Flexural strength (kg/cm²)</th>
<th>Slab thickness</th>
<th>Fatigue life consumed</th>
<th>Corner stress (kg/cm³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>C.C</td>
<td>46.7</td>
<td>31</td>
<td>0.98</td>
<td>17.17</td>
</tr>
<tr>
<td>G.F.R.C</td>
<td>71.9</td>
<td>23</td>
<td>0.95</td>
<td>28.66</td>
</tr>
</tbody>
</table>

5. CONCLUSIONS

Compressive Strength enhancement ranges from 12.2% to 20.4% when % of fiber increases from 0.1% to 0.2% for GFRC when compared to the conventional concrete at 28 days.

As the fiber content is increased from 0.1% to 0.2% in weight of cement there is an increase in the split tensile strength from 17.05 to 43.77% compared to the conventional concrete at 28 days.

At the age of 28 days, there is a significant improvement in the flexural strength with the addition of fibers. The increment in the flexural strength is from 19.48% to 53.96% when % of fibers varied from 0.1% to 0.2% respectively. 0.2% is observed as the optimum value.

Addition of glass fiber in concrete, the pavement thickness is decreased by 25.8% and which is economical when compared to plain cement concrete.
REFERENCES


