BEHAVIOUR OF RETROFITTED RCC BEAMS USING SISAL FIBRES

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ABSTRACT

There is a pressing need to repairs and upgrade the building and civil infrastructure in many parts of the world in order to meet the current code requirements. The need for efficient strengthening and up-gradation of existing structures has resulted in research and development of composite strengthening systems. Fibre reinforced polymer (FRP) composite has been accepted in the construction industry as a promising substitute for repairing and incrementing the strength of structures. Though the FRP technique enhances the strength, stiffness, it is proved to be costlier. Here an effort has been made replace the costlier artificial fibres by naturally available, renewable, cheaper natural fibre for retrofitting of RC beams. In this work, research was carried out to study the flexural behavior of RC beams retrofitted with Sisal Fibre Reinforced Polymer Composites sheets. For this the beams were retrofitted with NSFRP sheets at the flexural zone. The results obtained were then compared with the control beams. The conclusions were drawn based on the ultimate load carrying capacity of the beams, deflection obtained and the stiffness of the beams based on the load deflection curves. Improvement in the load carrying capacity and deformation capacity of retrofitted RC beams over control beams were observed.

Key Words: Fibre reinforced polymer, Polymer Composites sheets, NSFRP (Natural Sisal Fibre Reinforced Polymer)

1. INTRODUCTION.

Retrofitting of flexural concrete elements is traditionally accomplished by externally bonding steel plates to concrete. Although this technique has proved to be effective in increasing strength and stiffness of reinforced concrete elements, it has the disadvantages of being susceptible to corrosion and difficult to install. In the last decade, the development of strong epoxy glue has led to a technique which has great potential in the field of upgrading structures. Basically the technique involves gluing steel plates or fibre reinforced polymer (FRP) plates to the surface of the concrete. The plates then act compositely with the concrete and help to carry the loads. Also recent development in the field of composite materials, together with their inherent properties, which include high specific tensile strength good fatigue and corrosion resistance and ease of use, make them an attractive alternative to any other retrofitting technique in the field of repair and strengthening of concrete elements.
FRP can be convenient compared to steel for a number of reasons. These materials have higher ultimate strength and lower density than steel. The installation is easier and temporary support until the adhesive gains its strength is not required due to the low weight. They can be formed on site into complicated shapes and can also be easily cut to length on site. Carbon Fiber Composites are the most frequently used system in previous research and retrofitting field applications. This material has superior properties which include very high tensile strength accompanied with a reasonable modulus of elasticity (almost equals that of steel). On the other hand, the Glass Fiber Composites (GFC) are comparatively cheap and have high tensile strength but with relatively low modulus of elasticity (about one-third that of carbon and reinforcing steel is also another sought after retrofitting material.

It is to be kept in mind that the materials chosen for structural up-gradation must, in addition to functional efficiency and increasing or improving the various properties of the structures, fulfil some criterion, for the cause of sustainability and a better quality. For example, these materials should not pollute the environment and endanger bio-reserves, should be such that they are self sustaining and promote self-reliance, should help in recycling of polluting waste into usable materials, should make use of locally available materials, utilize local skills, manpower and management systems, should benefit local economy by being income generating, should be accessible to the ordinary people and be low in monetary cost.

In recent years, natural fibers have emerged as a promising alternative retrofit solution. Among the various natural fibres sisal fibre reinforced composite is of particular interest as these composites have high impact strength besides having moderate tensile and flexural properties compared to other lingo-cellulosic fibres. Hence encouragement should be given for the use of natural fibres which are locally available materials, in the field of structural retrofitting.

2. EXPERIMENTAL PROGRAMME

The experimental program consists of following steps:

a) Casting of Sisal fibre composites.
b) Elongation test on Sisal Fibre composites.
c) Retrofitting of beams with Sisal fiber composites.
d) Static tests on controlled and retrofitted beams.
e) Evaluation of the performance of the retrofitted beams.
f) Cracking pattern.

a. Casting of Sisal fibre composites:

Since Sisal fibre reinforced polymer composite is not readily available in the market, it has to be cast on our own according to the requirements. In addition, the natural fibre has properties like low cost, lightweight, high specific strength, and free from health hazard, the presence of hydroxyl and other polar groups in the natural fibers would lead to the weak interfacial bonding between fibers and the hydrophobic polymers. One of the most important factors for obtaining good fiber reinforcement in the composite is the bonding strength between natural fiber and polymer matrix. Due to the presence of pendant hydroxyl and polar groups in various constituents of fiber, moisture absorption of fiber is considerably high, which leads to poor interfacial bonding with the hydrophobic matrix polymers. The hydrophilic natural fibers absorb a large amount of water in the composite leading to failure by delamination. Adequate adhesion across the interface can be achieved at desirable levels by better wetting and
chemical bonding between fiber and matrix. To make good use of bio-fiber reinforcement in composites, fiber surface treatment must be carried out to obtain an enhanced interface between the hydrophilic sisal fiber and the hydrophobic polymer matrices. Such treatments will decrease the moisture absorption and hydrophilic character of fibers. Surface modification is therefore necessary to obtain better performance of the resulting composites.

b. Elongation test on Sisal Fibre composites:

For determining the ultimate tensile strength and percentage elongation of Sisal fiber reinforced polymer composites, the specimens were tested in universal testing machine. Two samples were tested. The composite plates were casted in dimension (290 x 65 x 10)mm for elongation test. The gauge length of the specimen was 230mm and elongation were measured using dial gauge of range 0.001-10mm. Specimens were tested in universal testing machine as shown in Fig.

![Elongation test setup for NCFRP Plate](image)

**Table 1: Tabulated summary of results obtained from elongation test**

<table>
<thead>
<tr>
<th>Specimen type</th>
<th>Gauge length of specimen (mm)</th>
<th>Final elongation of the specimen (mm)</th>
<th>Percentage of elongation (%)</th>
<th>Ultimate load</th>
<th>Ultimate tensile strength</th>
<th>Average tensile strength</th>
<th>Young's modulus</th>
</tr>
</thead>
<tbody>
<tr>
<td>NSFRP</td>
<td>230</td>
<td>12.8</td>
<td>5.5652</td>
<td>3198.06</td>
<td>4.9201</td>
<td>4.7971</td>
<td>96.67</td>
</tr>
<tr>
<td></td>
<td>230</td>
<td>12.46</td>
<td>5.4174</td>
<td>3038.15</td>
<td>4.6741</td>
<td>4.7971</td>
<td>90.625</td>
</tr>
</tbody>
</table>

c. Retrofitting of beams with Sisal fiber composites:

After curing of beam for 28 days they were wrapped with NSFRP composite sheets for flexure zone. Wrapping was executed by hand lay-up method and later these beams were cured for 7 days. Before wrapping of composites the beam surface
finished to remove dust and debris. Then epoxy primer was applied to the surface, it has two components such as base and hardener. Base and hardener were mixed thoroughly before application. A thin layer of epoxy primer was applied on the concrete surface using a paint brush. After the epoxy primer was applied on the concrete surface was cured for 24 hours before the fibre sheets were installed.

The FRP application includes the resin system made of two parts namely the resin and the fibre sheets. The components of the resin system i.e hardener and base were thoroughly hand mixed for at least 5min. The concrete surface was cleaned and completely dried before the resin is applied. A first coat of thin layer of resin was applied and the NSFRP fabric, pre-cut to the desired dimensions was then wrapped directly on the surface. Special attention was taken to ensure that there was no void between the NSFRP sheet and concrete surface. After the application of the wrap of the NSFRP sheet, a second layer of resin was applied on the surface to allow impregnation. Adequate pressure was applied until the resin was squeezed out between the sheets and surface. The wrapped specimens were then left at room temperature to allow air curing for 7 days to allow bonding of the laminates as suggested by the manufacturer.

d. **Static tests on controlled and retrofitted beams:**

![Image](image-url)
All beams were tested under uniformly distributed load. Each beam was placed on the loading frame in such way that, the centre of the beam and the centre of the loading frame were adjusted and aligned as a line. The effective span of the beam was 1300mm; the load was distributed uniformly by means of mild steel roller placed on the beam throughout the effective span of the beam, above the roller mild steel I-section was placed for the distribution of load equally on the rollers. The hydraulic jack placed on the I-section and proving ring was placed on the hydraulic jack. I-section, proving ring and jack were tied to the frame using rope.

Dial gauge was placed below the centre of the specimen before loading is applied. Initial reading of the dial gauge was set to zero.

The load is applied with increment of 3.34kN at a time. Dial gauge readings were taken for each increment of the load. The cracks were marked by using marker; the initial crack load and maximum load (ultimate failure) were noted down.

The load was released slowly. The beam comes to normal position for some extent the cracks were marked with the marker pen and the photographs of each specimen were taken. Also the complete crack patterns and the failure load were recorded in each test.

e. Evaluation of the performance of the retrofitted beams:

The deflection near centre of the beam is a measure of the stiffness of the beam. Smaller the deflection, larger is the stiffness of the beam. Mid span deflection is been taken into consideration in this work and the same has been presented. Load versus deflection curves for mid span deflections are obtained from the experimental work has been presented.

In any structural design the two important criteria that are of concern is the limits state of serviceability and the limit state of collapse. Up to the service load, the deformation plays an important role while studying the behavior of structures. Beyond the service load, the limit state of collapse is considered. The load-deflection of the structures is generally drawn up to the cracking load. The final failure gives an indication of the overall strength of structures.

![Fig 5: Load v/s deflection curves for CB, NSFRP retrofitted beam](image-url)
From the comparison graph shown in the fig 6, it is clear that all the specimens strengthened using NSFRP sheets are much stiffer than the control beam.

It can be clearly made out from the above bar chart that the set of NSFRP retrofitted beams have given higher failure loads than the control beam.

Table 2 : Tabulated summary of results obtained from experimental investigation

<table>
<thead>
<tr>
<th></th>
<th>Series</th>
<th>Type</th>
<th>First crack load (kN)</th>
<th>Ultimate load (kN)</th>
<th>Average ultimate load (kN)</th>
<th>(%) of Strength Increase</th>
<th>Mode of Failure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control beams</td>
<td>CB-1</td>
<td></td>
<td>26.72</td>
<td>78.6</td>
<td></td>
<td></td>
<td>flexure</td>
</tr>
<tr>
<td></td>
<td>CB-2</td>
<td></td>
<td>30.06</td>
<td>80</td>
<td></td>
<td></td>
<td>flexure</td>
</tr>
<tr>
<td></td>
<td>CB-3</td>
<td></td>
<td>26.72</td>
<td>75</td>
<td></td>
<td></td>
<td>support crushing</td>
</tr>
<tr>
<td>Retrofitted beams</td>
<td>NSFRP-1</td>
<td></td>
<td>33.4</td>
<td>121</td>
<td></td>
<td></td>
<td>shear</td>
</tr>
<tr>
<td></td>
<td>NSFRP-2</td>
<td></td>
<td>40.08</td>
<td>122.5</td>
<td></td>
<td>57.7</td>
<td>shear</td>
</tr>
<tr>
<td></td>
<td>NSFRP-3</td>
<td></td>
<td>40.08</td>
<td>125</td>
<td></td>
<td></td>
<td>flexure</td>
</tr>
</tbody>
</table>

f. Cracking pattern

From the experimental investigation it was noticed that all the control beams failed by flexure failure, but in NSFRP beams cracks were observed beyond the retrofitted area (flexural zone). The flexural strengthening provided was too high which made the
beams too very strong and stiff, because most of the NSFRP beams could not fail by flexure so it failed by shear.

3. CONCLUSIONS

From the test results obtained from the experimental work of both retrofitted NSFRP control beams are compared and the following conclusions are obtained.

a) Retrofitted by NSFRP composite beams have carried more ultimate load by about 62.88% compared to that of control beam specimens.

b) The load v/s deflection curves reveals that the stiffness of retrofitted beams with NSFRP composite is increased by 8.08% compared to that of control beams.

c) The ultimate load carrying capacity was found to be high for beams retrofitted with NSFRP composites as compared to control beam.

d) The flexural strengthening provided was high, which made the beams strong and stiff, because of which most of the beams could not fail by flexure so the failed by shear.

4. REFERENCES


3. Amit Rai¹ and C.N. Jha² (2010), “Natural fibre composites and its potential as building material”.


