Mechanical Properties of Hybrid Fibre Reinforced Concrete with FRP Wrappings of 900 GSM
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¹,²,³Visvesvaraya Technological University

Abstract— In this experimental investigation Galvanized Iron fibers and steel fibers were incorporated into concrete forming 1% of total volume of concrete. Glass fiber reinforced polymer was wrapped around specimens and various strength tests for compression, shear, flexure and tension resistance has been performed. It was observed that all the properties evaluated showed significant improvement in comparison to ordinary concrete specimens.

Key words: Steel Fibers, Galvanized Iron Fibers, Glass Fiber Reinforced Polymer, Fiber Reinforced Polymer Wrappings, Epoxy

I. INTRODUCTION

A. General

In development industry and different structural building ventures concrete is a noteworthy and bounteously utilized development material as a part of the world. In no time India has taken significant activities to create different frameworks, for example, streets, spans, burrows and so on. To meet the different necessities of developing populace making cement to be used in a substantial quantum.

Because of broad use of cement, there is a steady inclination to enhance the natural properties of concrete. Being exceptionally feeble in tension which is one of the significant constraints of concrete and enhancing it is a big worry for construction engineers. Fusing fibers, for example, steel strands, Galvanized Iron (GI) fibers, polypropylene fibers and so on into the concrete will considerably enhance the ductility and different properties also. Concrete with these filaments are known as fiber reinforced concrete (FRC) which has enhanced pliability and execution against flexure.

In India a large portion of the structures are primarily built to resist gravity loading. However, these structures are profoundly vulnerable when horizontal seismic loading is applied. Advances in construction technology have led to utilization of seismic retrofitting i.e alteration and improvement of existing structures to make them safe against seismic movement. Concrete structures are significantly retrofitted by fiber reinforced polymer (FRP) wrappings. Glass fiber strengthened polymer (GFRP) and carbon fiber reinforced polymer (CFRP) are utilized to wrap basic components like segments and bars. Henceforth for important structures, there is a need to wrap auxiliary components like sections and shafts amid development.

B. Fiber Reinforced Concrete

When fibrous material is incorporated into the concrete it is called fiber reinforced concrete which generally has high auxiliary strength in contrast to traditional concrete. Strands are fundamentally short and discrete which are consistently circulated and haphazardly arranged. There are distinctive sorts of strands utilized which incorporates steel fibers, glass fibers, manufactured fibers and normal fibers. The character of FRC shifts with utilization of various strands furthermore with various cements, fiber materials, geometrics, introduction and circulation too. So in this manner composite material made of bond, total along with joining discrete irregular filaments is termed as Fiber fortified cement.

Why fibers have to be incorporated into concrete? Normally plain and unreinforced concrete has low ductility i.e. fragile material having low strain limit and low rigidity too.

Fibers have fundamental function to capture the cracks creating post splitting ductility. On the off chance that strands utilized are sufficiently strong having adequate clinging to material, could allow FRC to take huge hassles over vast strain limit in the post breaking stage. Sturdiness of concrete is essentially enhanced when strands are fused into it furthermore there is impressive change in resistance of routinely strengthened auxiliary part over breaking, diversion and other serviceability condition. Two components to be specific dividing system and break crossing over instrument are included when filaments work with cement.

C. Hybrid Fiber Reinforced Concrete

Whenever two or a greater number of fibers are brought into the concrete than it is termed as hybrid fiber reinforced cement (HYFRC). HYFRC has a novel property to withstand against pressure in concrete. Galvanized iron filaments and steel strands are utilized as a part of this trial examination. Both fibers are chosen such that both have high elastic moduli in order to enhance quality of concrete in expansive quantum.

D. Fiber Reinforced Polymer

A composite material made of polymer lattice reinforced with strands is termed as fiber reinforced polymer. Strands like glass, carbon, aramid and so on are utilized. Epoxy, vinyl ester, polyester thermostetting plastic are utilized as polymer. Be that as it may, for structural designing purposes glass and carbon fiber strengthened polymer are utilized generally. They have been utilized for restoration and seismic retrofitting of structures. Their use is as strips which are wrapped around basic individuals like shafts, sections, chunks which are seriously harmed because of stacking conditions. FRP composites are utilized as a part of pillars for enhancing flexural and shear strengthening. Chunks are likewise reinforced by applying FRP strips at their base face i.e. strain zone. For sections likewise they have been valuable as there is expansion in compressive quality under axial stacking and controlling the parallel extension of the segment when wrapped by FRP strips. As high quality cement is fragile material their pliability could be upgraded by utilizing FRP wraps in order to enhance the seismic resistance. As seismic retrofitting of existing structure is an excessive issue so in this trial examination concrete cured for 28 days is wrapped with Glass Fiber fortified polymer and is tested.

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II. PROJECT OBJECTIVES

The objectives of the study are
1) To investigate the variations in basic strength tests i.e. compressive test and tensile tests for hybrid fiber reinforced concrete of M30 grade concrete with nominal mix.
2) To compare basic strength properties and also flexural strength of hybrid fiber reinforced concrete and nominal mix concrete when both are wrapped with GFRP and without GFRP wrappings.
3) To observe the failure pattern of concrete for with and without wrappings of GFRP.
4) To investigate the reserve strength and cracking strength of hybrid fiber reinforced concrete when it is wrapped with GFRP.

III. MATERIALS USED

1) Cement
2) Fine Aggregates(sand)
3) Basalt Aggregates(20mm)
4) Super plasticizer
5) Water
6) Steel Fibers
7) Galvanized Iron Fibers
8) Glass fiber reinforced polymer

A. Cement

Conventional Portland concrete conforming with IS 12262-1987 was utilized. Birla Orient concrete OPC obtained from single source properties of which are tried in the lab and are given in table

<table>
<thead>
<tr>
<th>SL No</th>
<th>Properties</th>
<th>Test results</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Specific gravity</td>
<td>3.1</td>
</tr>
<tr>
<td>2</td>
<td>Normal consistency</td>
<td>29 %</td>
</tr>
<tr>
<td>3</td>
<td>Initial setting time</td>
<td>65 mins</td>
</tr>
<tr>
<td>4</td>
<td>Final setting time</td>
<td>260 mins</td>
</tr>
</tbody>
</table>

Table 1: Physical properties of cement

B. Fine Aggregate

Good quality zone-II fine aggregate was utilized. The diverse tests for physical properties of fine aggregate are completed in the research center and the same is introduced in table.

<table>
<thead>
<tr>
<th>SL no</th>
<th>Properties</th>
<th>Test results</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Specific gravity</td>
<td>2.59</td>
</tr>
<tr>
<td>2</td>
<td>Water absorption</td>
<td>1.0%</td>
</tr>
<tr>
<td>3</td>
<td>Bulk density</td>
<td>a) Compacted</td>
</tr>
<tr>
<td></td>
<td></td>
<td>b) Loose</td>
</tr>
</tbody>
</table>

Table 2: Physical properties of sand

C. Basalt Aggregate

In the present examination basalt aggregates available from neighborhood crusher was used. Here we have used two size divisions of basalt aggregates i.e. 20mm and 12.5mm cut back. Differing tests, for instance, specific gravity, mass thickness etc. were finished in laboratory for basalt sums. The test results are presented in table.

<table>
<thead>
<tr>
<th>Sl. No</th>
<th>Properties</th>
<th>Test results</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Shape of coarse aggregates</td>
<td>Angular</td>
</tr>
<tr>
<td>2</td>
<td>Bulk density</td>
<td>1.616 g/cc</td>
</tr>
</tbody>
</table>

D. Super plasticizer

In the present investigation super plasticizer was used as to obtain high strength by reducing water content for hybrid fiber reinforced concrete as per IS:9103(1999). super plasticizer used here was Sikament 586. Optimum dosage was found out to be 1.5% of weight of cement.

E. Steel Fibers

Gloved end steel fibers were used in this experimental investigation. Length used was of 50mm and width of 2mm. Thickness used was 1mm making aspect ratio 50.

F. Galvanized Iron Fibers

Galvanized iron fibers were used in this study. Length of 50mm was used and thickness of 1mm making aspect ratio of 50mm.

G. Glass Fiber Reinforced Polymer

Glass fiber reinforced polymer was used to wrap around the concrete. GFRP having 900 grams per square meter was used in this experimental investigation. Before wrapping two coatings of primer was applied on concrete later epoxy was applied on which GFRP was wrapped.

H. GFRP Wrapping Procedure

Application of GFRP involves following steps
- Firstly, specimens after 28 days of curing are kept in open atmosphere so that specimen become dry.
- Specimens are cleaned carefully removing dirt by using brush and also excess dust present on the surface is removed.
- Two coats of primer (Master brace 3600) is applied on the specimen surface and is kept for 24 hours.
- After 24 hours epoxy resin (Master brace 4600) is mixed with primer in suitable ratio and applied on concrete specimens
Within 30 minutes of application of epoxy GFRP is wrapped.

IV. EXPERIMENTAL METHODOLOGY AND RESULTS

In this present investigation certain tests on concrete are done to know their fresh state properties and strength properties for hardened concrete by different methods.

A. Fresh Concrete

1) Slump Cone Test

Slump test is utilized to gauge workability of cement. The test is essentially done to gauge the consistency of cement in particular batch for fresh green concrete. It is a test which could be performed in lab and additionally on location. This test is generally completed utilizing ABRAM s cone regularly known as slump cone. Cone is placed on hard non permeable surface. The slump cone is loaded with concrete in three layers. Every layer is packed utilizing a standard tamping rod. Subsequent to filling of cone overabundance cement is struck off. The mold is then lifted vertically upwards. Accordingly, solid appropriations. Generally, there

<table>
<thead>
<tr>
<th>SL No</th>
<th>Properties</th>
<th>Test results</th>
</tr>
</thead>
<tbody>
<tr>
<td>a)</td>
<td>Compacted condition</td>
<td>1.485 g/cc</td>
</tr>
<tr>
<td>b)</td>
<td>Loose condition</td>
<td>2.88</td>
</tr>
<tr>
<td>3</td>
<td>Specific gravity</td>
<td>2.88</td>
</tr>
<tr>
<td>4</td>
<td>Water absorption</td>
<td>0.4%</td>
</tr>
</tbody>
</table>

Table 3: Physical properties of basalt aggregates

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There are three methods of slump i.e. true slump, shear slump and collapse. The subsidence is normally known as slump.

B. Hardened Concrete

- Compression Test on concrete
- Indirect Tensile strength
- Flexural Strength
- Shear strength

1) Compression Test

Cubes of dimensions 150X150X150mm were casted as per IS 456-2000 accordance. Cubes with and without GFRP wrappings were tested when hybrid fibers were incorporated into concrete while casting. Loading of cube specimen was done in perpendicular direction of compaction. Concrete grade of M30 was used and was cured for 28 days. Test was carried out on compression testing machine comprising 2000 KN capacity as per IS: 516-1959 [8]. Resultant compression strength of concrete was measured in N/mm².

<table>
<thead>
<tr>
<th>SL No</th>
<th>Without wrapping of GFRP in N/mm²</th>
<th>With wrapping of GFRP in N/mm²</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>61.33</td>
<td>64.44</td>
</tr>
<tr>
<td>2</td>
<td>61.77</td>
<td>63.11</td>
</tr>
<tr>
<td>3</td>
<td>60.88</td>
<td>62.66</td>
</tr>
</tbody>
</table>

Table 1: Test results for hybrid fiber reinforced concrete

2) Tensile Strength

In this test concrete cylinder specimens were casted comprising dimensions of 150 diameter and 300mm height. Tensile strength was carried out for specimens for 28 days of curing. Specimens were tested on compression testing machine of 2000 KN capacity as per IS: 5816-1999 [9]. Concrete cylinder specimens for GFRP wrapped and unwrapped conditions were tested.

<table>
<thead>
<tr>
<th>SL No</th>
<th>Without wrapping of GFRP in N/mm²</th>
<th>With wrapping of GFRP in N/mm²</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>4.48</td>
<td>5.18</td>
</tr>
<tr>
<td>2</td>
<td>4.06</td>
<td>4.9</td>
</tr>
<tr>
<td>3</td>
<td>4.34</td>
<td>5.18</td>
</tr>
</tbody>
</table>

Table 2: Test results for hybrid fiber reinforced concrete

3) Flexural Strength Test

In this test concrete prisms were used to determine flexural strength. Prism dimensions used was of 100X100X500mm.

4) Shear Strength Test

In this experiment L shaped specimen were used. Their casting was done by inserting wooden cube of dimension 60X90X150mm into the cube mould of size 150X150X150 mm. Concrete was poured into it in three layers each layer having 25 blows. After 24 hours of casting specimens were removed from moulds and were kept for 28 days of curing. After curing half of the total number of specimens were wrapped with GFRP. And all shear test specimens were tested on compression test machine with loading arrangement shown in below fig.
### Table 4: Test results for hybrid fiber reinforced concrete

<table>
<thead>
<tr>
<th>SL No</th>
<th>Without wrapping of GFRP in N/mm²</th>
<th>With wrapping of GFRP in N/mm²</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>7.22</td>
<td>9.44</td>
</tr>
<tr>
<td>2</td>
<td>7.77</td>
<td>10</td>
</tr>
<tr>
<td>3</td>
<td>6.66</td>
<td>11.11</td>
</tr>
</tbody>
</table>

### V. Conclusion

The following conclusions are made after this experimental investigation:

- Slump of HFRC was found to be 85mm making it workable and cohesive mix as super plasticizer was added to concrete so as to improve workability.
- Compressive strength for HFRC was significantly increased by 69% with compared to conventional concrete mix. However when it was wrapped with GFRP it resulted in 5% increase in compressive strength.
- Tensile strength for conventional mix wrapped with GFRP showed 20% increase in strength as compared to conventional mix without wrapping. For HFRC also there was 20% increase in wrapped condition compared to unwrapped HFRC.
- Flexural strength for GFRP wrapped conventional mix showed 60% increase compared to conventional mix without wrappings. Hybrid fibers incorporation into concrete also increased strength by 73%. By wrappings of GFRP strength of HFRC further increased by 50%.
- Shear strength was also improved by 60% for conventional concrete when it was wrapped with GFRP. And HFRC showed significant 60% increase in strength with compared to conventional mix, there was 40% increase in shear strength when it was wrapped with GFRP.
- The crack pattern observed for HFRC was different due to fiber orientation with compared to conventional mix.
- Toughness of concrete was also increased when GFRP wrapping was made to concrete. Cracking of concrete was significantly decreased as there was no observation of cracks in flexural failure.

### VI. Scope for Further Study

GFRP wrappings could be tried for reinforced concrete slabs as there was significant improvement in tensile and flexural strength in this experimental study.

- There could be possible use of waste GI resulting from RCC work as lot of small size GI waste wires is generated during tying of rebar.
- GFRP wrappings could be tried for structural members like columns and beams as most strength parameters were significantly increased.
- Seismic analysis of structures with GFRP wrappings on structural components like beams, columns and slabs made with hybrid fiber reinforced concrete.
- Impact test could be carried out for HYFRC mix with and without GFRP wrappings.
- Carrying out cost analysis and feasibility study for structures made with HYFRC mix and also confining them with GFRP wrappings.

### References


