

Flexural Strengthening of Light Weight Reinforced Concrete Beams by Using Glass Fiber Reinforced Polymer

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Abstract- The use of Lightweight concretes has gained acceptance and popularity worldwide in the recent years in the construction and development of both the infrastructure and residential buildings. Light weight aggregate concrete has become more popular in recent advancements owing to the tremendous advantages it offers over the conventional concrete but at the same time light in weight and strong enough to be used for structural purposes. Replacement of natural aggregate with concrete such as light weight concrete by using sintered fly ash aggregate (natural aggregate), The main disadvantage of conventional concrete it is high self-weight. This heavy self-weight will make it to some extent an uneconomical structural material. Light weight concrete having low density facilitates reduction of dead load and to increase thermal insulation.

I. INTRODUCTION

• DATA ANALYSIS (MATERIAL USED)

A. Cement

Ordinary Portland Cement Birla Shakti (M43 Grade) conforming to IS 269-1976 was used throughout the investigation. Different test was performed on the cement to ensure that it confirms to the requirement of the IS specification. The physical properties of the cement were determined as per IS 4031-1968 and are presented in the following table 1.

TABLE 1
 Physical analysis of Birla Shakti (M43 Grade)
 Cement

| Sr. No | Properties | Value | Requirements of IS:8112 1989 |
|--------|---|---------|------------------------------------|
| 1 | Specific Gravity | 3.15 | - |
| 2 | Standard Consistency | 31% | - |
| 3 | Initial Setting Time | 104 min | Min 30 min |
| 4 | Final Setting Time | 205 min | Max 600 min |
| 5 | Soundness | 3.5 | Less than 10% |
| 6 | Fineness | 5.5 | Less than 10% |
| 7 | Compressive strength (N/mm ²) | | |
| | 3 Days | 28.35 | Not less than 22 N/mm ² |
| | 7 Days | 35.48 | Not less than 33 N/mm ² |
| | 28 Days | 52.68 | Not less than 43 N/mm ² |

B. Sand

TABLE 2
 Properties of Fine Aggregate

| Sr. No. | Properties | Value |
|---------|--------------------------------|-------|
| 1 | Specific Gravity | 2.72 |
| 2 | Fineness modulus | 3.342 |
| 3 | Silt content | 4% |
| 4 | Water absorption (after 24hr) | 2.6% |

C. Sintered Fly Ash Aggregate

TABLE 3
Properties of sintered fly ash Aggregate

| Sr. No. | Properties | Value |
|---------|-------------------------------|--------|
| 1 | Specific Gravity | 1.50 |
| 2 | Fineness modulus | 6.24 |
| 3 | Water Absorption (after 24hr) | 14.20% |

D. Admixtures

Admixture Used for Project: - Algisuperplast N

E. Water:

Water is an important ingredient to make concrete. The purpose of adding water to concrete is, to distribute the cement evenly, react with cement chemically to produce calcium silicate hydrate gel and provide workable one. Small amount of water is needed to hydrate cement. Additional water is required to lubricate the mix. Excess water leads to bleeding stage ultimately creation of pores. Quantity of water is controlled by the w/c ratio. The water used must be free from oil, acid and alkali, salts and organic material. It should be potable.

II. M20 GRADE CONCRETE MIX DESIGN

M20 Grade Concrete mix design was done by using trial and error method with 100% Replacement of Natural Aggregate by Sintered Fly Ash Aggregate)

TABLE 4
FINAL MIX PROPORTION USING 100% REPLACEMENT OF NATURAL AGGREGATE BY SINTERED FLY ASH AGGREGATE

| Cement | Sand | Sintered Fly Ash Aggregate | Water | Chemical |
|--------|---------|----------------------------|--------|------------------------|
| 365 | 868.727 | 584.865 | 175.20 | 1% of Cement by Weight |
| 1 | 2.377 | 1.602 | 0.48 | |

TABLE 5
QUANTITY OF INGREDIENT NEEDED FOR CASTING

| Items | For 1 Cube | For 1 Beam | For 1 Cylinder |
|---------------------------------|------------|------------|----------------|
| Cement (Kg) | 1.232 | 1.825 | 0.573 |
| Sand (Kg) | 2.929 | 4.339 | 1.362 |
| Coarse Aggregate (Kg) | 0.000 | 0.000 | 0.000 |
| Sintered Fly Ash Aggregate (kg) | 1.974 | 2.924 | 0.918 |
| Water (Kg) | 0.591 | 0.876 | 0.275 |
| Chemical (gm.) | 12.32 | 18.250 | 5.730 |

III. STRENGTHENING OF BEAMS

Before bonding the composite fabric on to the concrete surface, the required region of concrete surface was made rough using a coarse sand paper texture and cleaned with an air blower to remove all dirt and debris. Once the surface was prepared to the required standard, the polyester resin was mixed in accordance with manufacturer’s instructions. Mixing was carried out in a plastic container (Accelerator Cobalt 3% (Intense blue liquid) and Hardener 1.5%) and continued until the mixture in uniform colour. When this was completed and the fabrics had been cut to size, the resin mixture was applied to the concrete surface. The composite fabric was then placed on top of polyester resin coating and the resin was squeezed through the roving of the fabric with the roller. Air bubbles entrapped at the epoxy/concrete or epoxy/fabric interface were to be eliminated. Then the second layer of the resin was applied and GFRP sheet was then placed on top of resin coating and the resin was squeezed through the roving of the fabric with the roller and the above process was repeated. During hardening of the resin, a constant uniform pressure was applied on the composite fabric surface in order to extrude the excess resin and to ensure good contact between the resin, the concrete and the fabric. This operation was carried out at room temperature. Concrete beams strengthened with glass fiber fabric were cured for 24 hours at room temperature before testing.

The experimental work consists of casting of four sets of reinforced concrete (RC) beams having grade M20, cross-sectional dimensions of 100mm x 200mm and 1100mm length. We provided 2-10mm Ø bottom reinforcement and 2-10mm Ø top with 6mm Ø vertical stirrups @ 300 mm c/c. The strengthening of the beams using GFRP sheet is done on bottom side wrap with three different length configurations namely Central 1/3 length of Testing (300 mm Length), Central 2/3 length of Testing (600 mm Length) & Full length of Testing (900 mm Length).

The experimental study consists of casting of four sets of reinforced concrete (RC) beams of grade M20, with 100% Replacement of Natural Aggregate with Sintered Fly Ash Aggregate. Total 12 no. of RC beam are cast and curing for 28 days.

1. First set of (3 no.) Light Weight RC beams designated as control beams (SET I).
2. Second set of (3 no.) Light Weight RC beams (SET II); all are strengthened using single GFRP mat wrap, (for Central 1/3 length of Testing [300 mm]).
3. Third set of (3 no.) Light Weight RC beams (SET III); all are strengthened using single GFRP mat wrap, (for Central 2/3 length of Testing [600 mm]).
4. Fourth set of (3 no.) Light Weight RC beams (SET IV); all are strengthened using single GFRP mat wrap, (for Full length of Testing [900 mm]).

IV. TESTING SETUP

All the specimens are tested in Universal testing machine (UTM). The testing procedures for the all specimens are same. After the curing period of 28 days is over, control beams (SET I) are washed and its surface is cleaned for clear visibility of cracks. Where other set of Light Weight RC beams (SET II, SET III, SET IV) are strengthened by GFRP sheets. The load arrangements for testing of all sets of beam is consist of two-point loading as shown in Figure 1A and 1B.,

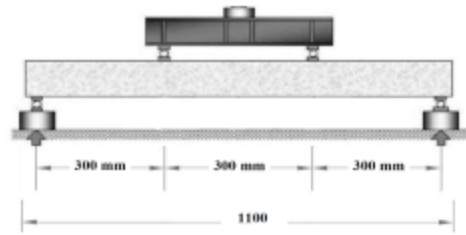


Figure 1 B: Experimental setup for testing of beams

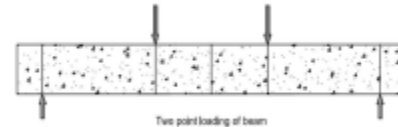


Figure 1 B: Experimental setup for testing of beams

A. Testing procedure

All the specimens were tested in the loading frame. The testing procedure for the entire specimen was same. After the curing period of 28 days was over, the beam as washed and its surface was cleaned for clear visibility of cracks. The most commonly used load arrangement for testing of beams will consist of two-point loading. This has the advantage of a substantial region of nearly uniform moment coupled with very small shears, enabling the bending capacity of the central portion to be assessed.

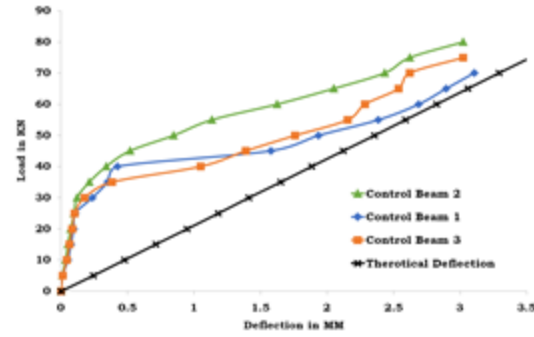
V. RESULTS ANALYSIS WITH RESPECT TO DEFLECTION

A. Introduction

This chapter describes the experimental results of all SETS beam (SET I, SET II, SET III, SET IV). Their behavior throughout the static test to failure is described using recorded data on deflection behavior, and the ultimate load carrying capacity. The mid-span deflection of each beam was compared with that of their respective control beams(as a practical deflection) and actual theoretical deflection. Also the load-deflection behavior was compared between three wrapping schemes having the same reinforcement (Central 1/3 length of Testing, Central 2/3 length of Testing and Full length of Testing). The mid-span deflections were much lower when bonded externally with GFRP sheets.

B. Load Deflection History

The two point static loading is applied on the beams and at the each increment of the load (1KN/sec). Deflections at the middle in beams are noted down and load Vs deflection curve of all the sets of beams is plotted. The Load- deflection of each strengthened beam is compared with that of their respective control beams (as a practical deflection) and actual theoretical deflection.



Graph 1 Load vs Deflection Results of control RC beams (SET I)

C. Load vs Deflection Results of Light Weight RC beams designated as control RC beams (SET I)

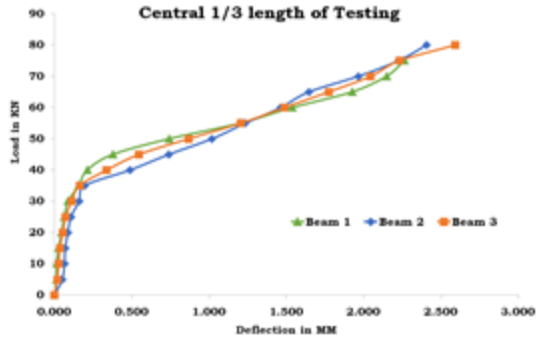
TABLE 6
LOAD VS DEFLECTION RESULTS OF CONTROL RC BEAMS (SET I)

| Load In KN | Deflection in MM | | | |
|------------|------------------|----------------|----------------|----------------|
| | Theoretical | Control Beam 1 | Control Beam 2 | Control Beam 3 |
| 0 | 0 | 0 | 0 | 0 |
| 5 | 0.243 | 0.014 | 0.0124 | 0.0132 |
| 10 | 0.478 | 0.053 | 0.035 | 0.044 |
| 15 | 0.712 | 0.076 | 0.053 | 0.0645 |
| 20 | 0.947 | 0.096 | 0.0721 | 0.08405 |
| 25 | 1.182 | 0.108 | 0.0984 | 0.1032 |
| 30 | 1.412 | 0.235 | 0.12 | 0.1775 |
| 35 | 1.651 | 0.351 | 0.212 | 0.383 |
| 40 | 1.885 | 0.425 | 0.341 | 1.049 |
| 45 | 2.12 | 1.578 | 0.52 | 1.39 |
| 50 | 2.355 | 1.935 | 0.845 | 1.76 |
| 55 | 2.589 | 2.385 | 1.135 | 2.1555 |
| 60 | 2.824 | 2.687 | 1.624 | 2.284 |
| 65 | 3.058 | 2.894 | 2.05 | 2.538 |
| 70 | 3.293 | 3.105 | 2.432 | 2.621 |
| 75 | 3.527 | | 2.621 | 3.021 |
| 80 | 3.762 | | 3.021 | |

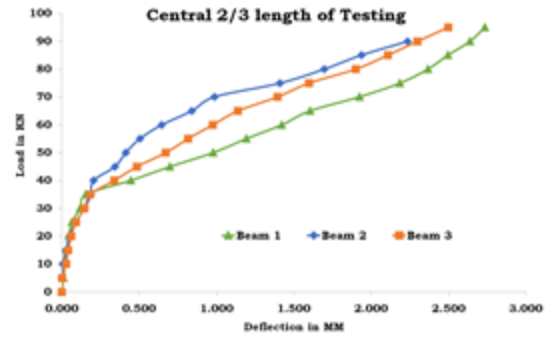
D. Load vs Deflection Results of Light Weight RC beams (SET II); all are strengthened using single GFRP wrap for Central 1/3 length of Testing (Length = 300mm).

TABLE 7
LOAD VS DEFLECTION RESULTS OF LIGHT WEIGHT RC BEAMS (SET II) (GFRP WRAP LENGTH = 300MM)

| Load In KN | GFRP Wrap for Central 1/3 length of Testing | | |
|------------|---|--------|--------|
| | Beam 1 | Beam 2 | Beam 3 |
| 0 | 0.000 | 0.000 | 0.000 |
| 5 | 0.012 | 0.051 | 0.019 |
| 10 | 0.014 | 0.065 | 0.027 |
| 15 | 0.027 | 0.070 | 0.036 |
| 20 | 0.046 | 0.087 | 0.054 |
| 25 | 0.064 | 0.107 | 0.073 |
| 30 | 0.089 | 0.160 | 0.112 |
| 35 | 0.157 | 0.196 | 0.164 |
| 40 | 0.213 | 0.488 | 0.338 |
| 45 | 0.379 | 0.740 | 0.547 |
| 50 | 0.742 | 1.019 | 0.868 |
| 55 | 1.201 | 1.235 | 1.205 |
| 60 | 1.539 | 1.462 | 1.488 |
| 65 | 1.926 | 1.646 | 1.773 |
| 70 | 2.148 | 1.965 | 2.044 |
| 75 | 2.264 | 2.226 | 2.233 |
| 80 | | 2.407 | 2.591 |



Graph 2 Load vs Deflection Results of Light Weight RC beams (SET II)(GFRP Wrap for Central 1/3 length of Testing, i.e.Wrap Length = 300mm)



Graph 3 Load vs Deflection Results of RC beams (SET II) (GFRP Wrap for Central 2/3 length of Testing, i.e.Wrap Length = 600mm)

E. Load vs Deflection Results of Light Weight RC beams (SET III); all are strengthened using single GFRP wrap for Central 2/3 length of Testing (Length = 600mm).

F. Load vs Deflection Results of Light Weight RC beams (SET IV); all are strengthened using single GFRP wrap for Full length of Testing (Length = 900mm).

TABLE 8

Load vs Deflection Results of Light Weight RC beams (SET III)(GFRP Wrap Length = 600mm)

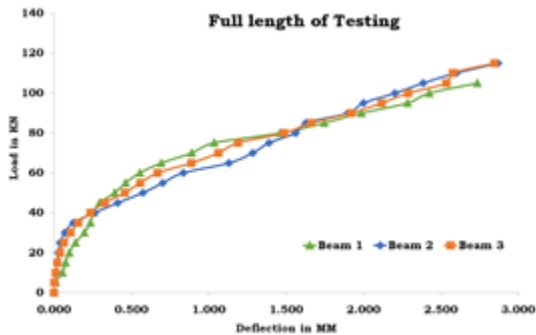
| Load In KN | GFRP Wrap for Central 1/3 length of Testing | | |
|------------|---|--------|--------|
| | Beam 1 | Beam 2 | Beam 3 |
| 0 | 0.000 | 0.000 | 0.000 |
| 5 | 0.010 | 0.000 | 0.001 |
| 10 | 0.024 | 0.006 | 0.028 |
| 15 | 0.029 | 0.027 | 0.040 |
| 20 | 0.046 | 0.050 | 0.060 |
| 25 | 0.066 | 0.090 | 0.090 |
| 30 | 0.118 | 0.147 | 0.145 |
| 35 | 0.155 | 0.187 | 0.183 |
| 40 | 0.447 | 0.206 | 0.339 |
| 45 | 0.698 | 0.343 | 0.484 |
| 50 | 0.978 | 0.414 | 0.673 |
| 55 | 1.194 | 0.506 | 0.816 |
| 60 | 1.421 | 0.646 | 0.976 |
| 65 | 1.605 | 0.840 | 1.138 |
| 70 | 1.924 | 0.987 | 1.394 |
| 75 | 2.185 | 1.411 | 1.598 |
| 80 | 2.366 | 1.698 | 1.901 |
| 85 | 2.496 | 1.937 | 2.109 |
| 90 | 2.638 | 2.236 | 2.300 |
| 95 | 2.735 | | 2.498 |

TABLE 9

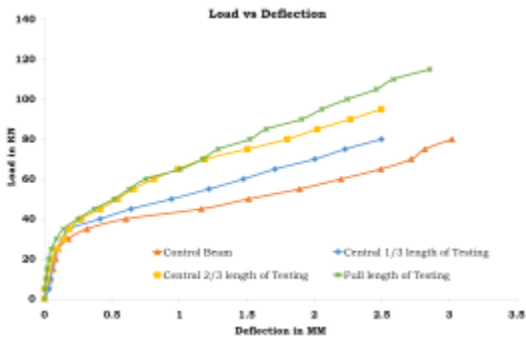
LOAD VS DEFLECTION RESULTS OF LIGHT WEIGHT RC BEAMS (SET IV) (GFRP WRAP LENGTH = 900MM)

| Load In KN | GFRP Wrap for Central 1/3 length of Testing | | |
|------------|---|--------|--------|
| | Beam 1 | Beam 2 | Beam 3 |
| 0 | 0.000 | 0.000 | 0.000 |
| 5 | 0.010 | 0.006 | 0.001 |
| 10 | 0.055 | 0.015 | 0.010 |
| 15 | 0.075 | 0.018 | 0.022 |
| 20 | 0.098 | 0.028 | 0.038 |
| 25 | 0.138 | 0.039 | 0.064 |
| 30 | 0.195 | 0.070 | 0.108 |
| 35 | 0.235 | 0.125 | 0.155 |
| 40 | 0.254 | 0.263 | 0.234 |
| 45 | 0.294 | 0.411 | 0.328 |
| 50 | 0.391 | 0.575 | 0.458 |
| 55 | 0.462 | 0.701 | 0.557 |
| 60 | 0.554 | 0.835 | 0.670 |
| 65 | 0.694 | 1.130 | 0.887 |
| 70 | 0.888 | 1.283 | 1.061 |
| 75 | 1.035 | 1.390 | 1.188 |
| 80 | 1.459 | 1.560 | 1.485 |
| 85 | 1.746 | 1.626 | 1.661 |
| 90 | 1.985 | 1.898 | 1.917 |
| 95 | 2.284 | 1.998 | 2.116 |

| Load In KN | GFRP Wrap for Central 1/3 length of Testing | | |
|------------|---|--------|--------|
| | Beam 1 | Beam 2 | Beam 3 |
| 100 | 2.425 | 2.201 | 2.288 |
| 105 | 2.735 | 2.385 | 2.535 |
| 110 | | 2.600 | 2.575 |
| 115 | | 2.870 | 2.845 |



Graph 4 Load vs Deflection Results of Light Weight RC beams (SET II) (GFRP Wrap for full length of Testing, i.e. Wrap Length = 900mm)



Graph 5 Load vs Deflection Results of Light Weight RC beams (All SETS)

VI. DISCUSSION ON DEFLECTION

It is observed from Graph 8.15, Graph 8.19, Graph 8.23, that the deflection of beams (SET II, III and IV) when bonded with GFRP sheets with bottom side wrap is lesser than the control beams (SET I).

With reference to graph 5,

1. Maximum deflection of Control Beam (SET I) is 3.02 mm @ Load 80 KN
2. Maximum deflection of SET II is 2.499 mm @ Load 80 KN

3. Maximum deflection of SET III is 2.49 mm @ Load 95 KN
4. Maximum deflection of SET IV is 2.80 mm @ Load 115 KN

With reference to Tables and Graphs it is observed that for load of 80 KN the deflection of Light Weight Light Weight RC Beams designated as control Light Weight RC Beams (SET I) is 3.021 mm similarly for the same load the deflection of Light Weight RC Beams strengthened using single GFRP mat wrap for Central 1/3 length of Testing [300 mm] (SET II) is 2.4993 mm, Light Weight RC Beams strengthened using single GFRP mat wrap for Central 2/3 length of Testing [600 mm] (SET III) is 1.7991 mm and Light Weight RC Beams strengthened using single GFRP mat wrap for Full length of Testing [900 mm] (SET IV) is 1.5226 mm.

CONCLUSION

Successfully achieved reduction in deflection for Strengthening of Light Weight RC Beams with GFRP wrap for Full length of Testing (i.e. 900mm length) by 40.44 %.

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