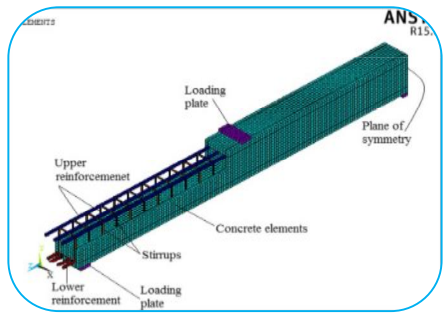
REVIEW OF RESEARCH
ISSN: 2249-894X
IMPACT FACTOR : 5.7631(UIF)
VOLUME - 13 | ISSUE - 3 | DECEMBER - 2023

STRENGTHENING OF REINFORCED CONCRETE BEAMS BY FRP TECHNOLOGY

Ranganath T. V. L.
Lecturer, Civil and Architectural Engineering Section,
Department of Engineering, Higher College of Engineering,
University of Applied Science and Technology, Muscat, Sultanate of Oman.

ABSTRACT :

The failure of RC beams depends on various factors like overloading, seismic loads, uneven settlement of the foundation, and environmental conditions. The mode of failure largely depends on the amount and distribution of longitudinal steel reinforcement. The shear failure is caused by the development of diagonal cracks. The progressive micro cracking appears in the tip of the inclined cracks. An experimental investigation was carried out to study the impact of the application of FRP composites in improving the shear resistance of failed beams. In the present paper, the experimental results of eight beams are reported. The beams were cast and loaded till failure, without wrapping. Later the failed beams were wrapped with Glass and Carbon fiber polymers and again loaded and tested. The recovery of ultimate strength in wrapped beams is recorded.



KEYWORDS : *Fiber Reinforced Polymer, Glass Fiber, Carbon Fiber, Reinforce Concrete Beams.*

1. INTRODUCTION

Flexural failure and shear failure are the common types of failures in Reinforced concrete beams. Shear failure is one of the main modes of failure of reinforced concrete structures, which happens due to shear deficiency between the two materials- concrete and steel. Shear failure is a brittle failure that transpires without warning and has a great concern in the field of structural engineering. Shear failure of RC beams may be due to underestimating of the applied loads, lapses in construction, and damages due to wind, earth quake and other natural calamities. Restitution of structures failed in shear is absolutely necessary.

In the recent past, the rehabilitation and strengthening of reinforced concrete beams using Fiber Reinforced Polymer (FRP) have gained the popularity worldwide. Fiber Reinforced Polymer is a composite material and consists of fibers (glass, carbon, and aramid) and matrices (epoxy). The efficacy of the FRP depends on the type of fibers used, stiffness and tensile strain of the fiber, and epoxy properties like bond, creep, and chemical resistance. The most commonly used FRPs are E Glass fiber and carbon fiber polymers.

An experimental investigation is carried out by casting 8 reinforced concrete beams that were loaded to failure. Later they were wrapped with Glass and Carbon fiber polymers and again loaded to study the improvement in the shear resistance of beams. The parameters like ultimate load for prewrapped and post-wrapped beams, crack pattern, and load-deflection characteristics were studied.

2. PROPERTIES OF COMPOSITE MATERIALS

The materials used for the casting of beams are cement, fine aggregates, coarse aggregates, water, steel, and composite fiber system (fibers and epoxy)

2.1 Composite fiber system

For experimental work the composite fiber system used was carbon fiber, E-glass fiber, Nito bond PC-40, Nito wrap 310 primer, and Nito wrap 410 Saturant

2.1.1 Carbon fiber

The properties of carbon fiber listed below are provided by the manufacturer

Table 1- Properties of E Glass fibers

Properties of E glass fiber	Technical Data
Fiber orientation	Unidirectional
Weight of the fiber	920 gm/m^2
Density	2.6 gm/CC
Fiber thickness	0.9 mm
Tensile Modulus	73000 MPa
Tensile strength	3400 MPa

2.1.2 Glass fiber

The properties of glass fiber listed below are provided by the manufacturer

Table 2- Properties of Carbon fibers

Properties of Carbon fiber	Technical Data
Fiber orientation	Unidirectional
Weight of the fiber	200 gm/m^2
Density	21.8 gm/CC
Fiber thickness	0.3 mm
Tensile Modulus	285000 MPa
Tensile strength	3500 MPa

3. Structural Design Details of the beams

Effective length of beam = 2140 mm
Clear span = 2100 mm
Effective depth of beam =192 mm
Grade of concrete = M20
Grade of steel = Fe415

The longitudinal sections and cross sections of the RC beams cast are as shown in figure 1 and 2 below

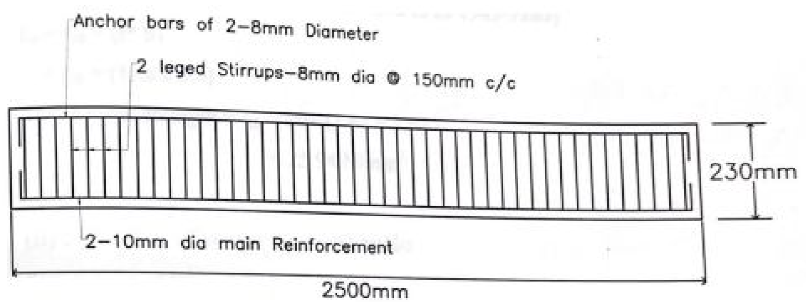


Fig 1 Longitudinal section of the beam

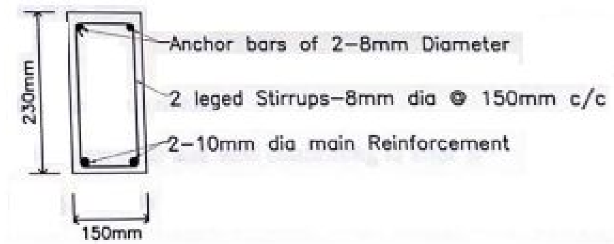


Fig 2 Cross section of the beam

4. Preparation of Test Specimens and Test setup

4.1 Preparation of Beams Prior to the Testing

The following steps were carried out before carrying out the loading of beams

1. Surface preparation
2. Filling op the blow holes and imperfections
3. Coating with white primer
4. Marking of support points and loading points

4.2 Arrangements for Test Setup

The beams were prepared and tested in a properly arranged system for loading on the beam. The test setup for loading the beams is shown in Figure 3 below.

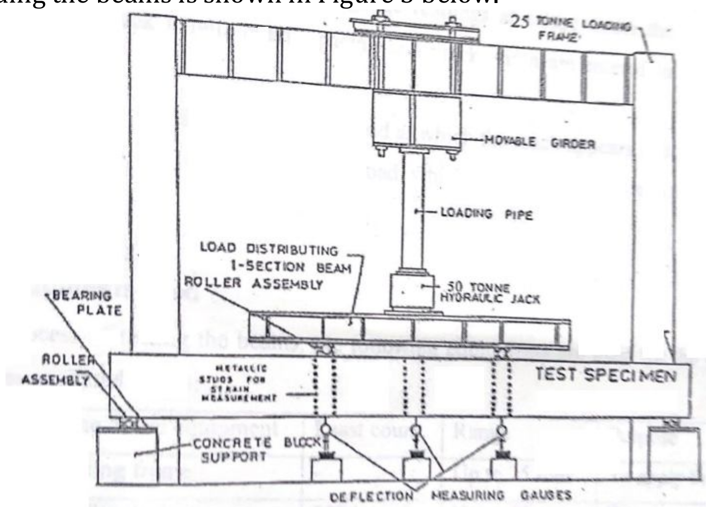


Fig 3 Loading of Test specimen beams

The loading system consists of Supports, a loading frame, a loading jack, and a load transfer system as shown in the figure. After the test setup, the load is applied at a regular increment of 500 Kgs. At every increment of load transfer dial gauge readings at the center and under loading points, crack number, crack spacing, and crack width are measured and entered in a tabular column.

4.3 Details of test specimens

Table 3 Test Specimen Details

Sl. No.	Specimen designation	Specifications	Number of specimens
1	BG-SL 1 BG-SL 2	Beams wrapped with glass fiber on the full face of the shear	2
2	BG-SI 1 BG-SI 2	Beams wrapped with glass fiber strips on the full face of the shear	2
3	BC-SL 1 BC-SL 2	Beams wrapped with carbon fiber on the full face of the shear	2
4	BC-SI 1 BC-SI 2	Beams wrapped with carbon fiber strips on the full face of the shear	2

5. Test Results

The beams were tested under two-point loading till the failure and during testing the following parameters were adopted.

1. The load increment was 0.5 Ton.
2. The stains were measured with a Demak Gauge.
3. The crack widths were measured using a traveling telescope of least count of 0.02 mm,
4. The deflections were measured with dial gauges of least count of 0.01 mm.

The following tables give the test results.

Table 4. Service load, Theoretical ultimate load, and Experimental ultimate load for Prewrapped beams

Sl. No.	Beam number	Service load P_{cr} in kN	Theoretical Ultimate load $P_{U\,Th}$ in kN	Experimental Ultimate load $P_{U\,EX}$ in kN
1	B1	28	42	67
2	B2	28	42	69
3	B3	28	42	70
4	B4	28	42	68
5	B5	28	42	65
6	B6	28	42	69
7	B7	28	42	68.5
8	B8	28	42	66.5

Table 5. Ultimate Experimental load of post-wrapped beams and effect of Wrapping

Sl. No.	Beam Type	Beam no.	Experimental Ultimate load $P_{u\,Exp}$ in kN	$P_{u\,Exp}$ Post wrapped / $P_{u\,Exp}$ Pre-wrapped
1	BG-SL 1	B1	56	0.87
2	BG-SL 2	B2	57.5	0.88
3	BG-SI 1	B3	52	0.77
4	BG-SI 2	B4	54	0.78
5	BC-SL 1	B5	62	0.91
6	BC-SL 2	B6	63.5	0.92
7	BC-SI 1	B7	59	0.9
8	BC-SI 2	B8	59	0.88

6. DISCUSSION ON TEST RESULTS AND CONCLUSIONS

Based on the test results the following conclusions were drawn.

1. It was found that the load-carrying capacity of the strengthened beams in comparison to the pre-wrapped beams was regained up to 91 % in the carbon-wrapped beams
2. It was observed that beyond the service loads, the difference in the magnitude of deflection between the control and wrapped beams becomes narrower.
3. The beams of a particular series of post wrap showed a similar failure load carrying capacity for bending.
4. It was found that the distressed beams wrapped with carbon fibers were has a greater load carrying capacity when compared with beams wrapped with glass fibers.

7. REFERENCES:

- M.N.S. Hadi, *Retrofitting of shear-failed reinforced concrete beams*, Composite Structures, Volume 62, Issue 1, 2003, Pages 1-6,
- Jianli Jia, Yousef Zandi, Abouzar Rahimi, Sara Pourkhorshidi, Mohamed Amine Khadimallah, H. Elhosiny Ali, *Numerical performance evaluation of debonding strength in fiber reinforced polymer composites using three hybrid intelligent models*, Advances in Engineering Software, Volume 173, 2022, 03193, ISSN 0965-9978,
- L.C. Hollaway, *Key issues in the use of fiber reinforced polymer (FRP) composites in the rehabilitation and retrofitting of concrete structures,* Woodhead Publishing, 2011, Pages 3-74, ISBN 9781845693985,
- S.T Smith, J.G Teng, *FRP-strengthened RC beams. I: a review of debonding strength models,*
- *Engineering Structures,* Volume 24, Issue 4, 2002, Pages 385-395, ISSN 0141-0296,
- Balaguru, Permalsamy P.N, N & Chang.C, *High strength composites for repair, rehabilitation & Strengthening of Concreete Strucures,* ICI Journal, Jan-Mar 2003

Ranganath T. V. L.
Lecturer, Civil and Architectural Engineering Section,
Department of Engineering, Higher College of Engineering,
University of Applied Science and Technology, Muscat, Sultanate of Oman.