REPAIR OF DAMAGED REINFORCED CONCRETE BEAM EXTERNALLY BONDED WITH GFRP PLATES

Sarita R. Khot[1] *H.S.Jadhav*[2]

[1] *Asst. Professor Department of Civil Engg., RMD Sinhgad School of Engineering, Warje, Pune, Maharashtra, India*

[2]*Head & Associate Professor, Department of Civil Engg., Rajarambapu Institute of Technology, Rajaramnagar, Tal-Walwa, Dist-Sangli , Maharashtra, India*

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Abstract - Reinforced cement concrete with steel bars is an extremely popular construction material. Reinforced concrete is the most frequently used for many years to build a wide variety of structures from houses to bridges. Many reinforced concrete structures are suffering from various deterioration such as spalling of concrete, excessive deflection.etc. Undetected and unrepaired damage may lead to structural failure demanding costly repair and huge loss of lives. Now days it is very much essential to find alternative strengthening technique in terms of low cost and shorter duration for repair and rehabilitation. Therefore it is necessary to increase the service life and load carrying capacity of damaged original structures. In this study RC beams with various degree of damage, repaired with 100 mm single layer and double layer with GFRP are studied with reference to load carrying capacity and energy absorption capacity. In this study RC beams with various degree of damage repaired with 100 mm single and double layer plates are studied with reference to load carrying capacity and energy absorption capacity

Key Words: Damage degree, Flexural strengthening, Glass fibre Reinforced Polymer (GFRP)

I. INTRODUCTION:

Structures can be damaged due to over-loading, earthquakes, fire, blast loading, mistakes in design calculations, corrosion of reinforcement and improper concrete mix design. Damage can be defined as the change in structural performance, which can be identified in terms of discrete cracks or a weak zone formation. Undetected and unrepaired damage may lead to structural failure demanding costly repair and huge loss of lives. It is important to study the behavior of damaged RC members, since it involves huge expenditure to demolish and reconstruct them. Therefore it is necessary to increase the service life and load carrying capacity of damaged original structures. In past various techniques were used for strengthening and repair of structural members. In recent years, it is necessary to find strengthening techniques suitable in terms of low cost and fast processing time. Externally bonded FRP has emerged as a new structural strengthening technology for strengthening of RC structures. It has higher strength to weight ratio, durable, less labour and equipments required for installation, ease in handling. The main objective of this experimental study to carry out to investigate the flexural performance of damaged RC beams strengthened with GFRP plates for different damage degree.

II. EXPERIMENTAL PROGRAM:

A. Details of the R C beams:

The experimental work consist of eighteen reinforced concrete beam specimens .All beams had the same dimensions and reinforcement. The beams had rectangular cross section with 150mmϕ x 150 mm x 700mm. Total eighteen beams are casted by M20 grade concrete with tor steel of 10 mm Φ 2 nos at bottom and 8 mm Φ 2 nos at top and stirrups of 6 mm Φ at 150 mm c/c were placed. The reinforcement details of the columns are given in fig. 1. The concrete consisted of coarse aggregate maximum size of 20 mm sieve and retained on 10mm sieve, locally available river sand and 53 grades Portland cement. The specimens were compacted by a tamping rod for good compaction.

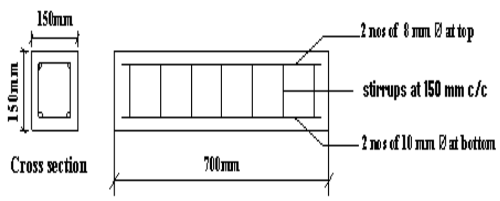

Fig.1 Reinforcement details of beam

B. Preparation of the specimen:

The beams were casted by using mould specimens. Specimens were filled using concrete and compacted using tamping rod after 24 hr. mould was removed and place specimen in a water tank for 28 days. The test beam specimens were divided into five groups. Group I- Reference beams (RB), Group II-0% damage degree beams, beams, Group III-80% damage degree Beams, Group IV- 90% damage degree beams, Group V-100% damage degree beams. GFRP wrapping was done as per procedure given by manufacturer.

C. GFRP APPLICATION METHODOLOGY:

1. Surface preparation of concrete:

The behavior of beams strengthened with GFRP system is highly dependent on the proper surface preparation of the beams. An improperly surface preparation can result deboning of GFRP and beam surface. The concrete or repaired surface to which GFRP system is to be applied should be free from dust, oil, dirt, curing compound, exiting matter and any other matter. This matter can interfere with bonding of GFRP to the beam.

2. Application of primer:

Primer was applied on the concrete surface at the tension side.

3. Mixing of epoxy resin:

Mixed resin is applied on tension the face of concrete surface which is to be strengthened.

4. Application of glass fibre plate on concrete surface:

The FRP laminates was placed on the epoxy resin in a manner that are recommended by the GFRP system manufacturing. Entrapped air between the layers was released by the roller. After 24 hrs.another layer of epoxy resin is placed on GFRP for application of double layer of GFRP sheet.

D. Test procedure and Instrumentation:

All the beams were tested under simply supported condition. The testing was done under two point loading using the Universal Testing Machine of 600 kN capacity. Each beam was instrumented with dial gauge to observe the midspan deflection. The deflections were recorded for each incremental load of 5 kN. All the beams were tested up to the failure of beam in a single load cycle. The crack pattern was observed during the testing. The beam testing set up is shown in Fig. 2 and 3

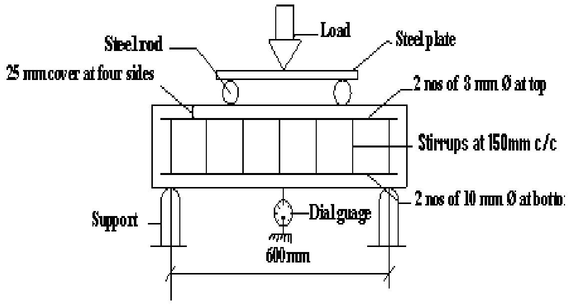

Fig.2 Beams test set up

Fig.3 Beams test set up

III. RESULT AND DISCUSSION:

The experimental result is as follows *Table no.1 Group I-Reference beams (RB).*

Identification	Ultimate load (kN)	Deformation at yield (Δy) mm	Average Deformation mm
RB1	78.50	1.30	3.5
RB2	78.50	1.14	

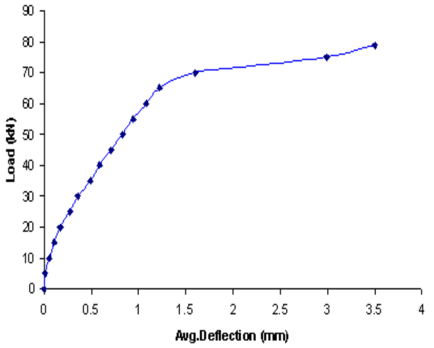

Fig.4 Load Vs Avg. deflection curve for reference beams (RB)

Table no.2 Group II- 0% Damage degree beams strengthened GFRP plate.

Identification	Ultimate load (kN)	Deformation at yield (Δy) mm	Average Deformation mm
ABSL1	105	1.1	3.1
ABDL1	111	1.1	3.96

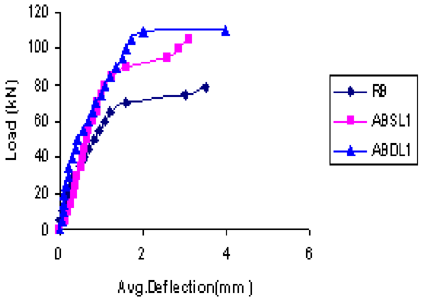

Fig.5 Load Vs Avg. deflection curve fo RB, ABSL1, ABDL1 (Width=100 mm) GFRP Plate

Table no.3 Group III- 80% Damage degree beams strengthened GFRP plate

Identification	Ultimate load (kN)	Deformation at yield (Δy) mm	Average Deformation mm
CBB	62.50	0.5	1.05
BBSL1	78	1	2.1
BBDL1	82	1.6	3.5

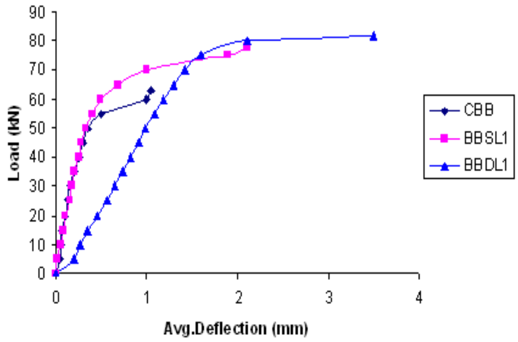

Fig.6 Load Vs Avg. deflection curve fo CBB, BBSL1, BBDL1 (Width=100 mm) GFRP Plate

Table no.4 Group IV- 90% Damage degree beams strengthened GFRP plate

Identification	Ultimate load (kN)	Deformation at yield (Δy) mm	Average Deformation mm
CCB	70.65	0.75	2
CBSL1	71	1.7	3
CBDL1	74	1.1	3.5

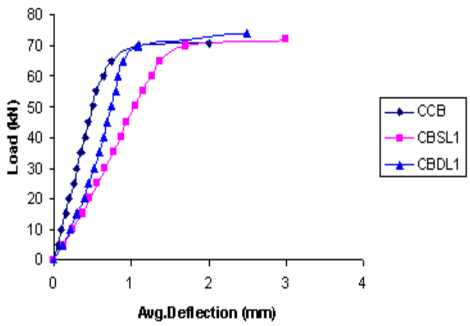

Fig.7 Load Vs Avg. deflection curve for CCB, CBSL1, CBDL1 (Width=100 mm) GFRP Plate

Table no.5 Group V- 100% Damage degree beams strengthened GFRP plate

Identification	Ultimate load (kN)	Deformation at yield (Δy) mm	Average Deformation mm
RB	78.50	1.30	3.5
DBSL1	42	0.8	2.1
DBDL1	52	1.04	2.6

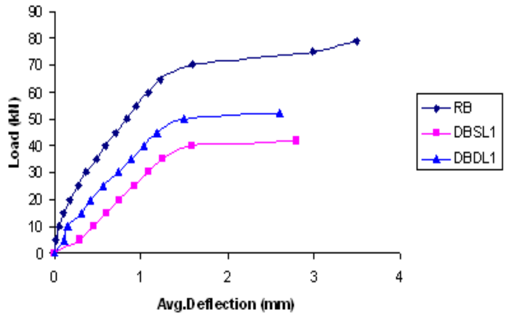

Fig.8 Load Vs Avg. Deflection curve for RB, DBSL1, DBDL1 (Width=100 mm) GFRP Plate

Table no.6 Comparison between RB, ABSL1, BBSL1, CBSL1, DBSL1

Identification	Ultimate load (kN)	Deformation at yield (Δy) mm	Average Deformation mm
RB	78.50	1.30	3.5
ABSL1	105	1.1	3.1
BBSL1	78	1	2.1
CBSL1	71	1.7	3
DBSL1	42	0.8	2.1

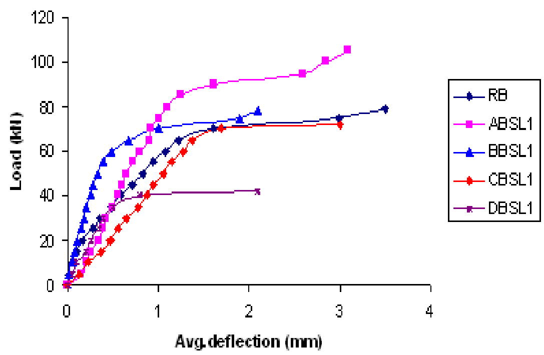

Fig.9 Load Vs Avg, deflection curve for the beams for damage degree in single layer with 100 mm width.

Table no.7 Comparison between RB, ABDL1, BBDL1, CBDL1, DBDL1

Identification	Ultimate load (kN)	Deformation at yield (Δy) mm	Average Deformation mm
RB	78.50	1.30	3.5
ABDL1	111	1.1	3.96
BBDL1	82	1	3.5
CBDL1	74	1.1	3.5
DBDL1	52	1.04	2.6

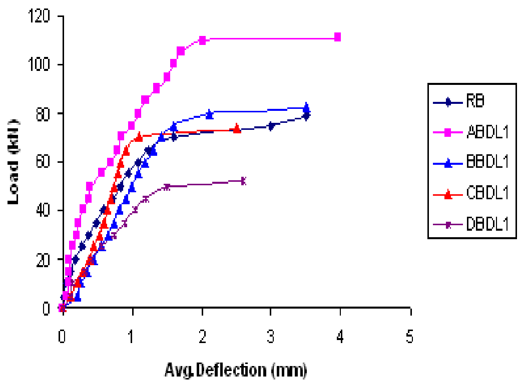

Fig.10 Load Vs Avg. deflection curve for the beams for damage degree in double layer with 100 mm width.

DISCUSSION:

Failure Modes and Crack pattern:

Normally four flexural failure modes were observed with GFRP plate externally bonded reinforced concrete beams. These failure modes occur after considerable flexural cracking and development of yielding steel reinforce bars. The width of GFRP plate and improper surface preparation affect on the failure mode of the damaged strengthened beams. The reference beams (RB) failed by crushing of concrete at top of beam after yielding of steel bar and occurrence of many flexural cracks on the tension face of the beam.

Total eighteen RC beams were cast. Two beams from each group are considered as reference beam (RB), without GFRP plates. The value of ultimate load at failure reference beam is known to obtain the damage degree. The beams were damaged with fixed damage degree (0%, 80%, 90%, and100%). For the all RB, first, second, third shear crack was seen in the shear zone of the beam at a load of about 25kN, 45kN, 55 kN. The load increases crack width goes on increasing from tension face to compression face was observed. These beams were failed at the ultimate load of 78.50kN, 62.80kN, 70.65kN, 100kN respectively. The result and load deflection response curves are presented in table. Development of the shear crack was clearly seen at the support as shown in fig. 5.18. Then these cracks come at the midspan by existing flexural cracks. Finally, it leads to the failure of beam with sudden propagation of cracks. The flexural cracks appeared at midspan followed by yielding of steel reinforcement. It was observed that strengthening of the damaged beams with GFRP plates improved the load carrying capacity of the damaged beams.

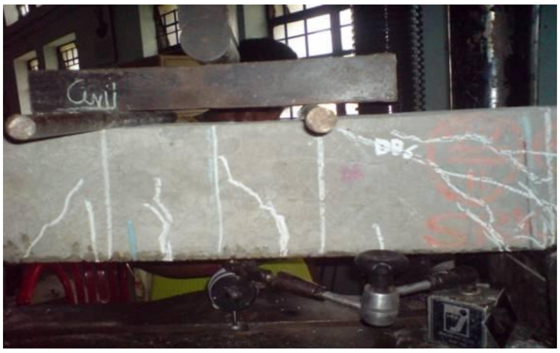

Fig.11 Shear and flexural cracks

Damaged Beams Strengthened With GFRP Plate:

The beams ABSL1, ABDL1, having 0% damage degree failed at 105kN, 111kN, respectively. These beams increases 34%, 42%, ultimate load carrying capacity and decrease energy absorption 6.21%, 2.33% as compared with RB. The load carrying capacity and energy absorption of the beams BBSL1, BBDL1 increases 24.20%, 30.57% and increase in 17.46%, 21.69% as compared to damaged control beam (CBB). From experimental results it is clear that 90% damaged beams when strengthened by using 100 mm GFRP plate (CBSL1, CBDL1) in single and double layer restore its original strength by 0.5% and 5% respectively. The single layer, double layer of width 100 mm (DBSL1, DBDL1) beams decrease both load carrying capacity and energy absorption by 46.49%, 33.75% and 61.44%, 60.45% respectively as compared with RB.

Effect Of Damage Degree Of Beams:

From the experimental results it is observed that for any damage degree the GFRP plate provides higher mechanical performance. The mechanical performance of damaged beams with different damage degree in terms of ductility and energy absorption decrease than those of reference beam. It was seen that for any damaged degree the strengthening of beams using GFRP laminate is effective. From this it was clear that the beams having 0% and 80% damage degree give higher performance in terms of load capacity and energy absorption. The 90% damage degree strengthened beams exhibits lowest increase in load carrying capacity. The 100% damage degree strengthened beams there is loss in the load carrying capacity and loss in energy absorption as compared to reference beam (RB).

Effect Of GFRP Plate Width:

Bonding of GFRP plates to the tension face of RC beams, weak in shear is not adequate structural solution either to increases their bearing load capacity or to change their mode of failure. In order to observe the effect of effectiveness of GFRP plate on the load carrying capacity and energy absorption of the damaged beams, then these damaged beams when strengthened with single layer, double layer of different width 100 mm shear cracks were observed. As increase the plate width and two layers of GFRP the no. of cracks goes on decreases. Finally the experimentally result shows that GFRP plate have more influence on the mechanical behavior of damaged beams than the effect of concrete and steel properties.

Energy Absorption Of Damaged Beams:

The Energy absorption curve Of damaged Beams strengthened with GFRP plate as shown in fig.

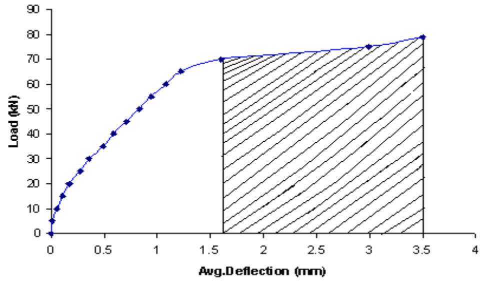

Fig.12 Energy absorption curve for reference beam

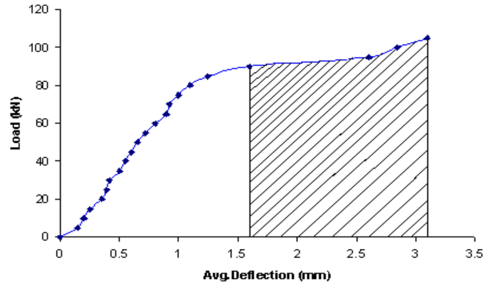

Fig.13 Energy absorption curve for 0% damage degree beams.

CONCLUSION:

In order to evaluate the effectiveness of using GFRP plates to strengthened damaged beams, a series of beams were designed, cast, damaged for different damage degree (0%, 80%, 90% and 100%) and then tested up to the failure.

From the results of this study the following conclusions shall be drawn:

1. The load carrying capacity for 0% damage degree beams is increased after strengthening with single and double layers of 100 mm width of GFRP plates is 34%, 42% and 5%, 17% respectively compared with reference beam.

2. The 80% damage degree beams increases load carrying capacity 4.45% when strengthened with 100 mm width of GFRP plate in double layer as compared with reference beam.

3. From experimental results it is clear that 90% damage degree beams when strengthened by using 100 mm GFRP plate in single and double layer restore its original strength.

4. The 100% damaged beams when strengthened in single and double layers of 100 mm loss in load carrying capacity and also loss in energy absorption as compared with reference beam.

5. The results show that, applying GFRP plate in double layers to the tension face of RC beam is most effective. The ultimate load carrying capacity of unstrengthened RC beams can be nearly doubled by using a proper combination of GFRP sheets coupled with the proper epoxy.

6. The experimental result indicates that a significant gain in flexural strength can be achieved by bonding GFRP plates in different width and layers to tension face of damaged RC beams , hence contribute higher mechanical performance.

7. The load carrying capacity and performance (failure mode, deflection, crack pattern etc.) of damaged strengthened GFRP beams are strongly depends on the effectiveness of the GFRP plate.

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BIOGRAPHIES

B.E,M.E.CIVIL*(Engg.Rajarambapu Institute of Technology, Rajaramnagar*)
Asst. Professor *Department of Civil Engg., RMD Sinhgad School of Engineering, Warje, Pune, Maharashtra, India*

B.E, M.E ,Phd. (Engg. *Rajarambapu Institute of Technology, Rajaramnagar)*
Professor & Head *Rajarambapu Institute of Technology, Rajaramnagar Maharashtra, India*