REHABILITATION OF REINFORCED CONCRETE BEAMS BY USING MATERIALS GFRP, CFRP AND BONDING STEEL PLATE

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ABSTRACT: This research paper shows that materials GFRP (glass fiber reinforced polymer) CFRP (carbon fiber reinforced polymer) and bonding steel plate, were used to rehabilitate 12 numbers of reinforced concrete (RC) beam of size 75x150x1750mm for M20 grade of concrete. These were distressed in flexure by adopting av/d ratio 3 and 4 under two point loading conditions by taking 90% of the ultimate load. Then, these distressed beams were repaired and retested up to failure. The aim of this study is to determine the suitability of best rehabilitate material type to be used in RC beams for repairing and restoring good strength and for considering economical aspects. Hardened concrete specimens were tested for compression and flexure test. The results of these experiments show that beams repaired using bonding plate gave less deflection than other two materials. The flexural strength increased significantly up to 13% for concrete beams repaired with bonding plate similarly, flexural strength increased up to 10% for GFRP and 8% for CFRP.

I. INTRODUCTION

The maintenance, rehabilitation and upgrading of structural members, is perhaps one of the most crucial problems in civil engineering applications. Moreover, a large number of structures constructed in the past using the older design codes in different parts of the world are structurally unsafe according to the new design codes. Since replacement of such deficient elements of structures incurs a huge amount of public money and time, Strengthening has become the acceptable way of improving their load carrying Capacity and extending their service lives. Infrastructure decay caused by premature deterioration of buildings and structures has lead to the investigation of several processes for repairing or strengthening purposes. One of the challenges in strengthening of concrete structures is selection of a strengthening method that will enhance the strength and serviceability of the structure while addressing limitations such as constructability, building operations, and budget. Previously, the retrofitting of reinforced concrete structures, such as columns, beams and other structural elements, was done by removing and replacing the low quality or damaged concrete or/and steel reinforcements with new and stronger material. However, with the introduction of new advanced composite materials such as fiber reinforced polymer (FRP) composites, concrete members can now be easily and effectively strengthened using externally bonded FRP composites. Retrofitting of concrete structures with wrapping FRP sheets provide a more economical and technically superior alternative to the traditional techniques in many situations because it offers high strength, low weight, corrosion resistance, high fatigue resistance, easy and rapid installation and minimal change in structural geometry. In addition, FRP manufacturing offers a unique opportunity for the development of shapes and forms that would be difficult or impossible with the conventional steel materials. Although the fibers and resins used in FRP systems are relatively expensive compared with traditional strengthening materials, labor and equipment costs to install FRP systems are often lower. FRP systems can also be used in areas with limited access where traditional techniques would be impractical.

II. EXPERIMENTAL PROGRAMME

2.1 Materials properties

The concrete mix used for all the beams is designed for a M20 with a water cement ratio of 0.45. Main reinforcing bars of Fe 415 of dia. 8 mm at top and 10 mm at bottom are used. Rectangular closed stirrups of 6 mm mild steel bars.

2.2 Testing Program

Table 1: Designations of beams

Materials	**a_v/d ratio 3**		**a_v/d ratio 4**	
	Partial Wrapping	Fully Wrapping	Partial Wrapping	Fully Wrapping
CFRP	Pc3 beam	Fc3 beam	Pc4 beam	Fc4 beam
GFRP	Pg3 beam	Fg3 beam	Pg4 beam	Fg4 beam
Bonding Steel Plate	Ps3 beam	Fs3 beam	Ps4 beam	Fs4beam

The beams were designated as Pc3, Pg3, and Ps3 for partial wrapped with a/d ratio 3 similarly, Pc4, Pg4 and Ps4 were partial wrapped with a/d ratio 4 and Fc3, Fg3 and Fs3 were fully wrapped beams with a/d ratio 3 similarly, Fc4, Fg4 and Fs4 were fully wrapped beams with a/d ratio 4 respectively. So that each four beams have been repaired with different type of adhesive materials and compared their strength.

Moulds were removed after 24 hours and the specimens were placed for curing. Three dial gauges were fixed at bottom in order to record the strains. Three gauges were fixed below the beam at middle third and midspan to observe the deflections. The beams were tested in a Universal Testing Machine under two point loading at middle third points of the span. The whole set up was placed with Universal Testing Machine of 200 ton capacity and subjected to two points loading.

2.3 Experimental set up

The load is applied in small increments and the dial gage readings are taken every 4kN until failure occurs. The deflections are recorded at each level of loading. Cracks are detected and their widths are recorded at several levels of loading. Figure (2) shows the loading arrangement used throughout the tests.

Where,

Adopt a_v/d =3 and 4

a_v= shear span

Fig 1: loading arrangement of beams

III. REPAIR OF CRACKS IN CONCRETE STRUCTURES:

Cracks need to be repaired if they reduce the strength, stiffness, or durability of the structure to an unacceptable level, or if the function of the structure is seriously impaired.

3.1Repair Procedure by applying of GFRP

The surface for application must cleaned and made free from dirt, grease oil and loose particles before application of GFRP resins, thoroughly removed the dirt's by any mechanical means. Firstly albumin 15ml mix with 1 liter resin and then catalyst 16ml mix with those mixtures. Sealing the crack by using those mixtures after 1hour give one coating to that beam. After wrapping the beam by using glass fibers mat.

Fig.2 shows that after fully wrapping of beam by using GFRP

Fig.3 shows that after Partially wrapping of beam by using GFRP

3.2Repair Procedure by applying of CFRP

The surface for application must cleaned and made free from dirt, grease oil and loose particles before application of CFRP resins, thoroughly removed the dirt's by any mechanical means. Firstly albumin 15ml mix with 1 liter resin and then catalyst 16ml mix with those mixtures. Sealing the crack by using those mixtures after 1hour give one coating to that beam. After wrapping the beam by using Carbon fibers mat.

Fig.4 shows that Wrapping of beam by using CFRP

Fig.5 shows that Partial Wrapping of beam by using CFRP

3.1Repair Procedure by applying of Bonding Steel plate

The surface for application must cleaned and made free from dirt, grease oil and loose particles before application of FRP resins, thoroughly removed the dirt's by any mechanical means. Firstly albumin 15ml mix with 1 liter resin and then catalyst 16ml mix with those mixtures. Sealing the crack by using those mixtures after 1hour give one coating to that beam. After wrapping the beam by using Bonding steel plate.

Fig.6 shows that Partial Wrapping of beam by using Bonding plate

Fig.7 shows after Wrapping of beam by using bonding steel plate

IV. TEST RESULT AND DISCUSSIONS

4.1 behaviors of original beams

Generally, in the original beam, the first shear crack started at one shear span at the beam bottom, near the support, and it propagated towards the nearest loading point as an inclined crack (diagonal crack). Some fine flexural cracks were observed before and at the appearance of the first diagonal crack. In some beams (such as set A), after increasing the applied load, another diagonal crack was developed at the other shear span of the beam. With more applied load, the first (major) diagonal crack rapidly propagated to the nearest loading point, and then collapse happened by splitting the beam along this crack.

RETESTING AFTER BEAM'S REPAIR

After the repair process is completed, the repaired beams are retested to evaluate the efficiency of the repair work. Loading arrangement and test procedures of the repaired beams are the same as those described for the original beams.

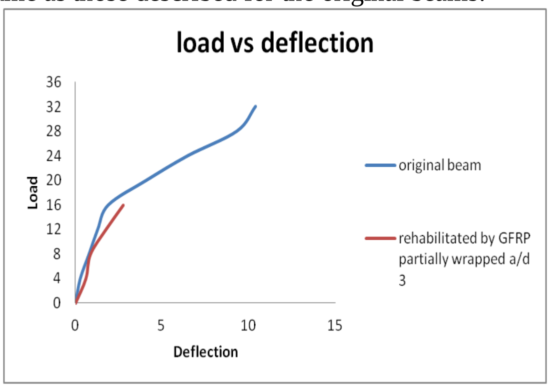

Fig.8 shows that Load vs deflection for original beam and Pg3 beam

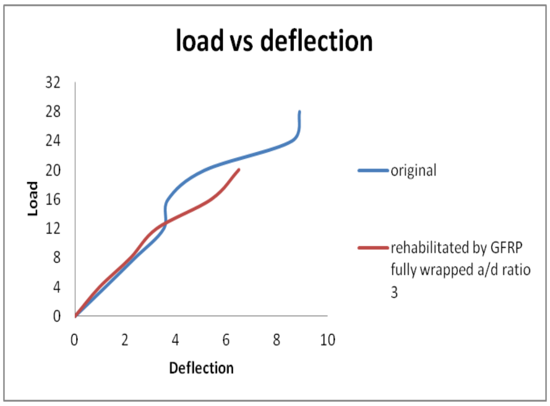

Fig.9 shows that Load vs deflection for original beam and Fg3

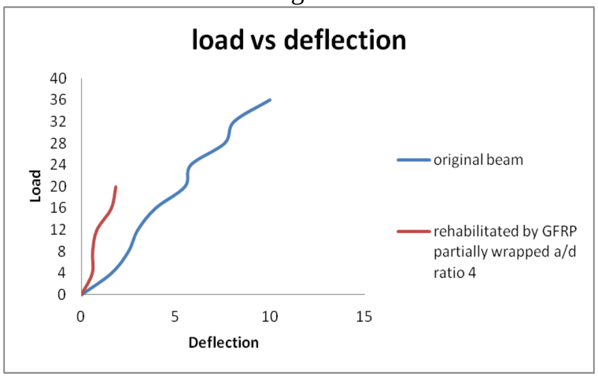

Fig.10 shows that Load vs deflection for original beam and Pg4 beam

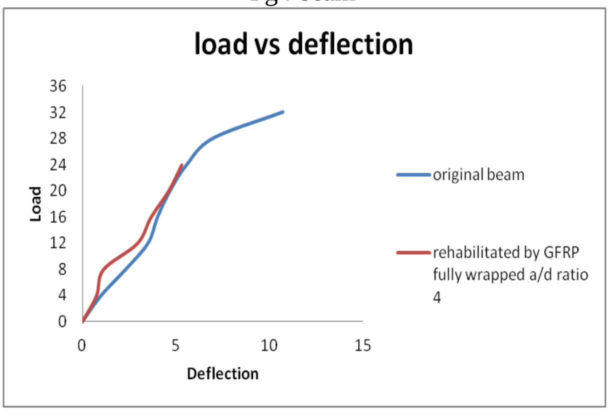

Fig.11 shows that Load vs deflection for original beam and Fg4 beam.

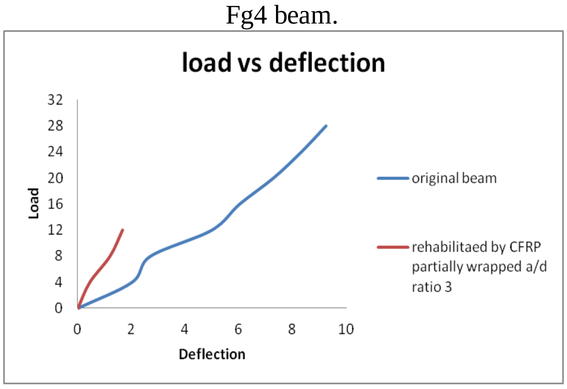

Fig.12 shows that Load vs deflection for original beam and Pc3 beam.

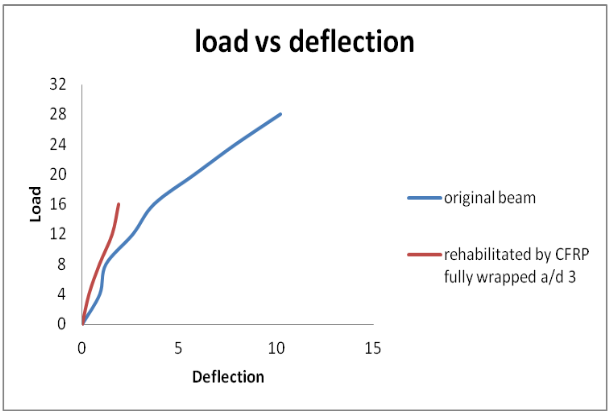

Fig.13 shows that Load vs deflection for original beam and Fc3 beam.

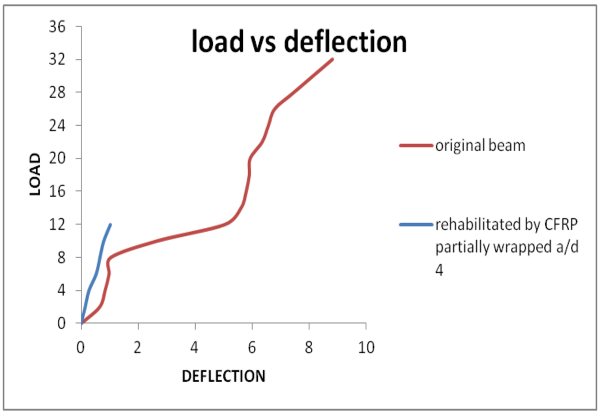

Fig.14 shows that Load vs deflection for original beam and Pc4 beam.

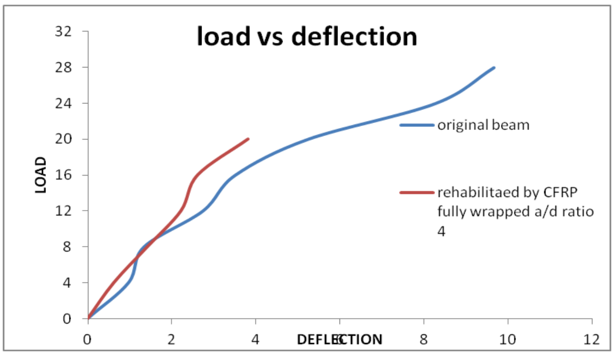

Fig.15 shows that Load vs deflection for original beam and Fc4 beam.

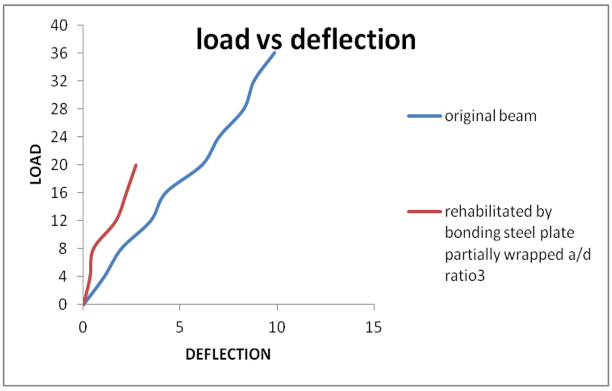

Fig.16 shows that Load vs deflection for original beam and Ps3 beam.

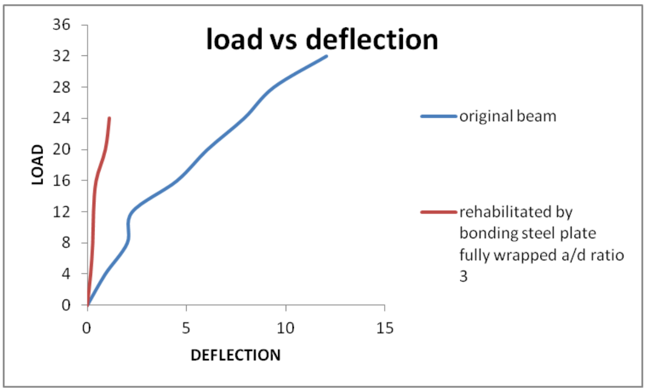

Fig.16 shows that Load vs deflection for original beam and Fs3 beam.

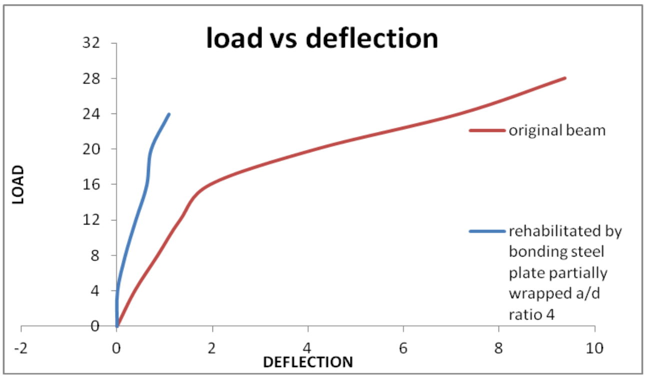

Fig.17 shows that Load vs deflection for original beam and Ps4 beam.

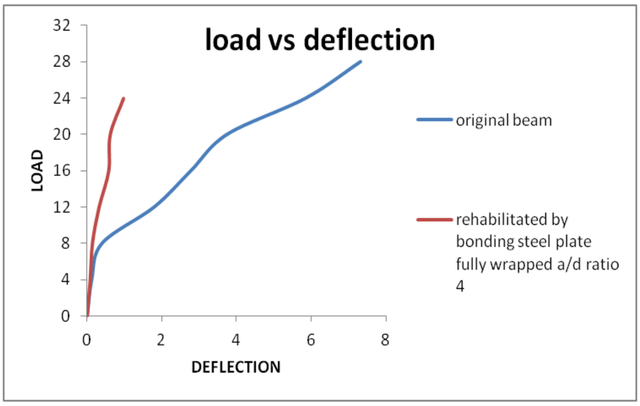

Fig.18 shows that Load vs deflection for original beam and Fs4 beam.

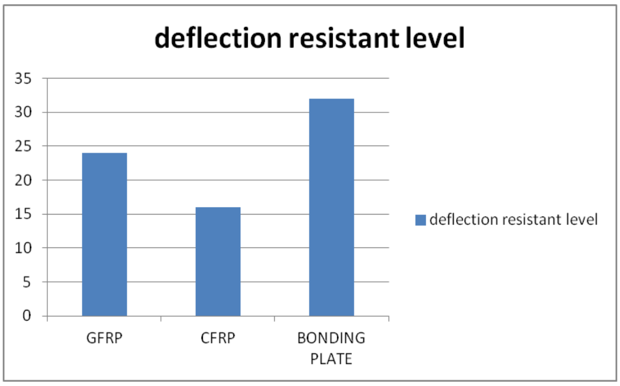

Fig.18 Bar Chart shows Deflection tolerance for each material used based on ultimate load

From this result bonding plate gives better strength among the other.

V. CONCLUSIONS

The structural behaviors of the repaired beams by adhesive materials are similar to that of original beams. Failures in a/d ratio 3 are characterized by flexural crack on mid- span only and Failures in a/d ratio 4 are characterized by flexural crack on mid-span and diagonal crack on shear span. The repaired beams showed lower stiffness and ductility compared to the original beams. Among the three adhesive resin materials used for repairing, bonding plate was more economical, because it covered major cracks and didn't allow them to reopen and the partially wrapped beams failed due to debonding and fully wrapped beams failed due to deflection.

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