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PERFORMANCE AND ANALYSIS OF REINFORCED CONCRETE BEAMS BY CFRP LAMINATES

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ABSTRACT

Worldwide a great deal of research is currently being conducted concerning the use of fiber reinforced plastic wraps, laminates and sheet in the repair and strengthening of reinforced concrete member, fiber reinforced polymer (FRP)application is a very effective way to repair and strengthen structures that have become structurally weak over their life span , FRP repair system provide an economically viable alternative to traditional repair system and materialsExperimental investigations on the flexural and shear behavior of RC beams strengthened using continuous carbon fiber reinforced polymer (CFRP)sheets are carried out externally reinforced concrete beams with epoxy bonded CFRP sheets were tested to failure using a symmetrical two point concentrated static loading system .five beams were casted for this experimental test program .in one control beam ,other four beam first layer, two layer and three layer beam in flexural were casted were strengthened using laminates of carbon fiber reinforced polymer(CFRP) sheet. Experimental data on load deflection and failure modes of each of the beams were obtained .the detail procedure and application of CFRP sheet for strengthening of RC beams is also included .the effect of number of CFRP layers and its orientation on ultimate load carrying capacity and failure mode of the beams are investigated.

Keywords: *FRP,CFRP,Carbon fiber,RC beam.*

1 GENERAL

The maintenance rehabilitation and upgrading of structural members is perhaps one Of the most crucial problems in civil engineering application 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 code since replacement of such Deficient elements of structures increase 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 theStructure while addressing limitations such as constructability building operations and budget structural strengthening may be required due to many different situations

- Additional strength may be needed to allow for higher loads to be placed on the structures .this is often required when the use of the structure changes and higher load carrying capacity is needed .this can also occur if additional mechanical equipment filing system ,planter or other items are being added to structures
- Strengthening may be needed to allow the structure to resist loads that were not ant capped in the original design this may be encountered when structural strengthening is required for loads resulting from wind and seismic force or to improve resistance to blast loading
- Strengthening systems can improve the resistance of the existing structure to internal forces in either a passive or active manner .passive strengthening systems are typically engaged only when additional loads

.beyond those existing at the time of installation .are applied to the structure .bonding steel plates or fiber –reinforced polymer (FRP) composite on the structural member .whether passive or active .the , challenge is to archived composite behavior between the existing structure and the new strengthening element

The selection of the most suitable method for strengthening requires careful consideration of many factors including the following engineering issue

- Magnitude of strength increase
- Effect of changes in relative member stiffness
- Size of project (method involving special material and ,methods)
- Environmental conditions (methods using adhesives might be unsuitable for applications in high temperature environment ,external steel methods may not be suitable in corrosive environment)
- In –place concrete strength and substrate integrity (the effectiveness of methods relying on bond to the existing concrete can be significantly)
- Dimensional /clearance constraints (section enlargement might be limited by the degree to which the enlargement can approach on surrounding clear space)
- Availability of materials equipment and qualified contractors
- Construction cost, maintenance cost and life cycle cost
- Load testing to verify existing capacity or evaluate new techniques and material

2 LITERATURE REVIEW

Mohammed , (2011) This paper investigates the response of as-built and carbon fiber reinforced polymers (CFRP)-strengthened concrete beams subjected to a free fall drop hammer impact loading. The free fall impacting drop hammer height varied from 0.6 m to 4 m. Three-dimensional complex nonlinear finite element analysis (FEA) models of as-built and CFRP-strengthened concrete beams were developed. An experimental study on six as-built reinforced concrete beams reported in the literature was used to validate the accuracy of the proposed FEA models. FEA results also showed that the optimum amount of CFRP energy absorption capacity depends on the amount of tensile steel bars. impact loading of reinforced concrete beams externally strengthened with CFRP laminates and steel plates. The authors reported that both retrofitting materials improved the impact resistance of the concrete beams. The U-shaped CFRP strengthening not only contained flexural cracks but also changed the overall failure mode of RC concrete beams from flexure to local crushing of the concrete at the impact location

Habibur Rahman Sobuz(2011) In the present paper, experimental study designed to investigate the flexural behavior of reinforced concrete beams strengthened with CFRP laminates attached to the bottom of the beams by epoxy adhesive subjected to transverse loading. The response of control and strengthened beams were compared and efficiency and effectiveness of different CFRP configurations were evaluated. It was Observed that tension side bonding of CFRP sheets with U-shaped end anchorages is very efficient in flexural strengthening. The need for rehabilitation or strengthening of bridges, building and other structural elements may arise due to one or a combination of several factors including construction or design defects, increased load Carrying demands, change in use of structure, structural elements damage, seismic upgrade, or meeting new code requirements.

Chin (2011) This paper presents the study of strengthening R/C beams with large circular and square opening located at flexure zone by Carbon Fiber Reinforced Polymer (CFRP) laminates. A total of five beams were tested to failure under four point loading to investigate the structural behavior including crack patterns, failure mode, ultimate load and load deflection behavior. Test results show that large opening at flexure reduces the beam capacity and stiffness; and increases cracking and deflection The strengthening configuration of CFRP laminates around large openings at flexure significantly decreased the cracks formed around the opening and greatly reduced the beam deflection approximately 61% as in the case of square opening. No significant reduction in beam deflection with large circular opening was observed. Strengthening of beam containing a large circular opening at mid-span with CFRP laminates remarkably restore the beam original structural capacity.

Abdel-Jaber (2011), present a reasonable model for strengthening. The experiments investigated the shear behavior of reinforced concrete beams strengthened by the attachment of different configurations and quantities of CFRP using epoxy adhesives External plate bonding is a method of strengthening which involves adhering additional reinforcement to the external faces of a structural member. The success of this technique relies heavily on the physical properties of the material used and on the quality of the adhesive, generally an epoxy resin, The increase in strength was governed by the anchorage of the strips on each sideof the projected shear crack.)Appears to be an efficient method of shear strengthening

Jan piekar et.al (2011) The paper Improvement of performance of building objects particularly made of concrete and stone (bridges, ceilings, girders) is more and more often obtained via reinforcing with thin, high-strength bands made of carbon polymers. The reinforcement comprises gluing high-module, or high-strength thin carbon laminate (using suitable resin) to the building element at its supporting side. Additional reinforcement is obtained in result of gluing carbon laminate, having suitable orientation at the beam side planes, within shearing areas. Bending strength tests, measurements of fracturing energy and measurements of static Young's modulus A further improvement of the building element load capacity is obtained as a result of gluing the carbon laminate to shearing zones Reinforcement of beams reinforced with carbon laminate multiplies the amount of energy which should be delivered to destroy the system

Hojatkashani1,(2012):The paper investigate the effect of Carbon Fiber Reinforced Polymer (CFRP) composites on the fatigue response of reinforced concrete beams. 6 reinforced concrete (RC) beams, from which 3 were retrofitted with CFRP sheets, were prepared and subjected to fatigue load cycles. To predict and trace the failure occurrence and its growth, a small notch was induced at the middle span in bottom surface of all RC specimens Also, a discussion on possibility of the local deboning phenomenon resulted from such interfacial stresses was presented. Load–deflection curves, strain responses and propagation of tensile cracks provided an insight on the performance of the CFRP strengthened beams subjected to different cycles of fatigue loading. An experimental program was carried out to examine the monotonic and fatigue behavior of intact and CFRP retrofitted RC beams. The main objective of this paper was to study the variation of strains at the critical regions through fatigue loading cycles.

Aravindan (2013): The paper present experimental results of the flexural strengthening of reinforced concrete beams by CFRP Laminates attached to the tensile soffit of the beams by epoxy adhesive. The remaining one beam were used a control specimen. static response of all the beams were evaluated in terms of strength, stiffness, ductility ratio, energy absorption, capacity factor, compositeness between CFRP fabric in concrete and the associated The external bonding of CFRP fabrics offers an externally effective means of strengthening Reinforced Concrete (RC) beams flexure. failure modes CFRP fabric property bonded to the tension face of RC beams can enhance the flexural strength substantially the strengthened beams exhibit an increase in flexural strength for 40 to 45 percent for two layers static loading .Respectively .At any given load level, the deflection are reducedsignificantly thus by increasing the stiffness for the strengthened beams, an ultimate load level of control specimen, the strength beam exhibit a decrease of deflection . . In this investigation CFRP strengthened beam gives appreciable strength, stiffness, stability and ductility when compared to control beam.

Lakshmikandhan ,(2013)The present study was carried out to arrive at the percentage of damage in reinforced concrete beam from its stiffness degradation. The repair and rehabilitation of concrete structures has become a necessary measure for deficient structures. The visual damages can be comfortably observed during visual inspection, but the damages occurred internally needs examination through experimental and/or analytical investigation. The bonding strength of CFRP governs the strength of the repaired beams in most cases. The bonding of CFRP is better in the cracked beams than in the un-cracked beam

Shamsher (2013) The present investigation addresses the shear strengthening of deficient reinforced concrete (RC) beams using carbon fiber-reinforced polymer (CFRP) sheets. The effect of the pattern and orientation of the strengthening fabric on the shear capacity of the Strengthened beams were examined corresponding to each applied shear force. It is concluded that Beam-0°/90°/45° show about 25%, 19%, and 40% increases in shear-load carrying capacity in comparison to the control beam, respectively. Also, there exists a critical value of shear force up to which there is no appreciable shear strain in the CFRP sheets/beam. There is an increasing demand for damaged reinforced concrete structures to be rehabilitated without increasing their self-weight., this force marks the ultimate shear resistance of the control beam. However, the strengthened beams show appreciable strength well beyond their critical shear force

3 R.C.C. BEAM DESIGN

Five reinforced concrete beam with simply supported span length of 1.1m ,and cross section 150mmx120mm were cast under two point loading details of the beam geometry and flexural reinforcement locations are illustrated .these dimensions were selected by considering the following facilities available in structural engineering construction ,testing and handling facilities

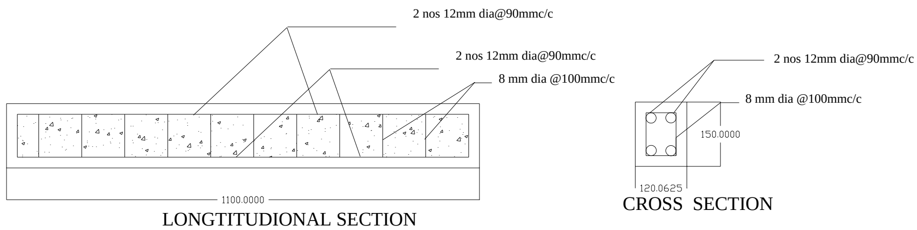

Fig.1 REINFORCEMENT DETAILS

3.1 Carbon fiber

Carbon fiber is the most expensive of the more common reinforcement but in space applications the combination of excellent performance characteristic Carbon fibers are used for their high performance and are characterized by high Young modulus of elasticity as well as high strength.. FRP composites based on carbon fibers are usually denoted as CFRP.

Fig.2 Carbon Fiber

Table 1 Physical Properties of CFRP

Materials	Property	Values
CFRP Laminates	Sheet form	Uni directional roving
	Yield strength(MPa)	1315
	Modulus of Elasticity(GPa)	165
	Elongation at ultimate(%)	2.15
	Design thickness (mm/ply)	1.2
	Density(g/cm^3)	1600
	`Tensile strength(MPa)	1685

Table 2 Properties of Epoxy Resin

Property	Range
Density (g/cm2)	1.2-1.3
ensile Modulus, Mpa	55-130
Tensile strength, Gpa	2.75-4.10
Thermal expansion	45-65
Water absorption	0.08-0.15

4 EXPERIMENTAL SETUP

The beam specimens are to be tested under static third point loading.. By applying third point loading free bending can be achieved between the points of action of loads.

Fig.3 Experimental Setup

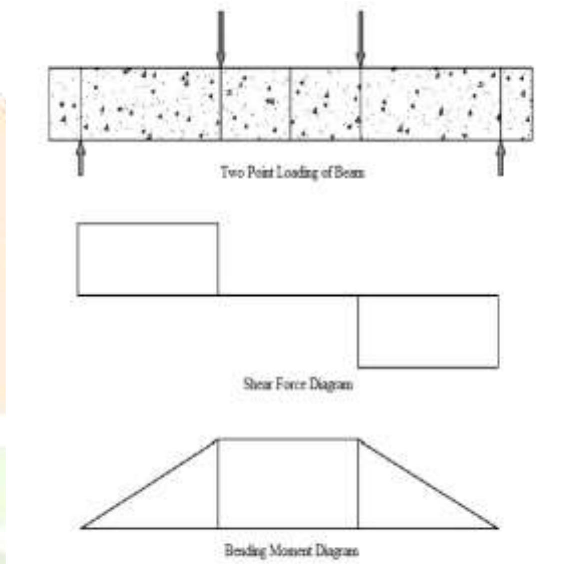

Fig.5 Bending moment & shear force diagram

Table 3 Experimental results for RC Beam

Beam designation	Frst crack		Ultimate moment (kNm)	Maximum deflection (mm)	Energy absorption factor (KNmm)	Ductility factor
	Load (kN)	Deflection (mm)				
Control	16	1.11	48	9	248.6	2.4
FB-1L	18	1.74	64	8.8	288	1.87
FB-2L	22	1.23	72	8.6	359	1.675
FB-3L	32	1.42	82	8.4	372.4	1.28

4.1 Ultimate moment is expressed by the following equation:

$M_u = 0.36 \times f_{ck} x X_U \times b(d - o.42X_U)$

Table 4 Analytical Results

Beam designation	First crack load (kN)	Ultimate Moment (kNm)
Control	10.8	40
FB-1L	20.7	70
FB-2L	23.1	86
FB-3L	33	97

Fig.6 Crack pattern of RC all beams

4.2 Comparison of analytical and experimental results

The ultimate moment capacity of every specimen was experimentally calculated by testing the RC beams under two point loading ,The experimentally calculated ultimate moment values were compared with that predicated analytical moment values and as shown from the comparison of results .it was clearly established that the proposed analytical equation for the calculation of ultimate moment capacity of strengthened beams using CFRP laminates.

Table 5 Comparison of experimental and analytical load values of RC beams

Beam designation	Experimental ultimate moment (kNm)	Theoretical ultimate moment (kNm)	Ratio of experimental ultimate moment to theoretical ultimate moment
Control	10.6	8.89	1.2
FB-1L	15.5	14.2	1.09
FB-2L	19.1	16	1.21
FB-3L	21.5	17.2	1..25

5 CONCLUSION

5.1 Conclusions based on the analytical results based CFRP laminates

A simplified approach to estimate the ultimate moment capacity of cracked load CFRP laminates was developed in this research and results from the simplified approach developed in this study had good correlation with the experimental results.

5.2 Conclusions based on the Experimental and Analytical results of strengthened RC Beams

- The addition of CFRP laminates to the tension face of the reinforced concrete beams substantially delays the first crack load Mechanical properties such as load carrying capacity, energy absorption factor, and stiffness was found to be increased for strengthening beams and ductility factor was found to be decrease for strengthening.
- The epoxy resin used for bonding the CFRP laminates to the tension face of the reinforced concrete beams ensures that the lines does not break before failure of beams.
- The failure of the composite beam is characterized by development of flexural cracks over the tension zone .the spacing of the cracks is also reduced for strengthened beam .the indicates the better stress distribution.
- Similarly ultimate moment capacity of strengthened beams calculated in from analytical calculation goes in hand with experimental values
- CFRP fabric properly bonded to the tension face of RC beams can enhance the flexural strength substantially .The strengthened beams exhibit an increase in flexural strength of 18 to 20 percent for single layer and 40 to 45 percent for two layers.

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