STRENGTHENING OF REINFORCED CONCRETE BEAMS USING FIBER REINFORCED POLYMER COMPOSITES

Mr. Prashant P. Rangari[1], Ms. Deepa P. Telang[2]

[1]M. Tech Student (SE), Department of Civil Engineering, GHRAET, Nagpur, India
[2]Assistant Professor, Department of Civil Engineering, GHRAET, Nagpur, India

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Abstract - *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 systems provide an economically viable alternative to traditional repair systems and materials. The purpose of this research is to investigate the flexural and shear behavior of reinforced concrete beams strengthened with varying configuration and layers of GFRP sheets. More particularly, the effect of the number of GFRP layers and its orientation on the strength and ductility of beams are investigated. Two sets of beams were fabricated and tested up to failure. In SET I three beams weak in flexure were casted, out of which one is controlled beam and other two beams were strengthened using continuous glass fiber reinforced polymer (GFRP) sheets in flexure. In SET II three beams weak in shear were casted, out of which one is the controlled beam and other two beams were strengthened by using continuous glass fiber reinforced polymer (GFRP) sheets in shear.*

Key Words– Strengthening, Reinforced concrete beams, Glass fiber reinforced polymer, Composites, Epoxy resin.

1. INTRODUCTION

Over the past decade, an augment in the application of FRPCs has been seen in construction business as of their high-quality engineering property. Additionally, these are being measured as a replacement to the conventional steel in reinforced concrete structures due to continuing thrust in the price of FRPC materials. Various aspects of FRPC materials mutually with guiding principle for assortment of polymer adhesives for concrete have been proposed. This section provides beginning to the strengthening of reinforced concrete (RC), pre-stressed concrete and steel members using externally bonded steel plate or fiber reinforced polymer (FRP) composites sheets and plates by reviewing the most important investigations reported in the literature. In addition, a segment is committed to the strengthening of RC members in shear utilizing FRP plates and sheets. Though, external plating and its function as a strengthening technique has merely been made achievable by the improvement of suitable adhesives, consideration is also given to the types of adhesive which can be used for external plate bonding and their necessities for this application. After making an allowance for reported plate bonding studies, a brief review of surface preparation techniques applicable to FRP and concrete adherends is presented.

2. METHODOLOGY

The methodology of experiment consists of casting of two sets of reinforced concrete (RC) beams. In SET I three beams weak in flexure were casted, out of which one is controlled beam and other two beams were strengthened using continuous glass fiber reinforced polymer (GFRP) sheets in flexure. In SET II three beams weak in shear were casted, out of which one is the controlled beam and other two beams were strengthened by using continuous glass fiber reinforced polymer (GFRP) sheets in shear. The strengthening of the beams is done with varying configuration and layers of GFRP sheets. Experimental data on load, deflection and failure modes of each of the beams were obtained. The change in load carrying capacity and failure mode of the beams are investigated as the amount and configuration of GFRP sheets are altered.

3. REVIEW

V. N. Kaliakin et.al[1] analyze the concrete beams reinforced with externally bonded woven composite fabrics. In the experiments, woven composite fabrics made of aramid, E-glass, and graphite fibers were bonded to the webs of T-beams using a two-component epoxy. The beams were loaded in flexure and tested to failure. All beams failed in shear. The ultimate strengths of the externally reinforced beams were 60-150% higher than the strengths of beams without external reinforcement.

G. Spadia et.al[2] investigate structural behavior of composite RC beams with externally bonded CFRP. Four beams, three with bonded CFRP plates on the tension face, and two of which were provided with carefully designed external anchorages at the ends of the plates and along the span, were tested under four-point bending over a span of 4.8 m. The tests were carried out under displacement control. The beams were extensively instrumented to monitor strains, deflection, and curvature over the entire spectrum of loading to total failure, and to determine the structural response to load of the composite beams.

B. Taljsten et.al[3] presents different methods and tests for the application of carbon fibre reinforced plastic (CFRP) fabrics and tapes to concrete beams. The purpose of the tests were twofold; first to study the shear force capacity of the beams both before and after strengthening; and second, to examine three different ways of applying the fabrics. These were: two hand lay-up systems, one vacuum injection system and one pre-preg system. The total number of beams tested was eight.

V. P. Ramana et.al[4] summarizes the results of experimental and analytical studies on the flexural strengthening of reinforced concrete beams by the external bonding of high-strength, light-weight carbon fiber reinforced polymer composite (CFRPC) laminates to the tension face of the beam. Four sets of beams, three with different amounts of CFRPC reinforcement by changing the width of CFRPC laminate, and one without CFRPC were tested in four-point bending over a span of 900 mm.

A. Khalifa et.al[5] examines the shear performance and modes of failure of rectangular simply supported reinforced concrete (RC) beams designed with shear deficiencies. These members were strengthened with externally bonded carbon fiber reinforced polymer (CFRP) sheets and evaluated in the laboratory. The experimental program consisted of twelve full-scale RC beams tested to fail in shear. The variables investigated within this program included steel stirrups, and the shear span-to-effective depth ratio, as well as amount and distribution of CFRP.

C. Diagana et.al[6] evaluate shear strengthening effectiveness with CFF strips. The RC beams are designed with shear deficiencies and strengthened by externally bonded carbon fibre fabrics. Four different configurations of externally bonded carbon fibre fabric strips are used to strengthen the reinforced concrete beams in shear. The experimental study consists of two control beams and eight strengthened RC beams. The reinforced concrete beams are strengthened with carbon fiber fabric vertical strips and 45° inclined strips in the form of U-wrap or in the form of a ring.

Z. Zhang et.al[7] investigate the shear behavior of RC beams with externally bonded CFRP shear reinforcement, 11 RC beams without steel shear reinforcement were cast at the concrete laboratory of the New Jersey Institute of Technology. After the beams were kept in the curing room for 28 days, carbon-fiber strips and fabrics made by Sika Corp. were applied on both sides of the beams at various orientations with respect to the axis of the beam. All beams were tested on a 979 kN s220 kipsd MTS testing machine.

A. Mehran et.al[8] experimental investigation together with a numerical study on reinforced concrete beams subjected to torsion that are strengthened with FRP wraps in a variety of configurations. In the experimental study, the increase in the ultimate torque for different strengthening configurations, failure mechanisms, crack patterns, and ductility levels are monitored and presented. Experimental results show that FRP wraps can increase the ultimate torque of fully wrapped beams considerably in addition to enhancing the ductility. The experimental results upgrade the weak archival data on torsional strengthening by application of FRP. The numerical section reports on analyses performed by the ANSYS finite element program.

C. E. Chalioris et.al[9] investigate the torsional strengthening of concrete beams without stirrups using epoxy-bonded carbon fibre-reinforced-polymer (FRP) sheets and strips as external transverse reinforcement. The experimental program comprises 14 rectangular and T-shaped beams tested under pure torsion. The strengthened rectangular beams using full wrapping with continuous FRP sheets performed enhanced torsional behaviour and higher capacity than the strengthened beams with FRP strips.

R. K. Akogbe et.al[10] investigate size effect on compressive strength of CFRP confined concrete cylinders subjected to axial compressive loading. In total 24 concrete cylinders with different sizes were tested, small specimens with a diameter of 100mm and a height of 200mm, medium specimens with a diameter of 200mm and a height of 400mm, and big specimens with a diameter of 300mm and a height of 600mm. The lateral confining pressure of each specimen is the same and from that hypothesis the small specimens were confined with one layer of CFRP, medium and big specimens were performed by two and three layers of CFRP respectively.

A. Mofidi et.al[11] evaluate the performance of the RC beams strengthened in shear with externally bonded (EB) L-shaped plates as affected by the embedment length of the L-shaped FRP plates. In total, six tests were performed on 2,500-mm long T-beams. Three specimens were strengthened in shear using epoxy-bonded L-shaped CFRP plates with different embedment lengths in the RC beam flange. One specimen was shear-strengthened with fully embedded CFRP plates in the concrete beam flange. The second specimen was strengthened with partial embedment of the L-shaped CFRP plate. The third specimen was shear-strengthened with L-shaped CFRP plates with no embedment in the concrete beam flange. In addition, the performance of the beams strengthened with L-shaped CFRP plates was compared with that of a similar specimen strengthened with EB FRP sheets without embedment.

4. FUTURE PROSPECTS

The review given in above is based on steel plate and composite sheet and plate bonding and has been covered extensively but not exhaustively. It has demonstrated the improvement in structural strength and stiffness brought about by externally bonded material. The worldwide level of interest in the technique reflects its potential benefits and also the current importance placed on economical rehabilitation and upgrading methods. Although the level of experience in the bonding technique of composite plates is limited, the investigations reported in this chapter have gone some way to illustrate its potential and to establish a basic technical understanding of short term and long term behaviour. Despite the growing number of field applications, there remain many material and structural implications that need to be addressed, in particular with regard to long term performance under loads.

5. CONCLUSION

Two sets of reinforced concrete (RC) beams, in SET I three beams weak in flexure and in SET II three beams weak in shear were casted and tested. When the beam is not strengthen, it failed in flexure but after strengthening the beam in flexure, then flexure-shear failure of the beam takes place which is more dangerous than the flexural failure of the beam as it does not give much warning before failure. Therefore it is recommended to check the shear strength of the beam and carry out shear strengthening along with flexural strengthening if required. Flexural strengthening up to the neutral axis of the beam increases the ultimate load carrying capacity, but the cracks developed were not visible up to a higher load. Due to invisibility of the initial cracks, it gives less warning compared to the beams strengthen only at the soffit of the beam. By strengthening up to the neutral axis of the beam, increase in the ultimate load carrying capacity of the beam is not significant and cost involvement is almost three times compared to the beam strengthen by GFRP sheet at the soffit only. When the beam is strengthen in shear, then only flexural failure takes place which gives sufficient warning compared to the brittle shear failure which is catastrophic failure of beams. The bonding between GFRP sheet and the concrete is intact up to the failure of the beam which clearly indicates the composite action due to GFRP sheet. It was found that analytical analysis predicts lower value than the experimental findings. Restoring or upgrading the shear strength of beams using GFRP sheet can result in increased shear strength and stiffness with no visible shear cracks. Restoring the shear strength of beams using GFRP is a highly effective technique.

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