Comparative Study on Strengthening of RC Beam in Flexure using CFRP & GFRP: A Review

By Anurag K. Jain
M. Tech. Student
Department of Civil Engineering
GHRCE Nagpur

D. S. Padole
Assistant Professor
Department of Civil Engineering
GHRCE Nagpur

Abstract

The paper and its study deals with the comparison in flexural strength of RC beams laminated with Carbon fibre reinforced polymer (CFRP) and/or Glass fibre reinforced polymer (GFRP). The main aim of this study to provide alternatives for CFRP as it is very costly material and made from non-renewable sources which are available in very few quantity. Various existing structures need changes in it due either end of its load bearing capacity or effects of corrosive chemicals, seepage, and other various defects in structure. Seismic retrofitting of constructions vulnerable to earthquakes is a current problem of great political and social relevance. The study is based on the behaviour and comparison of RC structures which were laminated and strengthened with CFRP and GFRP.

Keywords: Flexural Strength, CFRP, GFRP, Comparison, Seismic Retrofitting

I. INTRODUCTION

Civil Engineering structures are an important part of infrastructures and provide good service to the user; they experience distresses on account of reason and need of strengthening and retrofitting to bring them back to their originally intended service condition. A large numbers of structures constructed in the olden days using old design codes in different parts of world are structurally unsafe compared to today’s codes. As replacement of total structure or part of the structure is uneconomical, time consuming therefore strengthening has become possible way of improving the load carrying capacity and extending life of structure. If the effective method is used for strengthening and retrofitting it is possible to bring structures back to their originally intended service usage, many modern techniques are involved to proper effective strengthening and retrofitting methods. [2]

Strengthening of RC beams is necessary to obtain the expected lifespan of structures. Life span of RC beam may reduce because of improper beam design, ingestion of chemical agents etc. Strengthening of RC beams using steel plates and FRP composites are most common globally. In order to minimize the disadvantages of steel such as corrosion, high unit weight, connection difficulties; many researchers have tried various FRP composites such as Aramid, Glass and Carbon. In future, Fibre Reinforced Polymer (FRP) materials could play an important role for the construction industry. Nowadays, retrofitting work for RC structural members, GFRP composites are commonly used because of its excellent properties such as high strength, less weight to strength ratio, non-corrosive nature and easy handling. [1]

Commercial material commonly has glass or carbon fibres in matrices based on thermosetting polymers, such as epoxy or polyester resins. Sometimes, thermoplastic polymers may be preferred, since they are mouldable after initial production. Externally bonding fiber reinforced polymer (FRP) sheets with an epoxy resin is an effective technique for strengthening and repairing the reinforced concrete (RC) beams under flexural loads.

Fibre-reinforced polymer (FRP), also Fibre-reinforced plastic, is a composite material made of a polymer matrix reinforced with fibres. The fibres are usually glass, carbon, or aramid, although other fibres such as paper or wood or asbestos have been sometimes used. The polymer is usually an epoxy, vinylster or polyester thermosetting plastic, and phenol formaldehyde resins are still in use. FRPs are commonly used in the aerospace, automotive, marine, and construction industries, chemical processing equipment and civil infrastructure such as bridges and buildings.

Fiberglass refers to a group of products made from individual glass fibers combined into a variety of forms. Glass fibers can be divided into two major groups according to their geometry: continuous fibers used in yarns and textiles, and the discontinuous (short) fibers used as bats, blankets, or boards for insulation and filtration. Fiberglass textiles are commonly used as a reinforcement material for moulded and laminated plastics.

In addition carbon-fiber-reinforced polymer or carbon-fiber-reinforced plastic (CFRP or CRP or often simply carbon fiber), is a very strong and light fiber-reinforced polymer which contains carbon fibers. Carbon fibres are created when polyacrylonitrile fibres (PAN), Pitch resins, or Rayon are carbonized (through oxidation and thermal pyrolysis) at high temperatures. Carbon fibres are manufactured in diameters analogous to glass fibres with diameters ranging from 9 to 17 μm. [3]
II. PROPERTIES

In general, it is seen that the higher the tensile strength of the precursor the higher is the tenacity of the carbon fiber. Tensile strength and modulus are significantly improved by carbonization under strain when moderate stabilization is used. X-ray and electron diffraction studies have shown that in high modulus type fibers, the crystallites are arranged around the longitudinal axis of the fiber with layer planes highly oriented parallel to the axis. Overall, the strength of a carbon fiber depends on the type of precursor, the processing conditions, heat treatment temperature and the presence of flaws and defects.

With PAN based carbon fibers, the strength increases up to a maximum of 1300 °C and then gradually decreases. The modulus has been shown to increase with increasing temperature. PAN based fibers typically buckle on compression and form kink bands at the innermost surface of the fiber. However, similar high modulus type pitch-based fibers deform by a shear mechanism with kink bands formed at 45° to the fiber axis. Carbon fibers are very brittle. The layers in the fibers are formed by strong covalent bonds. The sheet-like aggregations allow easy crack propagation. On bending, the fiber fails at very low strain. [3]

III. APPLICATION

The two main applications of carbon fibers are in specialized technology, which includes aerospace and nuclear engineering, and in general engineering and transportation, which includes engineering components such as bearings, gears, cams, fan blades and automobile bodies. Recently, some new applications of carbon fibers have been found. Others include: decoration in automotive, marine, general aviation interiors, general entertainment and musical instruments and after-market transportation products. Conductivity in electronics technology provides additional new application.

These carbon adsorbents can be converted into a wide variety of textile forms and nonwoven materials. Cheaper and newer versions of carbon fibers are being produced from new raw materials. Newer applications are also being developed for protective clothing (used in various chemical industries for work in extremely hostile environments), electromagnetic shielding and various other novel applications. The use of carbon fibers in Nonwovens is in a new possible application for high temperature fire-retardant insulation. [3]

IV. RESEARCH SIGNIFICANCE

Structural engineers typically design RC beam loaded in such a way that torsion is not a major concern and therefore, effect of torsion is usually neglected in structural analysis. Torsional effects are rarely occur alone. These torsional moments may increase stresses on the member and can change the response of entire structure. Eccentric loads are typically avoided in designing of beam; however these loads are very frequent in bridges and cause combine twisting, bending, and shearing forces within the beam. The combined effect of torsion, flexure, and shear under eccentric load on beam has hardly been cited experimentally in literature; therefore achievements are not significant as seem in area of bending, shear and torsion individually. Similarly, strengthening options are individually available for flexural shear and torsion however combine effect of torsion, flexural and shear strengthening options are required to propose. [4]

V. STUDY OBJECTIVE

The objectives of proposed study are as follows:
1) For comparative study of strengthening of RC beam using CFRP and GFRP.
2) To increase the experimental test data for strengthening of RC beam using externally bonded composites.
3) To investigate the combine effects of flexural strength of RC beams by using CFRP and GFRP.
4) To design the most effective repair system using GFRP laminates to strengthen the damaged RC beams combine effects of flexure.

![Fig. 1: Comparison between experimental and predicted total applied load. [7]](image-url)
VI. LITERATURE REVIEW

Some of the research work carried out on comparative study between experimental and analytical work in FRP strengthening describe below,

A. Review Paper 1:

Amer Ibrahim performed Numerical analysis on RC beams by ANSYS finite element program and results show that the general behaviour of the finite element models represented by the load-deflection curves at mid span show good agreement with the test data. They also conclude that the load carrying capacity of the Flexure strengthening beam predicted by the finite element analysis is higher than that of the control beam. [5]

B. Review Paper 2:

Saifullah performed destructive test on simply supported beam in laboratory and load-deflection data of that under RC beam. They compared both the computer modelling and experimental data and found that computer based modelling is can be an excellent alternative of destructive laboratory test with an acceptable variation of results.

C. Review Paper 3:

Jayajothi carried out the nonlinear Finite Element Analysis of Reinforced Concrete (RC) beams strengthened in flexure and shear by Fibre Reinforced Polymer (FRP) laminates and they found that the ultimate load carrying capacity of all the strengthened beams is higher when compared to the control beams and general behaviors of the FE models show good agreement with observations and data from the experimental tests. [7]

D. Review Paper 4:

Patil described analysis of two beams subjected to two point loading with different span to depth ratios using nonlinear FEM. They found that the smaller the span/depth ratio, the more pronounced was the deviation of strain pattern at mid-section of the beam. As the depth of the beam increases in the variation in strength, flexural steel and deflection were found to be more experimentally than the nonlinear FEM analysis. [6]

E. Review Paper 5:

Uma performed the flexural response of Reinforced Geopolymer Concrete (RGPC) beam. Results were compred on both ANSYS modelling and experiment data found that the deflection obtained was low due to the meshing of element in the modelling. Author also came to the conclusion that comparative result gives 20% difference for experimental and ANSYS 12.0 [2]

F. Review Paper 6:

Two types of strengthening system named namely hybrid carbon fiber/glass fiber-reinforced polymer (H CF/GF-RP) strengthening and CFRP strengthening and six beams were used to carry out compressive test. Flexural performance of beams were checked and results had shown significant increase of ductility and a remarkable decrease of strengthening cost with slight varieties in load carrying capacity and stiffness of strengthened beams. Under similar failure loads the deflection ductility, stiffness, and strengthening cost of H-CF/GF-RP strengthening beams were 89.7% higher, 10 and 38% lower than those of the CFRP. [11]
G. Review Paper 7:
Author carried out experimental work which consisted of testing 14 simply supported beams. Beams had the same dimensions and flexural and shear reinforcements. Mid-span load of 44.8 kN was applied. After cracking, each beam was strengthened with a FRP material. Five FRP strengthening systems were used in this research project. These systems consisted of two types of CFRP sheets (Systems I and II), two types of GFRP sheets (Systems III and IV), and CFRP plates (System V). It was concluded that, in addition to the longitudinal layers, the fibers oriented in the vertical direction forming a U-shape around the beam cross section significantly reduce beam deflections and increase beam load carrying capacity. [12]

H. Review Paper 8:
The main objective of the presented article on this paper was to examine the effects of glass fiber reinforced polymer (GFRP) composite rehabilitation systems on the fatigue performance of reinforced concrete beams. Experiments were conducted on beams with and without GFRP composite sheets on their tensile surfaces. Fourteen beams were tested under cycling load at different load ranges. Six were non-strengthened and eight were strengthened. Both strengthened and non-strengthened beams exhibited the same primary mode of failure, yielding of the steel reinforcement due to fatigue. The only noticeable difference between them is that shear cracks were also noticed in all the strengthened beams, usually very close to failure. [13]

VII. CONCLUSION
1) There is a need to switch over from the utilization of artificial fibres, which are non-renewable and fossil fuel products, to environmental beneficial materials like glass fibres.
2) Carbon fibre is available in very small quantity and too much costly and GFRP is available in low cost and has shown good characteristics strength so could be good alternative for CFRP.
3) Reduction in stiffness of strengthened beams after yielding the tensile steel was observed by increasing the number of CFRP layers. The stiffness of the beam strengthened with GFRP is less than the beams strengthened with CFRP after yielding the tensile steel.
4) Increasing the number of CFRP layers reduced loss in stiffness of strengthened beams after yielding the tensile steel. The stiffness of the beam strengthened with GFRP is less than the beams strengthened with CFRP after yielding the tensile steel.
5) Increasing the number of CFRP layers reduced loss in stiffness of strengthened beams after yielding the tensile steel. The stiffness of the beam strengthened with CFRP is less than the beams strengthened with CFRP after yielding the tensile steel.

REFERENCE