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Study on Fibre Reinforced Polymer Beams with BFRP Wrapping

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Abstract - *In this study, research was conducted in order to determine the effectiveness of rehabilitating corroded steel beams using BFRP fabric. The fundamental objectives of this research study are the following: The change in load-carrying capacity of corroded steel beams after rehabilitation using BFRP can be determined. Any changes in ductility due to the rehabilitation can be determined .To model the behaviour of rehabilitated beams using finite element analysis. To determine the optimum thickness of BFRP needed for different percentages of corrosion using finite element models. The various characteristics of the beams with BFRP wrapping along with the failure mode and crack pattern were also studied.*

***Key Words*:** **FIBRE REINFORCED POLYMER, BASALT FIBRE, RC RETROFITTING, BEHAVIOUR OF BEAMS, LOAD CARRYING CAPACITY**

1. INTRODUCTION

In the past few years, there is a significant focus on developing and inventing new sustainable more efficient materials to replace traditional steel reinforced bars (rebar) that are used in concrete structural elements. This is predominately due to deterioration of concrete structures being caused by the corrosion of the steel rebar inside the structure (American Concrete Institute Committee 440, 2006). The ability of Basalt Fibre Reinforced Polymer (BFRP) to be used for structural application in concrete beams has been investigated in several studies. The variable findings in these studies implicated that a further refined experimental model needed to be developed to produce results that are more robust (Fan & Zhang, 2016; Gohnert, Gool& Benjamin, 2014; Lapko& Urbanski, 2014). Along these lines, the general point of this examination was to improve the present comprehension of BFRP rebar solid beams' flexural behavior. The following objectives were outlined in this study to meet the overall aim: right off the bat, to decide the mechanical properties of BFRP rebar and contrast them and the mechanical properties of steel rebar. Secondly, to investigate how different BRFP rebar reinforcement setups affect the flexural performance of the concrete beam. Thirdly, to determine whether and how the slippage phenomenon affects flexural behaviour and load taking capacity of BFRP rebar reinforced concrete beams. Lastly, to test the level of accuracy of traditional steel reinforcement design principles used to design the BFRP rebar reinforced concrete beams.

Fibre Reinforced Polymers (FRPs) are composite materials containing an epoxy matrix reinforced with fibres. Common types of FRPs are Carbon (CFRP), Glass (GFRP), Aramid(AFRP) and Basalt (BFRP). Due to its high strength-to-weight ratio, the use of FRPs has been beneficial for the rehabilitation of structures in recent years. Basalt rocks are melted, and then drawn through bushings to create filaments. These filaments are easily manufactured to create fabrics. Due to its composition of rock, Basaltfabrics are corrosion resistant and environmentally friendly. In this study, the effectiveness of Basalt fabrics for rehabilitating corroded steel beams is explored.

1.1 Objectives

In order to determine the effectiveness of rehabilitating corroded steel beams using BFRP fabric. The objectives of this research study are the following:

a) To determine the change in load-carrying capacity of corroded steel beams after

rehabilitation using BFRP.

b) To determine any changes in ductility due to the rehabilitation.

c) To model the behaviour of rehabilitated beams using finite element analysis.

d) To determine the optimum thickness of BFRP needed for different percentages of corrosion using finite element models.

2. MATERIALS USED

2.1 Concrete

In the present , typical bond of 53 OPC evaluation conventionalist to IS 12269-1987 was utilized. locally available clean stream sand are utilized in this work. The coarse total was pulverized (precise) blend traditionalist to IS 383:1970. The most size of total considered was 20 millimeter ,it demonstrates all the texture properties and that were assessed with the assistance of tests in the lab, according to Indian Standard details . In understanding ,the blend proportion weight of cement:sand:coarse total was observed to be 1:1.85:3.1 and water-concrete proportion is 0. The usefulness tests performed with this water bond quantitative connection, that droop investigate worth of 36.5mm and has 9 scope of solid shapes were moreover threw utilizing the communicated consolidate extent and water concrete proportion, and hence the normal comp. quality for 7 days was 18.25 N/mm2 , for 14 days was 26 N/mm2 and for 28 days was 32 N/mm2.

2.2 Reinforcement

In this, Fe 415 HYSD of eight millimeter remove over, exceptional yield quality, and hot rolled twisted bars having trademark nature of 415 N/mm2 are utilized 3 test of bars were put inside the UTM one when another and tried for his or her lastingness. it had been discovered the bars had normal yield quality of 390 N/mm2 .Thus utilization of the bar example as support was sheltered. Metal Fe 415 of eight millimeter distance across bars are utilized for the longitudinal support with respect to giving stirrups.

2.3 Epoxy Resin

The Most of the epoxy pitch primarily relies upon the execution utilized for holding of FRP to solid surface different sorts of epoxy saps with a huge scope of mechanical properties are economically accessible inside the market. The applications for epoxy-based materials are broad and incorporate coatings, cements and composite materials, for example, those utilizing carbon fiber and fiberglass fortifications. These epoxy saps are ordinarily accessible in 2 segments, a pitch and a hardener. The tar and hardener utilized in this investigation are Armladite LY 566 and Hardan HY 951 separately in a very extent of 10:1.

2.4 Fibre Reinforced Polymer

The Basalt fiber reinforced polymer (BFRP)was created in 2-directional-twin type. It is naturally available and it is derived from Basalt rock that is formed by solidification of lava that comes out during volcanic eruption. Table 1 which shows the various properties of BFRP.

Table-1: PROPERTIES OF BFRP

Reinforcing Material	Yield Strength ksi (MPa)	Tensile Strength ksi (MPa)	Elastic Modulus ksi (GPa)	Strain at Break percent
Steel	40-75 (276-517)	N/A	29,000 (200)	N/A
Glass FRP	N/A	70-230 (480-1,600)	5,100-7,400 (35-51)	1.2-3.1
Basalt FRP	N/A	150-240 (1,035-1,650)	6,500-8,500 (45-59)	1.6-3.0
Aramid FRP	N/A	250-368 (1,720-2,540)	6,000-18,000 (41-125)	1.9-4.4
Carbon FRP	N/A	250-585 (1,720-3,690)	15,900-84,000 (120-580)	0.5-1.9

Fig -1: Basalt Fibre

3. LITERATURE REVIEW

3.1 BFRP Rebar Concrete Beams Subjected To Flexure

Research into alternatives to steel rebar to replace traditional rebar used in concrete structural elements have included basalt, glass, carbon and aramid rebar (Dhand et al., 2015; Fiore et al., 2015; Gohnert, Gool& Benjamin, 2014; Lapko & Urbanski, 2014; Urbanski, Lapko & Garbacz., 2013). It has been found that the performance of glass, carbon and aramid as rebar are affected by the alkaline environment within the concrete causing them to breakdown, whereas basalt as an alternative does not break down in the alkaline environment (Fan & Zhang, 2016). Basalt is a naturally occurring volcanic rock that originates from frozen lava that can be found in abundance in the Earth's crust. Basalt Fibre Reinforced Polymer (BFRP) rebar is formed by crushing basalt rock into a powder which is then heated to melting point (approximately 1450 degrees Celsius). A fine nozzle is then used to extrude the molten material to form a thin continuous strand. These strands are bundled and bound together by using a polymeric compound, to produce long straight rebars.

3.2 Corrosion

Corrosion is one of the main causes of deterioration for steel structures. The five most common types of corrosion are; uniform corrosion, galvanic corrosion, crevice corrosion, pitting corrosion, and stress-induced corrosion. Uniform corrosion causes a uniform loss of area throughout the member. Galvanic corrosion is caused by the contact of two dissimilar materials in a conductive medium. Crevice corrosion is caused by a microenvironment which leads to the depletion of oxygen within the crevice. Pitting corrosion causes small pits to form on the metal and these small pits penetrate deep into the metal, while showing little signs of corrosion on the outside. Stress-induced corrosion forms in areas where the stress concentration of the metal is higher. Localized corrosion types (pitting, crevice, and stress-induced corrosion) are more dangerous due to the accelerated rate of corrosion in a localized environment. However, all of these types of corrosion cause a loss of mass and thus, decreases the load-carrying capacity of particular member. In order for a member to be structurally sufficient, the corrosion of the member needs to be repaired (rehabilitated) or entire corroded member must be replaced with a new member.

3.3 Flexural Repair Using BFRP Fabrics

BFRP materials are relatively new to the construction industry and hence, a limited number of research papers on use of BFRP products in rehabilitation of damaged structures are available. Research articles on the use of BFRP fabrics for the rehabilitation of steel structures were not found. However, some studies were conducted using BFRP fabrics rehabilitation/strengthening of concrete beams. This section briefly discusses the results of these studies, as relative to the objectives of this research. For alkali resistance and weathering resistance

3.4 Composite Materials

Composite materials are often the combination of two different constituents which when combined, gives the material unique properties. A composite can be defined as the combination of a matrix (epoxy, polyester, polyimide etc.) and reinforcement (glass, aramid, carbon etc.). The reinforcement is responsible for bearing the load and the matrix material is responsible for transferring the load evenly to the reinforcement. Composite materials have been used for centuries, mainly to improve undesirable properties of individual materials. For example, using steel to reinforce concrete due to the weak nature of concrete under tensile loads. Another composite material is fiberglass ,which has a plastic matrix and glass as reinforcement. The plastic matrix allows the composite material to be bent, which would normally fracture the glass fibres

3.5 Fibre Reinforced Polymers (FRP)

Fibre Reinforced Polymers are composite materials which use various types of fibre as the reinforcement and many type of adhesives as matrix. Some of the different types of fibres are carbon, aramid, glass, and basalt. The matrix usually consists of epoxy; however, polyester, polyimide etc. are used for different applications. For example, polyimide is a heat-resistant material and has found uses in electrical and aerospace industries. Due to the high variety of available epoxies and fibres, different combinations of FRPs can be produced to satisfy the strengthening requirements of various projects.

4. EXPERIMENTAL PROCEDURE

4.1 Materials Used For Experimental Work

The materials which were used in this study included OPC, Fine aggregate (Msand), Coarse aggregates, water, CFRP ,BFRP sheets and epoxy resin. The cement used was 53 grade OPC conforming to IS 12269:2013. The fine aggregate that is used in the was M-sand(manufactured sand). The size of coarse aggregate that was used is 20mm. The water that is used for curing process and mixing for specimens was Potable water thoroughout the experiment. Unidirectional CFRP & BFRP sheets of thickness 0.3mm were used respectively. Arladite AW106 with Hardener HV 953 IN was used as epoxy resin for binding of FRP sheets to concrete and to bind layers of FRP sheets together .To get adequate binding property equal amounts of Arladite and Hardener were mixed properly.

4.2 Usage of Carbon for Flexural Rehabilitation Corroded Steel Beams

The studies of CFRP and GFRP were done. Moreover, studies were not conducted on rehabilitation corroded steel beams with Basalt Fibre Reinforced Polymer (BFRP). In this study the effectiveness and feasibility of taking BFRP fabric for rehabilitation corroded steel beams were studied by doing various tests and by developing finite elemental models. From this study it is found that the yield load and ultimate load carrying capacity of steel beams which were corroded could be restored effectively by providing significant thickness for BFRP fabrics that are used. It tends to be hard to reestablish the malleability of steel pillar which gets consumed, yet the flexibility that can be improved , that improvement chiefly on the thickness of BFRP texture.

4.3 Method of Casting Of Column Specimens

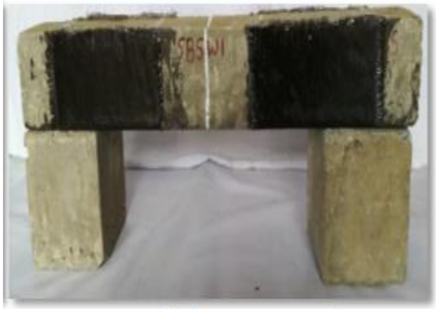
For this study the dimensions of column is taken into account as 150mm diameter and 600mm height and M25 grade concrete experiment carries with it total fourteencolumns includes two management columns , two columns wrapped with single layer of CFRP sheets (CC1), two columns wrapped with single layer of BFRP sheets (CB1), two columns wrapped with two layer of BFRP sheets (CB2), two columns wrapped with two layer of CFRP (CC2), two columns wrapped with BFRPCFRP hybrid sheets (CB1C1) and a couple of columns wrapped with CFRP-BFRP hybrid sheet (CC1B1). result of variety of layers of individual FRP sheets and effectiveness of exploitation hybrid FRP sheet to confine RC columns is investigated.4 Nos of 8mm diameter bars are used as main reinforcement and 6mm dia bars at 100mm c/c spacing stirrups are provided.

4.4 Retrofitting Of RCC Beams

Subsequent to preloading, a definitive heap of control pillar, they were checked like the wrapping example to that they should be wrapped. All the free particles of solid surface at the ideal space was made harsh utilizing sand paper surface and clean with dry pieces of clothing to dispose of all earth and residue particles and prepared to the ideal standard. The surfaces were then cut by the estimation. The mixing is finished with the help of plastic compartment (100 segments by weight of Arladite LY 566 to ten areas by weight of Hardener HY 952) and was continuing till the mix was uniform. At that point the epoxy is connected to the solid surface. At that point the BFRP sheet is put over rosin epoxy stick engineered pitch covering and along these lines the tar is pressed through the meandering of the texture with the roller air entangled at the epoxy are wiped out. It demonstrates the retrofitted example through the whole solidifying of the epoxy, a consistent uniform weight is connected on the texture surface to deliver the surplus epoxy and to reach between the epoxy, the solid and in this manner the material. Solid pillars retrofitted with basalt fiber texture were relieved for 6 hours at room temperature before testing.

(a) Diagonal wrapping

Fig -2



(b) shear zone wrapping

Fig -3

4.5 Failure Mode and Crack Pattern

Failure mode and crack pattern of control beam and retrofitted beams were noted and explained on an individual basis. For control beams, since the beam specimens were weak in shear, the shear crack tends to propagate at the initial stages of loading itself. very little flexural cracks were determined within the flexural zone at later loading stages. because the load will increase, shear crack widens and propagates quickly. The specimens clearly failed in a very brittle manner with sudden destruction. both the control beams failed in same manner. Fig. 6 shows the failure patter of all beams. For beams wrapped within the shear zone, at the initial loading stage alittle vertical crack regenerated within the flexural zone. because the loading will increase, these crack began to propagate slowly in vertical direction. At later loading stages, this crack began topropagate in inclined direction. The failure mode was flexural shear failure. that's BFRP wraps on the shear zone modified the mode of failure from brittle to ductile which supplies enough warning before failure. In each the beams only single crack was seen, that widened as load increased and each the beams failed in similar manner. There was no rupture or debonding of the BFRP. There was no concrete crushing Fig.3 shows the enlarged view of the crack pattern.

For beams wrapped in diagonal manner, there have been no cracks at the initial loading stages,because the load increased little cracks began to form within the flexural zone. At the initial loading stage there started a little vertical crack within the flexural zone. Because of the loading increased, further cracks were formed and started to propagate vertically. Diagonal wraps arrested the cracks from widening. At later loading stages, these cracks tend to propagate in inclined direction. The failure mode was flexural shear failure. both the beam showed similar failure behaviour. The crack width of each beams was terribly less compared to other beams. There was concrete crushing at the loading points and debonding of BFRP strips from the concrete surface. Fig.4 shows the enlarged view of failing beam.

(a) Shear zone wrapped beam

Fig-4

(b) Diagonal wrapped beam

Fig-5

5. CONCLUSIONS

Thus the experimental study on Fibre Reinforced Polymer beams with BFRP wrapping is studied and the various characteristics of the beams with BFRP wrapping along with the failure mode and crack pattern were also studied.

- The change in load-carrying capacity of corroded steel beams after rehabilitation using BFRP were studied.
- Any changes in ductility due to the rehabilitation were reviewed.
- The model of the behaviour of rehabilitated beams using finite element analysis were done.
- The optimum thickness of BFRP needed for different percentages of corrosion using finite element models were determined.

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