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Repair and Rehabilitation of Structures

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***Abstract*— The objective of this research is to provide an overview of the state of the art concerning the structural behavior of concrete beam externally reinforced with Fiber Reinforced Polymers (FRP) systems effective to enhance the structural load-carrying capacity. Basalt FRP (BFRP) fabric is a promising material for the application to structure strengthening with its advantages of low cost, corrosion resistant and sound mechanical property, but only limited studies of using Basalt FRP fabric to externally strengthen RC beam are available. This study is to experimentally explore the effectiveness of application of UD-Basalt FRP fabric with epoxy to strengthen RC beams under two-point bending test. Totaly twelve RC-beams are casted which consist of six control beams and six single BFRP U-warpping beams and result are compared for flexural strength of beam with M-15 grade of concrete as per IS 10262-2009. UD Basalt fabric retrofited with U-wrapping pattern improved ultimate load carrying capacity and flexural strength for beam controlspecimens.**

***Keywords*—RC Beams , Strengthening, BFRP UD- fabric, epoxy, U-warping pattern, Flexural strength, load deflection Behavior, failure mode, ultimate load-carrying capacity, crack behavior.**

I. Introduction

There is a pressing need to repair or upgrade the building and civil infrastructure in many parts of the world. For instance, with the modernization of buildings, it is sometimes desirable to remove supporting walls or individual supports, leading to the need for local strengthening. The strengthening and enhancement of the performance of deficient structural elements or the structure as a whole is referred to as retrofitting. The strengthening or retrofitting of existing concrete structures is frequently required due to deterioration of structural members, excessive loading associated with the change in use of the structure, design or construction errors, inadequate maintenance and exposure to severe environmental conditions.

Several conventional materials and construction techniques have been used to strengthen concrete structures. Strengthening and retrofitting increase the load bearing capacity, increase ductility and repair deterioration damages. Retrofit aims to strengthen a building to satisfy the requirements of the current codes for seismic design.

By wrapping FRP sheets, retrofitting of concrete structures 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. FRP systems can also be used in areas with limited access where traditional techniques would be impractical. However, due to lack of the proper knowledge on structural behavior of concrete structures, the use of these materials for retrofitting the existing concrete structures cannot reach up to the expectation. Successful retrofitting of concrete structures with FRP needs a thorough knowledge on the subject and available user-friendly technologies/ unique guidelines. Beams are the critical structural members subjected to bending, torsion and shear in all type of structures. Similarly, columns are also used as various important elements subjected to axial load combined with/without bending and are used in all type of structures.

Therefore, extensive research works are being carried out throughout world on retrofitting of concrete beams with externally bonded FRP composites. Several investigators took up concrete beams retrofitted with carbon fiber reinforced polymer (CFRP), Glass fiber reinforced polymer (GFRP) Aramid Fiber reinforced polymer(AFRP), composites in order to study the enhancement of strength and ductility, durability, effect of confinement, preparation of design guidelines and experimental investigations of these members.

The repair and strengthening of RC-concrete member like beam, column, slab, beam-column junction in structural engineering applications has increased over past 20 years.

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II. Ease Of Use

A. Materials

1. *Cement:* Ordinary Portland Cement (OPC) 53 grade production by UltraTech cement company was used in concrete mixes correlate with IS: 1489 (part-1) 1991.the specific gravity of cement is 3.15.
2. *Sand:* Natural river white sand (Narmada River) is used as a fine aggregate. The grading zone of fine aggregate is zone I As per IS 383-2016. The fine aggregate/sand is passing through 4.75 mm sieve and having a specific gravity of 2.61 and water absorption 1.00% as per IS 2386 (Part III)-1963.
3. *Coarse aggregate:* Crushed stone of maximum size 20mm are used as a coarse aggregate. The specific gravity of2.89 and water absorption 0.74 % as per IS 2386(Part III)-1963.
4. *Water:* Clean portable tap water was used to prepare concrete mixing in all the mix and for the curing.
5. *Admixture as a super Plasticizer:* For this study Admixture as a super plasticizer Foreshock Auromix 350 DISalight brown liquid, instantly dispersible in water was used. Aura mix 350 is a unique combination of new generation super plasticizer based on polycarbonic ether polymer with long lateral chain.
6. *Fiber reinforced polymer:* One type of FRP fabric was used during the tests i.e., a unidirectional BFRP (basalt fiber reinforced polymer) with the fiber oriented in one direction was used manufactured by Composite tomorrow, due to the flexible nature and ease of handling and application, the BFRP fabric are used for flexural strengthening. Basalt fabric is a material made from extremely fine fiber (are basically fiber from basaltic rock) of basalt rock. Basalt rocks are volcanic dense rock, it is not an organic product, so it will not degrade with time. Basalt fiber is somewhat more economical because no other adhesive present in it. it has good tensile strength, good resistance to chemical attack, impact load and fire with less poisonous hazes.

TABLE -I
PROPERTIES OF UD FABRIC

Thickness	0.300mm
Density	2.8 g/cc
Elongation at Break	3.15%
Tensile Modulus	89 GPa
Linear Expansion coefficient	$5.5X10^{3}$
Tensile strength	4840 MPa
Cost of fiber per meter	750
Woven pattern	Uni- directional

7. *Epoxy Resin:* The epoxy resin used for bonding of FRP to concrete surface. The ease of processibility, good melting characteristics, excellent adhesion to various types of substrates, low shrinkage during cure, superior mechanical properties of cured resin, and good thermal and chemical resistance have made epoxy resin a material of choice in advanced fiber reinforced composites. These epoxy resins are generally two-part systems, a resin and a hardener. The resin and hardener mixing ratio by weight (100:80) used in this study. Resin Araldite®AW106/Hardener HV953U, is a paste adhesive of high strength, room temperature curing and good toughness. It is suitable for bonding a wide variety of metals, ceramics, glass, rubber.

III. Experimental Work

A. Casting of Beams

One wooden (plywood) mould are used for casting beam. Mobil oil was then applied to the inner faces of form work to easy removal of specimen.

B. Mixing, Compaction and Curing of Concrete

Mixing of concrete is done thoroughly with the help of standard concrete mixer machine, to ensure that uniform quality of concrete is obtained. All specimens were compacted by using form surface vibrator for good compaction of concrete. Finally the surface of concrete was leveled and smoothened by metal trowel and wooden float Curing is done by spraying water on the jute bags over the surface for a period of 7 days to prevent the loss of water which is essential for the process of hydration and hence for hardening.

C. Test Setup of Beam

Six control beam and Six strengthened beam with U-warping basalt UD-fabric were tested for flexural strength under two point loading on UTM having capacity 100KN with simply supported conditions, two point load is place on beam at a distance of 216.67mm(effective length/3) from left and right support. Steel rollers are used to support the beam. The load was applied at a uniform rate until the ultimate failure.

D. Strengthening of Beam B With BFRPUD-Fabric

The required region of concrete surface at the beams was made rough using a coarse sand paper texture and cleaned with an air blower to remove all dirt and debris particles. Once the surface was prepared to the required standard, the epoxy resin was mixed in accordance with manufacturer's instructions (100 parts by weight of Araldite® AW 106 to 80 parts by weight of Hardener HV 953 U). After the fabrics are cut according to the size then the epoxy resin is applied to the concrete surface then the BFRP UD-Fabric is placed on top of epoxy resin coating and gently pressed onto the coated epoxy resin through the roving of the fabric with the roller.

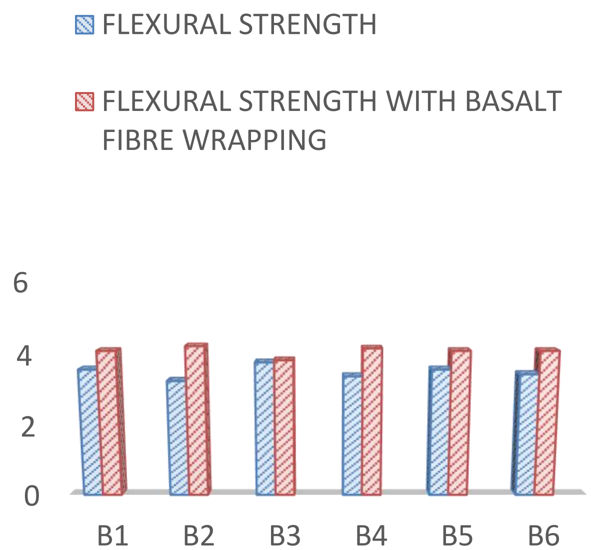
E. Test Results

The results obtained from the testing of beams for the experimental program are interpreted. Their behavior throughout the test is described with respect to initial crack load and ultimate load carrying capacity, deflection, crack pattern and modes of failure. It was observed that the control beams had less load carrying capacity when compared to that of the externally strengthened beams using BFRP UD-Fabric.

TABLE-II
SUMMARY OF TESTING DATA

GRADE OF CONCRETE	BEAM SAMPLE	LOAD AT FAILURE IN (KN)	LOAD AT FAILURE WITH BASALT FIBRE WRAPPING (KN)
M 15	B 1	5.5	6.3 (15%)
M 15	B 2	5	6 (20%)
M 15	B 3	5.8	6.5 (13%)
M 15	B 4	5.2	5.9 (14%)
M 15	B 5	5.5	6.4 (17%)
M 15	B 6	5.3	6.4 (21%)

Grade of Concrete	Beam sample	Flexural strength (MPa)	Flexural strength with basalt fiber wrapping (MPa)
M 15	B 1	3.57	4.09
M 15	B 2	3.25	4.22
M 15	B 3	3.77	3.83
M 15	B 4	3.38	4.16
M 15	B 5	3.57	4.09
M 15	B 6	3.44	4.09



A. Load-Displacement Behavior

The experimental load-displacement curves obtained for the tested beams from graphs the effect of BFRP on normal RC beams it can the improvement on behavior of strengthened specimens respect to unstrengthen.

B. Failure Behavior

The failure and crack pattern of all the beams. For test specimens, all the beams failed in flexural mode. As it clearly shows the existence by the several flexural cracking in tension at mid span scoff.

IV. Summary Of Results And Discussion

It has been observed that the ultimate load of beams with BFRP UD-fabric wrapping using U-wrapping pattern are higher than that of beams without BFRP wrapping increase in ultimate load for beams.

V. Conclusions

Flexural load carrying capacity of strengthened beams was increased by 24% as comparative to control beams. Formation of crack gets delayed due to the use of BFRP UD-fabric. Among the two types of failure (shear and flexural failure) in beams flexural failure. From overall study, it can be concluded that the strengthening with basalt UD-fabric is more efficient.

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