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Experimental Investigation on Strengthening of RC-Beam and Column Using Epoxy-Bonded Unidirectional Basalt Fibre Fabric

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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 and column 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 and column 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 and Columns under axial load. Totally five RC-beams and five RC-columns will be casted which will consist of two control beams and columns and three single BFRP U-warpping beams and fully single layer BFRP warpping columns and result are compared for flexure strength of beam and axial strength of columns with M-40 grade of concrete as per IS 10262-2009.UD Basalt fabric retrofitted with U-warpping pattern improved ultimate load carrying capacity (flexural strength) for beam and ultimate load (axial load) carrying capacity for short column than control specimens.***

Keywords—RC Beams and RC Short Columns, Strengthening, BFRP UD- fabric, epoxy, U-warpping pattern, Load deflection Behavior, Failure mode , Ultimate load-carrying capacity.

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 warpping 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 and columns with externally bonded FRP composites. Several investigators took up concrete beams and columns 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.

II RESEARCH AIM

To study the effect of (unidirectional)UD Basalt fabric strengthening in single layer U-warpping pattern on flexural behaviour of reinforced concrete beams and UD Basalt fabric strengthening in single layer fully warpping pattern on axial behaviour of reinforced concrete columns.To analyze the effect of UD Basalt fabric strengthening on ultimate load carrying capacity, load deflection behaviour and failure pattern of reinforced concrete beams and ultimate load carrying capacity,failure pattern and load deflection behaviour of columns.Moreover, to study and compare the effect of without warpping and single layer wrapping of BFRP fabric on reinforced concrete beams and columns.

III MATERIAL PROPERTIES AND MIXPROPORTION

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:C*rushed stone of maximum size 20mm are used as a coarse aggregate.The specific gravity of 2.89 and water absorption 0.74 % as per IS 2386(Part III)-1963.
4. *Water:*Clean portable tap water was used to prepared concrete mixing in all the mix and for the curing.
5. *Admixture as a super Plasticizer:*For this study Admixture as a super plasticizer Forsrock Auromix 350 DIS a light brown liquid, instantly dispersible in water was used.Auramix 350 is a unique combination of new generation super plasticizer based on polycarboxilic 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 directions 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. Basic properties of basalt UD-fabric is given in Table I.

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® AW 106 / Hardener HV 953 U, 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, rigid plastics and most other materials in common use.

B. Mix Design

Standard mix M40 grade was calculated as per Indian standard (IS 10262:2009).the mix design is given in Table III.

TABLE II
TARGET MEAN STRENGTH OF CONCRETE

Target mean strength of concrete(f'ck)	f'ck = f ck+ (1.65 *s)= 40 + (1.65*6)= **49.9 N/mm^2**
f' ck	Target mean Compressive strength at 28 days in N/mm²
f ck	Characteristic Compressive strength at 28 days in N/mm²
s	Standard deviation 5 N/mm² as per IS456

TABLE III
MIX PROPORTION FOR M40 GRADE OF CONCRETE AND MIX RATIO(PER M³)

OPC Cement	433 kg/m³	**1**
Water-cement ratio	0.36	
Water contain	156 liter	
Fine aggregate	738.11kg/m³	**1.70**
Coarse aggregate	1225.93 kg/m³	**2.83**
Admixture fosrock auromix350 DIS	2.17 kg/m³	**2.17**

TABLE IV
COMPRESSIVE TEST RESULT OF CUBE FOR MIX PROPORTION

No. Of days	Avg. Compressive strength(N/mm2)
At 7 Days	31.75
At 28 Days	59.10

IV EXPERIMENTAL WORK

A. Reinforcement Details for Beams and Columns

TABLE V
REINFORCEMENT DETAILS FOR BEAMS AND COLUMNS

Specimen	No. of Specimen	Size of beam/column (mm)	Top Reinforcement	Bottom Reinforcement	Stirrups Detail
Control Beam (CB1,CB2)	2	230 × 230 ×1000	2 – 10 mm Φ	2 – 10 mm Φ+ 1 – 12 mm Φ	8 mm Φ @100 mm c/c
Single Layer U-warp beam(SFB1,SFB2, SFB3)	3	230 × 230 × 1000	2 – 10 mm Φ	2 – 10 mm Φ+ 1 – 12 mm Φ	8 mm Φ @ 100 mm c/c
Short Control Column (CC1,CC2)	2	230 × 230 × 750	2– 12 mm Φ +2-16Φmm Longitudinal bar	-	8 mm Φ @ 190 mm c/c
Single Layer full warp short column(SFC1,SFC2 ,SFC3)	3	230 × 230 × 750	2– 12 mm Φ+ 2-16Φmm Longitudinal bar	-	8 mm Φ @ 190 mm c/c

B. Casting of Beams and Columns

One wooden(plywood)mould are used for casting beam and one mould for column.Mobil oil was then applied to the inner faces of form work to easy removal of specimen.beam and column reinforced with reinforcement is shown in Fig.1 according to detail given in Table v.

Fig. 1 Casting Of Beams &Columns

C. Mixing,Compaction and Curing of Concrete

Mixing of concrete is done thoroughly with the help of standard concrete mixer machine, to ensure that a uniform quality of concrete is obtained.All specimens were compacted by using form surface vibrator for good compaction of concrete, and sufficient care was taken to avoid displacement of the reinforcement cage inside the form work.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 28 days to prevent the loss of water which is essential for the process of hydration and hence for hardening.

D. Test Setup of Beam and column

Two control beam and three strengthened beam with U-warpping basalt UD-fabric were tested for flexural strength under two point loading on UTM having capacity 1000KN.The beam were arranged shows in Fig 2. with simply supported conditions, two point load is place on beam at a distance of 233.33 (effective length/3) from left and right support.steel rollers are used to support the beam.The load was applied at a uniform rate till the ultimate failure.

Fig. 2 Test set up of with and without strengthening of beam

Two control short column and three strengthened short column with fully warpping basalt UD-fabric were tested for Axial loading on UTM having capacity 1000KN.The load was applied on longitude axis of column shows in Fig.3 till the ultimate failure took place.

Fig. 3 Test set up of with and without strengthening of column

E. Strengthening of Beams and columns With BFRP UD-Fabric

The required region of concrete surface at the beams and columns 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 is shown in Fig.4. 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.

Fig.4 strengthening of column and beam

V TEST RESULTS

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

Fabric.Deflection behavior,ultimate load carrying capacity of the beams and columns along with the nature of failure is given in Fig.5,Fig. 6,Fig.7.

TABLE VI
SUMMARY OF TESTING DATA

specimen	CB1	CB2	SFB1	SFB2	SFB3	CC1	CC2	SFC1	SFC2	SFC3
First crack load (KN)	182	175	212	287	235	250	267	347	343	340
Ultimate load(KN)	280	289	351	357	353	389	384	433	449	454
Deflection at ultimate load (mm)	8.1	8.5	9.33	11.8	10.9	3.5	3.69	4.5	4.62	4.70
Load capacity increase(%)	-	-	23.15	25.26	23.85	-	-	11.88	16.02	17.31
Failure Mode	Flexural					Crushing				

A. Load-Displacement Behaviour

The experimental load-displacement curves obtained for the tested beams and columns are shown in Fig 5. From graphs the effect of BFRP on normal RC beams and columns it can the improvement on behaviour of strengthened specimens respect to unstrengthened.

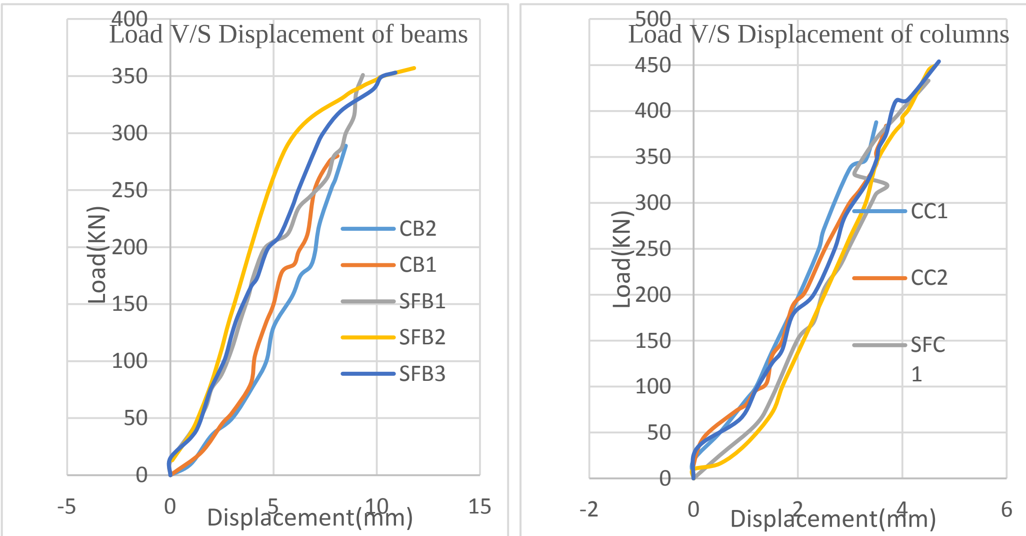

Fig.5 Load V/S Displacement graphs of all the beams and columns

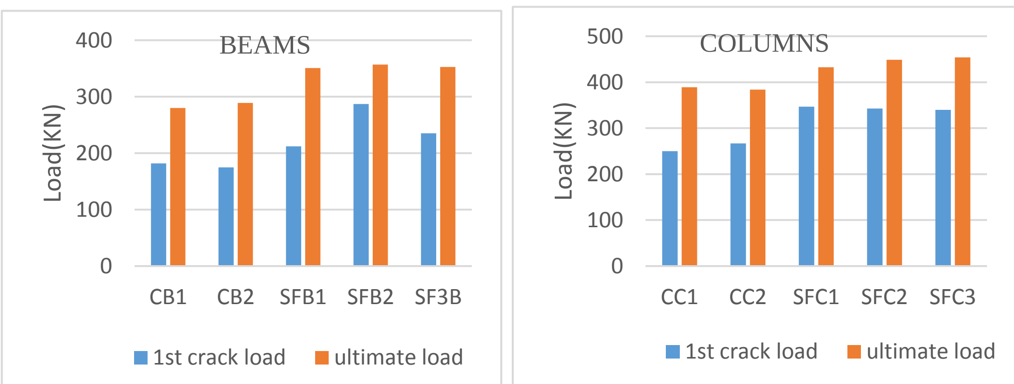

Fig.6 First crack load and Ultimate load graphs of all the beams and columns

B. Failure Behaviour

The failure and crack pattern of all the beams and columns are shown in Fig.7.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 soffit.for test specimens, all the columns failed due to crushing of concrete on compression face of column c/s at the upper zone of the columns.

Fig 7. Failure behaviour of beam and column

VII SUMMARY OF RESULTS AND DISCUSSION

It has been observed that the ultimate load of beams and columns with BFRP UD- fabric warpping using U-warpping pattern are higher than that of beams and columns without BFRP warpping.The increase in flexural load for beams is 23.15%,25.26%,23.85% for SFB1,SFB2,SFB3 respectively,and The increase in axial load for columns is 11.18%,16.02%,17.31% for SFC1,SFC2,SFC3 respectively.
It has been observed that the initial crack formed at a higher load in strengthened beams are 18.43%,60.33%,31.28% and columns 33.97%,32.43%,31.27% compared to the control beams and columns.

VIII CONCLUSIONS

Flexural load carrying capacity of strengthened beams was increased by 24% as comparative to control beams.Axial load carrying capacity of strengthened columns was increased by 15% as comparative to control columns.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 was observed during experimental testing.During the experimental program it was noticed that the failure of the axially loaded columns occurred at the compression side.From overall study,it can be concluded that the strengthening with basalt UD- fabric is more efficient.

REFERENCES

1.Chen W, Pham TM,Sichembe H,Chen L,Hao H,*Experimental Study of Flexural Behaviour of RC Beams Strengthened by Longitudinal and U-shaped Basalt FRP Sheet*, 10.1016/j.compositesB .2017.09.053

2.Azadeh Parvin and David Brighton,*FRP Composites Strengthening of Concrete Columns under Various Loading Conditions*,Polymers 2014, 6, 1040-1056; doi:10.3390/polym6041040

3.N. Attari,S. Amziane, M. Chemrouk, *Flexural strengthening of concrete beams using CFRP, GFRP and hybrid FRP sheets*, Construction and Building Materials 37 (2012) 746–757

4. Akshay P. Mote1, H. S. Jadhav,*Experimental Study of Axially Loaded RC Short Columns Strengthened With Basalt Fiber Reinforced Polymer (BFRP) Sheets*, Int. Journal of Engineering Research and Applications www.ijera.com ISSN : 2248-9622, Vol. 4, Issue 7(Version 4), July 2014, pp.89-92

5.Jiangfeng Dong , Qingyuan Wang, Zhongwei Guan, *Structural behaviour of RC beams with external flexural and flexural–shear strengthening by FRP sheets*, Composites: Part B 44 (2013) 604–612

6. Ratish Y Chengala, D. Vigneshkumar, B Soundara, *EXTERNAL STRENGTHENING OF REINFORCED CONCRETE COLUMN WITH CFRP*, International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056 ,Volume: 05 Issue: 04 | Apr-2018, p-ISSN: 2395-0072

7.Giuseppe Spadea, Francesco Bencardino, Fabio Sorrenti , Ramnath Narayan Swamy, *Structural effectiveness of FRP materials in strengthening RC beams,* Engineering Structures 99 (2015) 631–641, Engineering Structures ,ELSEVIER

8. Asst. Prof. Dr. Mohammed M. Rasheed,*Experimental Study of Reinforced concrete Columns Strengthened with CFRP under Eccentric Loading,* Journal of Engineering and Development, Vol. 16, No.3, Sep. 2012 ISSN 1813-7822.

9. Cheng Yuana , Wensu Chena, Thong M. Phama , Hong Hao,*Bond behavior between basalt fibres reinforced polymer sheets and steel fibres reinforced concrete*,Engineering Structures 176 (2018) 812–824,ELSEVIERS

10. K.Pradeeba, Dr.A.Rajasekaran, Dr.P.Anupriya,*Strengthening Of RC Circular Column Wrapped With Carbon Fiber Reinforced Polymer (CFRP)* ,IJIRSET, Volume 7, Special Issue 5, April 2018

11. Henrik Thomsen; Enrico Spacone; Suchart Limkatanyu ; and Guido Camata, *Failure Mode Analyses of Reinforced Concrete Beams Strengthened in Flexure with Externally Bonded Fiber-Reinforced Polymers*, Journal Of Composites For Construction © Asce /March/April 2004/ 131
12. Assi,Prof Anumol Raju,*Retrfitting of RC beam using FRP*, IJERT,vol 2, Issue-1jan 2013,ISSN 2278-0181
13. Kaushal Parikh, C.D.Modhera, *Application of GFRP on preloaded retrofitted beam for enhancement in flexural strength*, NTERNATIONAL JOURNAL OF CIVIL AND STRUCTURAL ENGINEERING Volume 2, No 4, 2012
14. Anilkumar D D, Mutturaj A D ,Thippeswamy j, Umesh F M,Prof. Devi Prakash Upadya, *BEHAVIOUR OF SQUARE CONCRETE COLUMN CONFINED WITH CARBON FIBER RIENFORCED POLYMER (CFRP) SHEET*, May 2017 IJSDR | Volume 2, Issue 5.