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Retrofitting of Simply Supported Beam by BFRP and AFRP Wrapping

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Abstract: As per current scenario major cities in India facing issues regarding land availabilities for construction, renovations of old structure or cost of re-construction of whole structure. In most the metro cities it is difficult to demolish and re-construct of whole old building structure. Retrofitting of existing concrete structures has become an important issue nowadays in the construction industry. Such necessity had been caused by several factors, especially when concrete is subjected to severe environmental and loading conditions. In such situations, the remedy is either to demolish the existing structure and construct a new one or to retrofit the existing structure by an appropriate strengthening methodology. It is very essential to find easy and fast alternative ways in field of retrofitting to avoid complete re-construction of building. This research paper aims at introducing new materials for strengthening or retrofitting of structure by U-shaped wrapping of Basalt fiber reinforced polymer and Aramid fiber reinforced polymer unidirectional sheets

Keywords: Retrofitting, Basalt, Aramid, Simply supported beam fiber reinforced polymer

I. INTRODUCTION

Now a days retrofitting is most preferable way to restore and strengthen building structure as compare to re-construction of building. Retrofitting is cost effective as compare to re-construction. There are too many factors affecting the performance of reinforced concrete structure such as deterioration due to corrosion of steel, new design standards, change in use of building structure, exposure to aggressive environment and natural accident like earthquake which increases the requirement of retrofitting. In such condition there two possible solutions replacement or retrofitting. Full structure replacement might have disadvantages such as high cost for material and labour. When possible, it is best to repair or upgrade the structure by strengthening of structure. The development of strong epoxy resin bond lead to new technique which has great potential in the field of upgrading structure. Basically this technique involves gluing the steel plate or Fiber Reinforced Polymer sheets (FRP) on to the surface of structure member to confine the structure. The plates and FRP then act compositely with the concrete and help to carry the loads. FRP can be convenient compared to steel plates for a number of reasons. These materials have higher ultimate strength and lower density than steel. The application is very easy and temporary support is not required until adhesive gain its strength due to its low weight. We can apply such FRP sheets on any odd shape and easily cut to length on site. This study intend to integrate the behavior of simply supported concrete beam retrofitted with basalt FRP and aramid FRP.

II. METHODOLOGY

An experimental investigation have been carried out to evaluate the performance of simply supported beam wrapped with U shaped of BFRP and AFRP. To achieve this objective we have used the methodology of strengthening of beam. Total fifteen numbers of beams specimen were casted using M-35 grade concrete with 2#10mm compression and 3#10mm tension reinforcement. Size of beam is 150mm x 150mm in cross-section and 700m in length as per IS-516-1959. All specimen are tested after 28-days of curing period. Three are tested on UTM (Universal testing machine) to find out ultimate load carrying capacity of beam. Remaining twelve beams de-stressed at 60% load of average ultimate load carrying capacity of the beam. Distressed beams wrapped with two different unidirectional fiber reinforced sheets. Beam Specimen tested on UTM after three days to carried out the performance of beam wrapped with BFRP and AFRP.

III. EXPERIMENTAL WORK

3.1 Analysis of beam
Cross-section of beam = 150mm × 150mm
Length: - 700mm

Top reinforcement: - 2#10mm (A_{sc} =157 mm2)
Bottom reinforcement: - 3#10mm (A_{st} =235.5 mm2)
Cover on all side: - 25mm
f_{ck} = 35 N/mm^2 (Characteristics strength of concrete)
f_y= 500 N/mm^2(Characteristics strength of steel)
f_{cc} = 0.446 f_{ck}= 0.446 × 35 =15.61 N/mm2 (SP-16 /C.2.3.2)
f_{sc} = 370 N/mm^2 (SP-16,Table:-F)
d'/d =25/125 = 0.2

X_u (Depth of neutral axis)

C1 + C2 = T1
$0.36*f_{ck}*b*X_u + (f_{sc} - f_{cc})\ A_{sc} = 0.87*\ f_y*A_{st}$ (IS 456:2000 ANNEX G)
$0.36 \times 35 \times 150 \times X_u + (370 – 15.61) \times 157 = 0.87 \times 500 \times 235.5$
X_u = 24.76 mm
X_u max = 0.456 × d (SP-16, Table:-B)
= 0.456 × 125 =57 mm
X_u<X_u max (Under reinforced section)

Mu (Total moment resistant)

$C_1\ Z_1 + C_2\ Z_2 = M_u$
$(0.36\times f_{ck}\times b\times X_u) \times (d – 0.42\ X_u) + ((f_{sc} - f_{cc})\ A_{sc}) \times (d – d') = M_u$
$0.36 \times 35 \times 150 \times 24.76\ (125 – 0.42(24.76)) + (370 – 15.61) \times 157 \times (125 - 25) = 10.927$ kNm ≈ 11 kNm

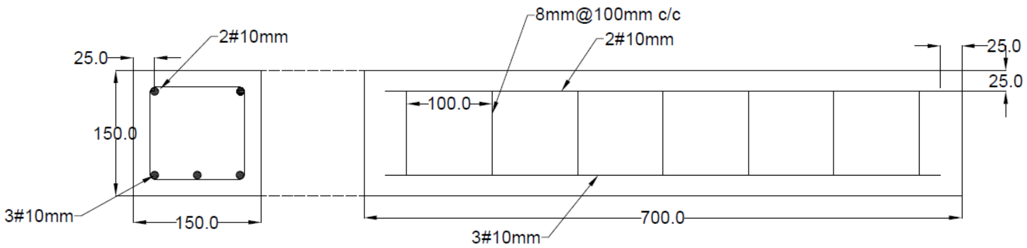

Fig. 1. Detailing of model beam

Total bending moment resisting capacity of singly reinforced beam is 11kNm with given reinforcement.

3.2 Material used for retrofitting
3.2.1 Basalt unidirectional fiber reinforced polymer
Tensile strength (MPa): - 2100
Area weight (g/m^2): -320
Thickness: - 0.38 ± 10%
3.2.2 Aramid (Kevlar) unidirectional fiber reinforced polymer
Tensile strength (MPa): - 2760
Area weight (g/m^2): -220
Thickness: - 0.28 ± 10%

3.2.3 Sikadur-330
Sikadur-330 is normally used both as the substrate primer and as the fabric impregnating resin.

3.3 Casing of beam specimen
Total 15 number of beams were casted as shown in fig. 2 of M-35 grade of concrete of size 150mm x 150mm in cross section and 700mm in length and 9 number of concrete cube were casted to ensure grading of concrete.

3.4 Testing and distressing of beams
Out of 15 beams 3 beams were tested for ultimate load carrying capacity on UTM (Universal testing machine) by application of single point load on center of span by keeping 60mm unsupported length on either side i.e. effective span is 580mm. Remaining 12 beams were distressed at 60% of ultimate load capacity which need repair or retrofitting work.

Fig. 2. Casted beam specimen

3.5 Wrapping of beam with FRP

U-shaped wrapping carried out by BFRP and AFRP unidirectional sheets by “dry application method”. Six beams are wrapped with BFRP and remaining six with AFRP. Before wrapping surface should be properly clean with brush to remove loose particle and dust particle from member. Place the pre-cut dry BFRP and AFRP fabric in the required direction onto the Sikadur-330 priming layer. Apply second coat of sikadur-330 as impregnating resin until it is squeezed out between and through the fibre strands should distribute evenly over the whole of the fabric surface. Keep all wrapped beam in dry environment for at least 7 days to ensure bonding between fabric and adhesive.

Fig. 3. Finished wrapped beam

3.6 Testing of beams (After wrapping)

Ultimate load carrying capacity of wrapped beam is measure by applying single point load on center of beam span by UTM. Then corresponding flexural strength is find out from failure load carried by wrapped beam.

Fig. 4. Beam test on UTM

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3.7 Test results

3.7.1 Cube test result

Table:- cube test result

Title	Size of cube(mm)	Maximum load (KN)	Result (N/mm^2)	Average (N/mm^2)
Concrete cube test	150 × 150 × 150	890	39.56	36.50
		753	33.47	
		821	36.49	
		908	40.36	36.86
		798	35.47	
		782	34.76	
		801	35.60	38.36
		952	42.32	
		836	37.16	

Table:-2 Control beam test result

Title	Results (kN)	Average (kN)	Moment (N.mm^2)	Bending stress(N/mm^2)
Control beam	1. 92.15	89.98	13047100	23.20
	2. 91.78			
	3. 86.00			

Hence results are satisfied as per M-35 grade of concrete
Average ultimate load carrying capacity= F = 90 KN
Reaction on both support = 45 KN
In simply supported beam with center point load, maximum bending moment will be happen at center of span

Max. bending moment = $\frac{Wl}{4} = \frac{90 \times 10^3 \times 580}{4}$ = 13047100 N.mm

Section modules of section = Z = $\frac{bd^2}{6} = \frac{150 \times 150^2}{6}$ = 562500 mm^3

Bending stress = $\frac{M}{Z} = \frac{15750000}{562500}$ = 23.20 N/mm^2

3.7.2 Beam wrapped with BFRP

Table:-3 BFRP wrapping test result

Title	Load (kN)	Average(kN)	Moment (N.mm)	Bending stress (N/mm^2)
Wrap with basalt fiber	1. 111.50	124	17980000	31.97
	2. 131.60			
	3. 128.90			
	4. 118.80	119.83	17375350	30.89
	5. 124.30			
	6. 116.40			

3.7.3 Beam wrapped with AFRP

Table:-4 AFRP wrapping test result

Title	Load (kN)	Average (kN)	Moment (N.mm^2)	Bending stress(N/mm^2)
Wrap with aramid fiber	1113.94	116.72	16924400	30.08
	2.114.74			
	3.121.50			
	4.107.20	114.46	16596700	29.50
	5.115.50			
	6.120.70			

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IV. CONCLUSION

1. Load capacity increase by 34.02 kN i.e. by 37.8% as compare to ultimate load carrying capacity after U-shaped wrapping of basalt fiber reinforcement polymer (BFRP) sheets.

- Bending stress or flexural strength increases by 8.77 N/mm^2 as compare to original flexural strength after U-shaped wrapping of basalt fiber reinforcement polymer (BFRP) sheets.
- Increment in load carrying capacity after wrapped with BFRP sheets is “344.44%” of load carrying capacity of 60% distressed beam specimen.
- Increment in flexural strength of beam after retrofit with BFRP sheets is 22.69 N/mm^2 i.e. by about 2.45 times of flexural strength of 60% de-stressed beam.

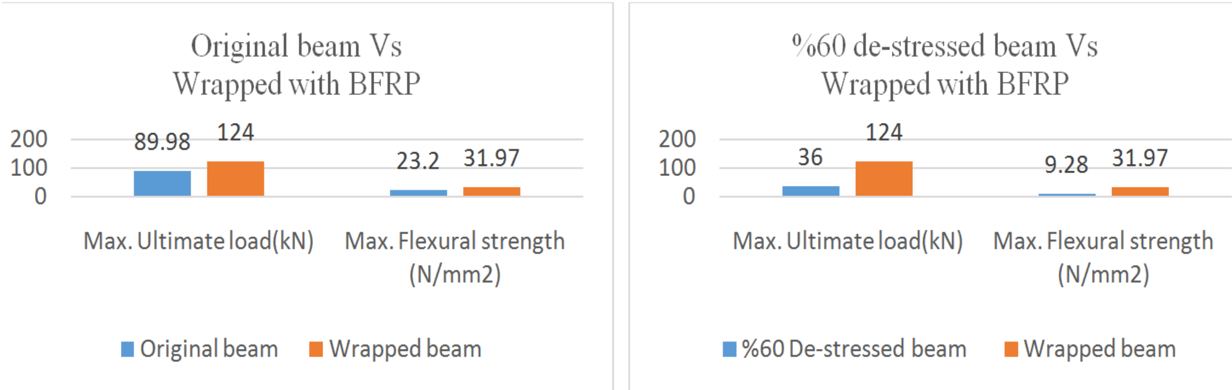

Fig. 4. Beam wrapped with BFRP

2. Load capacity increase by 26.7 kN and by 29.67% as compare to original load carrying capacity after U-shaped wrapping of Aramid fiber reinforcement polymer (AFRP)

- Bending stress or flexural strength increases by 6.88 N/mm^2 as compare to original flexural strength after U-shaped wrapping of Aramid fiber reinforcement polymer (AFRP)
- Increment in load carrying capacity after wrapped with AFRP sheets is “224.22%” of load carrying capacity of 60% distressed beam specimen.
- Increment in flexural strength of beam after retrofit with AFRP sheets is 20.80 N/mm^2 i.e. by about 2.25 times of flexural strength of 60% de-stressed beam.

3. AFRP and BFRP has tensile strength 2760 N/mm^2 and 2100 N/mm2 which is approximately 4-5 times more than the tensile strength of conventional reinforcement bar i.e.250-500 N/mm^2 which help to give more ductility load carrying capacity

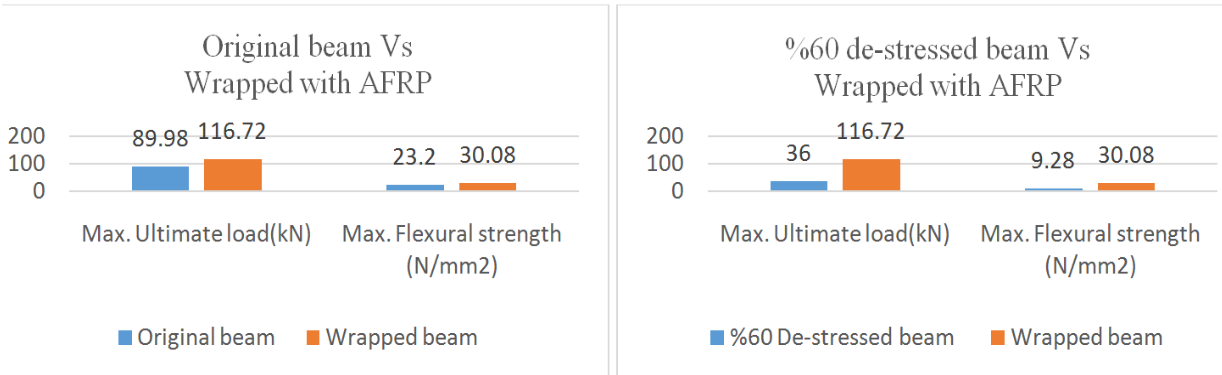

Fig. 5. Beam wrapped with AFRP

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