Serviceable RCC Beam by Glass Fibre for Sustainable Building

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ABSTRACT

The purpose of this study is to identify the strength of RCC Beams which is wrapped with selective fibre sheet. Fibre reinforced polymer (FRP) application is a very effective way to repair and strengthen structures that have become structurally weak over their life span. FRP repair systems are observed to be the cost effective technique which has a vast application in the repair and rehabilitation and is an alternative to the current repair systems and materials. In this experimental study glass fibre reinforced polymer sheets are used to strengthen the load bearing RCC beams, the experimental investigations for flexural behaviour is analyzed. Two sets of beams were casted, one as control and other as experimental specimen. Static loading system is used in identifying the strength of RCC beam. The strengthening of the beam is done with different amount and configuration of GFRP sheets. Comparing with control the flexure and strength of RCC beam shows an effective performance. Experimental Data on load, deflection and failure modes of each of the beams were obtained. The effect of number of GFRP layers and its orientation on ultimate load carrying capacity and failure mode of the beams are investigated.

Keywords *- Fibre reinforced polymer (FRP), Flexural Strength, Glass Fibre, reinforced polymer sheets (GFRP).*

I. INTRODUCTION

Stability in structural behaviour is one of the predominant problems identified in civil engineering applications [1]. The service lives of existing buildings could be preserved based on new code designs rehabilitation. Normally concrete structural strength is maintained to withstand wind and seismic forces. A non corrosive, magnetic and chemical resistive fiber reinforced polymers are used in this study, which enhance the flexural, shear and torsional capacity of RC beams. The purpose of this research is to investigate the flexural and shear behaviour of RCC beams strengthened with varying configuration and layers of GFRP sheets and addition of number of GFRP layers and its orientation. The main objective of this work is to design the mix for fiber reinforced concrete and to identify behavior of RC beams with varying percentages of fibre.

II. MATERIALS AND METHODS

The proposed methodology for the current study is given in figure 1.

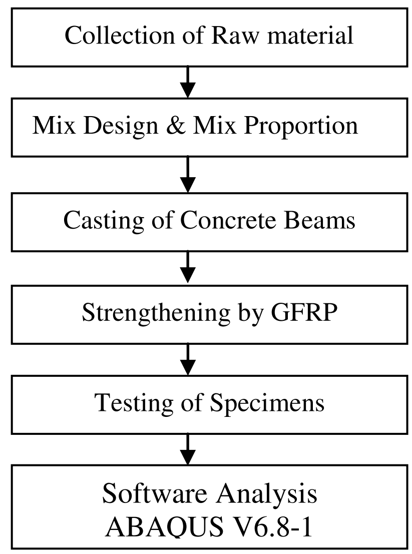

Fig 1: Proposed Methodology

The raw material OPC (Ordinary Portland Cement) used is Sankar Cement 43 grade, fine aggregate collected from river bed of tamirabarani, coarse aggregate collected from quarry in tirunelveli region. HYSD (High Yielding Strength Deformed) bars of 12 mm dia are used as main reinforcement, 6 mm dia mild steel bars used as shear reinforcement. The mix design M40 is followed from IS: 10262-1982. The experimental study consists of casting of two sets of reinforcement concrete (RC) beams [2]. In set 1 three beams (C1, C2, C3) as control and set 2 three beams using continuous glass fiber reinforced polymer (GFRP) sheets. The cross sectional dimensions of the both the set of beam is 250 mm by 200 mm and length is 2300 mm as shown in figure 2. Testing of specimens is carried out by two point loading method and the loading is done by hydraulic jack of capacity 100kN.

Fig 2 (a): Mould for Casting Specimen

Fig 2 (b): Casted Specimen

Fig 2 (c): Fibre Wrapped Specimen

III. RESULT AND DISCUSSION

The materials used in this investigation are analysed and their properties are listed in table 1. Suitable formwork designed has been framed in such a way that it can withstand the dead load and live load during construction and their composition of mix proportion and mix design was illustrated in table 2. Curing of concrete is carried out for 28 days by covering wet cloth over the surface [3]. The surface of casted beam is applied with epoxy resin and then the composite fabric was applied on top of the resin coating. Before applying second layer of epoxy resin, the air bubble entrapped among the interface of concrete, resin and fabric should be eliminated; now the GFRP (Glass Fibre Reinforced Polymer) sheet was applied on top of epoxy resin coating. Concrete beam strengthened with glass fibre fabric were cured for 24 hours at room temperature before testing.

Table 1(a): Properties of cement

S/No	Test	Result
1	Standard consistency	30%
2	Initial Setting Time	35 Minutes
3	Final Setting Time	330 Minutes
4	Specific Gravity	3.18
5	Fineness	7%
6	Compressive Strength of Mortar cubes	52.81 N/mm^2

Table 1(b): Properties of Fine Aggregate

S/No	Test	Result
1	Specific gravity	2.87
2	Bulk Density	1.64 g/cc
3	Fineness Modulus	2.83

Table 1(c): Properties of Coarse Aggregate

S/No	Test	Result
1	Specific gravity	2.8
2	Bulk Density	1.64 g/cc
3	Fineness Modulus	6.61
4	Normal Size	12 mm

Table 2(a): Composition of Mix Proportion

Water	Cement	Fine Aggregate	Coarse Aggregate
0.4	1	0.909	2.35

Table 2(b): Composition of Mix Design

Sample M40	1 (N/mm^2)	2 (N/mm^2)	3 (N/mm^2)
3 Days	30	31.5	32
7 Days	40	42	41.5
28 Days	48.5	49.5	51

The test specimen was transmitted in the loading frame for crack observations, deflection reading and strain measurement. The composition of fibre application and depth of neutral axis and moment of resistance of beams are shown in table 3 and 4.

Table 3: Amount of Fibre in the Test Specimen

Beam	Size (mm)	Specimen	% of Fibre
C1	2100X200X150	1	0
C2	2100X200X150	1	0
C3	2100X200X150	1	0
F1	2100X200X150	1	soffit
F2	2100X200X150	1	Sides
F3	2100X200X150	1	Middle

Table 4: Moment of resistance and neutral axis of beams

Beams	**X_u (mm)**	**M_u (KNm)**
Control Beams	36.59	17.12
Flexural Beams	54.54	24.60

The observed moment of resistance for beam F1 is 24.60 KNm, which comparatively higher than moment of resistance for beam C1 and it is due to application of two layers of GFRP sheet at the soffit of F1 beam. The specimens are tested to find the ultimate load carrying capacity of control and GFRP strengthened beam and is shown in table 5.

Table 5: Load carrying capacity of beams

Specimen	**Fibres**	**Crack Load (kN)**	**Ultimate Load (kN)**
C1	0	40	92
C2	0	40	92
C3	0	40	92
F1	Soffit	45	98
F2	Sides	40	100
F3	Middle	40	102

The control and F1 beams are deficient in flexure and failed at the earliest. The loading and deflection of respective specimens are graphically shown in figure 3. The flexure – shear failure of beam F2 occurs due to fracture of GFRP sheet in to two pieces and crushing of concrete on top of the beam. Beam F3 shows major flexural cracks at the ultimate load and flexural – shear failure due to delamination of the GFRP sheet. The experimental result obtained is validated using standard finite element analysis software, ABAQUS the latest software tool.

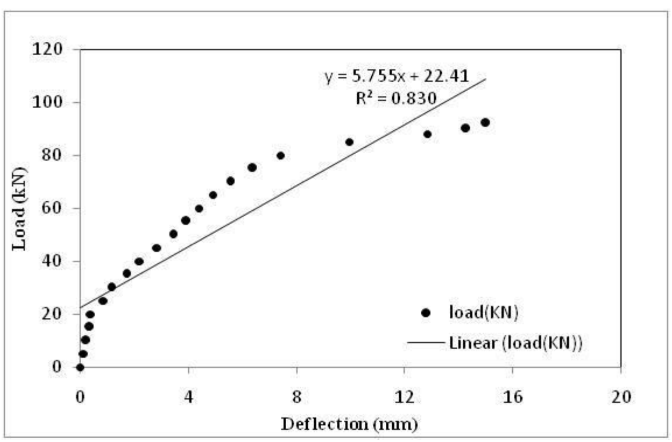

Fig 3 (a)**:** Deflection against Load of Control beam

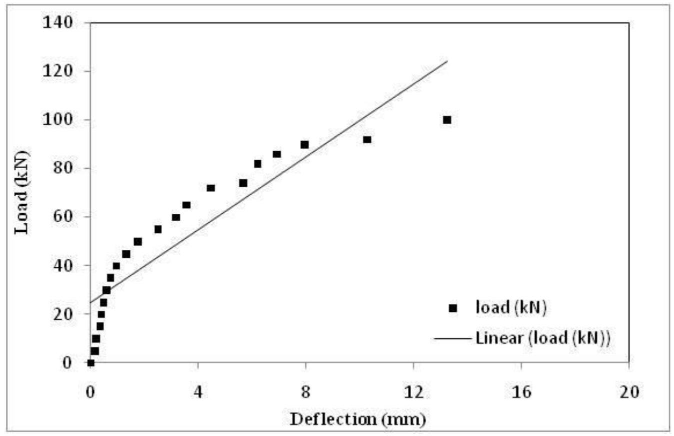

Fig 3 (b): Deflection against Load of beam F1

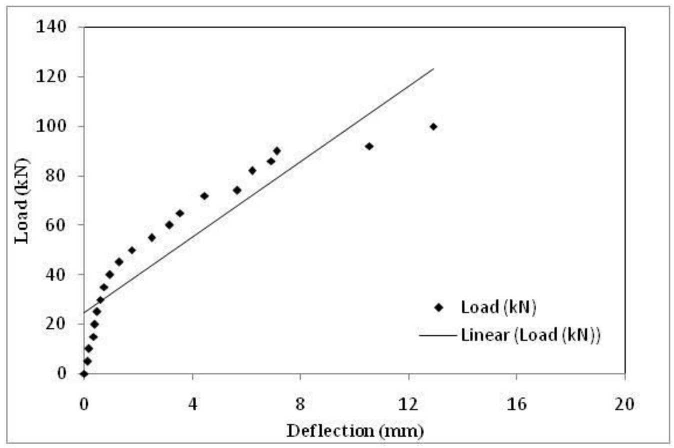

Fig 3 (c)**:** Deflection against Load of beam F2

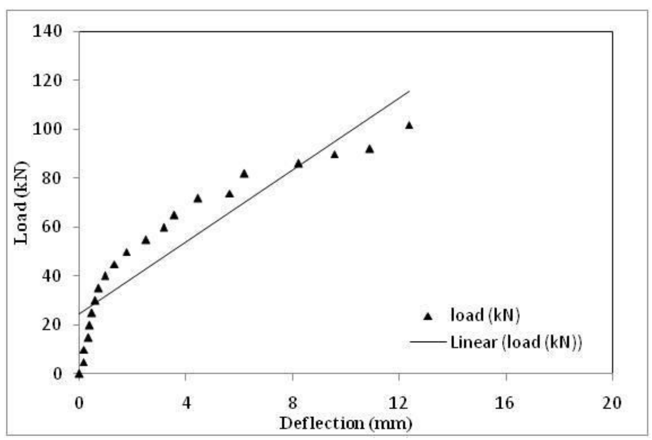

Fig 3 (d): Deflection against Load of beam F3

The meshing of the reinforcement is special cases compared to the concrete volumes and are shown in figure 4.

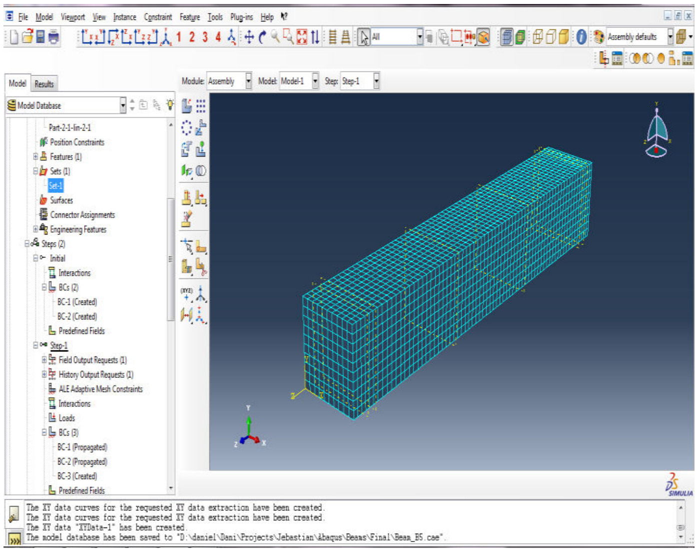

Fig 4: Model showing meshes for analysis of beam

The final results for both experimental and analytical are shown below in the table 6.

Table 6: Load carrying capacity of beams

Specimen	Experimental		Analytical	
	KN	mm	KN	mm
C	92	15.24	91	15.84
F1	98	13.12	96	13.72
F2	100	12.89	95	12.19
F3	102	12.36	94	12.16

From the result it is clearly shown that the analytical results value are lower than the experimental this may be due to the difference in placing, compacting, curing and other physical difficulties in the RCC beam casting.

IV. CONCLUSION

Initial flexural crack appear at higher load by strengthening the beam at soffit than the control beams. The ultimate load carrying capacity of the strengthened beam F2 is 14% more than the controlled beam. Load at initial cracks is further increased by strengthening the beam at the soffit as well as on the two sides of the beam up to neutral axis from the soffit.

The load carrying capacity of the strengthened beam F3 is 6% more than F1. Analytical analysis is also carried out to find the ultimate moment carrying capacity and compared with the experimental results; it was found that analytical analysis predicts lower value than experimental findings.

V. ACKNOWLEDGEMENT

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