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Retrofitting of RC Beams Partially Replaced with Quarry Dust using GFRP

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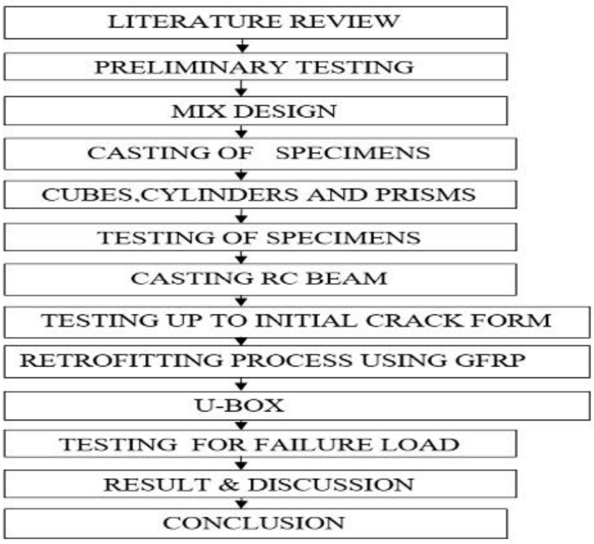
Abstract**—** *This project deals with the study of retrofitting of RC beams using Glass fiber reinforced polymer (GFRP). RC beams were designed and cast of 1m length. The effective use of GFRP in strengthening of RC beams is studied by measuring the load carrying capacity, energy absorbing capacity, deflection behavior and by observing failure patterns. Mixes were prepared for M25 grade and the results were obtained for compressive strength, split tensile strength and flexural strength. It was observed that for concrete with 50% replacement of fine aggregate with quarry dust, the average compressive strength was 34.15 N/mm², whereas for concrete with 50% replacement of fine aggregate with quarry dust, it was 30.94 N/mm² respectively. The deflection of the beams was minimized due to U-BOX wrapping technique around the three sides of the beam. Retrofitted of RC beams partially replaced with quarry dust using GFRP had an ultimate load of 195 kN, 15% greater than that of control specimen.*

Keywords—GFRP Sheets, Epoxy Resin Ly 556, *Quarry Dust****, EB technique, Flexural strengthening.***

I. INTRODUCTION

The deterioration of civil engineering structures takes place either due to poor maintenance, corrosion or impact of natural forces i.e., earthquake. Such deteriorated structures cannot take the load for which they had been designed. Complete demolition of whole structure is not a wise choice. In the modern civil engineering there are plenty of options available to increase the strength of damaged structures without demolishing the whole structure. Over the years, since the discovery of seismic forces, there has been rigorous change in the design codes because the magnitude of seismic forces are uncertain which always creates a vague idea of stability of the structure. Along with that, poor maintenance gradually decreases the strength of a structure, as corrosion weakens the strength of fundamental part of RCC structures i.e., reinforcement and ageing decreases the strength of a structure. So it is not always possible to demolish the structure as it does not prove economic. For a solution of this retrofitting has been proposed. Depending upon the conditions, various methods of retrofitting can be used, but these can be chosen as per experience. Some methods of retrofitting are jacketing of steel to structural elements, steel bars bonded to structural elements, external pre-stressing for the bridge girders, chemical methods (filling up the cracks by chemicals or adhesives) and using Fiber-Reinforced Polymer (FRP) composites bonded to surface of concrete. One of the techniques out of these for strengthening is glass fiber reinforced polymer sheets applied externally by wet layup method. Inclined GFRP sheets are used for retrofitting of beams which are weak in shear. Detail study was done on orientation, width and spacing of GFRP strips and their effect on re-strengthening of flexural members. It was concluded that shear strength was improved by external application of GFRP. As tensile strength of glass fiber reinforced polymer sheet is quite good, it can also be used as strengthening material in tension face of flexural members**.**

II. METHODOLOGY



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III. MATERIALS

Experimental Investigations have been carried out on the specimens to ascertain the workability and strength related properties in order to check the quality of concrete.

A. Materials Used

Cement is defined as the building material made by grinding calcined limestone and clay to a fine powder, which can be mixed with water and poured to set as a solid mass or used as an ingredient in making mortar or concrete. In this project, Ordinary Portland Cement (OPC) 53 grade was used.

The aggregate fraction from size 4.75 mm to 150 µ is termed as fine aggregate. The graded fine aggregate is represented by its zone. In this project, river sand belongs to zone – II conforming IS 383-1970 was used.

The aggregate fraction from size 80 mm to 4.75 mm is termed as coarse aggregate. In this project, crushed granular aggregate of 20 mm was used.

Quarry dust was used as fine aggregate. Crushed rock aggregate quarrying generates considerable volumes of quarry fines, often termed as “quarry dust”. Quarry dust can be defined as residue, tailing or other non-voluble waste material after the extraction and processing of rocks to form fine particles less than 4.75mm.

B. EB technique

Epoxy resin is one types of adhesive which is used to stick fiber to concrete surface. It has two components, component A as resin and component B as hardener which has to be mixed thoroughly in the ratio 10:1 by weight

Fig : 1 Epoxy resin and GFRP sheets

IV. MIX DESIGN

The concrete mix M30 is designed as per IS10262:1982, IS 456:2000 for the conventional concrete. Mix design is given below in table I.

TABLE I. MIX PROPORTIONS

Cement	Fine Aggregate	Coarse Aggregate	W/C
1	1.5	2.44	0.45

V. EXPERIMENTAL PROGRAM

The experimental work consists of 3no of control beam and 3no of RC beam was partially replaced with quarry dust was casted. RC beams having grade M25, cross sectional dimensions of 150mm×250mm and 1000mm length. 2-10mm Ø bottom reinforcement and 2-8mm Ø top with 6mm Ø vertical stirrups @ 150mm c/c was provided. First set of control RC beam strengthened using GFRP mat wrap at U-Box method .Second set of RC beam was partially replaced with quarry dust strengthened using GFRP mat wrap at U-Box method. The flexural test is carried out to study the flexural behavior of strengthened Beams. The fig. shows the beam detailing of RC Beam.

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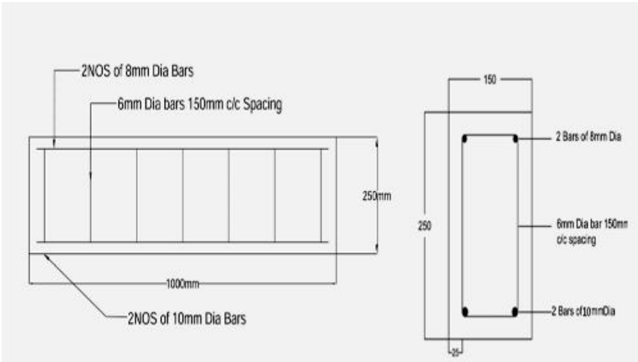

Fig: 2 Reinforcement details of RC beam

VI. TESTING UPTO INITIAL CRACK FORM

The specimen was placed over the 2 steel rollers leaving 50mm from the ends of the beam. The remaining 900 was divided into 3 equal parts of 300mm. Loading was done by hydraulic jack. One dial gauge was placed at the centre to measure the maximum deflection at mid span.

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TABLE 2. TESTING UPTO INITIAL CRACK FORM

Beam	Initial Crack Load (kN) (Control beam)	Initial Crack Load (kN) (50% Q.D AND 50% R. S CONCRETE)
1	75	85
2	80	92
3	75	85

The first crack occurs at 77kN for all three control beams and the first crack occurs at 87kN for all three quarry dust replaced with river sand beam.

A. Load Vs Deflection curve

Mid span deflection at initial loading for control and replacement of 50% Q.D AND 50% R. S beam. Load deflection curve is given below in Fig 3

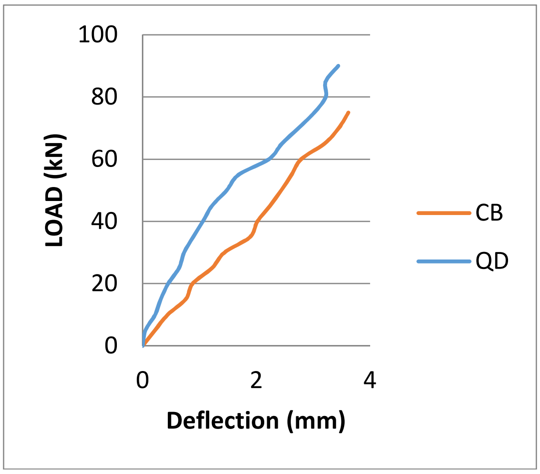

Fig : 3 Load Vs Deflection curve

B. GFRP WRAPPING PROCESS

While doing the wrapping process, first the beams were washed with acetone to remove the dust, dirt and were made clean. The surfaces of the beams were rubbed with paper to make the surface rough. Then wrapping of GFRP sheets on the surface of the beams was done. The wet lay up or hand layup technique was adopted. Concrete beams strengthened with glass Fibre fabric was cured for 48 hours at room temperature before testing.

TABLE 3 Properties of fiber

FIBER	GLASS
Diameter (μm)	9-15
Density (10^3kg/m^3)	2.60
Young's modulus(kN/mm^2)	70-80
Elongation of break (%)	2-3.5
Tensile strength (kN/mm^2)	2-4

TABLE 4

Specifications of the epoxy

Properties	Epoxy Resin LY 556	Hardener HY 951
Colour	Clear	Colourless
Odour	Slight	Ammonia
Physical State	Liquid	Liquid
Solubility in water	Insoluble	Miscible
Vapour Pressure	$<$0.01 Pa at 20^{0}C	$<$0.01 mmHg at 20^{0}C
Specific Gravity	1.15 – 1.2 at 25^{0}C	1 at 20^{0}C
Boiling Point	$>$200^{0}C	$>$200^{0}C
Decomposition Temperature	$>$200^{0}C	$>$200^{0}C

C. Mixing ratio of Epoxy Resin

Epoxy resin is one types of adhesive which is used to stick fiber to concrete surface. It has two components, component A as resin and component B as hardener which has to be mixed thoroughly in the ratio 10:1 by weight.

VII. TESTING FOR FAILURE LOAD

A. ULTIMATE LOAD CARRYING CAPACITY

`Six sets of beams were tested for their ultimate strengths. It is found that all the beams were failed in flexure. It is observed that the control beam had less load carrying capacity and high deflection values compared to that of the externally strengthened beams using FRP sheets.

The deflection of each beam for two point loading is analyzed. The deflections of each type of retrofitted beams are compared and the load deflection behavior is compared between control and quarry dust replace with sand beams retrofitted with FRP sheets having the same reinforcement. It is noted that the Behavior of the beams when bonded with FRP sheets is better than the control beams. The deflections are lower when bonded externally with FRP sheets. The use of FRP sheet had effect in delaying the growth of crack formation.

TABLE 4 ULTIMATE LOAD CARRYING CAPACITY

Beam	*ULTIMATE LOAD CARRYING CAPACITY (kN)* (Control beam)	*ULTIMATE LOAD CARRYING CAPACITY (kN) (50% Q.D AND 50% R. S CONCRETE)*
1	165	195
2	170	190
3	165	195

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The deflection of the beams was minimized due to U-BOX wrapping technique around the three sides of the beam. Retrofitted of RC beams partially replaced with quarry dust using GFRP had an ultimate load of 195 kN, 15% greater than that of control beam.

VIII. CONCLUSION

The main objective is to thoroughly study the behavior of RC beams strengthened with GFRP sheets and their various effects. This had been studied from reputed journals for initiating work.

The preliminary investigations were done for basic materials of conventional concrete and concrete with 50% quarry dust and 50% river sand. From the material properties, mix proportion was arrived for conventional concrete of M25 grade. The results were obtained for compressive strength, split tensile strength and flexural strength. It was observed that for 50% of quarry dust the average compressive strength was 34.15 N/mm², whereas for natural sand, it was 30.94 N/mm². RC beam were designed and cast of 1m length. The first crack occurs at 77kN for all three control beams and the first crack occurs at 87kN for all three quarry dust replaced with river sand beam. The deflection of the beams was minimized due to U-BOX wrapping technique around the three sides of the beam. Retrofitted of RC beams partially replaced with quarry dust using GFRP had an ultimate load of 195 kN, 15% greater than that of control beam.

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