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Study on GFRP Reinforced Beams under Flexure

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Abstract:

Acute shortage of raw materials and deterioration of reinforced concrete structural elements lead to implementation of new substitute materials and innovative technologies. Reinforced Cement Concrete structures are usually reinforced with steel bars which are subjected to corrosion at critical temperature and atmospheric conditions. The structures can also be reinforced with other materials like Fibre Reinforced Polymers (FRP). In this line Fibre Reinforced Polymer based reinforcement replacing conventional steel rod for a precast element of a prefabricated structure is considered. The precast member cast out of M25 grade concrete reinforced exclusively with locally produced Glass Fibre Reinforced Polymer (GFRP) bars including GFRP stirrups is designed, cast. Flexural behaviour of rectangular concrete beams reinforced with FRP bars and stirrups is examined with two specimens one with conventional sand as fine aggregate and another with quarry dust as fine aggregate. The load at cracking and ultimate, type of failure and crack patterns are observed and compared with those of conventional cement concrete.

Keywords: Reinforced cement concrete, steel reinforcement, corrosion, fibre reinforced polymer, flexural behaviour.

I. INTRODUCTION

Reinforced concrete is one of the common and efficient building materials in the world. But such concrete structures that include buildings, bridges are subjected to aggressive environments reducing the alkalinity of the concrete resulting in the rebar corrosion. Corrosion problem is widely addressed across the world and are moving towards corrosion less composite materials.FRP is announced to be the best non corrosive material emerged as an alternative material for producing rebars for concrete structures. Aramid(AFRP) and glass (GFRP) based rebars are used for RCC and carbon(CFRP) based FRP rebars are used for prestressed concrete offering advantages over steel and high tensile rebars respectively. FRP structural members are stronger than many steels along the length, and weigh up to 75% less. Compared to steel, FRP offers the advantages like,

- The strength of steel at 1/4 the weight
- Has a very high strength to weight ratio
- Simple fabrication with standard tools — no welders or cutting torches
- Moulded-in color and resin options, including fire retardant.

FRP products include, rebars of different diameter, plain-ribbed or sand coated surface nature with different bunch of fibres and different cross sections similar to structural steel sections. The FRP based RC structures are used all over the world.

Many developed countries such as USA, UK, Australia, Germany etc.., have moved from conventional reinforced concrete to FRP reinforced concrete structures, in order to increase the life span, durability, high strength of the structures. FRP reinforcement moves the concrete technology from low volume/high technology applications to high volume/relatively low technology applications. Before it becomes widely accepted for concrete structures, several significant aspects of the materials have to be demonstrated, including the durability of FRPs embedded in concrete, the ability to produce suitable reinforcement shapes and the ability to produce large quantities of materials of a consistent quality. In India it is still in the laboratory level and yet to reach the main stream of construction. FRP reinforcements are being imported in the beginning of its development and now it is being supplied in India but slightly at higher rates.

The trend of using FRP reinforcements is still not in popularity in India due to the lack of awareness on its better utility. At the initial stages, FRP bars have been imported from developed countries and the cost is about double the cost of conventional steel rebars. As the FRP bars in different sizes are now locally available within the state, there is a need to study the performance of these material and the members reinforced with these bars.

II. EXPERIMENTATION

Cement (of specific gravity 3.16) as a binder, fine river sand and quarry dust as fine aggregates, 20mm maximum size as coarse aggregate and water are used for making concrete. M25 concrete is designed using IS method of mix design. The properties of the constituent materials are presented in Table 1.

Mix proportion of concrete is obtained as 1:1.4:2.3 and w/c ratio 0.43 for a slump of 84mm.Quantities of constituents requiredare weigh-batched and mixed thoroughly. Slump test is conducted before casting of control specimens and also

cast three numbers of 150mm cubes. The slump of conventional concrete and FRP beam concrete and QD based FRP concrete are found to be 85mm and 63mm respectively.
The beam size planned is 100×200×2000mm. Beams are cast in twin type wooden moulds. After applying the mould oil to the inner faces, the rebar grill is placed inside the wooden mould with cover blocks at bottom.The mixed concrete is then poured inside in three layers. It is compacted by using tamping rods and made sure that the concrete is completely filled without any air voids in concrete. The top surface of beam concrete is perfectlyfinished.
The next day, the concrete cubes and the beams are removed from the moulds and cured by covering with wet gunny bags for 28 days. The beams are reinforced with two 10mm bars at bottom and two 8mm bars at top with 8mm two legged stirrups. The materials and fabrication details are shown in figure 1.Three beams are cast and the details are given in Table 2.

Table 1 Properties of the constituent materials

No	Properties	River sand	Quarry dust	Jelly
1	Fineness modulus	2.60	2.54-2.60	6.93
2	Bulk relative density(kg/m3)	1460	1720-1810	1830
3	Absorption (%)	0	1.20-1.50	0.76
4	Moisture content (%)	1.5	0	0
5	Fine particle less than 0.075mm	6%	12-15%	-
6	Grading by Sieve analysis	Zone II	Zone II	-

(a) FRP bars and stirup

(b) Concrete constituents

(c) Twin type mould

(d) Conducting slump test and casting of beams

(e) Cast beams

Fig.2 Fabrication details of the beams

Table 2 Beam details with variation in materials

No	Beam type	Fine aggregate	Main rebars	Stirrups
1	CCB	River sand	Steel	Steel
2	FRPB 1	River sand	FRP	FRP
3	FRPB 2	River sand and quarry dust	FRP	FRP

III. TESTING OF BEAMS

The beams are tested under simply supported condition with two point loading systemas shown schematically in figure 3 in a 60kN capacity loading frame.The load is applied gradually and continuously on an increasing mode using a hydraulic jack. The load is applied through a load cell and a proving ring and for each incremental load; the corresponding mid span deflection is noted using a mechanical deflectometer.

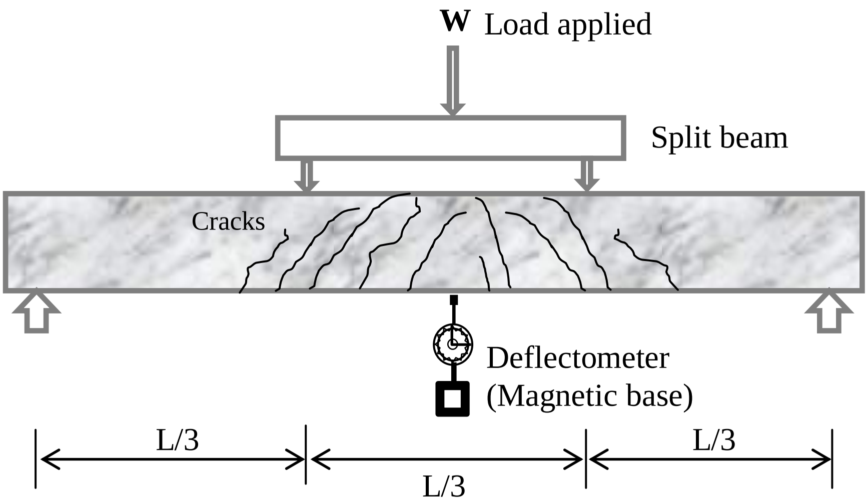

Fig. 3 Schematics of Load testing and observation

The loads at cracking and at ultimate stages are noted. The crack pattern and the load stages are also marked using a marker as soon as the cracks occur. The load deflection relationship of beams are obtained and compared. The results are presented in Table 3. The loading arrangements and the cracking of the beams are shown in figure 4. The load deflection relationship of the three beams is obtained as shown in figure 5.

Table 3 Results of the flexure test

No	Beam designation	Load (N) at		Deflection(mm) at	
		Cracking	Ultimate	Cracking	Ultimate
1	CCB	1100	5800	0.694	8.842
2	FRPB 1	1900 (+73%)	6500 (+12%)	0.599 (-14%)	12.632 (+43%)
3	FRPB 2	700	4000	1.142	14.683

Fig.4 The loading arrangements and the crack patter of the beams

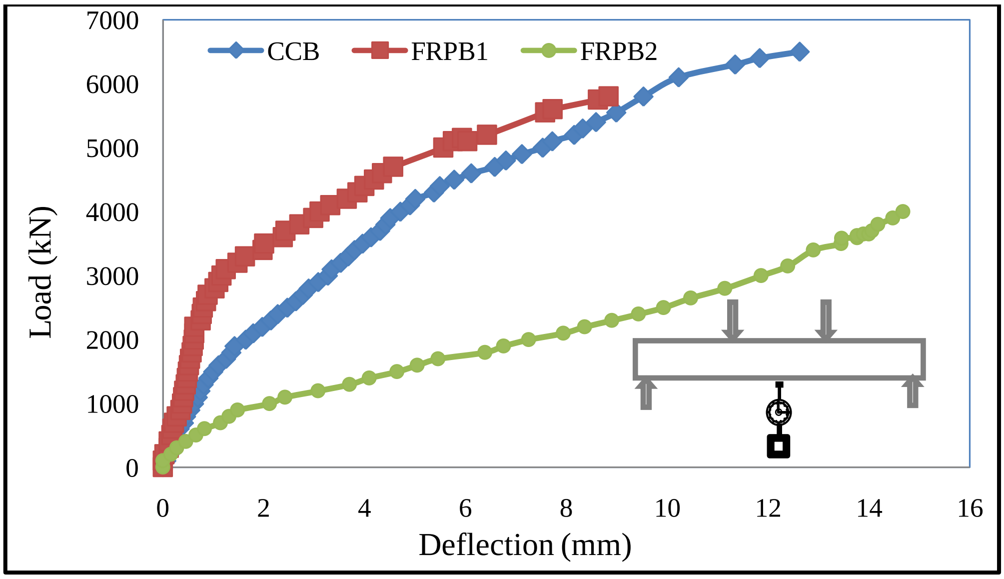

Fig.5 Load deflection relationship of beams

IV. RESULTS AND DISCUSSIONS

- The slump of concrete used conventional concrete beam and FRP beam concrete is obtained as 85mm and that of quarry dust based concrete is 63mm respectively. Hence quarry dust concrete is less workable demanding for excess mixing water compared to river sand based concrete.
- The initiation of first crack is experienced first for quarry dust based concrete beam, followed by conventional concrete beam then the FRP beam.
- The cracking load of FRP beam is 73% higher than that of conventional concrete beam but the corresponding deflection at cracking is 14% less comparatively.
- The ultimate load of FRP beam is 12% more than that of conventional concrete beam and the ultimate deflection is also 43% more comparatively.
- FRP beam shows ductility nature of performance.
- The quarry dust based FRP beam did not give encouraging results. The cracking and ultimate loads are very less and the deflections also are high. This may be due to the presence of fine particles in the quarry dust used as fine aggregate.

V. CONCLUSIONS

- FRP beam experiences ductility behaviour
- The cracking and ultimate loads of FRP beam are high compared to conventional beam.
- The deflection at the corresponding loads also is less comparatively.

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