EXPERIMENTAL STUDY ON BEHAVIOR OF RC BEAMS WITH GFRP REBARS

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Abstract: In the construction industry, there is a vast demand for construction materials due to increase in construction activities across the globe. For more than 100 years, steel rebars have performed quite well as a reinforcing medium in concrete structures except where members have been exposed to aggressive environments such as coastal and marine structures, bridges, chemical plants, and wastewater treatment facilities. The corrosion problem has become a tremendous concern since extensive salting of bridges and highways began in the late 1960's. This is one of the foremost problems in deteriorating the life of reinforced concrete structures. Several methods have been found to overcome corrosion problems in steel reinforcement such as use of admixtures to improve the impermeability of concrete and use of epoxy-coated steel rebars. While they are effective in some situations, such remedies could not eliminate the problems of steel corrosion completely. As a result, in the last 15 years there has been an increase in the use of alternative reinforcing materials for concrete in harsh environments.

Keywords – Corrosion, Rebars, Coated steel.

1. INTRODUCTION

The Fibre Reinforced Polymer (FRP) technology is emerging as a promising alternative for steel in preventing the corrosion problems. They are made of polymers reinforced with fibres. They are having high tensile strength, light weight and non corroding in nature. Different types of FRPs include Glass Fibre Reinforced Polymer (GFRP) Carbon Fibre Reinforced Polymer (CFRP), Basalt Fibre Reinforced Polymer (BFRP) and Aramid Fibre Reinforced Polymer (AFRP). Among these, GFRP is cost effective and proficient in structural applications. These rebars are made of a plastic matrix reinforced by fine fibres of glass. Its advantages include high longitudinal strength and tensile strength, resistance to corrosion and chemical attack, light weight and electromagnetic neutrality. Hence, they have found their applications in structures built near seashore, wastewater treatment plants, petrochemical plants, pulp paper mills and various nuclear power and dump plants. Thus, investigations on GFRP rebars are being carried out across the globe as a substitute for steel reinforcement. However, their extensive use in reinforced concrete structural engineering has been very limited, due to lack of research data and design specifications. Also one of the considerable disadvantages of GFRP rebar is its poor ductility. Various measures are taken to improve its ductility behaviour. This thesis investigates the flexural behaviour of concrete beams reinforced with both GFRP and Thermo Mechanically

Treated (TMT) rebars under static monotonic loading and also the influence of fibers and hybrid reinforcement on the ductility behaviour of GFRP reinforced concrete beams. Literature review, Material properties and hardened concrete properties were included in phase I.

2. LITERATURE REVIEW

Abdelmonem Masmoudi et al. (2012) presented an investigation of reinforced concrete beams with GFRP rebar. Six numbers of concrete beams reinforced with GFRP and steel rebars were cast and tested to study their flexural behaviour. The results of this investigation proposed a reinforcement ratio and should guide structural engineers to a cost effective design of GFRP reinforced concrete members. In addition, study was also carried out with steel reinforced concrete section. Based on the experimental and analytical studies, it was concluded that GFRP rebars have a weaker elasticity modulus, which generate more deflection for equal loads and spans.

Yu Zheng et al. (2012) presented the results of an experimental study of one-third scaled concrete bridge deck models with several varying structural variables, including supporting beam sizes, percentages of reinforcement and reinforcing materials. Test was conducted on GFRP reinforced concrete bridge deck slab model and proposed the prediction methods on ultimate strengths of such slabs. Based on the results, it was concluded that GFRP reinforcement can substitute steel reinforcement without compromising strength in bridge deck slabs.

Mohamed S. Issa et al. (2011) studied the influence of fibres on flexural behaviour and ductility of concrete beams reinforced with GFRP rebars. The experimental program included seven numbers of concrete beams. The tested beams were divided into four groups. First three groups consisted of two numbers of beams; one beam had normal strength and the other had high strength. The fourth group consisted of one number of beam had normal strength. The first group is the reference group which had no internal fibres.

To avoid the possibility of a catastrophic failure due to reinforcing rebars rupture, a model to estimate the minimum required reinforcement ratio was suggested. The model was checked experimentally and pertained good agreement with test results. The engineering characteristics of the GFRP rebars considered in this study can be reasonably estimated. However, as the field data are still scarce and the relatively limited number of test specimens, careful attention should be paid to the limits and the capability of the models was suggested in this paper.

3. GLASS FIBER REINFORCED POLYMER

Fibre-reinforced polymer (FRP), also Fibre-reinforced plastic, is a composite material made of a polymer matrix reinforced with fibres. The fibres are usually glass, carbon, or aramid, although other fibres such as paper or wood or asbestos have been sometimes used. The polymer is usually an epoxy, vinylester or polyester thermosetting plastic, and phenol formaldehyde resins are still in use. FRPs are commonly used in the aerospace, automotive, marine, and construction industries. Composite materials are engineered or naturally occurring materials made from two or more constituent materials with significantly different physical or chemical properties which remain separate and distinct within the finished structure. Most composites have strong, stiff fibres in a matrix which is weaker and less stiff. The objective is usually to make a component which is strong and stiff, often with a low density. Commercial material commonly has glass or carbon fibres in matrices based on thermosetting polymers, such as epoxy or polyester resins. Sometimes, thermoplastic polymers may be preferred, since they are moldable after initial production. There are further classes of composite in which the matrix is a metal or a ceramic. For the most part, these are still in a developmental stage, with problems of high manufacturing costs yet to be overcome.

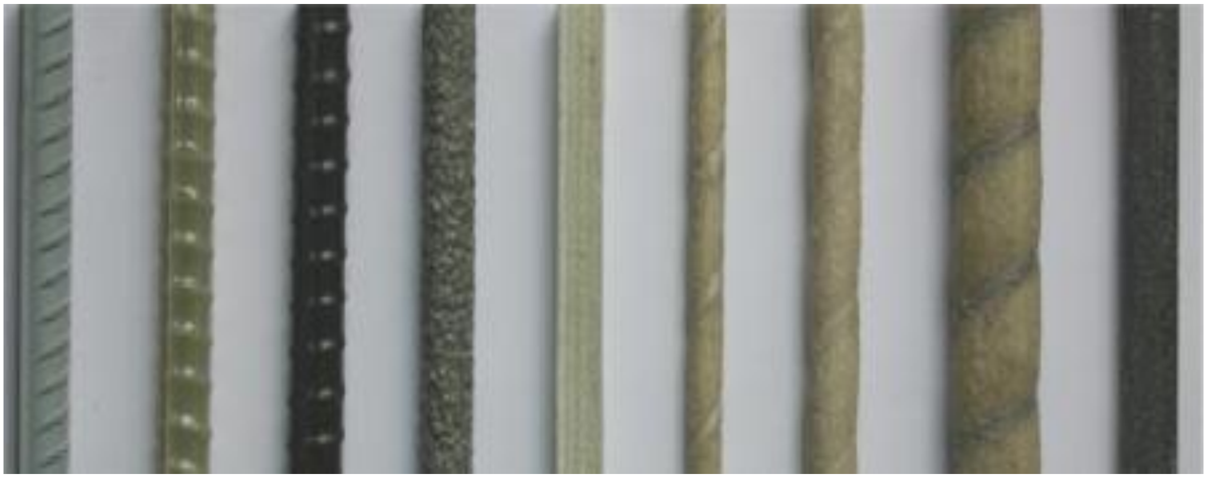

Fig.1. Glass Fibre Reinforced Polymer Rebar

FRP rebars are composite materials made of high strength fibres embedded in a polymeric resin. They are nonmagnetic and noncorrosive. Hence, the problems of electromagnetic interference and steel corrosion can be avoided with FRP reinforcement. Additionally, FRP materials exhibit several properties, such as high tensile strength and stiffness to weight ratios, resistance to chemical attack and controllable thermal expansion and damping characteristics. These advantages could lead to increased safety and life cycle as well as providing savings in fabrication, equipment, and maintenance costs.

4. METHODOLOGY

Specific gravity of cement is defined as the ratio of unit weight of the cement to the unit weight of water.It is denoted by "*G*". One of the methods of determining the specific gravity of cement is by the use of liquid such as kerosene that does not react with cement. A specific gravity bottle may be employed or a standard Le-Chatlier flask may be used and carried out as per IS 1727 - 1962. In order to that, the concrete may be placed in a position such that the initial setting time of cement is not too quick and after it has been laid, hardening should be rapid so that the structure can be made use of as early as possible. The initial set is a stage in the process of hardening after which any crack that may appear will not re-unite. The concrete is said to be finally set when it has obtained sufficient strength and hardness. This test has been carried out as per IS: 4031 (Part 5) 1988.

Fig.2. Cube Specimen after Failure

The bulk density or unit weight of an aggregate gives valuable information's regarding the shape and grading of the aggregate. For a given specific gravity the angular aggregates show a lower bulk density. The bulk density of aggregate is measured by filling a container of known volume in a standard manner and weighing it. Bulk density shows how densely the aggregate is packed when filled in a standard manner. The bulk density depends on the particle size distribution and shape of the particles. One of the early methods of mix design makes use of this parameter bulk density in proportion of concrete mix. The sample which gives the minimum voids or the one which gives maximum bulk density is taken as the right sample of aggregate for making economical mix. The method of determining bulk density also gives the method for finding out void content in the sample of aggregate.

5. RESULT ANALYSIS

Fig.3.Exprimental Setup

The conventional concrete and concrete specimens reinforced with steel fibers were subjected to static two points loading to study the flexural behavior. Cracks were initiated on the tension face of the beams and propagated towards the compression face with the increase in load. The various observations during the static tests on the five number of reinforced concrete beams are given below.The concrete beam was reinforced with four numbers of 16 mm diameter TMT bars. The inner and the outer spans were 350 mm and 1050 mm respectively. The crack was initiated at an applied load of 10.1kN and the corresponding moment was 2.26kN-m. The deflection at the crack initiated load was 1.9 mm. The ultimate load was 75.9 kN and the corresponding ultimate moment of resistance was 19.32kN-m. Crack initiation load was at 13.3% of the ultimate load and the corresponding deflection for ultimate load was 19.7 mm.

The concrete beam was reinforced with four numbers of 16 mm diameter GFRP bars and also with internal steel fibers. The inner and the outer spans were 350 mm and 1050 mm respectively. The crack was initiated at an applied load of 12.1kN and the corresponding moment was 2.96kN-m. The deflection at the crack initiated load was 2.1 mm. The ultimate load was 95.7 kN and the corresponding ultimate moment of resistance was 34.3kN-m. Crack initiation load was at 11.2% of the ultimate load and the corresponding deflection for ultimate load was 23.2 mm.

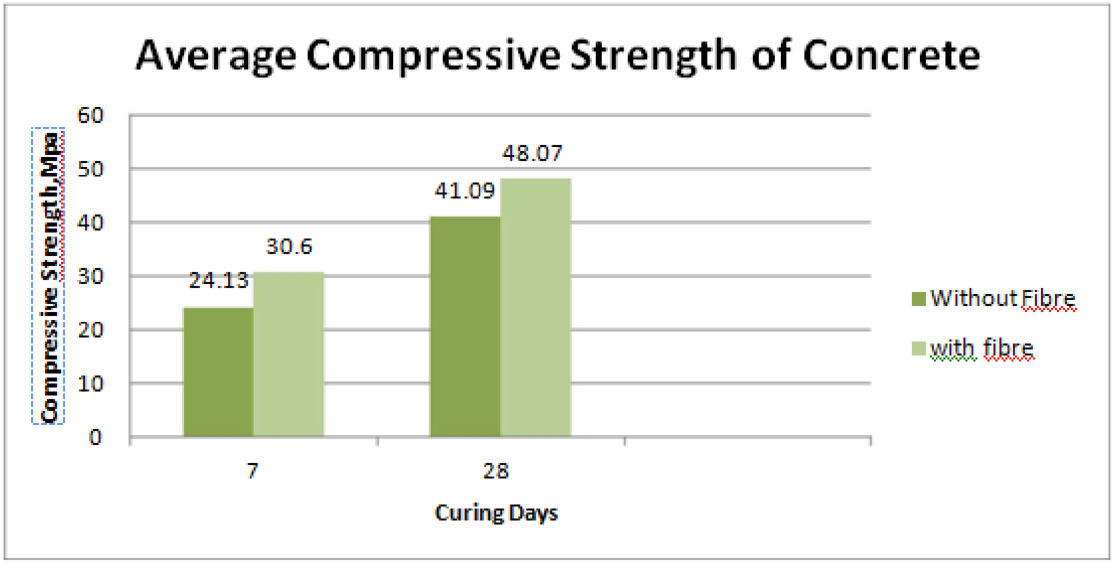

Fig.4. Average Compressive Strength of Concrete Specimen

CONCLUSION

Based on the experimental investigation carried out on concrete beams reinforced with GFRP and TMT bars under flexure the following conclusions are made:

(i) Cracks initiated at an early stage of 10.1 kN, 12.5 kN, 12.1kN, 10.1kN and 11.1kN for the beams TMT-S1, GFRP-G1, GFRP-G2, HYBRID-H1 and HYBRID-H2 respectively.

(ii) The ultimate load for TMT-S1, GFRP-G1 and GFRP-G2 were 75.9 kN, 81.4 kN and 95.7 kN respectively. Whereas the ultimate load for HYBRID-1 and HYBRID-H2 were 67 kN and 81kN respectively.

(iii) It was observed that the average ultimate load carrying capacity of GFRP-G1 beam was 6% higher than that of TMT-S1 beam. Moreover due to effect of internal steel fibers the ultimate load capacity of GFRP-G2 get increases up to 20.6% and 14.9% higher than that of TMT-S1 and GFRP-G1.

(iv) The deflection at the ultimate load for GFRP-G2 beam was observed to be 27.5% higher than that of a GFRP-G2 beam showing improved ductility

(v) The ultimate load capacity of HYBRID-H1 was found to be 20% lesser than that of HYBRID-H2. Also their deflection values at ultimate load were found to be 17mm and 19.2mm respectively.

It is clear that the effect of internal steel fibers have contributed to increase the load carrying capacity and ductility behaviour of concrete beams reinforced with GFRP rebars. Hybrid type reinforcement's didn't give any precise indications and further investigations as to be carried over it.

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