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LITERATURE REVIEW FOR FLEXURAL PERFORMANCE OF FIBRE REINFORCED CONCRETE BEAMS STRENGTHENED WITH FRP SHEETS

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ABSTRACT

The objective of this experiment is to strengthen the RC beams using fibres and FRP sheets in flexure. In this experimental program CFRP and GFRP sheets were applied to the bottom surface and sides of the concrete beam with different configuration and their performance in flexure were studied. In this experimental program eight RC beams of size 1500 x 150 x 200mm were casted with two 10mm dia. bars as tension zone, two 8mm dia. bars as compression zone and 8mm dia. bars @ 200mm c/c spacing as shear reinforcement. One of the specimen is considered as control beam i.e. B1 and one specimen was casted using steel fibres @ 1% by volume i.e. B2 and six beams were wrapped with different amount and configuration of CFRP and GFRP sheets in flexure zone.

Keywords: Beams; GFRP; CFRP; Sheets; Reinforcement mesh; Glass fibers.

1 INTRODUCTION

In the last decade, the effect of external application of fiber reinforced polymers (FRP) plates and wraps to a reinforced concrete beam to increase their performance has been investigated. The use of FRP offers several advantages, related to its high strength to weight ratio, resistance to corrosion, fast and relatively simple application. FRP technology has developed very quickly over the last few years and now more and more FRPs have been produced such as GFRP (glass FRP), CFRP(carbon FRP), AFRP (Aramid FRP), BFRP(basalt FRP). However experiments focus mainly on the behavior of CFRP or GFRP- confined concrete. Therefore, a systematic assessment of the effectiveness of concrete confined with various FRP is necessary. The rehabilitation of infrastructures is not new and various projects have been carried out around the world over the past two decades. One of the techniques of strengthening of the RC structural members is through confinement with a composite enclosure. This external confinement of concrete by high strength fiber reinforced polymer (FRP) composite can significantly enhance the strength and ductility and will result in large energy absorption capacity of structural members. FRP material, which are available in the form of sheet, are being used to strengthen a variety of RC elements to enhance the flexural, shear, and axial load carrying capacity of these elements [2].Only a few years ago, the construction market started to use FRP for structural reinforcement, generally in

combination with other construction materials such as wood, steel and concrete. FRPs exhibit several improved properties such as, high strength-weight ratio, high stiffness-weight ratio, flexibility in design, non-corrosiveness, high fatigue strength, and ease of application. Therefore now a day's FRP sheets are using for strengthening beams etc.

The objective of this experiment is to strengthen the RC beams using fibres and FRP sheets in flexure. In this experimental program CFRP and GFRP sheets were applied to the bottom surface and sides of the concrete beam with different configuration and their performance in flexure were studied.

1.1 General Properties of FRP

- Aesthetics: it gives finish of high quality, thus enhancing aesthetics appearance of the structure.
- Weight consideration: it has higher strength to weight ratio than either mild steel or aluminium.
- Dimensional stability: it holds its form and shape even under severe mechanical stress and severe environmental conditions.
- Durability: its performance under fatigue and creep is known to be superior that of others.
- Design flexibility: it allows large freedom in designing complex and artistic constructions to the architects.
- Insulation properties: it has non-conductive, non-corroding and non-magnetic properties, which makes it a sound insulating material.
- Thermal stability: it can with stand wide range of temperature variations.
- Light transmission: in thinner section, it gives a great deal of transparency.
- Light weight: It is 30% less than aluminium and 60% less than steel in weight, bearing same loads. Due to the lightweight of the elements, it is easy to assemble with minimum tools.

The mechanical properties are typically quite different from that of steel. The properties are dependent on the fiber and resin type. Generally FRP has lower weight, lower young's modulus, but higher strength than steel. In addition, the stress-strain curves of FRPs are straight up to failure, giving the material a brittle failure mode. Some of the physical and mechanical properties of FRP are as follows.

1.2 Physical Properties of FRP

1.2.1 Density

The specific gravity of FRP is nearly four times lower than that of steel, which leads to easier handling and shorter installation time at the job site compared with steel reinforcement. Densities of different materials are as shown in table 3.

1.2.2 Thermal expansion

Reinforced concrete is itself a composite material, where the reinforcement acts as the strengthening medium and the concrete as the matrix. The thermal expansion for FRP reinforcement ranges from $-1.0 \times 10^{-6}/^{0}C$ to $11.7 \times 10^{-6}/^{0}C$.

1.2.3 Tensile strength

FRP reinforcement is elastic up to failure and consequently fails in a brittle mode. The strength in the longitudinal direction is generally higher than that of steel. Furthermore, unlike steel, the tensile strength of FRP is a function of bar diameter. This effect is explained by shear lag, which means that fibres located near the surface are subjected to higher stress than those located at the centre. The values of tensile strengths of different materials are shown in table 3.

1.2.4 Modulus of elasticity

The longitudinal modulus of elasticity for GFRP is approximately 25% that of steel, while CFRP usually has a young's modulus just slightly less than that of steel as given in table 3.

1.2.5 Shear strength

As the shear strength of FRP is very low, the FRP reinforcement in members has to be oriented in such a way that, they will resist the applied loads through axial tensions.

1.2.6 Creep and relaxation

For fiber composites, creep and relaxation are highly dependent on the load direction relative to the fiber orientation. For CFRP and GFRP at service loads, the creep and relaxation taking place have been reported to be equal to or less than that of "low relaxation steel".

1.2.7 Fatigue

CFRP generally exhibit good fatigue resistance, while performance of GFRP is slightly worse than steel regarding this property.

1.3 Advantages of FRC:

The addition of fibres considerably improves the tensile strength of the member. The advantages of FRC can be summarized as follows:

- Addition of fibres delays the appearance of first crack. This increase the tensile strain capacity of the matrix.
- It gives the member a well-defined post-cracking behavior resulting in increase of post-crack ductility.
- It improves the resistance of the member to impact forces.
- It improves the energy absorption capacity of the member by enhancing the crack resistance.
- Fibres in tension zone contribute to improved flexural stiffness, whereas the fibres in compression zone delay the process of disintegration.
- With the incorporation of steel fibres in concrete, an unstable and uncontrolled crack growth is transformed into a slow and controlled crack growth.

1.4 Disadvantages of FRC

- High initial cost.
- Creep and shrinkage.
- Consistency of material properties.
- Global and local buckling.
- Requires high skilled labours.
- Lack of standards and design guides.
- Limited joining and connection technology.

1.5 Advantages of GFRP

- High strength to weight ratio.
- Low weight
- Impervious to chloride ion and chemical attack.
- Transparent to magnetic field.
- Non-conductive.
- High durability.
- Easy to repair.
- Light transmission.
- Non magnetic.

1.6 Applications of GFRP

i) Tunnelling applications
   - Soft eye in diaphragm walls
   - Soil consolidation.

ii) Corrosion applications
   - Bridge decks
   - Median barriers
   - Approach slabs
   - Parking structures
   - Rail road crossings
   - Salt storage facilities

iii) Concrete exposed to marine environment
   - Sea walls
   - Building and structures near waterfronts
   - Aquaculture operations
   - Artificial reefs and water breaks
   - Floating marine docks

iv) Chemically aggressive environment
   - Concrete used in chemical plants and containers
   - Concrete elements

- Pipe line and chemical distribution facilities
- Any polymer concrete requiring reinforcement

1.7 Advantages of CFRP Sheets

- Light weight
- High tensile strength.
- Very high modulus elasticity.
- High fatigue strength
- Good corrosion resistance
- Very low coefficient of thermal expansion
- Low impact resistance
- High electric conductivity.

1.8 Application of CFRP

- It has many applications in aerospace and automotive fields, as well as in sailboats, and notably in modern bicycles and motorcycles. It is also used in laptops, tripods, fishing rods, paintball equipment, archery equipment, racquet frames, stringed instrument bodies, classical guitar strings, drum shells, golf clubs and pools/billiards/snooker cues.
- It proved itself cost-effective in a number of field applications strengthening concrete, masonry, steel, cast iron and timber structures.
- Applied to reinforced concrete structures for flexures, CFRP typically has a large impacting on strength (doubling or more the strength of the section is not uncommon) but only a moderate increase in stiffness(perhaps a 10% increase)
- CFRP can also be applied to enhance shear strength of reinforced concrete by wrapping fabric or fibres around the section to be strengthened.
- CFRP could be used as prestressing materials due to their high strength. The advantages of CFRP over steel as prestressing material, namely its light weight and corrosion resistance, should enable the material to be used for nice applications such as offshore environment.

2 LITERATURE REVIEW

N das et al. Worldwide, a great deal of research is currently being conducted concerning the use of fiber reinforced plastic wraps, laminates and sheets in the repair and strengthening of reinforced concrete members. Fiber-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 provide an economically viable alternative to traditional repair systems and materials. Experimental investigations on the flexural and shear behavior of RC beams strengthened using continuous glass fiber reinforced polymer (GFRP) sheets are carried out. Externally reinforced concrete beams with epoxy-bonded GFRP sheets were tested to failure using a symmetrical two point concentrated static loading system. Two sets of beams were casted for this experimental test program. In SET I three beams weak in flexure were casted, out of which one is controlled beam and other two beams were strengthened using continuous glass fiber reinforced polymer (GFRP) sheets in flexure. In SET II three beams weak in shear were casted, out of which one is the controlled beam and other two beams were strengthened using continuous glass fiber reinforced polymer (GFRP) sheets in shear. The strengthening of the beams is done with different amount and configuration of GFRP sheets. Experimental data on load, deflection and failure modes of each of the beams were obtained. The detail procedure and application of GFRP sheets for strengthening of RC beams is also included. The effect of number of GFRP layers and its orientation on ultimate load carrying capacity and failure mode of the beams are investigated.[1]

Dat Duthinh et al. Seven concrete beams reinforced internally with varying amounts of steel and externally with carbon fiber-reinforced polymer (FRP) laminates applied after the concrete had cracked under service loads were tested under four-point bending. Strains measured along the beam depth allowed computation of the beam curvature in the constant moment region. Results show that FRP is very effective for flexural strengthening. As the amount of steel increases, the additional. strength provided by the carbon FRP laminates decreases. Compared to a beam reinforced heavily with steel only, beams reinforced with both steel and carbon have adequate deformation capacity, in spite of their brittle mode of failure. Clamping or wrapping of the ends of the laminate enhances the capacity of adhesively bonded FRP anchorage. Design equations for anchorage, allowable stress, ductility, and amount of reinforcement are discussed. [2]

G. Spadea, F. Bencardino et al. There is a large need for strengthening of concrete structure all around the world and there can be many reasons for strengthening, increased loads, design and construction faults, change of structure system and so on. The need exist for strengthening in flexure as well as in shear. Bonding of fiber reinforced polymers has shown to be a competitive method for strengthening structure and increasing load bearing capacity.[3]

Alsayed and Alhozaimy et al. The results indicate that the ductility of FRP beams is less than 50% of that of the respective steel beams. The results also reveal that the ductility of SF-FRP beams is directly related to the fiber content. In addition, the test results show that inclusion of 1% of hooked SF can improve the ductility of FRP beams to be the same as that of the steel beams. Furthermore, comparison between the predicted and measured flexural capacity of SF-FRP beams shows that the modified model can predict the measured results within a reasonable accuracy. [4]

Li and Wang et al. Reported that the GFRP sheets reinforced with engineered cementitious composite material showed much better flexural behaviours. The ductility was also found to be significantly improved. [5]

Charles H. Henager et al. reported that by using fiber lengths from 40mm to 60mm and varying fiber percentage of 1.22% to 1.51% by volume in their experiment and showed that Steel fibrous concrete increased the flexural load capacity of the reinforced beams by about 25% and crack width and crack spacing were less than in a conventional reinforced beam.[6]

Y.J. Kim, A. Fam et al. Reported that with the application of FRP sheets reinforced externally showed a significant increase in flexural capacity, up to 53%, and pseudo-ductile failure modes were also observed in beams.The objective of this experiment is to strengthen the RC beams using fibres and FRP sheets in flexure. In this experimental program CFRP and GFRP sheets were applied to the bottom surface and sides of the concrete beam with different configuration and their performance in flexure were studied. [7]

Chajes, M.J., T.A.Thomson,JR,et al. Composite materials are engineered materials made from two or more constitute materials with significant different physical or chemical properties and which remains separate and distinct on a macroscopic level within the finished structure. Fiber Reinforced Polymer is an example for composite materials. Composite materials made of fiber embedded in polymer resins are also known as Fiber Reinforced Polymer (FRP). The fiber is usually fiberglass, carbon or aramid, while the polymer is usually an epoxy, vinyl ester or polyester thermosetting plastic. [8]

Fardis,M.N., and Khalili et al. Fiber reinforced plastics are a category of composite plastics that specifically use fibrous materials to mechanically enhance the strength and elasticity of plastics. FRP composites can be manufactured in many shapes and forms. Applications of FRP composites in civil/infrastructure engineering are diverse and may include internal reinforcement, the most popular forms of FRP are smooth and deformed bars, pre-stressing tendons and pre-cured and cured-in place sheets/shells. FRP bars and tendons are currently produced with sizes and deformation patterns similar to those of steel bars and strands. FRP composites are light in weight, which means they are easier to transport and install. They are corrosion- resistant and therefore perform better in terms of long-term durability and maintenance cost. FRP pre-cured and cured-in-place sheets are used for external concrete reinforcement and FRP shells have been used as jackets for columns. [9]

3 CONCLUSION

- Initial flexural cracks appear at a higher load for the beam reinforced with steel fiber and still higher load when SFRC beams were wrapped with FRP sheets as compared to the control beam.
- The ultimate load carrying capacity of the SFRC beams wrapped with different configuration and amount of GFRP sheet has increased in range from 32.31% to 65.55% as compared to the control beam. SFRC beam wrapped with GFRP sheet to the soffit and around the sides (for full depth of beam) has shown the max increase in the ultimate load carrying capacity of 65.55% as compared to the control beam.
- The ultimate load carrying capacity of the SFRC beams wrapped with different configuration and amount of CFRP sheet has increased in range from 40.05% to 67.90% as compared to the control beam and 20.69% to 35.96% as compared to the SFRC beam. SFRC beam wrapped with CFRP sheet to the soffit and around the sides (for full depth of beam) has shown the max increase in the ultimate load carrying capacity of 67.90% as compared to the control beam and 35.96% when compared with the SFRC beam.

STATEMENTS ON COMPLIANCE WITH ETHICAL STANDARDS

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Disclosure of conflict of interest

No conflicts of interest regarding this manuscript.

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