FLEXURAL BEHAVIOUR OF CONCRETE BEAM WITH GLASS FIBER REINFORCED POLYMER BARS

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Abstract - *The objective of this study is to present the effectiveness of usage glass fiber reinforced polymer GFRP as reinforcement bars in concrete beams. This paper presents results of an experimental and analytical study on the behaviour of centrally loaded beams internally reinforced with GFRP rebars and steel bars and this experimental program conducted to examine the structural performance of GFRP stirrups as shear reinforcement for concrete structures.*

The GFRP reinforced beams indicated higher ductility than the steel reinforced beams. GFRP bars due to their excellent corrosion resistance, high tensile strength, and good nonmagnetic properties have been proposed for reinforcing concrete structures instead of traditional steel. Therefore, four beams are casted by M30 concrete. The GFRP provided as main reinforcement and HYSD bars provided as hanger bars for two beams. And the GFRP provided as main reinforcement and also hanger bars for next two beams.

Analyse and calculate the flexural strength for casted beams. The beams are casted by M30 concrete and investigation for M30 grade of concrete having mix proportion 1:2:03:2.96 with water cement ratio 0.45 to study the compressive strength, flexural strength, split tensile strength. Result data clearly shows the 7 days and 28 days compressive strength, split tensile strength, flexural strength for M30 concrete.

Key Words*: GFRP, flexural strength, shear strength, compressive*

1. INTRODUCTION

1.1 GENERAL

Reinforced Concrete is a most common building material for all the constructions and structures. Concrete have very limited tensile strength, steel rebar used as an effective and cost-efficient reinforcement. However, insufficient cover in concrete, poor design and poor workmanship and large amount of aggressive agents presence including environmental factors. All can lead to cracking of the concrete and corrosion of the steel rebar. Now a day in the world almost 40% of bridges are functionally obsolete or structurally deficient, and the percentage is increasing. The interest in FRP has arisen recently as prospective substitute for steel for many years, there have been many studies on this corrosion issue. The solution is careful consideration on potential of FRP rebars to fill the cost and performance needs.

Recently, FRP bars used as an alternative to steel reinforcement for concrete structures. It is made of fibers embedded in a polymeric resin. Polymeric resin is also known as fiber reinforced polymers.

The commercially available products for the construction industry carbon fiber reinforced polymer (CFRP), Aramid fiber reinforced polymer (AFRP) and glass fiber reinforced polymer (GFRP) rods. Steel reinforcement or steel pre stressing tendons used in non prestressed or prestressed concrete structures. The use of a FRPs reduced the problems of steel corrosion are because FRP materials are noncorrosive and non-metallic. In addition, the use as structural reinforcement in structures FRP materials exhibits several properties including high tensile strength that make them. Fibre reinforced polymers used as an alternative reinforcement material to steel for new construction. It is used for strengthening and repairing of existing concrete structures. Fiber reinforced polymer sheets and strips are most commonly used techniques. And this is also used for currently flexural and shear strengthening of concrete beams, slabs and columns. Externally bonded fiber polymer reinforcements are high susceptible to damage from fire and temperature, ultraviolet rays, and moisture absorption, collision. Insufficient protection may reduce the life and durability of the structure

1.2 OBJECTIVES

- To study the behavior of Reinforced concrete beam with Fiber reinforced polypropylene rods.

- To calculate the flexural strength of RC beams using different configuration of GFRP rods.
- To calculate the tensile strength of the GFRP rods.
- To study the deformation of the beam due to static loading.

- Minimize the usage of fine aggregate and ultimately reduce construction cost.

1.3 NEED FOR THE STUDY

Understanding of the behaviour of FRP reinforcement is essential because the FRP reinforcement used as an alternative reinforcement material and the effective use of this technique for strengthening of concrete structures and bridges. This study provides contribution to the current knowledge and it is leads towards durable as well as restorative procedures. And also used to prevent their replacement and to ensure public safety in concrete structures. This study offers information emphasizes the influence of the configuration of the original steel reinforcement and regarding debonding failures. This research will make more informative decisions regarding the repair and strengthening of flexural members.

And this study will assist in developing reliable and effective design procedures for strengthening of concrete structures and bridges with FRP reinforcement. Experimental results and analytical studies currently available on this topic. They are used as basis and support to the proposed equations, and areas of lacking knowledge are pointed out. Nowadays, FRP rods cab be used in place of steel and epoxy paste can replace cement mortar. The advantage is primarily the resistance of FRP to corrosion.

1.4 FIBER REINFORCED POLYMERS

Fiber-reinforce plastic or fiber-reinforced polymer is a composite material made of a polymer matrix reinforced with fibers. The fibers are usually glass, carbon, aramid, or basalt. Rarely, other fibers such as paper or wood or asbestos have been used. The polymer is usually an epoxy, vinyl ester or polyester thermosetting plastic, and phenol formaldehyde resins are still in use. FRPs are commonly used in the aerospace, automotive, marine, construction industries and ballistic Armor. A fiber is a long material made into a long filament with a diameter generally in the order of 10mm. The aspect ratio of length and diameter can be ranging from thousand to infinity in continuous fiber. The main functions of the fiber are to carry the load and provide stiffness, strength, thermal ability and other structural properties in FRP.

1.5 GLASS FIBER

Fiberglass reinforced plastics are commonly referred to simply as fiberglass. And many places will use textile grade glass fibres. These textile fibres are different from other forms of glass fibers used. Because that fibres consists deliberately trap air and used for insulating applications. Textile glass fibers include varying combinations SiO_2, Al_2O_3, B_2O_3, CaO, or MgO in powder form.

These mixtures are heated through direct melting at the temperatures around 1300 degrees Celsius, after that they are used to extrude filaments of glass fiber in diameter ranging from 9 to 17 μm. These filaments are then wound into larger threads and made the large diameter rods. Glass fiber is the most popular means to reinforce plastic and thus provides a wealth of production processes. In some cased, which are applicable to aramid and carbon fibers because these also shared their same fibrous qualities. The filaments are converted into larger diameter threads are called Roving process. These threads are used for woven reinforcing glass mats and fabrics. It is also commonly used in spray applications.

Fiber fabrics are fabric reinforcing material in web form that have both warped and also in weft directions. Mats are manufactured with chopped fibers in cut direction and in continuous mats, these are using continuous fibers. The lengths of glass threads are lies between 3 and 26 mm. It is used in plastics and most commonly used for moulding processes. Glass fiber short strands are short between 0.2-0.3 mm. The strands of glass fibers that are used to reinforced thermoplastics. And it is most commonly used for injection moulding.

2. LITERATURE REVIEW

2.1 OVER VIEW OF LITERATURE REVIEW

Various researches on this similar topic near surface mounted, fiber reinforced polymer rods are characterized. To utilization of fibers and polymers are used to increase the flexural stiffness and shear strengthening due to durability of the concrete structures. The study of literatures are broadly classified into three various topics (i.e.,) Reviews based on GFRP, reviews based on GFRP rods as making reinforcement and reviews based on GFRP rods as stirrups.

2.2 LITERATURE REVIEW ON GFRP

Mehmet Mustafa Onal (2014) experimentally investigated about concrete beams were strengthened by wrapping he shear edges of the beams twice at 45° in opposite directions by either CFRP of GFRP, the study include CFRP wrapped beams, 3 GFRP wrapped beams and control beams, all of which were 150x250x2200 mm and manufactured with C20 concrete Data were evaluated in terms of load displacement, bearing strength, ductility and energy consumption. In the CFRP and GFRP reinforced beams, compared to controls 38% and 42% respectively. Strength increase was observed. In all beams, failure flexural stress occurred in the center as expected. Mot cracking was observed in the flexural region. A comparison of CFRP and GFRP materials reveals that GFRP enforced parts absorbs more energy. Both materials yielded successful results. Thicker epoxy application in both CFRP and GFRP beams was considered to effective in preventing backups

Deepak Kumar and Govind Ravish (2015) investigated about the use of fiber reinforced polymer (FRP) reinforcements in concrete structures has increased rapidly in the last 10 years due to their excellent corrosion resistance, high tensile strength, and good non-magnetization properties. Fiber-reinforced polymer (FRP) application is a very advanced method for the purpose of repair and strengthens structures which are weak during their life span. FRP repair systems provide an economical and effective method for repairing repair systems and as a material.

2.3 LITERATURE REVIEW ON GFRP AS MAIN REINFROCEMENT

Christopher Bright et al (2016) present about a reinforcement system that utilize unique geometries in order to improve reinforced concrete beam stiffness, shear strength and reinforcement bond properties, as compared with conventional glass fiber reinforced polymer bar style reinforcement is introduced. These specimens were tested and compared to similar specimens with conventional strength GFRP bars in order to document their behaviour and assess the effect on beam performance of the new geometry under typical loading. Both failures that occurred in the control specimens were not present in the prototype specimens. Ultimate shear capacity in one of the prototype variations was increased by 26% over the bar reinforced control specimens.

Keru Suzan AA Mustafa and Hilal A Hassan (2017) paper presents about a nonlinear finite element model to investigate the behaviour of hybrid fiber reinforced polymers and steel reinforcement. Different types of fiber reinforced polymers. CFRP and GFRP were used along with steel rebars in the studied concrete beams. The study was conducted using nonlinear finite element program "ANSYS". Nonlinear material models for the components of the concrete beam were used in the three dimensional finite element models.

Alizadeh S.M. Hasanur Rahman et al (2017) in this paper, test results of six large scale glass fiber reinforced polymer RC continuous. T-Beams are presented. The test specimens include one steel RC beam to serve as reference, one GFRP RC beam designed to meet the serviceability criteria at the service load level calculated for the reference beam, and four GFRP RC beams designed to achieve the same theoretical ultimate load of the reference beam. The test variables included the assumed percentage of moment redistribution, the spacing of lateral reinforcement in flange, and the arrangement of shear reinforcement. The test results showed that moment redistribution from the hogging to the sagging moment region occurred in GFRP RC beams with T-section and that a small spacing of lateral reinforcement in the flange improved the moment redistribution through enhancing the stiffness of the sagging moment region.

2.4 LITERATURE REVIEW ON GFRP AS STRIRRUPS

A. Deifalla et al (2015) presents in international committee on shear and torsion reported that giving physical significance for the torsion design is an upcoming challenge. The purpose of this paper is to propose a reasonably accurate and relatively simply model capable of predicting the torsional strength of concrete beams reinforced with glass fiber reinforced polymer stirrups. In this paper, a database for concrete beams reinforced with gfrp stirrups, tested under torsion is complied. The implementation of the torsion design provisions of the conventional steel reinforced concrete design codes is discussed. A few deflected strength models were used to predict the ultimate torsional strength to he tested beams. The predicted strength was compared with hat measured during testing. The comparison showed that more improvement is required in calculating the inclination of the diagonal concrete strut and the effective strain in the GFRP stirrups. Two strength models were modified and proposed. The proposed models showed better compliance and consistency with the experimental results compared to the available models and design codes. However, further experimental testing will help refine the proposed models.

3. PROPERTIES AND MATERIAL USED

3.1 Coarse aggregate

Table 3.1-Properties of coarse aggregate

S.No	Properties	Result
1	Particle Size, shape	Angular, 12mm
2	Finess Modulus	7.13%
3	Specific Gravity	2.66
4	Water Absorption	0.62%
5	Bulk Density	1497Kg/m3
6	Flakiness Index	21.16%
7	Elongation Index	38.22%

3.2 Fine aggregate

Table 3.2-Properties of fine aggregate

S.No	Properties	Result
1	Particle Size, shape	Angular, 4.75mm
2	Finess Modulus	4.14%
3	Silt Content	1.67%
4	Specific Gravity	2.73
5	Bulking of sand	4.16%
6	Bulk Density	1793Kg/m3
7	Water Absorption	0.28

3.3 Cement

Table 3.3-Properties of cement

S.No	Properties	Result
1	Finess	91%
2	Normal Consistency	31%
3	Vicat Initial setting time	32 min
4	Vicat Final setting time	605 min
5	Specific gravity	3.10

3.4 HYSD Bars and GFRP Bars

Table 3.4-Properties of HYSD Bars & GFRP Bars

S.No	Properties	HYSD Bars	GFRP Bars
1	Diameter	12mm	12mm
2	Load for Yield	47KN	52.5KN
3	Yield Strength	423 N/mm2	465 N/mm2
4	Tensile Load	57.5 KN	71.5 KN
5	Tensile Stress	516 N/mm2	641 N/mm2
6	Changing Length	0.025	0.0178
7	Original Length	1	1
8	Strain	0.025	0.0178
9	Tensile Modulus	16KN/mm2	35KN/mm2
10	Lateral Strain	0.0102	0.0044
11	Poison Ratio	0.38	0.38

4. MIX DESIGN

4.1 Mix proportion

Cement	= 380 Kg/m3
Fine aggregate	= 772 Kg/m3
Coarse aggregate	= 1128 Kg/m3
Water cement ratio	= 172 Litres
Mix proportion in M30	**= 1:2.03:2.96**

5. CONCLUSION

Basic properties of cement Fine aggregate, Coarse aggregate and GFRP bars were tested and the values were discussed. In cement, finess, normal consistency, initial setting time, final setting time and specific gravity tests were conducted and the results of tests were adequate.

In fine aggregate, finess modulus, specific gravity, bulk density, bulking sand, silt content and water absorption tests were conducted and the results of tests were adequate. In coarse aggregate, finess modulus, specific gravity, bulk density, bulking sand, water absorption, flakiness index, elongation index and angularity number tests were conducted and the results of tests were adequate. In concrete, cubes, cylinders ad prisms were casted and compressive strength, tensile strength and flexural strength were calculated. GFRP bars tensile strength was calculated by UTM machine. GFRP bars tensile strength more than the HYSD bars. Poisson's ratio and tensile modulus values are within the permissible limits. Deflection values are low for Glass Fiber reinforced polymer bars compared to normal High Yield strength bars of Grade 500 depends upon the Load by using loading frame machine. 7 days and 28 days strength were calculated and compared the strengthened beams. GFRP reinforced beams have more strength than HYSD reinforced beams. GFRP reinforced beams deflection values are lower than HYSD bars as 5%, 7%, 8% for 7 days, 14 days and 28 days. Different views of various authors on bond strength flexural strength of concrete, steel slag and recycled aggregate have been discussed. This gives theoretical knowledge about utilization of

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