FEASIBILITY STUDY OF USING GLASS FIBER REINFORCED POLYMER REBARS AS REINFORCEMENT IN CONCRETE

A PROJECT REPORT

Submitted in partial fulfillment of the requirements for the Degree of

BACHELOR OF TECHNOLOGY
IN
CIVIL ENGINEERING

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MAY- 2020

STUDENT DECLARATION

I hereby declare that the work presented in the project report entitled **"FEASIBILITY STUDY OF USING GLASS FIBER REINFORCED POLYMER REBARS AS REINFORCEMENT IN CONCRETE"** submitted for partial fulfilment of the requirements for the degree of bachelor of technology in civil engineering at **Jaypee University of Information Technology, Waknaghat** is an authentic record of my work carried out under the supervision of **Mr. Kaushal Kumar**. This work has not been submitted elsewhere for the reward of any other degree/diploma. I am fully responsible for the contents of my project report.

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CERTIFICATE

This is to certify that the work which is being presented in the project report title **"FEASIBILITY STUDY OF USING GLASS FIBER REINFORCED POLYMER REBARS AS REINFORCEMENT IN CONCRETE"** in partial fulfillment of the requirements for the award of the degree of Bachelor of Technology in Civil Engineering and submitted to Department of Civil Engineering, **Jaypee University of Information Technology, Waknaghat** is an authentic record of work carried out by **Ngawang Dolkar** (Enrollment no. 161629) and **Ujjwal Nadda** (Enrollment no. 161678) for a period from July 2019 to November 2019 under the supervision of **Mr. Kaushal Kumar** (Assistant Professor), Department of Civil Engineering, Jaypee University of Information Technology, Waknaghat.

The above statement made is correct to the best of my knowledge.

Date: - ………………………

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ABSTRACT

Glass fiber reinforced polymer rebars are those materials made from the glass fibers in a polymeric matrix. The use of the glass fiber reinforced polymer rebars in modern world has proved to be advantageous in the civil infrastructures due to its corrosive resistant nature. Not only to this advantage, the GFRP rebars are light in weight and can be transported and handled easily with high factor of safety. The other mechanical characteristics of GFRP rebars such as non-conductive to electricity and heat makes them an ideal choice for specific infrastructures like hospitals and industries. Because they serve to be long lasting rebars than steel rebars they are considered to be cost effective product as not much maintenance is required. In this study the steel rebars and GFRP rebars are placed as reinforcement in the concrete cement and is compared with respect to the flexural property with each other for the feasibility of reinforcement.

The beams of cross section 100mm x 100mm of length 500mm with 12mm diameter of GFRP rebars and steel rebars are tested for flexural behavior. This paper also attempts to present the knowledge why the use of GFRP rebars is not common in some area’s despite of their various advantages.

Keywords: Glass fiber reinforced polymer (GFRP) rebars, flexural behavior test.

LIST OF FIGURES

LIST OF TABLES

TABLE OF CONTENT

CHAPTER 1
INTRODUCTION

1.1 General

This chapter discuss on feasibility of the use of glass fiber reinforced polymer rebars in concrete structures. It also deals with the need of the study of the GFRP rebars from the aspect of engineers. It also draws an outline of the manufacturing process of the GFRP rebars. It also explains the physical and mechanical characteristics of the GFRP rebars and the comparison made with the traditional steel rebars. This chapter also draws the growth of the GFRP rebars in the advanced world today.

1.2 Glass Fiber Reinforced Polymer rebars

Fig 1.1: Glass Fiber Reinforced Polymer

The use of GFRP rebars is becoming a wide acceptance by the engineers especially in the field of marine structures. This is because they don't corrode and can withstand the corrosive environments. They present much higher life service in reinforced concrete than the steel reinforcement. Hence the use of GFRP rebars is more durable than the steel rebars. Apart from being corrosive resistance GFRP rebars is also economic. Being light in weight, transportation cost as well as storage and maintenance cost is much less than steel. Likewise, in extreme weather, heat and cold can be conducted by steel bars but on the other hand the GFRP bars cannot conduct electricity or heat and cold which can assist extra assurance for not causing issues especially in building structures such as hospital rooms.

The GFRP are common among the other Fiber Reinforced Polymer (FRP) rebars as they are low in cost, exhibit high tensile strength and excellent insulating properties. There are various types of glass fibers used are of E-glass, S-glass and C-glass. The E-glass GFRP rebars are common among the rest due to its lowest cost compared to all commercial GFRPs, strength, electrical resistance and acid resistance are also excellent. The S-glass have higher strength, stiffness and ultimate strain than E-glass but are more expensive and more susceptible to degradation in alkaline environment.

Parameter	E-glass	S-glass	C-glass	AR-glass
Tensile strength (GPa)	3.45	4.3	3.03	2.5
Tensile modulus (GPa)	72.4	86.9	69.0	70.0
Ultimate strain (%)	4.8	5.0	4.8	3.6
Poisson's ratio	0.2	0.22	–	–
Density (g/cm^3)	2.54	2.49	2.49	2.78
Diameter (μm)	10.0	10.0	4.5	–
Longitudinal CTE (10^{-6}/°C)	5.0	2.9	7.2	–
Dielectric constant	6.3	5.1	–	–

Fig.1.2: Table showing typical physical and mechanical properties of commercial glass fibers [1]

GFRP rebar properties vary significantly depending on:

1. Volume and type of fiber and resin used
2. Fiber orientation
3. Quality control during manufacturing process.

1.3 Properties of Glass Fiber Reinforced polymer rebars (GFRP)

- **Tensile Strength:** The tensile strength of the GFRP rebars are higher compared to steel rebars. Tensile strength is described as the function of the diameters of the rebar. Hence, increase in diameter of the rebars will lead to decrease in the tensile strength of the rebars due to shear-lag which is the non-uniform stress distribution occurring in a tension member which is adjacent to a connection, in which all elements of the cross section are not directly connected. The fibers located near the center of the cross sections of the rebars are not subjected to as much of the stress in those of the fibers near the outer surface of the rebars so therefore they result in reduced strength and efficiency of the larger diameter of the rebars.

- **Compressive strength:** The compressive strength of the GFRP rebars is much lower than the tensile strength, is approximately about 40% to 60% of the tensile strength. However, the compressive strength of the GFRP rebar is not a primary concern so can be adjusted.

- **Modulus of Elasticity:** GFRP rebars behave linearly elastically until failure. The tensile modulus of elasticity of the rebars is much lower than the steel rebars (approximately, 25% of the steel). Moreover, the compressive modulus of elasticity is lower than the tensile modulus of elasticity in GFRP rebars about 83% to 89%.

- **Non-conductivity and Thermal expansion:** GFRP rebars are excellent in electrical and magnetic insulating properties. The coefficient of the thermal expansion is almost similar to the steel rebars so can be used in concrete structures.

- **Creep and fatigue strength:** The GFRP rebars are excellent in creep resistance however, due to the use of different resins they are not true for every type. Therefore, volume and orientation of fibers have great influence on creep behavior. The fatigue strength of the GFRP rebars are less than steel rebars but they do not fatigue when stressed to more than 50% of their ultimate strength.

1.4 Manufacturing process

The rebars are produced through the Pultrusion method which is defined as the continuous process in which the fiberglass is impregnated with resin, pulled out through a heated device and then molded to a desired shape with required length.

The materials required for the GFRP rebars include:

- Fiberglass filament
- Resin (polyester, polyurethane, vinyl ester, epoxy)
- Mechanism machines

In the process the fiberglass filaments are pulled from the continuous roll of fiber mats towards the tension roller. After they are pulled and formed as coil, they are immersed in the pastepot with the resin. The resin-soaked fibers are pulled out of the device pot and excess adhesive is removed. The impregnated strands are fed into the device which forms the ribbed surface and make the roving. They are further extended to the device like tunnel for the shape and polymerization. After that the solidified roving strands is passed to cool with air or water way. Then the cooled strands are set to pulling mechanism which ensures the fiberglass strands and finishes fitting at all stages of the production line. Lastly, they are cut to a required length and stored either by winding or by laying of rods in rack.

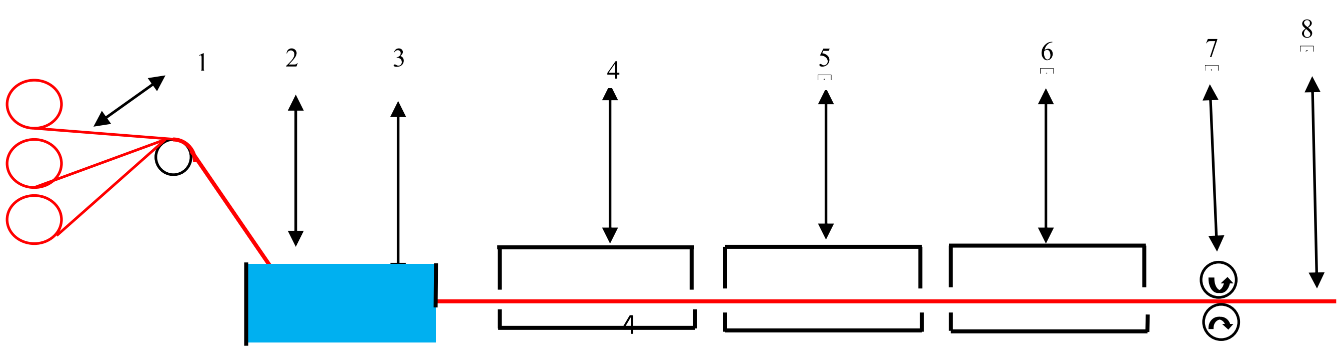


Fig.1.3: Diagram of the Pultrusion [9]
process

1. Continuous roll from fiber mat
2. Tension roller
3. Pastepot of resin
4. Device forming ribbed surface
5. Tunnel shaped device
6. Cooling device
7. Pulling mechanism
8. Finished hardened GFRP

1.5 Why GFRP rebars over steel reinforcement bars

GFRP rebars being characteristically corrosion resistance and electromagnetically neutral they strengthen the RC structures and help compete against corrosion for long period of time. Corrosion is defined as the deterioration of the metal surfaces rapidly when exposed to the atmosphere where the reduction-oxidation reaction takes place. Hence the GFRP rebars is an ideal option due to the following properties:

- The rebars are invulnerable to moisture and strong chlorides.
- They (GFRP rebars) do not react with the salts and other chemicals.

Table 1.1: Shows the comparison between the GFRP rebars and steel reinforcement rebars:

Glass fiber reinforced polymer rebars	Steel reinforcement rebars
Light weight (x4 lighter than steel).	Heavy in weight therefore is costly than GFRP rebars.
Provides less rigid to concrete therefore are milder stiff than steel.	Very high stiffness.

Thermal and electrical isolation.	High thermal and electrical conduction.
No corrosion effect observed on the rebars hence last longer.	Corrosive nature (even stainless steel is corroded) hence life service is shortened.
Less cracking observed in fatigue effect (2.5x lesser than steel)	Limited fatigue resistance.

1.6 The growth of GFRP rebars

In the recent years it has shown that the use of GFRP rebars are increasing in global markets. Their increase in market is mainly due to its advantage in constructing marine structures such as bridges and highway. Replacement for steel rebars has also influenced the growth of GFRP rebars as they are long lasting and requires less maintenance cost.

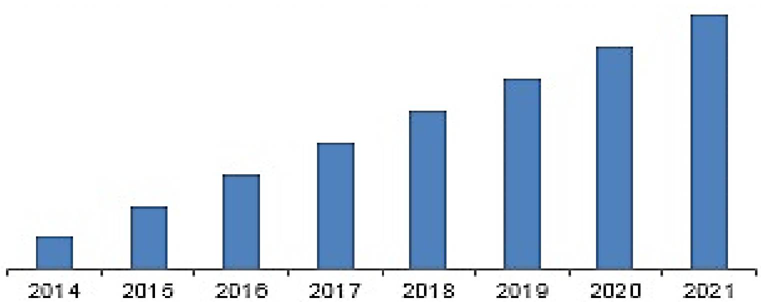


Fig.1.4: Graph showing increase of GFRP rebars in market. (source by industry ARC Analysis and expert Insight) [11]

1.7 Need of study

As concrete possess very good in compressive strength and is weak in tensile strength, we introduce reinforcement rebars in concrete structures so they impart tensile strength to the concrete and act as solitary unit when load is imposed on it. The GFRP rebars also function the same to that of the steel reinforcement rebars. Despite of various advantages of steel reinforcement rebars such as high modulus of elasticity, high ductility and even strong enough to withstand high impact load but when exposed to environment, the seawater react with the bars causing concrete to crack and when steel rebars are rusted they causes severe internal pressure on the surrounding of the concrete leading to crack. The steel rebars can also melt when exposed to high temperature. Hence to match these cons of the steel reinforcement rebars the GFRP rebars replaces them as they (GFRP rebar) have the tendency to be corrosive resistance to aggressive environment where alkaline solution attack and Sulphur attack are common. GFRP rebars also have high tensile strength as compared to steel reinforcement rebars and has high modulus of elasticity which provides no crushing and they can provide ample time to warn before failure as shown in fig.1. The use of GFRP rebars in civil engineering enables the engineers to achieve better functionality, economy and safety of construction.

CHAPTER 2
LITERATURE REVIEWS

2.1 General

This chapter presents a summary of different studies by researchers on the study of the glass fiber reinforced polymer rebars in reinforced concrete as reinforcement instead of steel reinforcement rebars. It includes various method and analysis based on parameters such as different diameters of the rebars used for both GFRP and steel rebars. It also presents how the researchers have developed the importance of the GFRP rebars over the steel rebars and the comparative measures between the rebars of GFRP and steel based on the ultimate load carrying capacity and ultimate deflection.

2.2 Reviews on research

Ankit Singh Mehra et.al (2016) concentrates mainly on the low-cost effective structure, as we all know that concrete has excellent compressive strength but poor in tensile strength. So, reinforcement is installed in order to increase the tensile strength of the structures. The reinforcement is the main constituent's part which holds a major impact on the cost of the structure. For example, the cost of steel is very high, therefore researchers use bamboo as a replacement for the steel reinforcements. In this particular research they have performed the following tests:

a. Durability test on bamboo splints
b. Three-point loading flexural test on cement concrete beam doubly reinforced with bamboo splints and with shear links.
c. Three-point loading flexural test on cement concrete beam singly reinforced with bamboo splints and without shear links.

After the above-mentioned test, they conclude loss of ultimate tensile strength of bamboo splints due to swelling and shrinkage of bamboo as they have high water adsorption. They placed the bamboo splints in three different solution of NaCl solution, Ca $(OH)^2$ solution and plain water.

Benmoktane, 0. Chaallal and R. Masmoudi (1995) [1] discussed the use of the glass fiber reinforced plastic in concrete structures. The authors prepared sample of two types of

GFRP rebars and compared it to the conventional steel reinforced concrete. The beams casted were of three different depths i.e. 300mm, 450mm and 500mm with equal width of 200mm and length of 3m. The beams were tested on the flexural testing setup. Hence, the authors concluded that even if the GFRP rebars were manufactured by two different companies under different manufacturing process and factors, they behaved in similar manner during flexural test. They also claimed that GFRP rebars can be used as an alternative in the concrete structures dues to its various properties discussed in the paper and that they have higher scope in future.

S.Sailey Sivaraja et.al (2013) [2] described mainly in terms of earthquake loading.The author constructed scaled masonry elements with and without the use of GFRP rebars. The experiment performed on the shaking table and elements subjected to base shock vibrations concluded that the simulation of the impact test for earthquake is reasonable.

Bogusław Jareka and Aleksandra Kubika (2015) [3] conducted examination on the GFRP rebars in RC with the static tensile test on three different manufacturers of the GFRP rebars. First manufacturer was glass fibers arranged in parallel and embedded in vinyl - ester resin finished with grooved ribs which results in discontinuity of fibers on the outer surface. Second manufacturer was prepared by the pultrusion method of glass fibers in epoxy resin and last manufacturer was also prepared by pultrusion method composed of continuous glass fiber embedded in thermosetting synthetic resin with grippy sand braiding surface. The sample prepared were mounted on the tensile machine and subjected to an axial force increasing at the constant of 10MPa/s at the temperature of 20°C. The result concluded that for different manufacturer of the GFRP rebars, the increasing load can change the Young modulus of elasticity which in fact changes the application in RC.

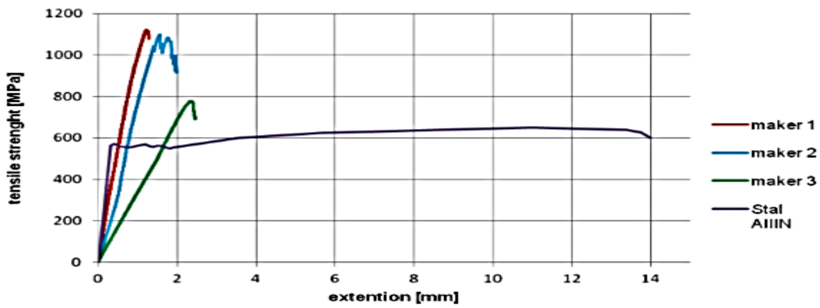


Fig.2.1: Comparison of the result of the axial tensile strength of three types of GFRP rebars and AIIIN steel [3]

Sudeep Vyas and Danish Khan (2016) discussed on the partial replacement of the cement in the concrete by different percentage of glass powder by the weight of cement. The sample prepared was arranged by various percentage of powder glass like 10%, 20%, 30% and 40%. The main objective being on the evaluation of the pozzolanic activity of the waste glass powder, various testing was done such as IST and FST of the sample and the compressive strength test. This paper resulted that 10% to 30% partial replacement by glass powder can be used because the compressive strength at 28 days is close to required strength but as a whole, they concluded that with increase in the percentage of powder glass the strength required decreases.

Sample	3 day strength	7 day strength	28 day strength
Normal OPC 43 grade	19.48	23.99	29.03
With 10% glass powder	18.49	23.92	28.96
With 20% glass powder	17.56	23.47	28.74
With 30% glass powder	18.22	23.69	28.59
With 40% glass powder	16.44	19.62	27.31

Fig 2.2: Table showing compressive strength of various sample

Doo Yeol Yoo, Nemkumar Banthia and Young Soo Yoon (2016) [4] researched on the flexural behavior of the GFRP rebars and steel rebars in ultra-high performance fiber reinforced concrete (UHPFRC) beams. Three GFRP rebar beams and four hybrid (steel + GFRP rebars) of different ratio reinforcement beams were fabricated and tested through sectional analysis based on the AFGC/SETRA and JSCE recommendations. From the test they concluded that all UHPFRC beams displayed very stiff load-deflection curve after cracking due to excellent fiber bridging capacity on the crack surfaces. They also said that higher the reinforcement ratio of GFRP rebars higher the post cracking stiffness and ultimate moment capacity. They also resolved that the maximum moment capacity was underestimated based on the sectional analysis by AFGC/SETRA and overestimated by JSCE recommendations.

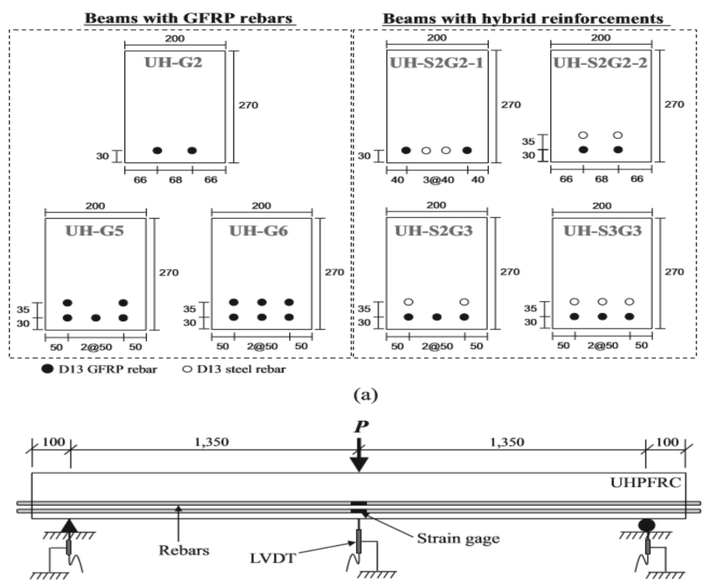
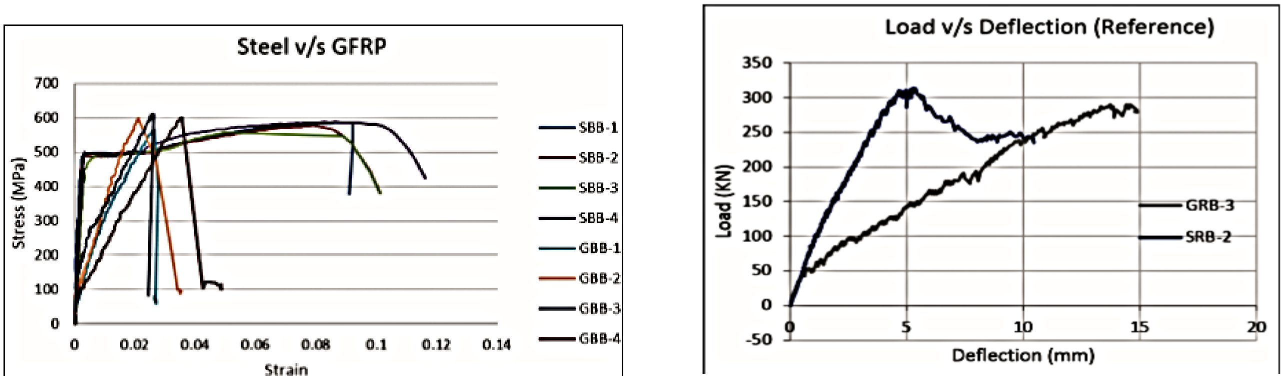


Fig.2.3: Details of test beams and test setup performed by the authors [4]

Aditya S. Rajput and Umesh K. Sharma (2017) dicussed the durability and the serviceability performance of GFRP rebars on concrete reinforcement in which durability of GFRP rebars were tested by exposing them to chemicals and serviceability was tested in terms of deflection and cracking. In the test the recording of reduction of the tensile strength was noted due to accelerated exposure and stress-strain graph was plotted. Total of 15 beams were prepared for the serviceability performance and flexural on two point loading set up was tested and load-deflection curve was plotted. The conclusion made was that durability performance of GFRP in carbonated concrete was better. They also concluded that crack propagation study indicates that GFRP reinforced beams when loaded results in wider cracks than steel reinforced beams.



(a) (b)

Fig.2.4: Graphs showing the comparison of (a) stress-strain and (b) load-deflection curve between steel and GFRP rebars

Renata Kotyniaa, Damian Szczecha and Monika Kaszubsk (2017) [5] researched on the bond behavior of GFRP bras to concrete in beam test. The authors prepared 12 rectangular concrete beams with cross section 150mm x 200mm of length 800mm. The beams were tested on the four point loading by the displacement control system with hydraulic jack of 200kN capacity. The system consisted of linear variable differential transducer (LVDT) and one strain gauge to record bar slip. The result concluded that the bond failure developed partially along the surface of the bar and in surrounding concrete by peeling off the external fibers of the bars.

Akhil raj .R, et.al (2017) discussed on using GFRP composite bars in RC flexural member. The test was prepared by arranging a beam of 200mm x 200mm with 700mm length set up on the single point loading applied at the mid span of the beam. To increase the bond between the concrete and the bars, sand coating was applied on the bars. The authors concluded that the ultimate load carrying capacity of the beam is the ultimate failure load of GFRP beam, resulted more than that of the steel reinforced concrete.

Suresh Barmavath, Kiran M V, CH Narendra Naik, G Sai Kumar, E Hari Naik, V Amulya, V Divya (2017) tested the flexural strength of the concrete by replacing Bamboo in RCC beam. The authors firstly designed M40 concrete grade and prepared the cube specimens of 15cm X 15cm X 15cm and tested their compressive strength in 3 days, 7days, 21 days and 28 days. Then they designed the beams of dimensions 250mm X 250mm X 700mm under single bamboo reinforced concrete, doubly bamboo reinforced concrete and steel reinforced concrete of singly and doubly reinforced for comparison. Then flexural test on the beams were done and concluded that the use of the materials i.e. bamboo in doubly reinforced concrete is better than singly bamboo reinforced concrete. They also mentioned that wet bamboo used as reinforcement has low strength and dry bamboo exhibit higher strength compared to it.

Shahad Abdul, Adheem Jabbar and Saad B.H. Farid (2018) [6] explained that the GFRP rebars in tensile loads direction of the beam displays flexural properties similar to the steel rebars and GFRP reinforced concrete offers high bending properties beside acceptable shear properties. The test was performed on blank concrete, steel reinforced concrete and GFRP reinforced concrete finished with sand coated surface and resulted that the GFRP reinforcing bar concrete have higher tensile strength and corrosive resistance. They also resulted in good bending strength and flexural strength in all curing ages. The sand coated surface of GFRP rebars concluded to be better than the smooth surface as they avoid slipping in stress conditions.

Amala James, et.al (2019) [7] discussed the corrosion detection and the restoration of the RC structures in coastal environments. The author explained that the test for corrosion is mainly to detemine the cause of it and the determination of the area infected. Here the test is done by visual inspection which identifys the initial signs of weakening and photographic survey which shows the vertical and horizontal structural elements.

Fang Yuan and Yu-FeiWu (2019) [8] explained the analytical method for derivation of stress block parameters for flexural design of FRP reinforced concrete members. In this paper the theoretical results were calculated and compared to practical test results. The researchers invesigated the flexural design by applying recently developed RC flexural theorem i.e. flexural strength (peak movement) can be calculated for under-reinforced member and second theorem for all RC members including over-reinforced member and the last theorem of true-ultimate curvature at which the concrete loses its compressive strength and risks instability. The researchers did the flexural test on the stress blocks and compared their results to those recommended by ACI 440.IR-15 and CSA-5806-12 standards. The paper concluded that stress block parameters are significantly affected by the concrete grade. They also concluded that the new model of the equivalent stress block parameters is developed based on the flexural theorems and can be use conveniently for practical designs.

2.3 Objectives of the current paper

1. To check the feasibility of using the glass fiber reinforced polymer (GFRP) rebars as reinforcement in concrete structures.
2. To check whether GFRP can act as a replacement of steel in concrete structures using flexural strength test.

2.4 Scope of the work

As world is becoming more advanced and the steel reinforcement rebars in concrete structures are being replaced by the fiber reinforced polymer (FRP) rebars due to its various advantages. Among FRP rebars glass fiber reinforced polymer (GFRP) rebars available in the market is increasing compared to carbon fiber reinforced polymer (CFRP) and basalt fiber reinforced polymer (BFRP) rebars due to its late establishment in the market, not very much of the product is available. Hence, the study of using GFRP rebars as an alternative reinforcement in concrete structures in corrosive environment is a must work to do from the aspect of field of engineers.

In this work with reference to the design codes, we will be casting beams using GFRP rebars instead of steel rebars as reinforcement. Then we will be setting up the beam to the three-point flexural bending test and provide the required load on the beam. Hence, we will be sketching the cracks occurring and note the deflection. We will then plot the graph of load-deflection curve and determine the flexural behavior of the beam according to which the judgment of using it (GFRP rebars) will be identified.

CHAPTER 3
METHODOLOGY

3.1 General

The following chapter contracts with the mechanism followed for the construction of beams. It also displays the method and experimental test performed on the beam with the GFRP reinforcement and steel reinforced concrete beams to identify its behavior in flexural. It displays the experimental test performed on the singly reinforced concrete beams without the application of the shear links.

As per the Indian standard codes' recommendation, concrete mix used for the prepared beams was of M30 grade (f_{ck}=30MPa) as shown in Table 1.

To improve the bond strength between the concrete and GFRP rebars, sand was coated over GFRP rebars with the help of resins i.e. 1 part of resin in 2 parts of sand.

3.2 Mix preparations

Three different types of total nine concrete beams of dimensions 50cm x 10cm x 10cm samples were prepared which included a) three samples of steel reinforced plain concrete beams(S- type), b) three samples of glass fiber reinforced polymer reinforced concrete beams(G-type II) and c) three sample of sand coated glass fiber reinforced polymer concrete beams (SG-type III).

All the samples were subjected to third point loading flexure test as per the procedure mentioned in codes after 28 days of curing period, individually on the ultimate testing machine at a constant rate of strain. The load-displacement readings were noted at a regular intervals and load-displacement curves were plotted.

The following mathematical expression was used for the calculations of the modulus of rupture for the samples tested.

$$f_b = \frac{3 * P * a}{b * d^2}$$

Where:

f_b= modulus of rupture, MPa;

p= maximum load, N;

b= width of beam, mm;

d= depth of beam, mm;

a= distance between line of fracture and nearest support, mm.

Table 3.1: Concrete mix design for singly reinforced beams

Concrete grade –M30 (all quantities for 1m3 volume of concrete)					
Requirements	Cement	Water	FA	CA	w/c ratio
Content	350	140	890	1110	0.40
Unit	Kg/m^3	Kg/m^3	Kg/m^3	Kg/m^3	-
Design mix	1: 2.54: 3.17				

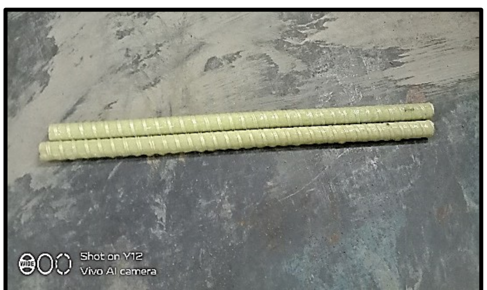
Table 3.2: Details of singly reinforced concrete beams

Specimen	Reinforcement dimension,		Clear cover cm	No. of stirrups
	Length, cm	Diameter, mm		
S-1	46	12	2.0	-
S-2	46	12	2.0	-
S-3	46	12	2.0	-
G-1	46	12	2.0	-
G-2	46	12	2.0	-
G-3	46	12	2.0	-
SG-1	46	12	2.0	-
SG-2	46	12	2.0	-

SG-3	46	12	2.0	-

The following displays the sample preparations of three types of specimens:

Fig 3.1: Preparation of steel reinforced beam specimen (type I)



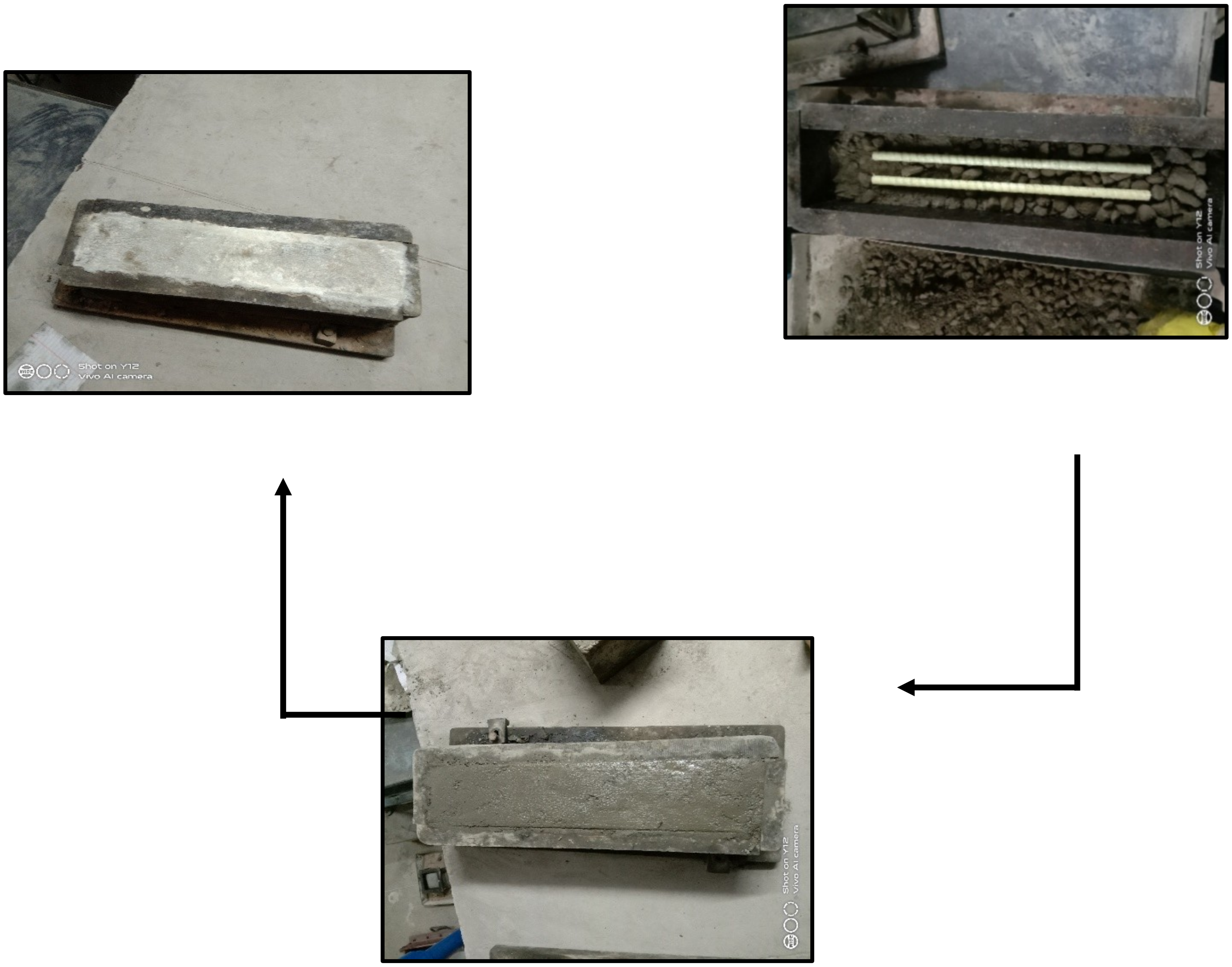


Fig 3.2: Preparation of GFRP reinforced beam specimen (type II)

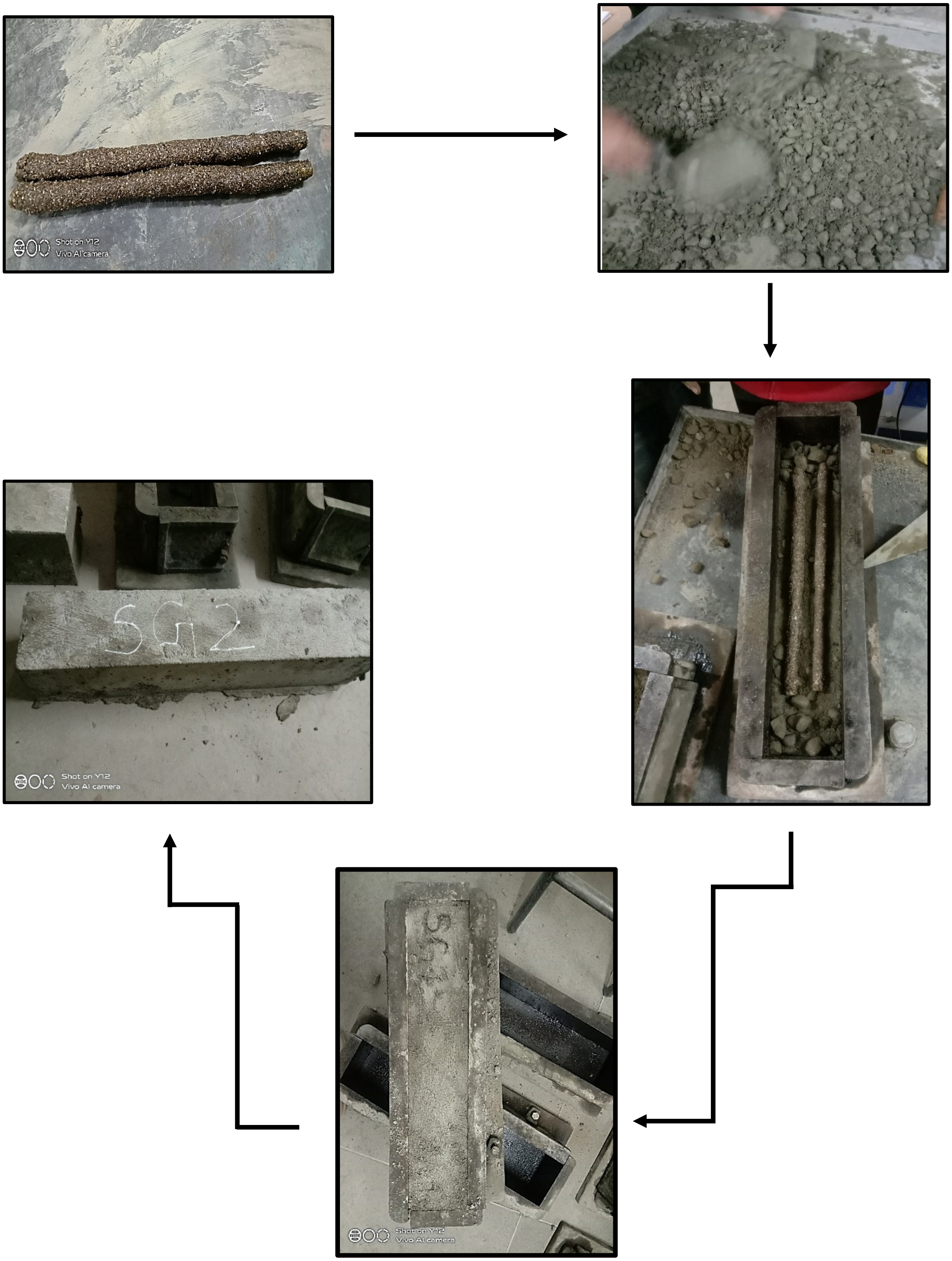


Fig 3.3: Preparation of sand-coated GFRP reinforced beam specimen (type III)

CHAPTER 4

RESULTS AND DISCUSSION

4.1 General

The following chapter displays the results and its interpretations obtained with the help of tables and graphs plotted. The chapter also display the **compressive strength**, **tensile strength** and the **modulus of rupture** of the samples kept in curing for 28 days.

4.2 Compressive strength and Tensile strength of reinforcements:

The given Table 3 shows the ultimate tensile strength of the steel rebars, GFRP rebars and sand-coated GFRP rebars. The compressive strength of each sample after 28 days curing is also shown.

Table 4.1: Compressive and tensile strength of the samples after 28days

Sample	Compressive strength (MPa)	Tensile strength (MPa)	% of tensile strength (MPa)
S-1 (standard sample)	29.25	585	-
G-1	29.65	593	1.36
SG-1	29.85	597	2.05

The chart plotted below also shows the comparison of the three samples for compressive strength and tensile strength.

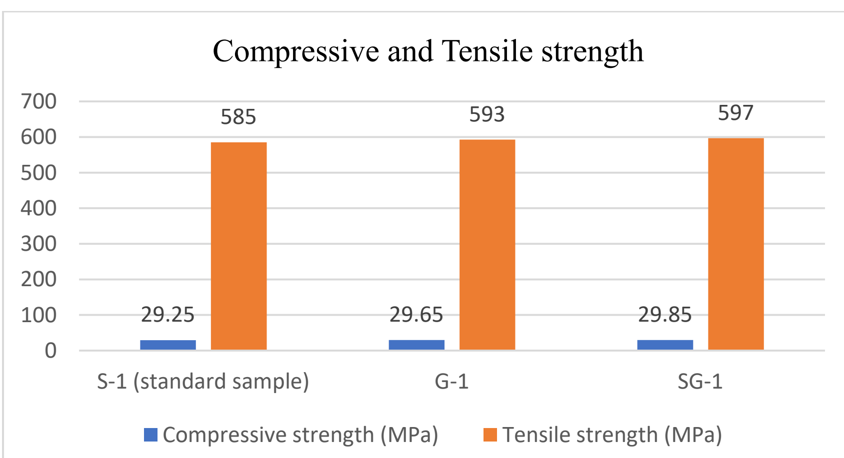


Fig 4.1 : Compressive and Tensile Strength

From the given chart result, the compressive strength of the three samples that is steel rebar, GFRP rebar and sand-coated GFRP for mix design of M30 grade is obtained as 29.25MPa, 29.65MPa and 29.85MPa respectively.

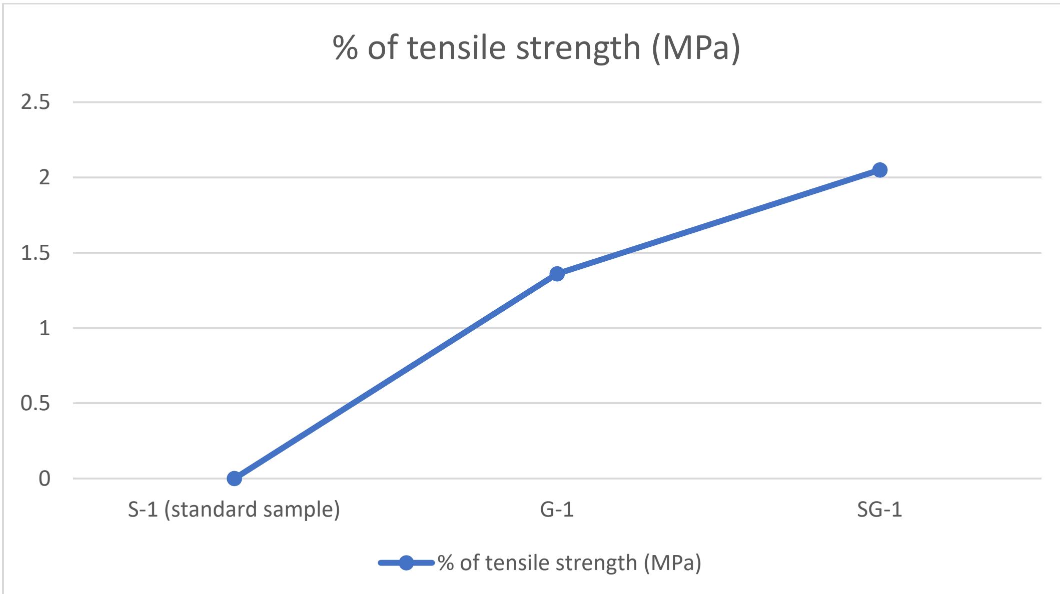


Fig 4.2: Percentage of Tensile Strength

From the given chart result the highest tensile strength of the sample is about 2.05% observed in sand-coated GFRP rebar with respect to the standard sample that is steel reinforcement. The GFRP rebar is about 1.36% respectively. The tensile strength of the sand-coated GFRP reinforcement is found high because of the improved bonding between the rebar and concrete. The bonding was increased by using a coarser sand coated on the rebar with the help of resin and hardener.

4.3 Third-point loading Flexural test on cement concrete beams of singly reinforced with various types of rebars:

As said flexural strength is also termed as Modulus of rupture or bend strength, is a maximum bending stress applied to a material before it yields. The flexural test is done by three-point loading in which two points loads are placed at third points along the span of the beam.

The following table shows the load at failure, deflection of mid-section and flexural strength values of the specimen tested.

Table 4.2: Testing of the specimen

Specimen	Curing period	Load at failure, KN	Displacement of mid-section at failure, mm
Steel reinforced beam	28 days	15.70	2.30
GFRP reinforced beam	28 days	52.30	0.095
Sand-coated GFRP reinforced beam	28 days	75.85	0.057

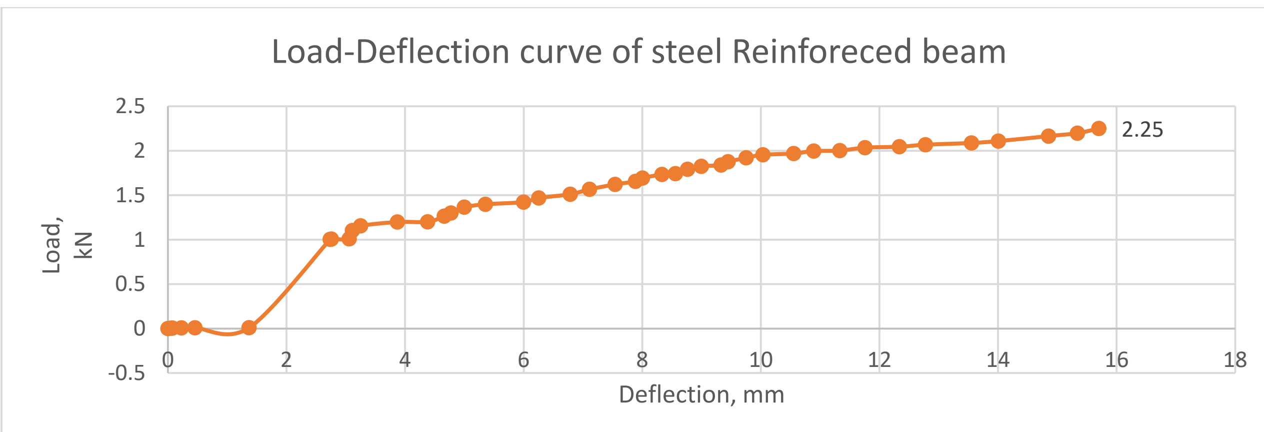


Fig 4.3: Load-Deflection curve of Steel Reinforced Beam

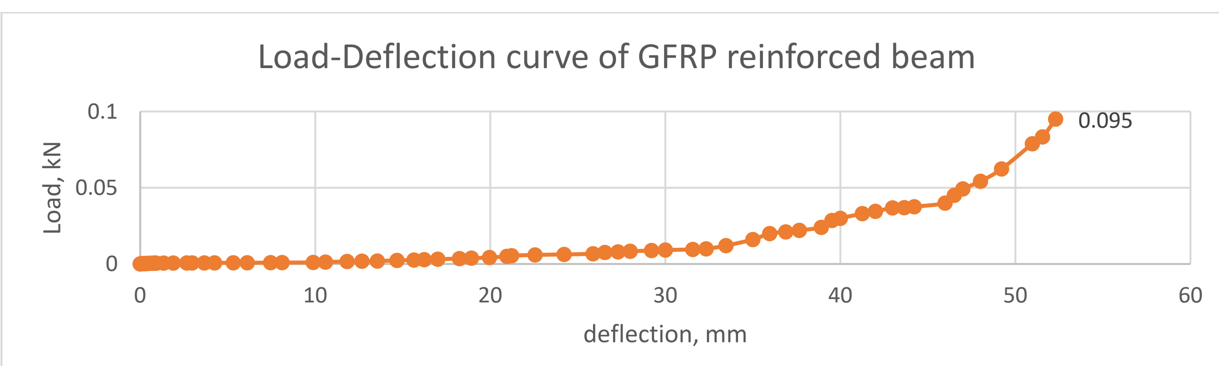


Fig 4.4: Load-Deflection curve of GFRP Reinforced Beam

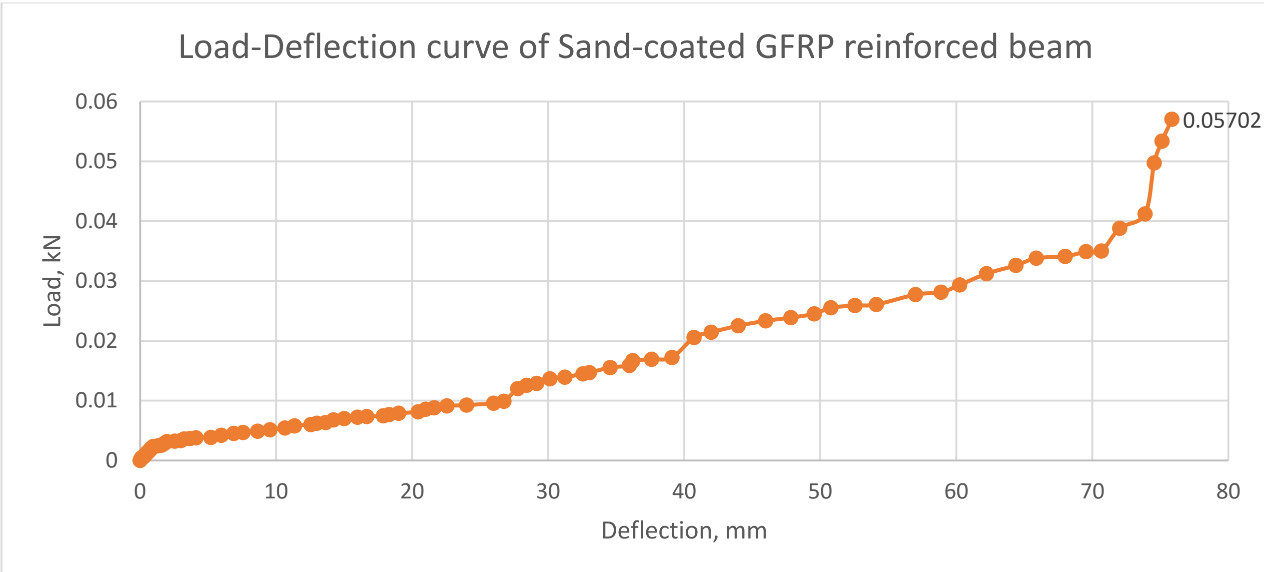


Fig 4.5: Load-Deflection curve of Sand-coated GFRP Reinforced Beam

From the curve shown above, we can conclude that the variation is followed by a straight-line until the first crack. In load-deflection curve of the steel reinforced beam there is an exhibition of local breakage in the profile after the disruption of the linearity. In GFRP reinforced beam and sand-coated reinforced beam, the curve explains the ductile behavior of the rebars. Therefore, by this property of GFRP reinforced beam it can provide ample of time to be alerted for the failures to take place. Therefore, GFRP is suitable to be used as an alternative for the steel reinforcement beam.

Table 4.3: Specification of the Specimens

Specimen	Flexural strength, MPa	Strain	Modulus of elasticity, MPa
Standard specimen, S-1	17.5	9	15000
G-1	12.8	16	500
SG-1	15.3	10.5	1000

The above graph shows the flexural strength of the specimens tested. The flexural strength of the standard specimen that is steel reinforced beam has a flexural strength value of 17.5MPa. whereas the decrease in flexural strength of GFRP reinforced concrete flexural strength is about 26.85% and sand-coated RC flexural strength is about 12.57% less than the standard steel RC.

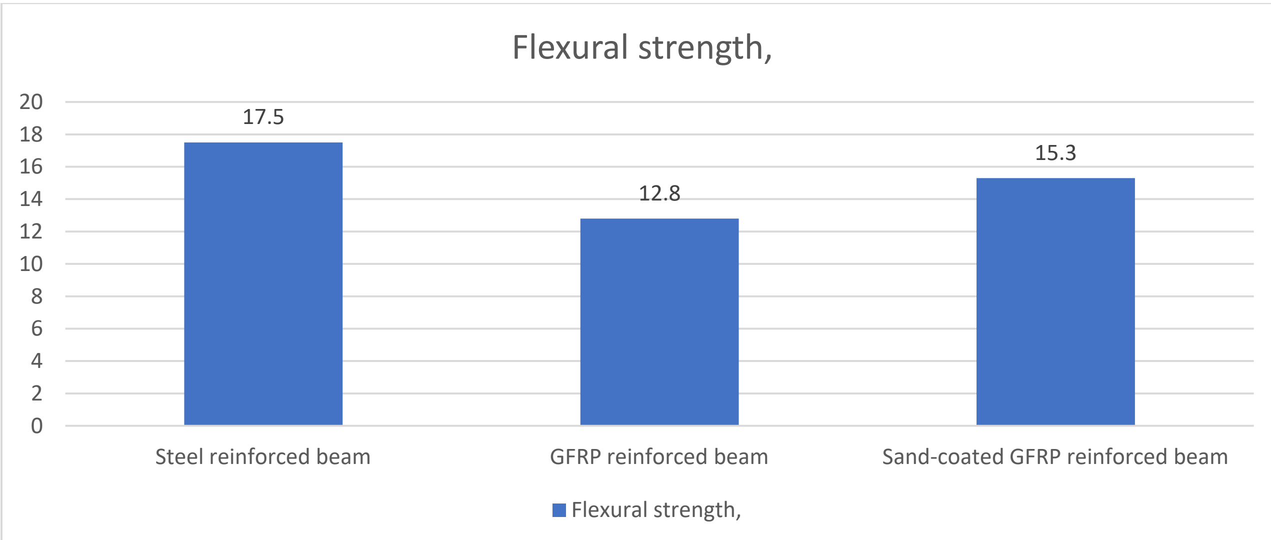


Fig 4.6: Flexural Strength, MPa

It can also be concluded that the flexural strength of sand-coated GFRP reinforced concrete are closer to steel reinforced concrete beam because it has higher strain as compared to the steel RC at the expense of the flexural modulus. The strength of the GFRP reinforced concrete is lower than sand-coated GFRP RC, as a result of lower flexural modulus. The strength in sand coated GFRP RC is also increased which is caused by the sand grains and in fact increases the brittleness of the GFRP rebars.

CHAPTER 5

CONCLUSION

As this paper presents the results on the flexural strength experiment of the three reinforced concrete specimens done by three-point flexural loading test, the following chapter discuss on the conclusion drawn.

The following points are the conclusion concluded from the paper:

1. The compressive strength of the three specimens after 28days of curing are 29.25MPa, 29.65MPa and 29.85MPa of steel reinforced concrete, GFRP reinforced concrete and sand-coated GFRP reinforced concrete respectively. Hence the required compressive strength of M30 grade concrete is obtained for the experiment.
2. The tensile strength of GFRP reinforced concrete and sand-coated GFRP reinforced concrete are found to be 593MPa and 597MPa respectively due to its composite nature, thereby they are stronger in tension and can provided premature warning of the failure which can alert the engineers.
3. The highest tensile strength is observed in sand-coated GFRP reinforced concrete and then in GFRP reinforced concrete of 2.05% and 1.36% respectively with respect to steel reinforced concrete beams.
4. The failure of GFRP reinforced are seen higher than the steel reinforced hence they can provide ample of time to alert for the failures to take place.
5. The flexural strength value of sand-coated GFRP reinforced concrete and GFRP reinforced concrete are closer to the steel reinforced concrete beams hence, it can be suitable to use as an alternative for the steel reinforcement construction.

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