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STUDY ON THE STRENGTH OF CONCRETE CYLINDERS WRAPPED WITH MULTIPLE LAYERS OF GFRP SHEET

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ABSTRACT:- As we know that, the concrete is composite material and it has relatively high compressive strength, but significantly low tensile strength. The use of externally bonded fiber-reinforced polymers (FRP) has become increasingly popular for civil infrastructure applications. The Glass fiber reinforced polymer (GFRP) has significantly enhanced the strength and ductility of concrete by forming perfect adhesive bond between concrete and the wrapping material.
The present investigation studies the behavior of the concrete wrapped with bidirectional GFRP sheet under uniaxial compression. Specimens considered for the work was cylinders having circular in shape of diameter 150mm and height 300mm. Experiments were conducted on concrete cylinders with and without FRP wrapping. Three specimens were tested with conventional concrete and 1 layer, 2 layers and 3 layers of 100mm center wrapping. The specimens were tested for compressive strength and split-tensile strength.
In addition, a stress–strain model is presented to predict the axial compressive behavior of GFRP Wrapped and unwrapped concrete cylinders. Comparisons between the analytical results obtained using the proposed model and experimental results are also presented.

Key words: GFRP, Epoxy Resin, Wrapping, Compression strength, Split-tensile strength, stress-strain

1. INTRODUCTION

Fiber reinforced concrete has several advantages over traditional materials used to build, such as light weight, rigidity, and high corrosion resistance. It creates the impact of minimal architecture because of low fiber thickness and ease of repair. However, it is expensive and has a linear stress-strain relationship leading to brittle fracture behavior. Currently, the main application in structural engineering is packing.
Steel reinforcements in the concrete have advantages and disadvantages such as corrosion, heavy weight and handling difficulties. In contrast, the glass fiber reinforced polymer and carbon (FRP) reinforcement sheets have more advantages, including a high strength to weight ratio, light weight, corrosion resistance, low conductivity, an electrical resistance high, and the mechanical properties of electromagnetic transparency at low temperatures. These are different from conventional reinforcing concrete, where in the steel bars are placed separately, and the concrete is cast around it, in the case of a polymer sheet reinforced concrete strengthened with fibers. Traditional rebar or reinforcing may or may not be there in the concrete structure, according to the particular application. This fiber polymer sheet the strengthening of concrete structures offer potential life increasingly, economic and environmental benefits. FRP sheets have different mechanical properties of steel bars, including brittle elastic stress-strain.
Fiberglass reinforced polymers are composed of extremely fine glass fibers. It turned out to be the solution, a major development in the technology of reinforced concrete. It has gross mechanical properties compared to the carbon fibers. However, it is stronger and more rigid or carbon fiber; it is much cheaper cost and materially less fragile. Therefore, these glass fibers are used as reinforcing agent for various polymeric products to build a very strong and adequately light material polymer composite reinforced with glass fibers known as glass fiber reinforced polymers (GFRP) along generally called “fiberglass".

1.1. Objectives

- To experimentally investigate the Compression and Split-tensile strength of concrete cylinder samples wrapped with several layers of GFRP sheet configurations.
- To compare the strengths of conventional concrete with wrapped concrete cylinder
- Develop stress-strain curve for conventional and wrapped concrete cylinders.

2. LITRERATURE

Muhammad and Shamim et al. (2005) assessed the efficacy of fiberglass reinforced polymer (GFRP) jacket in the reinforcement and repair deficient square damaged concrete columns. It concluded square concrete columns outside modernized by GFRP jackets and tested under axial compression and cyclic loading, simulating seismic loads, showed pronounced columns are unretrofitted.

Kumutha et al. (2007) conducted an experiment to measure the effectiveness of external FRP reinforcement for concrete columns of rectangular shape to calculate the effects of the number of FRP layers of glass on the ductility and tensile strength of the concrete confined or shrouded. . Better confinement was achieved when the number of frp layers GFRP was increased, resulting in improved compression load bearing strength of the column, beyond the development of ductility.

Nagaradjane et al. (2007) conducted an experiment on the cylinder smooth concrete 150mm diameter was cast with the concrete M30 grade of five samples were reinforced or wrapped in fiberglass reinforced polymer i.e. sheet, GFRP and has been observed that the resistance is increased due to Fiber wraps glass applications ranged from 39.49% to 56.20%.

Jyothi Kumari G. et al. (2013) studied the behavior of reinforced concrete beams with reinforced polymer flats of glass fibers and have also found that beams with coated glass fiber reinforced polymer silica (GFRP) apartments showed heavy loads failure. Finally, it is noticed that the concrete beams with GFRP coating flats silica failure showed shear reinforcement for heavy loads that failure to design loads.

2. MATERIAL PROPERTIES

2.1. Concrete

Ordinary Portland cement 53 Grade was used in this experiment. Casting of all cylinder specimens are conducted by using M20 grade concrete mix. The mix proportion for concrete is shown in Table 1.

Table-1: Mix proportion of M_{20} Grade concrete

Ingredients	Quantity
Cement	372 Kg/m^3
Water	186 Kg/m^3
Coarse aggregate	1197.61 Kg/m^3
Fine aggregate	585.34 Kg/m^3

2.2. GFRP Sheet

Materials used for strengthening of concrete are GFRP (Glass fiber reinforced concrete), Epoxy resin, Hardener as shown in figure 1. GFRP sheet was taken from Avigit Aerospace, Bangalore. The properties of these materials are given by the suppliers shown in table 1 and 2.

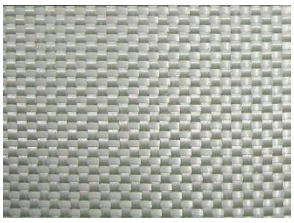
(a)  (b) 

Fig-1: (a) GFRP Sheet (Bidirectional), (b) Epoxy Resin

Table-1: Properties of GFRP

Parameter	Tensile Strength (Mpa)	Compression Strength (Mpa)	Density (g/cm3)	Thermal expansion (µm/m℃)	Softening T (℃)
E-Glass	3445	1080	2.58	5.4	846

Table-2: Properties of Epoxy

Property	Specification	Unit	Araldite LY 556	Aradur HY 951
Viscosity at 25℃	ISO 12058	mPa.s	10,000-12,000	10-20
Density at 25℃	ISO 1675	gm/cc	1.15-1.20	0.97-0.99
Flash point	ISO 2729	℃	>200	>180

2.3 Processing of Epoxy and Hardener

Araldite LY 556 is medium viscosity, a liquid epoxy resin unmodified based on bisphenol-A. Aradur HY 951 is a low viscosity, an unmodified polyamine, aliphatic. Araldite with Aradur provides a low viscosity, room temperature curing solvent-free lamination system. By varying the content of Aradur hardener From 10 to 12 parts, the reactivity of the system can be adapted to the processing conditions and curing. The processing ratio is given in table 3.

Table-3: Mixing Ratio of Epoxy and Hardener

Mixing Ratio	Parts by Weight
Araldite LY 556	100
Aradur HY 951	10-12

3. METHODOLOGY

In this investigation, the material used E-glass FRP sheet is attempted to strengthen the concrete. Many researchers have been carried out so far on E-GLASS FRP sheets. The results were obtained 100% when comparing FRP sheets to the normal concrete. The maintenance also very less need for FRP sheet compared to other types of construction works.

3.1. Casting of concrete cylinder specimens

The ingredients were mixed by hand. Molds cast iron 150 mm diameter 300 mm height of cylinder samples were used. Once the concrete has been poured into molds, they were compacted thoroughly by placing on table vibrator. Moldings were performed 24 hours after casting and the samples were stored for curing in the curing tank.

3.2. GFRP Wrapping

Concrete surface required to be cleaned with a wire brush to remove any loose dust particles. Both parts of the epoxy system used, consisting of a resin and a hardener, were thoroughly mixed by hand for at least 5 minutes before use. FRP sheets were then applied directly onto the surface of the samples providing a bidirectional lateral confinement in the circumferential direction. In this study the cylinders are wrapped center of 150mm height. The number of sheets per cylinder ranges from 1 to 3 as shown in figure 2.

(a)  (b) 

Fig-2: (a) Application of GFRP (b) After GFRP wrapping

3.3. Test Procedure

3.3.1 Compression test

When the test cylinders are cured and dried surface then it is placed vertically on the bottom plate of the compression testing machine (CTM) as shown in figure 3. The cylinder specimens are compressed and deformations at various loads were recorded. The compressive strength is calculated using the following expression.

Compressive strength: (ultimate load / contact area of cylinder) = $\frac{P}{\frac{\pi d^2}{4}}$

3.3.2 Split-Tensile test

The static compressive test or split-tensile test setup is given in figure 3. The test specimens were placed horizontally between the steel bearing plates. The split tensile strength and deformations at different loads were noted during split-tensile test. The Split-Tensile strength is calculated using the following expression.

Split-tensile strength: $\frac{2P}{\pi dl}$ Where, D = 150cm; L = 300cm;

(a)  (b) 

(c) 

Fig-3: (a) Compression strength test (b) Split-Tensile Test (c) Tested samples

4. TEST RESULTS AND DISCUSSIONS

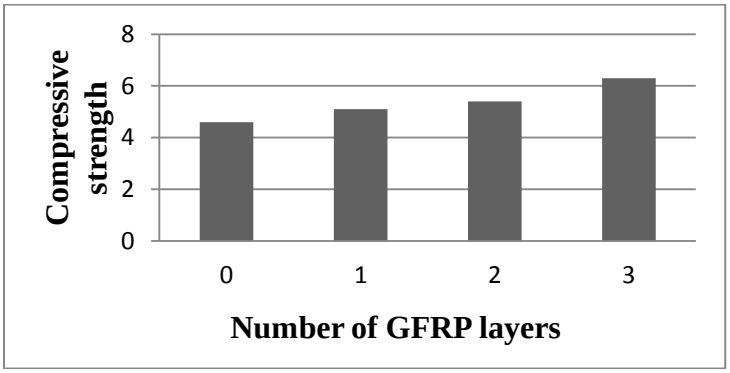
4.1. Compression test results

Compressive strength test indicates that the resistance of the aggregate samples with wrapping and unwrapping. Three cylinders were tested at a time. The results are presented in the table 4.

Table-4: Compression strength of specimens with and without GFRP wrapping

S.No.	Number of GFRP layers	Average compressive strength (Mpa)
1	0	26.5
2	1	28.2
3	2	29.5
4	3	30.15

The Compressive strength of every Specimen is shown in GRAPH 1. Maximum load was carried by specimen strengthened with three layers of GFRP center wrapping is 236.8KN. Compression strength is about 30.15 N/mm2. There is considerable increase in strength of concrete with 1 layer, 2 layers, and 3 layers of GFRP wrapping increased by6.41%, 11.32% and 13.7% compared with the conventional concrete strength.



Graph-1: Compressive strength of Concrete specimens

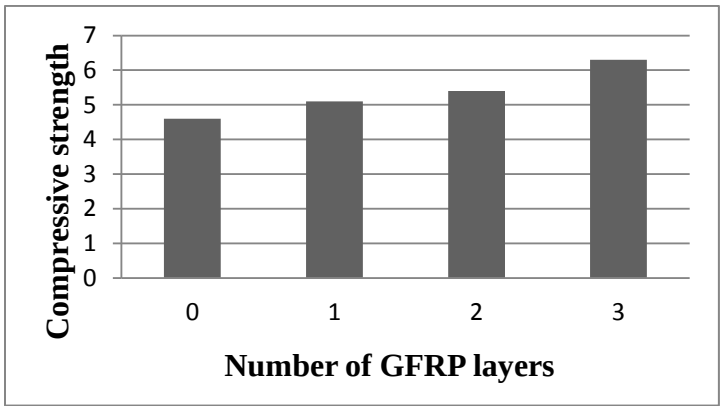
4.2. Split-Tensile test results

The indirect tensile strength indicates a downtrend of tensile strength when the aggregate percentage is increased. Tensile forces develop the cracks between concrete .Following Table 5 shows the average split-tensile strength of concrete noted during the test.

Table-5: Split-tensile strength of specimens with and without GFRP wrapping

S.No.	Number of GFRP layers	Average compressive strength (Mpa)
1	0	4.6
2	1	5.1
3	2	5.4
4	3	6.3

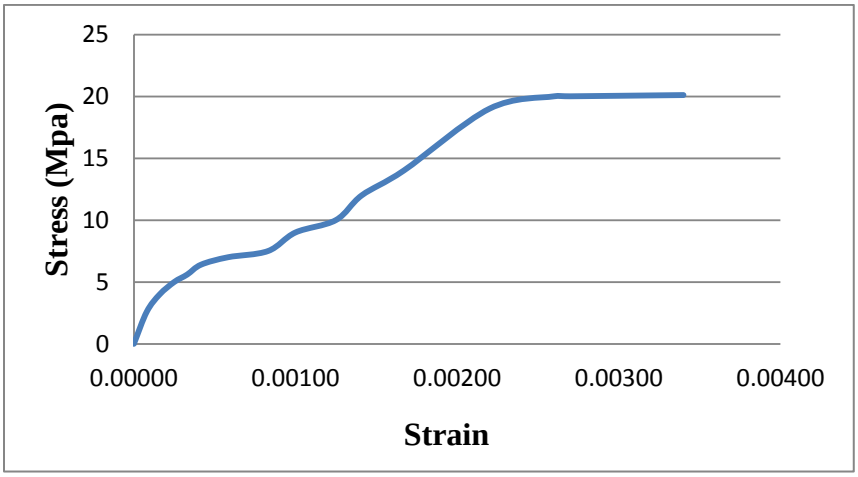
The Split-tensile strength of every Specimen is shown in GRAPH 2. From the chart the Maximum load was carried by specimen strengthened with three layers of GFRP center wrapping is 199.3KN. The maximum tensile strength is 6.3 N/mm2. There is considerable increase in strength of concrete with 1 layer, 2 layers, and 3 layers of GFRP wrapping increased by10.8%, 17.4% and 36.9%in comparison with conventional concrete strength.



Graph-2: Split-Tensile strength of specimens

4.3. Stress-Strain

4.3.1. Stress-strain for conventional concrete

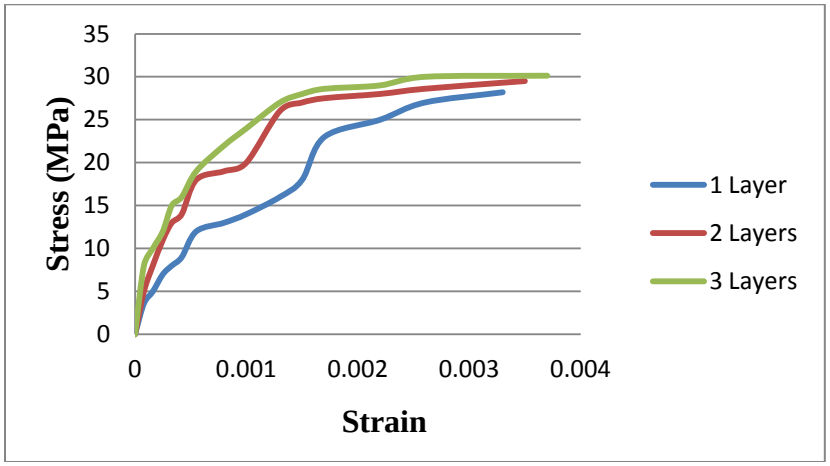


Graph-3: Stress-strain curve for conventional concrete

The stress-strain curves for the plain specimens are presented in Graph 3. This figure shows that the unwrapped concrete average strength is 26.5Mpa and corresponding strain of 0.0034 was calculated.

4.3.2. Stress-strain for concrete wrapped with GFRP sheet

4.3.3.



Graph-4: Stress-strain curve for concrete with GFRP wrapping

The axial stress-strain curves for the plain specimens are presented in Graph 4. This figure shows that the GFRP wrapped concrete strength varies between 28.2 and 30.15Mpa for 1, 2 and 3 layers and the corresponding strain of the wrapped concrete varies between 0.0033 and 0.0045.

5. CONCLUSION

This work is based on the testing results on the behavior of concrete cylinders with GFRP and CFRP wrapping sheets, the below conclusions are drawn:

- The maximum compression strength of concrete is obtained for 3 layers when compared to 1, 2, 0 layers of Wrapping with GFRP. This is about 30.15 Mpa. The cylinder specimens wrapped with 1 layer, 2 layers and 3 layers of GFRP shows 6.41%, 11.32% and 13.7% increase in Compression compared to the concrete specimens without wrapping.
- The maximum Split-tensile strength of concrete is obtained for 3 layers compared to 1, 2, 0 layers of Wrapping with GFRP. This is about 6.3 Mpa. The cylinder specimens wrapped with 1, 2 and 3 layers of GFRP shows 10.8%, 17.4% and 36.9% increase in Compression compared to the concrete specimen without wrapping.
- The unwrapped concrete average strength is 26.5Mpa and corresponding strain is 0.0034. The GFRP wrapped concrete strength varies between 28.2 and 30.15 Mpa for 1, 2 and 3 layers and the corresponding strain of the wrapped concrete varies between 0.0033 and 0.0045.

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