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Evaluation of Strength Characteristics of Concrete by Glass Fibre Reinforced Polymer (GFRP) And Carbon Fibre Reinforced Polymer (CFRP) Wrapping

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Abstract: ***The construction material mainly reinforced concrete is being used extensively for various type of construction projects. However, deterioration of RC structures is recognized as a major problem worldwide. Extension of the structures' life is an inevitable need for a healthy planet. Any deficiency caused to the members of the structure may affect the life of structure. Therefore, it is important that the members should provide adequate strength (for which it is designed) throughout its operational life. But, it has been observed that due to alteration in purpose of use of structure (very common in mega cities), improper design and deficiency caused due to earthquake, blast and impacts in structural members and as a result in the members structure can possibly be subjected to loads which have higher magnitude compared to its design loads. This study is based on experimental investigation to assess the behavior of CFRP & GFRP wrapped concrete under compressive loads. For this purpose, M_{30} grade concrete specimens have been casted and wrapped it with Glass and Carbon FRP and its strength against compressive loads have been found.***

Keywords: "Fibre-reinforced polymer(FRP)", "Carbon fibre reinforced polymer(CFRP)", "Glass fibre reinforced polymer(GFRP)","Rehabilitation", "Strengthening", "Epoxy Resin", "wrapped".

I. INTRODUCTION

Rehabilitation means something very similar to renovation, but it is often used in a slightly different context. Rehabilitation is the process which seeks to preserve the historical portions or features of a building while making the building compatible with a new use. Upgrading of certain building systems (existing structures) to make them more resistant to seismic activity (earthquake resistance) is really of more importance. Retrofitting proves to be a better economic consideration and immediate shelter to problems rather than replacement of building.

A. FRP (Fiber Reinforced Polymer)

A brief history of FRP Early man was aware of the basic principle that a composite material is greater than the sum of its parts. For example clay and straw were found to be stronger than clay alone; straw being the fibrous reinforcement and clay being the matrix. The first use of glass fibre reinforced polyester composites was in the aircraft industry during the 1940s. This was followed some years later by the first non-military application in the marine sector, where FRP proved a complete innovation – revolutionising the way boats were built. FRP (fiber reinforced polymer) is a composite material made of a polymer matrix reinforced with fibers. The fibers are: -

1) *Carbon Fibres:* Carbon fibres (alternatively CF or graphite fibre) are fibres about 5 to 10 micrometres (0.00020–0.00039 in) in diameter and composed mostly of carbon atoms. Carbon fibres have several advantages including high stiffness, high tensile strength, low weight, high chemical resistance, high temperature tolerance and low thermal expansion. These properties have made carbon fibre very popular in aerospace, civil engineering, military, and motorsports, along with other competition sports. However, they are relatively expensive when compared with similar fibres, such as glass fibres or plastic fibres.
2) *Glass Fibers:* Glass fibres is a material consisting of numerous extremely fine fibres of glass. Glassmakers throughout history have experimented with glass fibres, but mass manufacture of glass fibre was only made possible with the invention of finer machine tooling. In 1893, Edward Drummond Libbey exhibited a dress at the World's Columbian Exposition incorporating glass fibres with the diameter and texture of silk fibres.

3) *Aramid Fibres:* Aramid fibres are a class of heat-resistant and strong synthetic fibres. They are used in aerospace and military applications, for ballistic-rated body armour fabric and ballistic composites, in marine cordage, marine hull reinforcement, and as an asbestos substitute.
4) *Basalt:* Basalt is a common extrusive igneous or volcanic rock formed from the rapid cooling of basaltic lava exposed at or very near the surface. ϖ It is also known as a dark volcanic rock. The term basalt is at times applied to shallow intrusive rocks with a composition typical of basalt, but rocks of this composition with a coarse groundmass and are generally referred to as gabbro.

The polymers are: -

a) *Epoxy:* A thermosetting resin; used chiefly in strong adhesives and coatings and laminates. epoxy glue, epoxy resin. Adhesive, adhesive agent, adhesive material - a substance that unites or bonds surfaces together.
b) *Vinyl Ester:* A vinyl ester resin is a thermoset matrix resin that is considered a hybrid of epoxy and polyester. It is a molecular chain that consists of a few ester groups double-bonded to vinyl groups, different from polyester in terms of the location of the reactive sites.
c) *Polyester:* A polyester is a category of polymers that contain the ester functional group in every repeat unit of their main chain. As a specific material, it most commonly refers to a type called polyethylene terephthalate (PET).
d) *Thermosetting Plastics:* A thermosetting plastic is a polymer that irreversibly becomes rigid when heated. Such a material is also known as a thermoset or thermosetting polymer. Initially, the polymer is a liquid or soft solid. Heat provides energy for chemical reactions that increase the cross-linking between polymer chains, curing the plastic.

B. FRP Provides an Unrivalled Combination of Properties

1) Light weight
2) High strength-to-weight ratio (kilo-for-kilo it's stronger than steel)
3) Design freedom
4) High levels of stiffness
5) Chemical resistance
6) Good electrical insulating properties
7) Retention of dimensional stability across a wide range of temperatures.

II. BASIC MATERIAL TEST

1) *Cement:* The test on cement is done for specific gravity, initial setting time and final setting time. The results that we obtained are given in table below.

Table 1: Tests on Cement.

Grade	OPC 43
Specific Gravity	3.15
Initial Setting Time	22 mins
Final Setting Time	250mins

2) *Fine Aggregate:* The test on fine aggregates are done for specific gravity, water absorption and fineness modulus. The results that we obtained are given in table below.

Table 2: Tests on Fine Aggregate

Type	River sand(zone II)
Specific gravity	2.64
Water absorption	1%
Fineness Modulus	2.46

3) Coarse Aggregate: The test on coarse aggregates are done for specific gravity, water absorption and impact value. The results that we obtained are given in table below.

Table 3: Tests on Coarse Aggregate

Type	Passing 20mm and retained on 4.75mm
Specific gravity	2.7
Water absorption	0.5%
Impact value	16.92%

A. Properties of CFRP & GFRP

The properties of CFRP & GFRP are determined for 1.2 mm thick GFRP and 1 mm thick CFRP. The properties are given in the table below.

Table 4: Properties of CFRP and GFRP

Characteristics	GFRP	CFRP
Nominal thickness (mm)	1.2	1
Effective cross-sectional area,mm^2	2.30	1.65
Tensile strength (Mpa)	300 - 4800	2400 - 5100
Modulus of elasticity (MPa)	65000	230000
Maximum elongation (%)	2.60 – 3.03	1.85 - 1.9
Young's Modulus (Gpa)	390 - 760	70 - 90
Strain failure (%)	3.5 – 5.5	0.5 – 1.73
Density, gm/cm^2	2.5 – 2.6	1.85 – 1.9

B. Test on Hardened Concrete

The test on hardened concrete is done for compressive strength for cubes (150*150*150mm),split tensile strength for cylinders of diameter(D) 150mm and flexural strength for beams of (150*150*1000mm). The values for the time period of 7 days, 14 days and 28 days from the time of casting are shown in tables below.

Table 5: Compression Test Results

Types of specimen	M30	M30	M30
	7 days	14 day	28 days
Unwrapped specimens	17.62	23.82	28.25
Wrapped with GFRP mat(single rotation)	31.45	37.92	42.85
Wrapped with GFRP mat(double rotation)	37.03	43.77	48.92
Wrapped with CFRP mat (single rotation)	36.21	43.01	46.30
Wrapped with CFRP mat (double rotation)	42.04	49.42	52.50

Table 6: Split Tensile Test Results

Types of specimen	M30	M30	M30
	7 days	14 day	28 days
Unwrapped specimens	2.41	2.81	3.05
Wrapped with GFRP mat(single rotation)	3.2	3.94	4.25
Wrapped with GFRP mat(double rotation)	3.9	4.68	5.05
Wrapped with CFRP mat (single rotation)	4.09	4.84	5.15
Wrapped with CFRP mat (double rotation)	4.93	5.55	5.95

Table 7: Flexural Strength Test Results

Types of specimen	M30	M30	M30
	7 days	14 day	28 days
Unwrapped specimens	2.81	3.45	4.0
Wrapped with GFRP mat(single rotation)	4.24	5.31	5.85
Wrapped with GFRP mat(double rotation)	4.93	6.09	6.80
Wrapped with CFRP mat (single rotation)	4.76	5.66	6.35
Wrapped with CFRP mat (double rotation)	5.2	6.92	7.92

III. COMPARISON OF RESULTS

1) The graphical representation of test on hardened concrete for compression for the time period of 28 days from the time of casting are shown in figure.

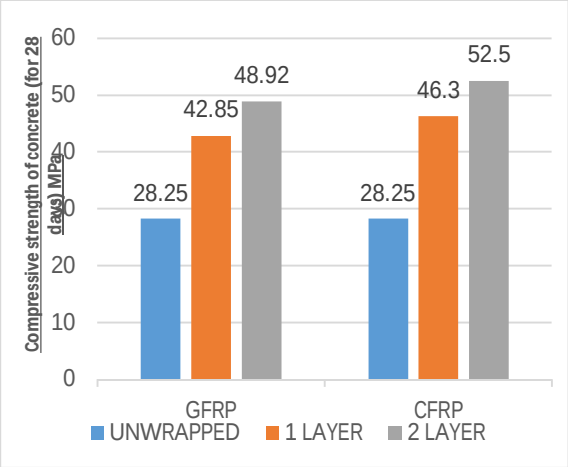

Figure 1: Graphical comparison of Compression Test Results after 28 days

2) The graphical representation of test on hardened concrete for tensile strength for the time period of 28 days from the time of casting are shown in figures below.

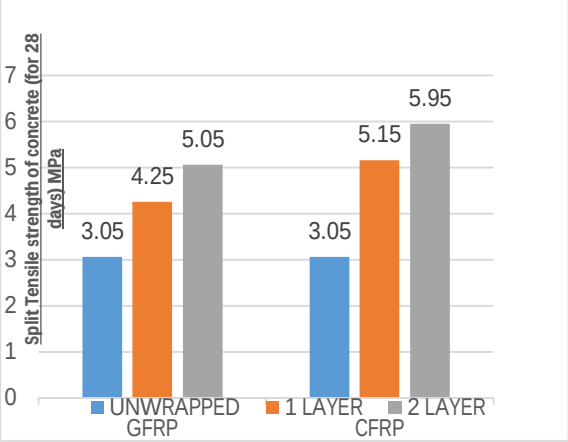

Figure 2: Split Tensile Test Results after 28 days

3) The graphical representation of test on hardened concrete for flexural strength for the time period of 28 days from the time of casting are shown in figure below.

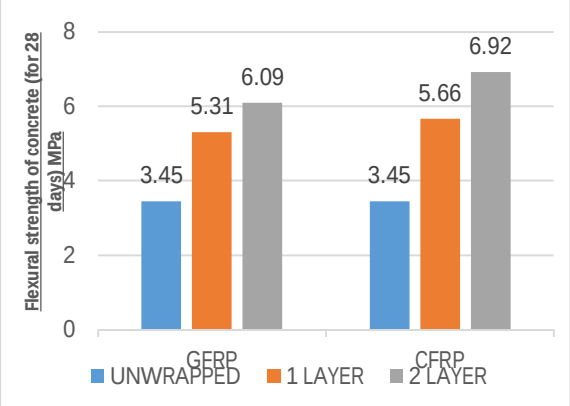

Figure 3: Flexural Test Results after 28 days

IV. RESULTS AND DISCUSSION

After 28 of days curing specimens are wrapped with 1.2 mm thick glass fibre mat by using epoxy polymers. Specimens are tested after 7 days of wrapping. The fiber that is used in this paper is a bi-directional one. To find out the effect of wrapping, the specimens are wrapped in both single and double rotation. One set of beams, cubes and cylinders are tested without wrapping, another set is tested with single rotation wrapping and another set is tested with double rotation wrapping. The compressive strength of concrete members confined with GFRP mat is improved by 1.7 times than the strength of unwrapped specimens. Strength of concrete members confined with CFRP mat is improved by 1.9 times than the strength of unwrapped specimens. The split tensile Strength of concrete members confined with GFRP mat is improved by 1.7 times than the strength of unwrapped specimens. The flexural Strength of concrete members confined with CFRP mat is improved by 2.05 times than the strength of unwrapped specimens. Strength of concrete members confined with GFRP mat is improved by1.7 times than the strength of unwrapped specimens. Strength of concrete members confined with CFRP mat is improved by 1.98 times than the strength of unwrapped specimens

V. CONCLUSION

The following conclusions are drawn from the experimental investigations carried out on concrete wrapped with CFRP and GFRP:

A. The strength of M30 grade concrete increased 1.5 times and 1.7 times when wrapped with single layer and double layer of GFRP when compared to unwrapped concrete
B. The strength of M30 grade concrete increased by 1.65 times and 1.9 times when wrapped with single layer of and double layer off CFRP when compared to unwrapped concrete
C. The compressive strength of M30 grade concrete wrapped with double layer of CFRP is found to be 52.50 N/mm2 which is 6.8% more than when wrapped with double layer of GFRP
D. The tensile strength of M30 grade concrete wrapped with double layer of CFRP is found to be 5.95 N/mm2 which is 15% more when compared to tensile strength off concrete wrapped with double layer of GFRP
E. The flexural strength of M30 grade concrete wrapped with double layer of CFRP is found to be 7.92 N/mm2 which is 14% more when compared to flexural strength of concrete wrapped with double year of GFRP
F. Hence the strength of CFRP wrapped concrete is more than that of GFRP wrapped concrete

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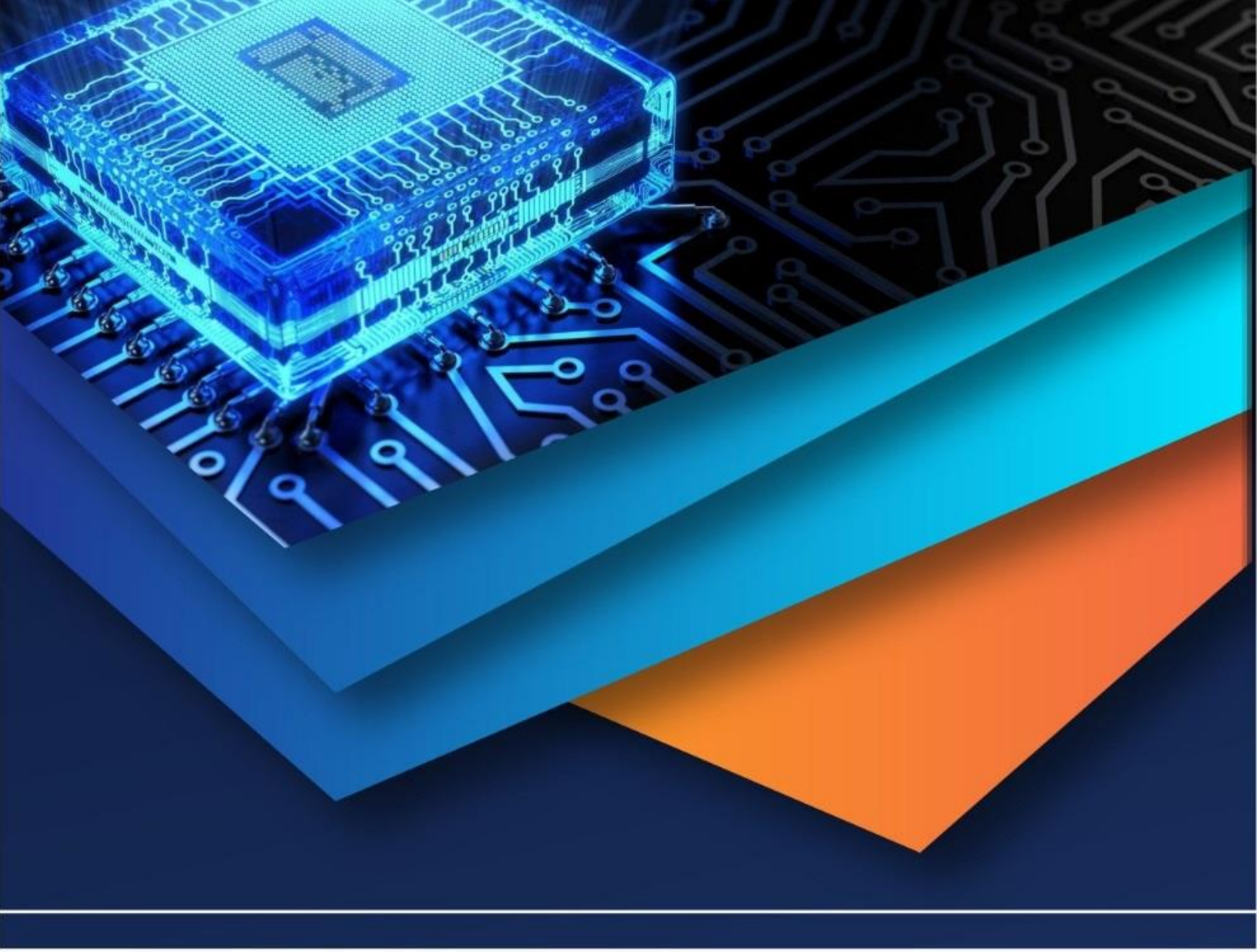

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