Rehabilitation of RC Column using Glass Fiber Reinforced Polymer

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Abstract---*Every Structural element should be designed for a particular type of loading as well as for adopting of different type of environment. Recent repairing or rehabilitation is generally increasing with the increase of age of concrete structures. In this paper, causes of deterioration of concrete as well as repairing or rehabilitation by using cement grout, mortar, concrete, sprayed concrete or shot Crete, epoxy, Glass Fiber Reinforced Polymer (GFRP) and the techniques of applying of these materials and also some resin based materials for bonding agent between interface of reinforced concrete columns and Glass Fiber Reinforced Polymer (GFRP) are reported. Finally styrene butadiene latex based liquid was used for high performance water proofing and multipurpose repair work.*

Keywords: *RC, GFRP, OPC*

1.0 INTRODUCTION

Columns are structural members subjected to combinations of axial compression and bending moment, rather than pure axial loading. The flexural effect may be induced by different factors, such as unbalanced moments at connecting beams, vertical misalignment, or lateral forces resulting from wind or seismic activity.

Confinement of Reinforced Concrete (RCC) Columns by means of fiber reinforced polymers (FRP) jackets is a technique being frequently used to seek the increment of load carrying capacity or ductility of such compression members. The need for improved strength results from higher load capacity demands because of design construction errors, change in the facility use, or revisions of code requirements. Improving ductility stems from the need for energy dissipation, which allows the plastic behavior of the element and, ultimately, of the structure.

Ductility enhancement is typically required in existing columns that are subjected to a combination of axial load and bending moment because of reasons similar to those listed for strengthening. Among these reasons, seismic upgrade and correction of detailing defects (i.e., improper splicing of the longitudinal reinforcement or lack of transverse ties) are most common Costs.

2.0 GLASS FIBER REINFORCED POLYMER COMPOSITES

GFRP Composites used in this study were formed embedding continuous fibers in a resin matrix that bound the fiberstogether using wet-layup method. The wet layupmethod is most commonly used which involves the institution application of resin to woven fabric.

3.0 OBJECTIVES OF THE PROJECT

The main objectives of the present investigation are to study the compressive strength, flexural strength, and split tension strength aspects of Concrete by conducting experiments in the laboratory.

A Study on Reinforced Concrete Columns with GFRP

i) The ultimate load carrying capacity of short columns for axial compression.

ii) Load – axial deformation characteristics & evaluation of ductility parameters of short column.

iii) The effectiveness of Glass Fiber Reinforced Polymer Composites toenhance the performance of concrete structures.

4.0 MATERIALS AND PROPERTIES

4.1 CEMENT

Cement is defined as the material with adhesive and cohesive properties which make it capable of bonding the constituents of concrete into a compact durable mass. Cement is obtained by grinding the raw materials (calcareous materials like limestone, chalk, marine shell and argillaceous materials containing silica, alumina and iron oxide).The mixture is then burnt in a large rotary kiln at a temperature of 1300°C to 1500°C. The resulting product called clinker is cooled and ground to fine powder called cement. In this project, Ordinary Portland Cement (OPC) 43 grade is used. Tests were conducted for cement as per IS8112:1989.

Table no: 4.1.1

S.NO	Physical property	Value obtained
1.	Fineness	2%
2.	Consistency	31.25%
3.	Initial Setting Time	36 minutes
4.	Final Setting Time	390minutes
5.	Specific Gravity	3.15

4.2 FINE AGGREGATE

Fine aggregate is added to concrete to assist workability to the concrete mix and to prevent segregation of the cement paste and coarse aggregates during its transportation. The aggregate fraction from size 150 micron to 4.75mm is termed as fine aggregate. The fine aggregate is represented by its zone. In this project, Natural River sand conforming to IS 383:1970 is used as fine aggregate.

Table no: 4.2.1

S.NO	Physical property	Value obtained
1.	Fineness modulus	3.8
2.	Grading zone	II
3.	Specific Gravity	2.624
4.	Moisture Content	2.4%
5.	Water Absorption	0.8%

4.3 COARSE AGGREGATE

The coarse aggregate is used primarily for the purpose of providing bulkiness to concrete. The aggregate fraction from size 4.75 mm to 80 mm is termed as coarse aggregate. The coarse aggregate is described by its nominal size. In this project, lightweight expanded clay aggregate of 4-10mm size conforming to IS 383:1970 is used as coarse aggregate.

Table no: 4.3.1

S.NO	Physical property	Value obtained
1.	Fineness modulus	5.39
2.	Nominal size	12.5 mm
3.	Specific Gravity	0.405
4.	Moisture Content	Nil
5.	Water Absorption	6.752%

4.4 WATER

The quality of water is important, because impurities in it may interfere with the setting of the cement and it may adversely affect the strength of the concrete or cause staining of its surface and may also lead to corrosion of the reinforcement. Water used for mixing and curing shall be clean and free from injurious amounts of oils, acids, alkalis, salts, sugar, organic material they may be deleterious to concrete or steel permissible limits.

4.5 GFRP

GFRP has a very high strength to weight ratio. Due to low weights of 2 to 4 lbs. per square foot means faster installation, less structural framing, and lower shipping costs. It has a durability, low maintenance, highstrength, light weight in nature, good resistance, seem less construction and able to mold complex shape.

4.6 STYRENE BUTADIENE

It is a waterproof repair plaster. For a bond coating- concrete to concrete, plaster to plaster and brick work. As a crack repair- plaster cracks around or more than 5mm, in gaps between RCC structures and masonry. As coating for corrosion prevention of rebar's.

4.7 WOVEN ROWINGS

The column is wrapped by Woven rowings which is made up of GFRP sheet for increasing the strength of the column. The characteristics of woven rowings is given below.

Table no: 4.7.1

CHARACTERISTICS	LIMITS	NORMAL VALUES
Standard Weight	± 10 %	610 g/ m^2
Roving Linear Weight (Tex)	± 10 (%)	1200
Roving Warp Well	± 5% ± 5 %	-27.0 -23.0
Thickness (mm)	Apex.	0.55
Loss on ignition (%)	± 0.2	0.40
Standard Width (mm)	± 25,-0	1500
Standard Length (meters)	± 5	60
Standard Roll Weight (kilos)	± 5	55

5.0 MIX DESIGN FORCONCRETE

DESIGN STIPULATIONS FOR PROPORTIONING

For **M_{20} grade** of concrete

a**. Maximum nominal size of aggregate**: 20 mm

b. **Workability**: 0.90mm (slump)

c. **Exposure condition**: Mild

d**. Degree of supervision**: Good

5.1 TEST DATA FOR MATERIALS

Cement used: OPC

Specific gravity of cement: 3.15

Specific gravity of

a. Coarse aggregate: 2.60

b. Fine aggregate: 2.60

Water absorption

a. Coarse aggregate: 0.5 %

b. Fine aggregate: 0.901 %

Free (surface) moisture

a. Coarse aggregate: Nil

b. Fine aggregate: 2%

Table no: 5.1.1

Water (L)	Cement	Fine Aggregate	Coarse aggregate
191.6	383 Kg	546 Kg	1188 Kg
0.50	1	1.425	3.10

For **M_{30} Grade** for concrete

a**. Maximum nominal size of aggregate**: 20 mm

b. **Workability**: 0.50mm (slump)

c. **Exposure condition**: Severe

d**. Degree of supervision**: Good

5.2TEST DATA FOR MATERIALS

Cement used: OPC

Specific gravity of cement: 3.15

Specific gravity Of

a. Coarse aggregate:2.7

b. Fine aggregate: 2.64

Water absorption

a. Coarse aggregate: 1 %

b. Fine aggregate: Nil

Free (surface) moisture

a. Coarse aggregate: Nil

b. Fine aggregate: 2%

Table no: 5.2.1

Water (L)	Cement	Fine Aggregate	Coarse aggregate
191.6	478.95 Kg	600 Kg	1090 Kg
0.4	1	1.253	2.28

PREPARATION AND CASTING OF SPECIMENS

The concrete after workability was used for casting test specimens. Moulds were used to cast the specimen. Since the maximum size of the aggregate is 20 mm, cube moulds of size 150x150x150 mm were used. The cube moulds were used for compression test specimens. The inner surface of the mould was coated with a thin layer of waste oil in order to help the remolding easy and to have sharp corners. Before applying oil, the inner surface was thoroughly cleaned and freed from moisture. The concrete was filled in three layers. Each layer was compacted with the standard tamping bar and the strokes of the bar were uniformly distributed across the cross section of the mould.

6.0 CASTING OF TEST SPECIMENS

6.1 Batching

The measurement of materials for making concrete is known as batching. Here, we have adopted weigh-batching method, and it is the correct method too. Use of weigh system in batching, facilitates accuracy, flexibility and simplicity. Different types of weigh batchers are available; the particular type to be used depends upon the nature of the job. When weigh batching is adopted, the measurement of water must be done accurately. Addition of water in terms of litre will not be accurate enough for the reasons of spillage of water, etc.

6.2 Preparation of the Mould

The moulds which are used for testing are cube, cylinder and column, which are made up of cast iron and the inside faces are machined plane. All the faces of the mould are assembled by using nuts and bolts and are clamped to the base plate. It is to be noted that, all the internal angle of the mould must be 90°. The faces must be thinly coated with mould oil to prevent leakage during filling. The inside of the mould must also be oiled to prevent the concrete from sticking to it.

DETAILS OF MOULDS

Table no: 6.2.1

Type of mould	Size (in mm)
Cube	150x 150x150
Cylinder	150mm diameter& 300mm height
Column	700 x150 x150

6.3 Mixing

Thorough mixing of materials is essential for the production of uniform course. The mixing should ensure that the mass becomes homogeneous, uniform in colour and consistency. In this project, we adopted machine mixing. As the mixing cannot be thorough, it is desirable to add 10% more materials.

A concrete mixer of capacity 500 litres is used in the mixing of concrete and appropriate rotation is given for proper mixing of materials without segregation.

6.4Pouring of Concrete

After the materials have been mixed, the moulds are filled immediately by pouring the concrete in to it. Concrete is filled in three layers, and each layer is compacted well by using a tamping rod of standard size, so as to avoid entrapped air inside the concrete cubes and honey combing effect on the sides. During pouring of concrete, it is better to avoid wasting of concrete for effective and economical usage. In order to avoid wastage, small trowels are used to collect the concrete that is coming out the mould while pouring, and it is again used in the process.

6.5 Reinforcement details

Lateral Ties**:** 6 mm Dia bars are used. Spacing = 100 mm @ Both ends & 100 mm @ Middle Portions as per IS 456-2000.
Main rod = 4 Nos @ 8mm dia.
20 mm cover was provided on two sides of the columns.

6.6Compaction of Concrete

Compaction of concrete is the process adopted for expelling the entrapped air from the concrete. In the process of mixing, transporting and placing of concrete, air is likely to get entrapped in the concrete. The lower the workability, higher is the amount of air entrapped. Here, we adopted hand compaction by using a tamping rod. When hand compaction is adopted, the consistency of concrete is maintained at a higher level.

Concrete is filled in layers of 15 – 20 mm, and each layer is compacted well using the compacting rod. After the top layer has been compacted, a strike-off bar is used to strike out the excess concrete, and a trowel is used to finish off the surface with the top of the mould, and the outside of the mould should be wiped clean.

6.7Demoulding

Test cube specimens are demoulded after 24 hours from the process of moulding. If, after this period of time, the concrete has not achieved sufficient strength to enable demoulding without damaging the cube specimens, then the process must be delayed for another 24 hours. Care should be taken not to damage the specimen during the process because, if any damage is caused, the strength of the concrete may get reduced.

After demoulding, each specimen is marked with a legible identification on any of the faces by using a waterproof paint. The mould is then thoroughly cleaned after the process. Ensure that grease or dirt does not collect between the faces because; it will not fit together properly, which will cause leakage through the joints resulting in an irregularly shaped cube in the future use.

6.8 Curing

The test specimens after compaction were kept as such for a period of 24 hours. After that period of time the moulds were removed and the specimens were kept in ordinary curing tank and allowed to cure for a period of 7,14 and 28 days.

7.0TESTING OF SPECIMENS

The testing of specimen includes following processes:

a. Slump Test
b. Split Tensile strength Test
c. Compressive Strength Test

7.1 SLUMP TEST PROCEDURE

1. The internal surface of the mould was thoroughly cleaned and freed from superfluous moisture and adherence of any old set concrete before commencing the test.
2. The mould is placed on a smooth, horizontal, rigid and non-absorbant surface.
3. The mould it then filled in four layers, each approximately ¼ of the height of the mould.

4. Each layer is tamped 25 times by the tamping rod taking care to distribute the strokes evenly over the cross section.
5. After the top layer has been rodded, the concrete was struck off level with a trowel and tamping rod.
6. The mould is removed from the concrete immediately by raising it slowly and carefully in a vertical direction.
7. This allows the concrete to subside. The subsidence is referred as SLUMP OF CONCRETE.

7.2 SPLIT TENSILE STRENGTH TEST

The cylindrical specimen (150mm diameter & 300mm height) is subjected to Split tensile strength test.Three numbers of specimens were tested for 7, 14 and 28 days. A total of 18 cylinder of M-20, M-30 were tested.

PROCEDURE

1. The internal surface of the mould was thoroughly cleaned.
2. Fill the concrete in the cylinder moulds in two layers each of approximately and ramming properly.
3.Each layer is tamped 25 times by the tamping rod taking care to distribute the strokes evenly over the cross section.
4.The specimens are removed from the moulds after 24 hours.
5. The specimen was taken out from the curing tank and allowed to dry for few hours.
6.The load was applied in uniform rate until the sample gets failed.

Then the load at failure has been noted.

7.3COMPRESSIVE STRENGTH

One of the important properties of concrete is its strength in compression. The strength in compression has definite relationship with all other properties of concrete i.e. these properties are improved with the improvement in compression strength

Cubes of size 150 x 150 x 150 mm were cast. Three numbers of specimens were tested for 7, 14 and 28 days. A total of 18 cubes of M-20, M-30 were tested.

Column size 700 x150 x 150 mm were cast. Three numbers of specimen were tested for 7,14and 28 days. A total of 3 columns of M-20, M-30 were tested.

Procedure

1. The specimen was taken out from the curing tank and allowed to dry for few hours.
2. The specimen was placed in compression testing machine in such a way that the load was applied in casted surface.
3. The load was applied in uniform rate until the sample gets failed

Then the load at failure has been noted.

8.0TEST RESULTS AND DISCUSSION

The specimens were casted and allowed to cure for 7,14and 28 days and were tested. The details of specimen type and the type of test conducted are shown in the table.

8.1 RESULTS FOR SLUMP CONE TEST

Table- 8.1 Slump Cone Test Results

Mix	Slump in (mm)
M20	28
M30	37

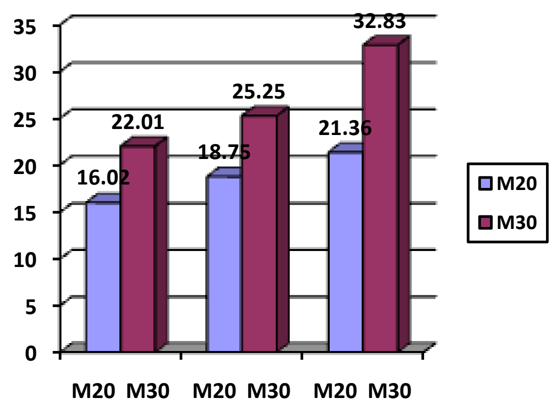
8.2 CUBE COMPRESSION RESULTS

First the conventional concrete cube of grade M-20, M-30, have been casted and tested for various period of curing. The cubes are cured for 7,14 and 28 days at laboratory temperature. The results have been tabulated.

Table- 8.2.1CUBE COMPRESSION RESULTS

Mix	7Days (N/mm^2)		14Days (N/mm^2)		28Days (N/mm^2)	
	M20	**M30**	**M20**	**M30**	**M20**	**M30**
Specimen 1	16.01	22.02	18.65	25.25	21.38	32
Specimen 2	16.03	22	18.73	25	21.28	33
Specimen 3	16.02	22.01	18.87	25.50	21.42	33.5
Average	**16.02**	**22.01**	**18.75**	**25.25**	**21.36**	**32.83**

Chart no: 8.2.1



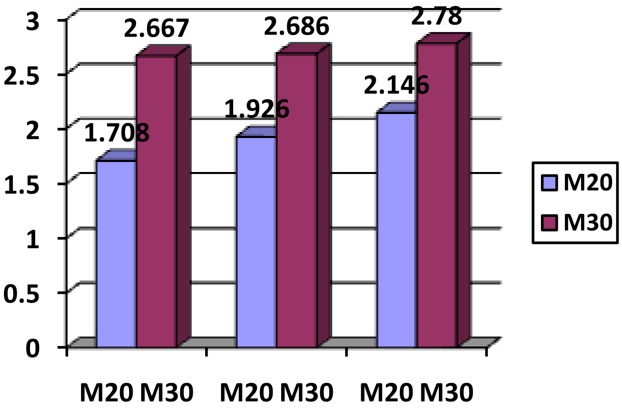
8.3 CYLINDER SPLIT TENSILE TEST RESULTS

First the conventional concretecylinder of grade M-20, M-30, have been casted and tested for various period of curing. The cylinders are cured for 7,14 and 28 days at laboratory temperature. The results have been tabulated.

Table 8.3.1 Split tensile testresults

Mix	7 Days (N/mm^2)		14 Days (N/mm^2)		28 Days (N/mm^2)	
	M20	**M30**	**M20**	**M30**	**M20**	**M30**
Specimen 1	1.708	2.751	1.956	2.42	2.15	2.59
Specimen 2	1.7	3	1.922	2.64	2.19	2.78
Specimen 3	1.716	2.251	1.9	3	2.098	2.96
Average	**1.708**	**2.667**	**1.926**	**2.686**	**2.146**	**2.78**

Chart no:8.3.1



8.4COMPRESSIVE STRENGTH OF CONVENTIONAL COLUMNRESULTS

Table 8.4.1 Compressive strength of conventional for short columns

No. of days	**Ultimate Load (kN)**	**Compressive Strength (N/mm^2)**
7 days	285	12
14 days	365	15.5
28 days	715	31.2

Table 8.4.1 Pictorial Representation OfConventional Column

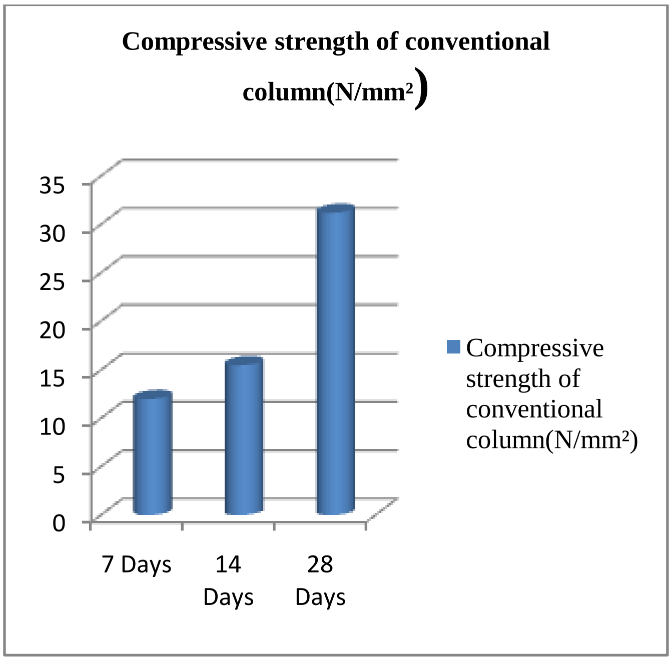
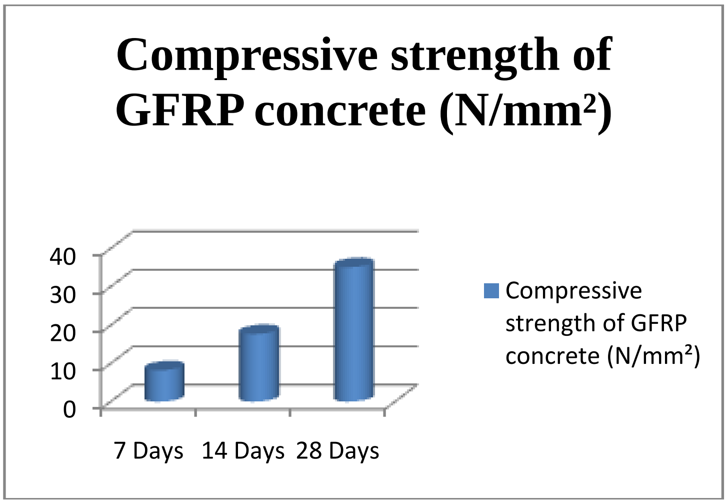


Table 8.4.2 Compressive strength of GFRP concrete
COLUMN (WRAPPED BY GFRP SHEET)

No. of days	**Ultimate load (kN)**	**Compressive strength (N/mm^2)**
7 days	185	8.2
14 days	415	17.7
28 days	805	35.1

Table 8.4.2 Pictorial Representation Of GFRP concrete Column



9.0CONCLUSION

In all the tests failure of the Columns occurred by crack and crushing of the concrete in the Head and Base of the column. The Ductility parameters namely Displacement Ductility, Curvature Ductility are showing appreciable increase compared to normal concrete columns. In all the tests failure of the Columns occurred by internal cracks and crushing of the concrete in the Head and Base of the columns. GFRP composite fails with Tear and Rupture. Strengthening the column with GFRP increases their load carrying capacity, ductility and energy absorption. The Ductility parametersnamely Displacement Ductility, Curvature Ductility are showing appreciable increase compared to normal concrete columns. Finally the styrene butadiene liquid was used for finishing.

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