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# Strengthening of RC Column using GFRP under Seawater Conditions

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**ABSTRACT:** Nowadays Advancement of technologies in the world of construction time is very fast, the use of concrete was applied not only on land but also in the area of extremes environmental such as regional seawater. Structures built in aggressive environments such as in the sea environment need to be carefully designed, due to possibility of chloride ion penetration into the concrete. One way to reduce the strength degradation in such environment is to use GFRP, which is attached to the surface of reinforced concrete using epoxy. A key issue in the design of GFRP strengthening RC structures using externally bonded GFRP composites is the bond behavior between GFRP and concrete.

In Present work, by using M-25 grade of concrete, total 15 specimen of reinforced concrete columns with dimension 300×230×600mm were casted. Three specimens were prepared as control column to check strength after 28 days, out of 15 specimens, three specimens wrapped with single layer GFRP, three specimens wrapped with double layer of GFRP, and three specimens wrapped with triple layer of GFRP, which were immersed in salt water for 56 days. The investigation focused on the performance of the columns wrapped with GFRP in terms of percentage increase in load carrying capacity.

**KEYWORDS:** GFRP, seawater, marine environment, and compression test

## I. INTRODUCTION

In the past few decades, many types of materials have been developed for the repair or strengthening of reinforced concrete (RC) structures, driven by the demands of the construction industry arising from the existence of concrete problems, such as deterioration, and the need for post-strengthening of structures to ensure their safety and serviceability. Among these materials, fiber reinforced polymer (FRP) has been widely used in construction engineering because of its tensile strength, corrosion resistance, and easier handling, in addition to the economic advantages.

Due to the shortage of land and resources, marine structures, including coastal structures and artificial islands, become more important in the coming decades for exploitation of various marine resources. Marine structures suffer severe environmental conditions, constant wave pressure, and unexpected disasters. Long term corrosion attack is a major problem found in steel reinforced concrete structures when subjected to marine environment and the effect of chloride ions (Cl<sup>-</sup>) is a major contributor to the corrosion of steel reinforcement. The corrosion of steel reinforcement can decrease the strength and durability of structures severely, resulting in substantial maintenance expenses and financial loss. In order to prevent corrosion of steel reinforcements, the content of chloride ions in the concrete is strictly limited. It is specified in the American Concrete Institute (ACI) 318 code that the content of chloride ions should be less than 0.15% and 0.08% of mass of cement in dry and wet circumstances for steel reinforced concrete (SRC) structures, respectively.

### 1.1. Research relevancy

A survey of the literature on the behavior of reinforced concrete columns externally strengthened with GFRP reveals that a considerable amount of effort has been devoted to this subject. The use of externally bonded FRP composite for strengthening and repair can be a cost-effective alternative for restoring or upgrading the performance of existing concrete columns. Even though a lot of research has been directed towards circular columns, relatively less work has been performed on square and rectangular columns, to examine the effects of external confinement on the structural performance. However, the vast majority of all columns in buildings are rectangular columns. Also Long term



corrosion attack is a major problem found in steel reinforced concrete structures when subjected to marine environment and the effect of chloride ions (Cl<sup>-</sup>) is a major contributor to the corrosion of steel reinforcement, hence, strengthening of structure with GFRP can be the solution to increase life of structure in seawater environment.

## II. EXPERIMENTAL INVESTIGATION

### 2.1. Details of Column specimens:

The experimental investigation is carried out with total 15 numbers of column specimens of size 300mm x 230mm x 600mm. Out of which three specimens casted as CC for 28 days. Three column specimens casted for single layer GFRP wrapping, three column specimens casted for double layer GFRP wrapping, three column specimens casted for triple layer GFRP wrapping and remaining three were cast as CC after 56 days while immersion in salt water.

Sr. No.	Notation	No. of. Specimens	No. of. GFRP layers	Compression test 28 (days)	Compression test 56 (days)
1.	CC-1	3	0	3	-
2.	CC-2	3	0	-	3
3.	GFSLC	3	1	-	3
4.	GFDLC	3	2	-	3
5.	GFTLC	3	3	-	3
<b>Total</b>					<b>15</b>

Table No. 1 Schedule of specimens preparation

### 2.2. Preparation of test specimen:

The description of the column specimen is summarised in Table no 2. The surface of the beam specimen was cleaned using polish paper or grind to ensure a good bond between the GFRP fabric and the concrete surface.

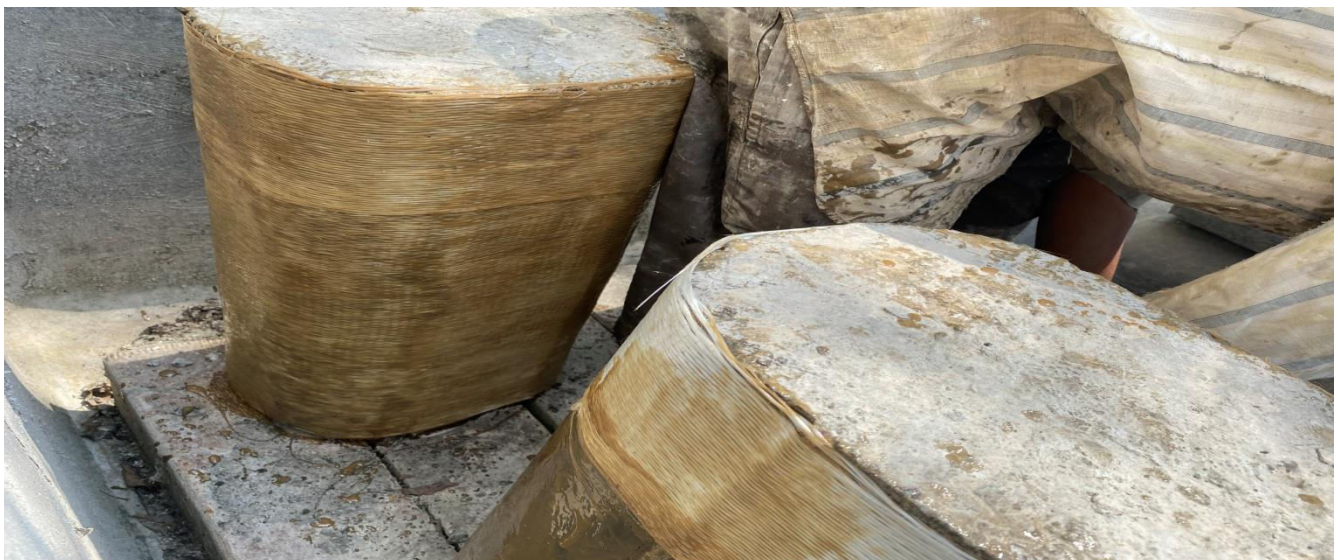
Column Designation	Description	Size of column
CC	Control Column	300mm x 230mm x 600mm
GFSLC	Glass fibre single layer column	300mm x 230mm x 600mm
GFDLC	Glass fibre double layer column	300mm x 230mm x 600mm
GFTLC	Glass fibre triple layer column	300mm x 230mm x 600mm

Table No:2 Description of specimen





**Fig 1 Application of load on Column**



**Fig. 2 Application of GFRP on column**

### 2.3. Application of GFRP

Glass fibre composite system for strengthening columns, beams and slabs of load bearing structures particularly where improvement to shear strength and deformation characteristics is required. It is ideal for seismic retrofitting also. Typical applications include piers, columns, beams, slabs, retaining walls, masonry bridges, pipes, chimney, tunnels and other structures.

#### 2.3.1 Surface Preparation

Concrete column surfaces to be treated shall be free from oil residues, demoulding agents, curing compounds, grout holes and protrusions. The concrete column surface to be wrapped shall be structurally repaired prior to treatment, for corrosion induced damage/ structural damage, by epoxy grouting and epoxy/polymer modified Renderoc repair mortar systems. All depressions, imperfections etc., shall be repaired with EFC/ EPG epoxy putty to even out undulations.



**2.3.2 Application of GFRP sheet on column**

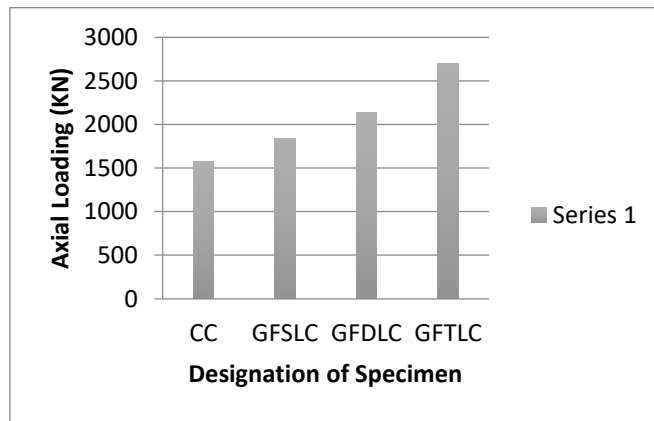
The GFRP shall be cut to required size and then pressed first by gloved hand on to the saturant applied area and then with a stiff spatula or a surface roller to remove air bubbles. One more coat of Saturant is applied over the glass fabric after a minimum lapse of 30 minutes.

**III. TEST RESULTS AND DISCUSSION**

The load applied on specimens is increased until its failure occurred. Three columns of each series was tested and average of the results are compared with control column.

After 28 days The control column has cracked load of 1486.72 KN and maximum load of 1571.72 KN. The column failure started with minor cracks at top right edge of the column with vertical cracking. The peak deflection varied from 10.28 mm to 12.36 mm.

GFSLC For this series, the columns were wrapped in GFRP single layer, and tested after 56 days of immersion in salt water, The column achieves its crack load at 1632.25 kN and fails at the load of 1838.91 KN. . The peak deflection varied from 9.24 mm to 11.23 mm.



**Graph. 1 Summary of results**

**Table 3. Summary of Results of Tested specimens**

Specimen	Axial load (KN)	Axial Displacement (mm)	Strain	Compressive stress (N/mm <sup>2</sup> )
CC	1571.72	12.36	0.0206	22.77
GFSLC	1838.91	11.23	0.0187	26.65
GFDLC	2137.53	9.21	0.0153	30.97
GFTLC	2703.35	9.65	0.016	39.17

GFDLC, for this, series the columns were wrapped in GFRP double layer, and tested after 56 days of immersion in salt water, The column achieves its crack load at 2012.32 kN and fails at the load of 2137.53 KN. The peak deflection varied from 8.36 mm to 9.21 mm.

GFTLC, for this, series the columns were wrapped in GFRP Triple layer, and tested after 56 days of immersion in salt water, The column achieves its crack load at 2012.32 kN and fails at the load of 2137.53 KN. The peak deflection varied from 8.23 mm to 9.65 mm.



#### IV. CONCLUSION

From the present experimental work, following conclusions can be drawn: As CC, GFSLC, GFDLC, GFTLC were tested for compressive loading using UTM. Comparative study was carried out between control columns and strengthened columns with GFRP.

Based on that, the following conclusions are made:-

- The axial compressive strength of RC column wrapped with single layer GFRP is increased by 14.55%, with decrease in deflection.
- Increase in axial compressive strength in double layer GFRP by 26.47%.
- The percentage decrease of deflection in double layer column is 74% and in triple layer column is 78.07%.

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