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Experimental and Analytical Investigation of Short Columns with GFRP Bars

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ABSTRACT- Glass fiber reinforced polymer (GFRP) Rebar 's has an innovative material it's been a potential application in construction practices due to its high tensile strength, corrosive resistance ease in its applications and relatively simple construction technique. To tap such potential, the existing body of knowledge on GFRP must be expanded to provide a proper basis for officials to add this method of construction to the provisions of the building code. This thesis aims to add to that body of knowledge through experimental investigation on performance of Glass fibre reinforced bar in compression members.
Load carrying capacities of long and short columns reinforced longitudinally with glass fiber reinforced polymer rebar and laterally with steel bar were compared with steel reinforcement in this research. Test series consisted of columns having 150 Ø mm diameter and 660 mm length of 3 short columns. The main study in this program is on replacing the longitudinal reinforcement partially with GFRP bars and cement replaced by 20% with silica fume. Comparing such differently reinforced column with fully steel reinforced and GFRP reinforced columns. Load carrying capacities and failure behaviour of columns were observed by experimental investigation and compared with theoretical values. From the obtained results, it is observed that the replacement in longitudinal reinforcement partially with GFRP bars in short & long columns show the higher load carrying capacities. And the failure of the column is changed for the short columns

KEYWORDS- GFRP bars, silica fume, concrete, replacement.

I. INTRODUCTION

The construction industry has seen an increase in demand in recent years to reinstate, rejuvenate, strengthen, and upgrade existing concrete structures. This can be attributed to a variety of factors, including environmental degradation, insufficient design, poor construction practises, a lack of regular maintenance, revision of codes of practise, increased loads and seismic conditions, and so on. When designing a structural member, it must meet specific strength, deflection, and stability requirements. A specialised type of concrete is Glass Fiber Reinforced Polymer (GFRP) added to concrete. Glass Fiber Reinforced Polymer (GFRP) bars have been developed as an alternative to steel reinforcement, which has emerged as one of many applications due to their excellent features such as high strength to weight ratios, corrosion resistance, and dimensional stability, Thermal expansion, damping characteristics, and so on are all controllable.

Table 1: Properties of cement

S. No.	Value Obtained Experimentally	Value as per IS-1489-1991
1	Fineness of cement	Min 0.01
2	Setting time Initial setting time	Min 30 mins
	Final setting time	Max 600 mins

Much research has been conducted to investigate the properties and behaviour of GFRP reinforcement in concrete under various conditions. In some applications, GFRP bars can provide cost and durability advantages. However, the behaviour of Glass Fiber Reinforced Polymer (GFRP) bars as longitudinal reinforcement in compression members remains an unresolved issue. As a result, the purpose of this thesis is to expand our understanding of Glass Fiber Reinforced Polymer (GFRP) bars used to internally reinforce concrete compressive members through experimental investigation. In 1952, the first tests on silica fume in Portland cement-based concretes were conducted. The most significant barrier to investigating the properties of silica fume was a lack of material with which to experiment. Early studies employed a costly additive known as fumed silica, an amorphous form of silica produced by the combustion of silicon tetrachloride in a hydrogen-oxygen flame. In contrast, silica fume is a very fine pozzolanic, amorphous by product of the production of elemental silicon or ferrosilicon alloys in electric arc furnaces. Silica fumes were simply vented into the atmosphere prior to the late 1960s in Europe and the mid-1970s in the United States. Silica fume, also known as micro silica, is an amorphous (non-crystalline) polymorph of silicon dioxide, silica (CAS number 69012-64-2, EINECS number 273-761-1). It is an ultrafine powder composed of spherical particles with an average particle diameter of 150 nm that was collected as a byproduct of the production of silicon and ferrosilicon alloys. The primary application is as a pozzolanic material in high-performance concrete. It is occasionally confused with fumed silica (also known as pyrogenic silica, (CAS number 112945-52-5). However, the production process, particle characteristics, and application fields of fumed silica differ from those of silica fume.

II. MATERIALS AND POPORTIONS

Columns were cast using cement, fine aggregates, coarse aggregates, admixtures, reinforcement steel bars, and Glass Fiber Reinforced Polymer (GFRP) bars. The materials' detailed specifications are discussed further below.

Cement\s Ordinary for the concrete mix, Portland Cement (OPC) of standard brand and 53 grade conforming to IS 12269-1987 was purchased locally. The cement should be fresh and uniform in consistency, with no lumps or foreign matter in the material. Cement should be stored in dry conditions for as short a time as possible. Table 3.1 lists the physical properties obtained from various tests. All tests are performed in accordance with the procedures outlined in IS-1489(Part1):1991.

Figure 1: Physical properties

Fine aggregate: Local sand was used as fine aggregate in concrete mix. The physical properties and sieve analysis results of sand are shown.

Coarse aggregate: Crushed stone aggregate of 10mm size were used for concrete. The physical properties and sieve analysis results of coarse aggregate are shown.

Figure 2: Coarse aggregate

Table 2: Properties of coarse aggregate

S no.	Property	Value Obtained
1.	Type	Crushed
2.	Specific gravity	2.68

Water The entire concreting was done with potable water that was free of organic matter, silt, oil, chloride, and acidic materials according to Indian standards.

Silica Fume It is an ultrafine material with spherical particles that are less than 1 m in diameter, with an average diameter of 0.15 m. This makes it roughly 100 times smaller than a typical cement particle. The bulk density of silica fume varies with soil densification and ranges from 130 (unidentified) to 600 kg/m3.

Figure 3: Literature Survey

Paramanantham (1993) tested fourteen concrete beam-columns reinforced internally with Glass FRP(GFRP) reinforcing bars. He reported that the glass fibre reinforcing bars were only stressed to up to 20% to 30% of the ultimate strength in compression members, and up to 70% of their tensile strength in flexural specimens.

Almusallam et al. (1997) studied the effect of different ratios of compression reinforcement on the behaviour of concrete beams reinforced with GFRP bars and indicated that the GFRP compression reinforcement has in significant influence on the behaviour of all tested beams.

Alsa yed (1999) tested fifteen 18 x 10 x 48 in. (450 x 250 x 1200 mm) concrete columns under concentric loads to investigate the effect of replacing longitudinal and/or lateral steel bars by an equal volume of GFRP bars. They showed that replacing steel bars with GFRP bars in columns reduced their capacity by about 13 percent. They also showed that replacing steel ties with GFRP ties reduced the columns capacity by 10 percent regardless of the type of longitudinal bars. They also noted that ACI 318-99 might overestimate the capacity of GFRPRC columns.

Deitz et al (2003) Concluded that the ultimate compression strength is equal to 50% of the ultimate tensile strength. Whereas modulus of elasticity in compression could be considered approximately equal to modulus of elasticity in tension.

DE LUCA ET AL (2010) They concluded that GFRP bars could be used in columns, but the contribution of GFRP bars could be ignored when evaluating nominal capacity and they noted that GFRP ties did not increase the ultimate capacity of longitudinal bars, but delayed their buckling

III. METHODOLOGY

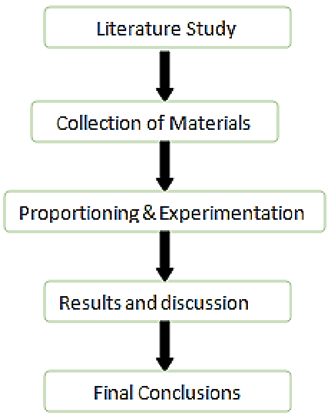

Figure 4: Methodology

IV. RESULTS AND DISCUSSION

The mean concrete cube compressive strength, tensile & flexural values of each tested specimen are shown in Table 5-1. Based on the visual observation made during the tests, it was observed that cubes made of plain concrete showed a sudden and brittle mode of failure immediately after reaching the maximum values which can be considered as their respective peak strength values Table 3: Test Results

Table 3: Results and discuission of properties

Constituents	M20+SILICAFUME (20%)	M20
Mix proportion	1:0.25:2.1:1.42:2.1 2	1:1.704:1.41:1.71 3
Cement ((kg/m^3)	315.864	394.3 2
SILICAFUME (kg/m^3)	78.864	-
Sand (kg/m^3)	670.439	672.04
Coarse aggregate(kg/m^3) 20mm	666.892	675.539
10mm	446.96	450.36
Water	197.16 lt	197.16 lt

The theoretical load carrying capacities of the column were calculated using the following formulation for concrete with characteristic compressive strengths of 34 N/mm2 and 27.16 N/mm2 and yield strength (fy) of 415 N/mm2. The maximum load capacity of a steel reinforced column.

P_u=0.68*F_{ck}. ($A_g A_s$)+(f_y.A_s)

The ultimate load carrying capacity of a GFRP reinforced column is calculated by taking the compression modulus of the GFRP bars and multiplying it by 80%. (Ching Chaw Choo, 2006).

P_u=0.68*F_{ck}(A_g-A_s) +0.002*E_{gc}.A_s.

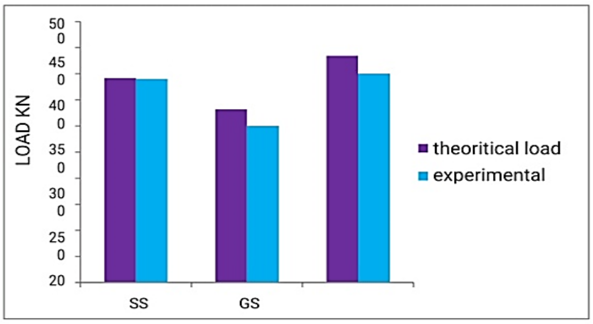

Figure 5: Graph represents load carrying capacity of short column

The difference in load carrying capacities of long and short columns from experimentalresultsareasinthebarchartitclearlymentionsthein creaseinloadcarryingcapacityofshort column by replacing the 50% of longitudinal reinforcing bars with GFRP bars and by replacing the 20% of cement with SILICAFUME

A. *Failure of short columns*

All of the GSS short columns (reinforced with both steel and GFRP with a 20% cement replacement) fail at higher loads than the SS and GS columns. We concluded from this observation that the failure of hybrid reinforced columns is very similar to the failure of steel columns. During testing of the GSS columns, cracks appeared prior to column failure, as shown in figures 5.3 (a), (b), and (c), and the obtained load carrying capacities from testing show lower values than the theoretically calculated values. Because of the composite behaviour of both steel and GFRP bars.

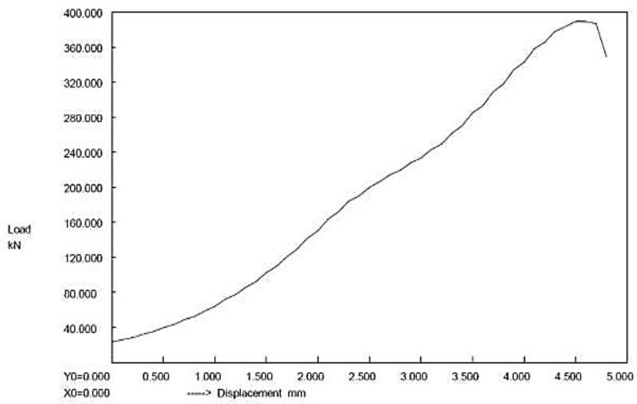

Figure 6: Load deflection curve for steel reinforced column

The compression test of short columns under UTM of 1000KN capacity yielded load-displacement graphs (fig 5.4, 5.5, 5.6). The GS-II short column in the graphs shows small variations in displacements at initial loading conditions. After a while, the graph became steeper as the load increased, and the failure of the GSS (20% replacement with SILICA FUME in cement) concrete reinforced column occurred at a higher load than the SS and GS columns. When compared to steel reinforced columns casted without replacement in concrete, the load deflection diagrams of the GSS column with GGBS concrete show greater deformations.

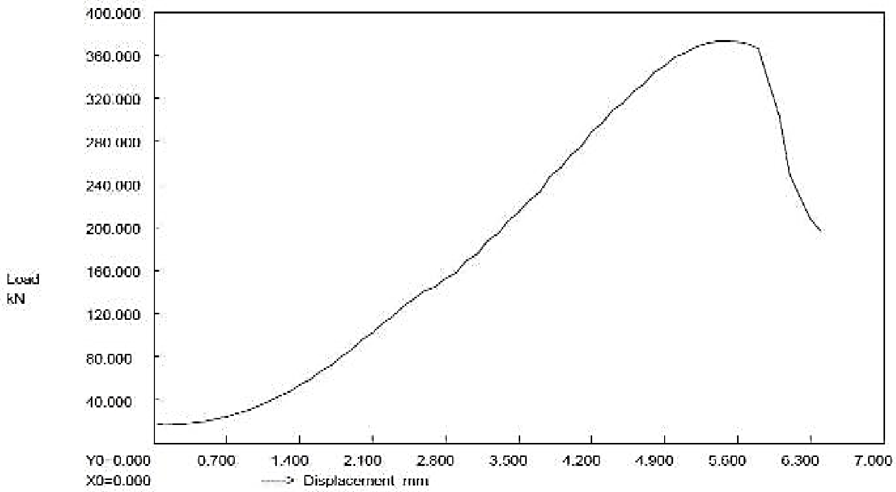

Figure 7: load deflection curve for 100% GFRP

V. CONCLUSION

Short columns reinforced with GFRP and steel bars to allow for maximum longitudinal displacement. The short GFRP+ failure mode Steel columns, like steel short columns, provide significant warning by forming cracks prior to failure. The lateral deflection observed at mid-height of the GFRP +steel (with SILICA FUME replacement in cement) column is greater than that of the steel short column but less than that of the GFRP column. HYFRC beam has higher compressive split tensile and flexural strength than GFRP beam. The use of GFRP bars in the column has resulted in not only increased flexural strength but also good shear capacities and bending moment. A 5% to 20% replacement of cement with silica fume results in an increase in compressive strength. Silica fume also reduces concrete voids. The addition of silica fume in the proper proportion improves durability against acidic attack and improves concrete conditions.

CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interest.

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