Study Of Influence Of Mineral Admixtures On Crushing And Buckling Load Of Columns

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***Abstract*— Glass fibre 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 rebars in compression members. Load carrying capacities of long and short columns reinforced longitudinally with glass fibre reinforced polymer rebar and laterally with steel rebar's were compared with steel reinforcement. in this research. Test series consisted of 6 columns having 150 Ø mm diameter and 2000 mm in length of 3 long columns, and 660 mm length of 3 short columns The main study in this program is on replacing the longitudinal reinforcement partially with GFRP rebars and cement replaced by 20% with ground granulated blast furnace slag(GGBS). Comparing such differently reinforced column with fully steel reinforced and GFRP reinforced columns. Load carrying capacities and failure behaviours of columns were observed by experimental investigation and compared with theoretical values. And the circular column behaviour analysed with help of P-M interaction diagrams. Ductility Factor also find out for short columns. From the obtained results, it is observed that the replacement in longitudinal reinforcement partially with GFRP rebars in short & long columns show the higher load carrying capacities. And the failure of the column is changed for both the short &long columns.**

***Index Terms*— GGBS, GFRP, Short Column, Long Column, Steel Reinforcement, Ductility, Buckling Load, Mineral Admixture.**

I. INTRODUCTION

In recent years, the construction industry has seen an increasing demand to reinstate, rejuvenate, strengthen and upgrade existing concrete structures. This may be attributed to various causes such as environment degradation, design inadequacies, poor construction practices, lack of regular maintenance, revision of codes of practice, increase in loads and seismic conditions etc

Whenever a structural member is designed, it is necessary that it satisfies specific strength, deflection and stability requirements. Glass Fiber Reinforced Polymer (GFRP) added to the concrete is a specialized form of concrete. Glass Fiber Reinforced Polymer (GFRP) bars have been developed as an alternative to steel reinforcement, which has emerged as one of the many applications, due to their excellent features like high strength to weight ratios, resistance to corrosion, controllable thermal expansion, damping characteristics etc.

Much research has been conducted to investigate the properties and behavior under various conditions of GFRP reinforcement in concrete. GFRP bars can offer benefits of cost and durability in some applications. However, the behavior of Glass Fiber Reinforced Polymer (GFRP) bars as longitudinal reinforcement in compression members is still a relevant issue that needs to be addressed. So, this thesis aims to further the knowledge of Glass Fiber Reinforced Polymer (GFRP) bars used to internally reinforce concrete compressive members through experimental investigation.

In recent years, the construction industry has seen an increasing demand to reinstate, rejuvenate, strengthen and upgrade existing concrete structures. This may be attributed to various causes such as environment degradation, design inadequacies, poor construction practices, lack of regular maintenance, revision of codes of practice, increase in loads and seismic conditions etc. Whenever a structural member is designed, it is necessary that it satisfies specific strength, deflection and stability requirements. Ground Granulated Blast Furnace Slag (GGBS) added to the concrete is a specialized form of concrete. Concrete has become the driving force area for construction material experts and researchers. Concrete has basic naturally, cheap and easily available ingredients as cement, sand, aggregate and water. After the water, cement is second most used material in the world. Ordinary Portland cement is one of the main ingredients used for the production of concrete. But this rapid production of cement creates problems for which we have to find out civil engineering solutions. First environmental problem is emission of CO_2 in the production process of the cement. We know that CO_2 emission is very harmful which creates lots of environmental changes. 1 tonne of carbon dioxide is estimated to be released to the atmosphere when 1 tonne of ordinary Portland cement is manufactured. On the other side, cost of concrete is attributed to the cost of its ingredient which is scarce and expensive, this leading to usage of economically alternative material in its production. This requirement has drawn the attention of investigators to explore new replacements of ingredients of concrete. Due to growing environmental awareness, as well as stricter regulations on managing industrial waste, the world is increasingly turning to researching properties of industrial waste and finding solutions on using its valuable component parts so that those might be used as secondary raw material in other industrial branches. The present technical report focuses on investigating characteristics of concrete with partial replacement of cement with Ground Granulated Blast furnace Slag (GGBS). The main problem is the original conventional materials are depleting and we are in hunt for alternate building materials which lands us here on the purpose of GGBS. Being a by- product and waste using it effectively up

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to some extent serves as a step for a greener environment and at the same time keeping in mind that the strength of the concrete doesn't degrade by the usage GGBS.
The topic deals with the usage of GGBS and advantages as well as disadvantages in using it in concrete. This usage of GGBS serves as replacement to already depleting conventional building materials and the recent years and also as being a by- product it serves as an Eco Friendly way of utilizing the product without dumping it on ground.

II. MATERIALS USED

Cement: Ordinary Portland Cement (OPC) in the local market of standard brand of 53 grade confirming to IS 12269-1987 was used for the concrete mix. The cement should be fresh and of uniform consistency and there is no evidence of lumps or any foreign matter in the material. The cement should be stored under dry conditions and for as short durations as possible. The physical properties obtained from various tests are listed in Table I. All tests are carried out in accordance to procedure laid in IS-1489 (Part 1):1991.

Table I: Physical properties of cement

S.No.	Property	Values Obtained Experimentally	Value as per IS-1489-1991
1.	Normal consistency	28	-
2.	Fineness of cement	0.5	Min 0.1
3.	Setting time Initial setting time Final setting time	42 min 450 min	Min 30 minutes Max 600 minutes
4.	Specific gravity	3.15	3.15

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

Table II: Physical properties of fine aggregate

S.No.	Property	Value Obtained
1.	Specific gravity	2.61
2.	Bulk density	1.5
3.	Fineness modulus	2.07
4.	Water absorption	1.5%
5.	Grading zone	Zone II

Fineness modulus of fine aggregate=2.07

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

Table III: Physical properties of coarse aggregate

S.No.	Property	Value Obtained
1.	Type	Crushed
2.	Specific gravity	2.68
3.	Water absorption	1.68%

Water:
Potable water, free from organic matter, silt, oil, chloride and acidic materials per Indian standard was used for the entire concreting.

Ground Granulated Blast Furnace Slag (GGBS):
Table IV: Physical properties of GGBS

S.No.	Property	Value obtained
1.	Specific gravity	2.61
2.	Fineness, cm^2/gm	3650

Table V: Chemical composition of GGBS

S.No.	Chemical compositions	percentage	As per requirements of IS 12089-1987
1.	Silicon dioxide	35	30-38
2.	Aluminum oxide	10	15-25
3.	Calcium oxide	40	30-45
4.	Magnesium oxide	8	4-17

Reinforcing steel:

In this experiment 6mm diameter HYSD steel bars are used as longitudinal reinforcement of yield strength of 415 N/mm^2 and 4mm diameter lateral ties are used as lateral confinement of longitudinal reinforcing bars. For the comparative analysis, glass fibre reinforced polymer rebar's (GFRP) are also used. With same diameter as steel bar is used. GFRP rebars are providing by CSK technologies and the properties of materials given by the company as follows (Table no VI).

Table VI: properties of reinforcing materials used in experiments

	Type	Dia. mm	Ultimate tensile strength (N/mm^2)	Young's modulus	Density Kg/m^3	Tensile strain
1	Steel	6	415	$2*10^5$ MPa	7850	0.002
2	GFRP	6	772	45 GPa	2	0.0179

III. EXPERIMENTAL PROGRAM

Test series consisted total of 6 reinforced columns (includes both long &short). The long columns of 150mm diameter and 2000m in length of slenderness ratio 13.33(>12) and short column of diameter 150 mm and length of 660 mm (>3xd). Total of 3 series of columns were casted with the grade of M20 (Cement + GGBS) concrete .Details and designation of the test specimens are shown in Table VII.

Table VII: Showing Details and Designation of Column Specimens

	Grade of concrete	Long Column	Short column
Series -I	M20	SL-I	SS-I
Series-II	M20	GL-II	GS-II
Series-III	M20(cement+ 20% GGBS)	GSLIII	GSS-III

Series -I columns are reinforced longitudinally with steel bars, laterally with steel ties

Series -II columns are reinforced longitudinally with GFRP rebars of 6 MM diameter. Laterally with steel ties L and S represents long and short columns. G and S represent steel and GFRP reinforcement.

Series -III columns designated as GSL and GSS represent the columns having 3 GFRP rebars and 3 steel rebars as longitudinal reinforcement bars.

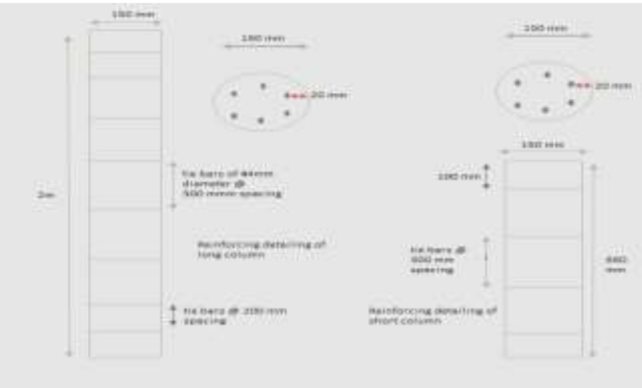

Fig 1: Showing Reinforcing Detailing of Long & Short Columns

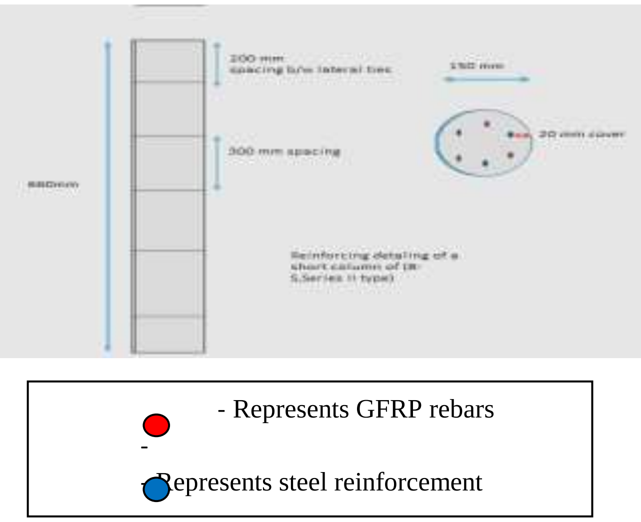

Fig 2: Showing Reinforcing Detailing Of Short Columns Partial Replacement of GFRP Rebars

PROPORTIONS OF CONCRETE MIX DESIGN

Concrete mix proportions for M20 with GGBS are calculated as per the IS10262:2009 codes provisions. Detailed concrete mix proportions are provided in Table VIII.

Table VIII: Mix Proportions of M20 (Cement + GGBS) Concrete

Constituents	M20+GGBS (20%)	M20
Mix proportion	1:0.25:2.1:1.42:2.12	1:1.704:1.41:1.713
Cement (kg/m3)	315.864	394.32
GGBS (kg/m3)	78.864	-
Sand (kg/m3)	670.439	672.04
Coarse aggregate(kg/m3) 20mm	666.892	675.539
10mm	446.96	450.36
Water	197.16 lt	197.16lt

Casting of specimens:

The column specimens were prepared by using the pvc pipe of diameter of 150 mm. for long(2000mm) and short column(660mm). To have the straight columns and ease in casting. The pipes are fitted in a wooden frame as shown in figure and reinforcement is placed in the pipes with cover blocks to provide cover of 20mm. The concrete of slump100mm (for better workability) was poured into the pvc pipes and vibrator was used to reduce the formation voids in the column. And cubes(150X150X150MM), cylinders (300 mm height 150 mm dia.) and prisms (100X100X500mm) are also casted on same day with same grade of concrete mix to find the compressive, flexural and split tensile strength of m20 grade concrete.

Fig 3: Samples of Cubes, Cylinders & Prisms

Fig 4: Showing Reinforcement Detailing and Arrangement Long and Short Columns of HYSD Steel& GFRP Rebar's In PVC Pipe

Test Set-Up and Procedure

Two tests were conducted in this research, material tests to establish the test data for compressive strength, flexural and tensile strength of concrete cubes, cylinders and prisms respectively and tensile strength of GFRP rebar and the compression test on long and short columns by the using the loading frame and UTM to study the behavior of both type of columns under axial compression.

Material Tests

In the material tests all cube samples were tested to establish their compressive strength values with three cubes for each column specimen. The test was performed at least 28 days curing after the day of casting. The test was conducted on an advanced fully automatic microprocessor controlled advanced concrete testing machine with 3000KN capacity. The load was applied slowly at the rate of approximately 5.2KN/sec by adjusting the options to the testing machine. Each cube was subjected to compression load until failure occurred. The average values of the compressive loads obtained from three cubes for each mix divided by the initial cross sectional area of the cube were evaluated as the compressive strength for that mix. The photographs of testing of concrete cube samples are shown in Figure 5.

Fig 5: Showing Compression Test of Cubes under & Cylinder

ACTM

Splitting tensile strength test on concrete cylinder is a method to determine the tensile strength of concrete. The concrete is very weak in tension due to its brittle nature and is not expected to resist the direct tension. And the test set up as shown in below figure. And also the flexure test for M20 grade concrete also had done.

Test set up for column testing:

The long columns were tested under the loading frame of capacity 1000 KN. the testing column placed vertically under the loading jack to apply axial load through centroid of the columns and also column caps were placed at the top & bottom ends of the column to reduce the premature compression failure at the ends. And then load applied slowly with help of hydraulic jack which is connected to the load cell and the mid height lateral deflection of column specimen was calculated by using the dial gauge arrangement as shown in fig.

Fig 6: Showing Loading Arrangement for Columns under Loading Frame

Fig 7: Showing Loading Arrangement for Short Columns under UTM

IV. TEST RESULTS AND DISCUSSION

The mean concrete cube compressive strength, tensile &flexural values of each tested specimen are shown in Table IX. 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 IX: Properties of M20 Grade Concrete Used in Project Work

Theoretical load carrying capacities of columns

The theoretical load carrying capacities of column were calculated from below formulation for characteristic compressive strength of 34 N/mm^2 and 27.16 N/mm^2 concrete with steel rebar's as longitudinal reinforcement as of yield strength (fy) 415 N/mm^2.

The ultimate load carrying capacity of steel reinforced column

Pu = 0.68*Fck. (Ag-As) +Fy. As

The ultimate load carrying capacity of GFRP reinforced column calculated from the compression modulus of GFRP rebars which is 80% of its tensile modulus (Ching Chaw Choo, 2006).

Pu =0.68*Fck (Ag-As) + 0.002*Egc.As.

And the ultimate load carrying capacity of 50% replacements in longitudinal rabars were calculated as

Pu =0.68*Fck (Ag-As) + 0.002*Egc.As+Fy. As

And there is considerable reduction in strength in long columns due to slenderness effect and reduction in strength calculated by strength reduction coefficient factor Cr multiplied to the ultimate load carrying capacity of column section.

Table X: Theoretical Load Carrying Capacities of Long And Short Columns

Type of column	Theoretical load (Pt)	Experimental load(Pex)	P_{exp}/ P_{th}	Lateral deflection in long columns (Δ mm)	Ductility μ
SS-I	391.89	390	0.99	-	1.216
SL-I	381	295	0.77	2.65	-
GS-II	333.22	300	0.9	-	1.3
GL-II	323.97	280	0.86	3.49	-
GSS-III	434.57	400	0.92	-	1.42
GSL-III	421.54	310	0.735	2.9	-

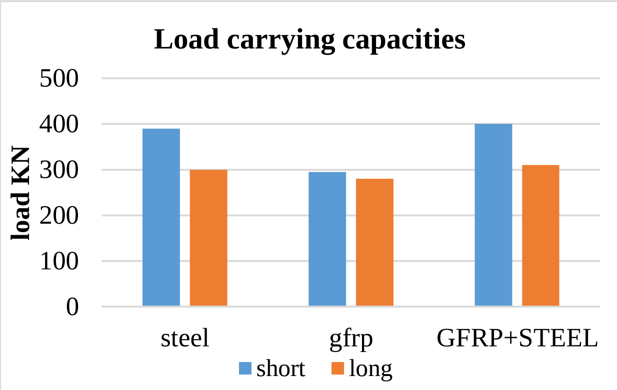

Fig 8: Graph Represents Load Carrying Capacity of Long & Short Columns

The difference in load carrying capacities of long and short columns from experimental results are as in the bar chart it clearly mentions the increase in load carrying capacities of columns(long &short) by replacing the 50% of longitudinal reinforcing bars with GFRP rebars and by replacing the 20% of cement with Ground Granulated Blast Furnace Slag(GGBS).

P-M interaction diagram

The axial load-moment (P-M) interaction strength of a reinforced concrete column cross-section is evaluated on the basis of the following assumptions:

- Plane sections remain plane under bending. Thus, the strain in the concrete and reinforcement are proportional to the distance from the neutral axis.
- Perfect bond exists between the reinforcement and concrete.
- The tensile strength of concrete can be neglected.
- The maximum strain, εc, in concrete nowhere exceeds an assumed ultimate concrete compressive strain, εcu – an Ultimate strength design assumption.
- The area of the concrete displaced by reinforcement in compression will be subtracted.

Note that the investigation of reinforced concrete columns in this dissertation is limited to columns with circular cross section.

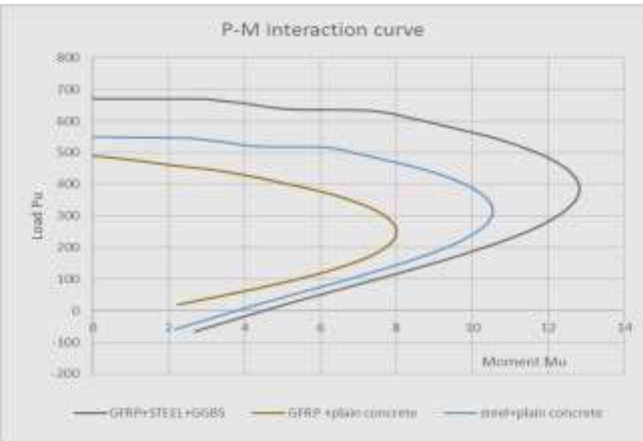

Fig 9: Combined Moment Interaction Diagrams for GFRP Rebar and Steel Rebar of Circular Cross- Section

The load -moment interaction diagram for partial replacements in concrete and longitudinal steel as shown fig 9, from the graph partial replacement in longitudinal rebars with steel rebars will reduce the chance of occurring the brittle failure in columns. And partial replacements in concrete gives higher load carrying capacities.

Failure of short columns

All the short columns GSS-III (reinforced with both steel and GFRP with 20% replacement in cement) are failed at higher loads than the SS-I, GS-II columns from this observation we concluded that the failure of hybrid reinforced columns is much closer to the failure of steel column. While testing the GSS-III columns crack were appeared before the failure of column as shown in below figures 10 (a), (b), (c) and the obtained load carrying capacities from the testing shows lower values than the theoretically calculated values. Due to composite behaviour of both steel rebars and GFRP rebars.

(a) (b) (c)

Fig 10: (a) Failure of 100% GFRP Column (b) Failure of Partial GFRP Reinforced Column (c) Failure of Conventional Steel Column

Load Deflection Graphs for Short Columns:

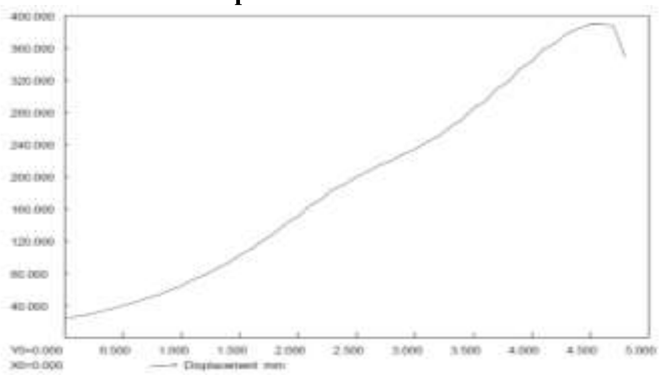

Fig 11: Load Deflection Curve for Steel Reinforced Column

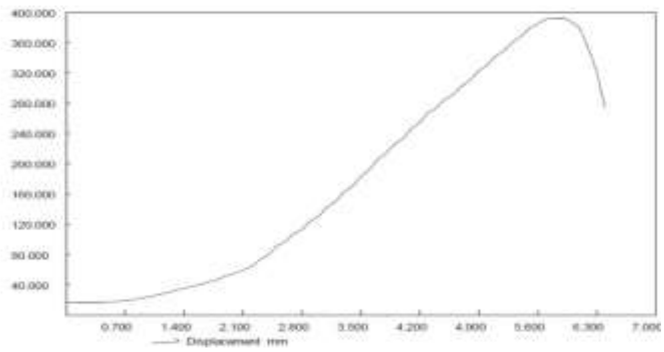

Fig 12: Load Deformation Diagram for GFRP + Steel Reinforced Column

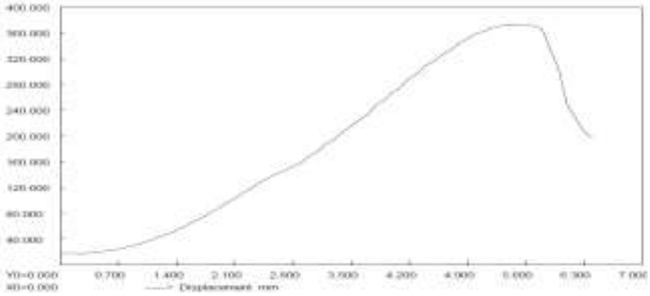

Fig 13: Load Deflection Curve for 100% GFRP

Load -displacement graphs (fig 11, 12, 13) are obtained from the compression test of short columns under UTM of 1000KN capacity. from the graphs the GS-II short column shows small variations in displacements at initial loading conditions after a while it have observed that the graph goes steeper at increasing loads, and the failure of the GSS-III (20% replacement with GGBS in cement) concrete reinforced column occurred at the higher load than the SS-1, GS-II columns. From the load deflection diagrams of the GSS-III column with GGBS concrete shows greater deformations when compared with steel reinforced column casted without replacement in concrete.

Failure of long columns

The failure of the long columns SL-I was in compression failure shown in fig 14. The failure occurred at the ¼ distance from the top end and the reinforced rebar are buckled due to axial compression force. Before failure of column observed a central crack shown in fig 5.5 at the outer fiber of a column which is due to the lateral deflections at the center, and it was calculated by using dial gauges .and that lateral deflection is due to the slenderness effect. And the failure load of the column is much less than the theoretical load for a long column and less than the crushing load of a short column.

Fig 14: Showing Failure of Conventional Steel, 50%GFRP with GGBS And 100% GFRP Long Column and Central Crack Before Failure

In case of GL-II long column it's also a compression failure occurred at small distance from the top end but it was very sudden, the failure is due to internal fiber failure in GFRP bar as shown fig 14 and the lateral deflection due to slenderness effect was also determined by dial gauge and its greater than the steel column and the failure load of GL-II long column is little lower than steel reinforced long column.

In case of GSL-III long column it's also a compression failure occurred at small distance from the top end but it was not sudden and the failure is like SL-II, the failure is due to internal fiber failure in GFRP bar as shown fig 15 and the lateral deflection due to slenderness effect was also determined by dial gauge and it falls in between the values of SL-I & GL-II columns and the failure load of GSL-III long column higher than SL-I & GL-II columns. And the failure of columns is shown in below figures.

(a) (b)

Fig 15: Failure of Long Columns in (a) GFRP + STEEL with GGBS Column (b) Conventional Steel Column (c) 100% GFRP Rebars Column

V. CONCLUSION

1. Load Carrying capacity of short columns,and the longitudinal reinforcement replaced with GFRP bars and replacement in cement with GGBS gives 33.33%, 2.56% increment when compared with GFRP reinforced and steel reinforced columns respectively .
2. In long columns the ultimate load carrying capacity of Partial replaced GFRP rebars is more than the conventional steel columns,and the percentage increment is 10.71 %, and 5.0 % for GFRP reinforced and steel reinforced long columns respectively.
3. Short columns reinforced with GFRP+Steel rebars given maximum longitudinal displacement
4. The failure mode of short GFRP+Steel columns is like steel short column,significant warning is observed by formation of cracks before failure .
5. The observed lateral deflection at mid height of the GFRP+steel (with GGBS replacement in cement) column is greater than that of steel long columnand less than the GFRP column.
6. The strength interaction curve shows the improved behaviour in load carrying capacites of the column cross section reinforced with both GFRP and Steel rebars and 20 % replacements with GGBS in cement.

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