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Behavior of RC Short Columns with Partial Replacement of Fine Aggregate by Quarry Dust Using GFRP Reinforcement

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Abstract: **This paper presents the experimental investigations of concrete specimens reinforced with Glass fiber reinforced plastic (GFRP) reinforcements and quarry dust to improve the properties of concrete specimen. GFRP bars were used to reinforce the concrete columns instead of conventional rebars and that are experimentally investigated under axial compression to assess structural behavior of concrete. Four sets of column specimens of cross section 100 mm X 100 mm of length 600 mm were cast and tested under axial loading. Load-deformation characteristics of the specimens were plotted and energy absorption capacity, stiffness and ductility factor were calculated. The experimental results show that the column with GFRP reinforcement and quarry dust increases the strength properties of the column specimen. An analytical model has been developed using ANSYS 16 software in order predict the load deformation behavior of all specimens. The analytical results have been validated with the experimental results. It was found that the column with quarry dust and GFRP reinforcements shows better performance in all aspects. The investigation suggests that GFRP rebars as the best alternative to steel rebars in compression members.**

Keywords: **GFRC bars, Quarry Dust, columns, axial compression, ANSYS 16.**

I. INTRODUCTION

The main problem in RC structural element is due to corrosion. The high cost associated with corrosion of steel reinforcements demands an alternative for steel. FRP reinforcing bars provides a great alternative to steel reinforcement which leads to corrosion. Two types of FRP reinforcing bars are used alternate to steel bars specifically Glass Fibre Reinforced Polymer and Carbon Fibre Reinforced Polymer. FRP materials in general offer a lot of advantages over the conventional steel, including one quarter of the density of steel, greater tensile strength than steel, no corrosion even in cruel chemical environments and neutrality to electrical and magnetic disturbances. Quarry dust is a byproduct obtained from the devastating process of stone during quarrying activities and it can be used as partial replacement of fine aggregate in concrete which leads to the reduction in the cost of concrete production. Hogr Karim [6] investigated the behavior of concrete columns reinforced with GFRP bars and GFRP helices as longitudinal and transverse reinforcement respectively tested under axial compression. By reducing the spacing of the GFRP helices leads to improves the strength and ductility of the concrete specimens. Raga sai[11] investigated the consumption of quarry dust generated from quarries in concrete. Quarry dust satisfies the reason behind the alternative material as a alternate for sand. From the results, it is concluded that 40% replacement of fine aggregate by quarry dust can be used as a replacement for fine aggregate. Venu[12] presented the behavior of RC beams under flexure when reinforced with the GFRP rebars as a replacement of steel reinforcement. The deformation capacity of beams is comparable to that of steel reinforced beams. The effective utilization of GFRP rebar increases the flexural load carrying capacities, shear capacity and bending capacity of the beam. The objective of the study is to analyze the compressive behavior of Reinforced concrete short columns reinforced with GFRP rebars and partial replacement of fine aggregate by Quarry dust, under axial compression. To interpret the load versus axial deformation characteristics of the columns. To compare the experimental results of column with analytical investigation using ANSYS.

II. MATERIALS AND MIX PROPORTIONS

Ordinary Portland cement (53 grade) with specific gravity of 3.15 is used for the present study and conforming to IS 12269:1987. The fine aggregate passing through 4.75 mm sieve and having a specific gravity of 2.68 was used. The grading zone of fine aggregate was zone II as per Indian standard specification (IS: 383-1970). The maximum size of coarse aggregate used for this project work is 20 mm and the specific gravity is 2.40. Water should be portable and free from acids, oil, alkalis and other organic impurities. A superplasticizer by the name CERA PLAST 300 of Naphthalene Sulphonated base was used. Quarry dust passing through 4.75 mm sieve with a specific gravity of 2.7 and fineness modulus of 2.9 was used. The HYSD reinforcement with the tensile strength of 500 kN/m^3 was used with the diameter of 12mm. The sand sprinkled type Glass Fibre Reinforced Polymer (GFRP) with the tensile strength of 550 kN/m^3 with a diameter of 12 mm was used. The mix proportion for M-30 grade of concrete has been obtained using IS 10262:2009 and the mix ratio was 1:1.84:2.69:0.4.

III. CASTING OF SPECIMENS

The cube, cylinder and prism specimens are cast and tested for varying proportions of quarry dust. Fine aggregate can be replaced with 10%, 20%, 30% and 40% of quarry dust. The specimens are tested after 28 days curing. The test results of companion specimens are shown in Table 1. Totally 8 column specimens corresponding to four test series were casted and tested under axial compressive load. The cross section of column was 100 X100 mm the height of the column was 600 mm. The columns was reinforced with four numbers of 12 mm bars as longitudinal reinforcement and 8 mm bars are used as lateral ties with spacing 100 mm centre to centre. First set of column cast with conventional concrete, second set of column with optimum percentage of quarry dust, third set of column with four numbers of GFRP main reinforcement, fourth set of column with optimum percentage of Quarry dust and four numbers of GPRP main reinforcement.

TABLE 1: TEST RESULTS OF COMPANION SPECIMEN

S. No.	Percentage of Quarry Dust	Compressive Strength of cube (N/mm^2)	Split tensile strength of cylinder (N/mm^2)	Flexural Strength (N/mm^2)
1	0%	34	3.28	6.9
2	20%	39	4.8	9.1
3	30%	44.2	5.84	10.4
4	40%	41.4	5.31	9.9

IV. EXPERIMENTAL SETUP AND INSTRUMENTATION

The axial load was applied using a universal testing machine of 1000 kN capacity. Axial load was transmitted to the column through steel plates placed over it to provide hinge condition. The column specimens were adjusted so that the centre line of the axial load coincides with column faces. A dial gauge with a least count of 0.01mm was used to measure the axial deformation. A dial gauge was attached to the plate placed over the top column surface which is used to transfer the load uniformly to measure the deflection. Initially 8 column specimens were tested under axial load and the load versus deflection of columns was measured. The load was applied gradually and the deflections were measured at every 10 kN of load stages.

V. RESULTS AND DISCUSSION OF COLUMNS

The Ultimate load carrying capacity of conventional concrete column was 140 kN whereas GFRP+QD column was 500 kN. GFRP reinforcements with quarry dust increases the load carrying capacity and deformation characteristics and also increases the performance in all aspects. Table 2 shows the experimental results of column specimen under axial loading condition.

TABLE 2: EXPERIMENTAL RESULTS OF COLUMN SPECIMEN

Specimen code	Ultimate load (kN)	Ultimate Deflection (mm)	Stiffness (kN/mm)	Ductility factor	Energy absorption capacity (kN-mm)
Conventional Column (CC)	140	3.56	31	0.8	239.15
Quarry Dust Column (QD)	320	4.7	64	1.12	543.24
GFRP Column (GFRP)	450	5.5	77	1.25	745.87
GFRP and Quarry Dust Column (GFRP+QD)	500	5.6	83	1.52	868.9

VI. ANALYTICAL INVESTIGATION

The finite element analysis has been carried out to investigate the performance of short column with the replacement of fine aggregate by quarry dust and GFRP rods. The finite element modeling was performed using ANSYS 16.0. The finite element model of the short column was developed to test the performance of the column specimens. The geometry, material properties and boundary conditions were same as that used for the experimental investigation. Eight-node solid brick element (Solid65) was used for modeling concrete. Link8 element was used to model steel reinforcement. Unequal meshing was done along the cross section of the column to increase the efficiency of the model. The column model was created in ANSYS 16.0 and the reinforcement model, meshing of column specimen is shown in Fig. 1& 2 respectively. The failure mode of columns in ANSYS is shoen in Fig.3. The Comparison load-deflection curve from experimental and ANSYS for conventional concrete column and GFRP+QD column is shown in Fig. 4.

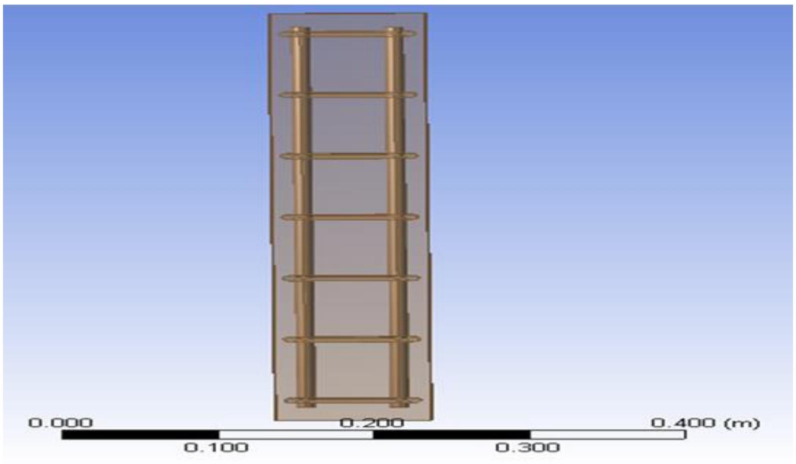


Fig. 1 Reinforcement model

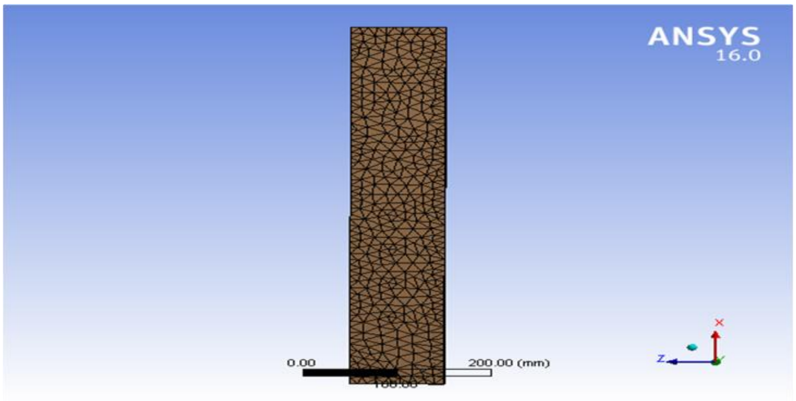
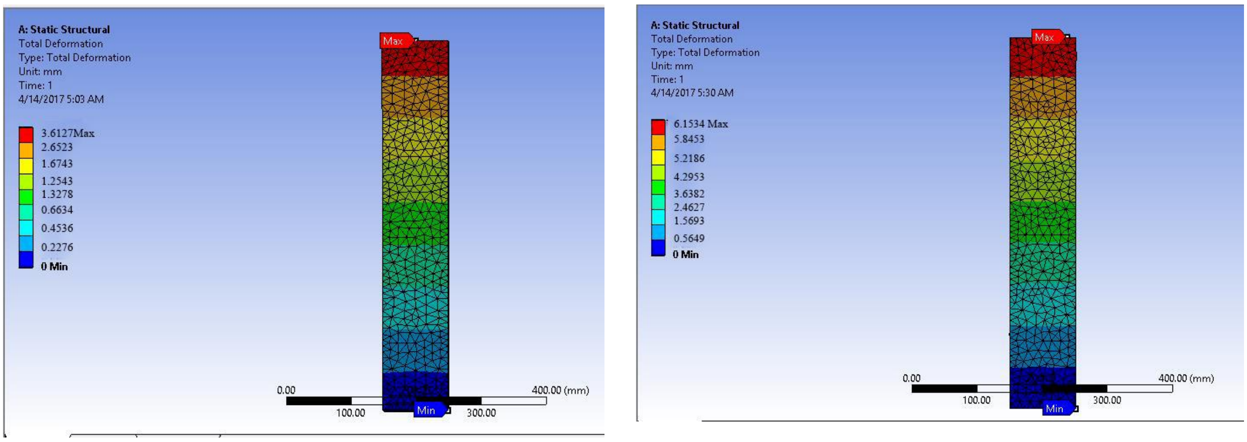


Fig. 2 Mesh Created in ANSYS for column specimen



(a) CC **(b) GFRP + QD**

Fig. 3 Deformation profile of column in ANSYS

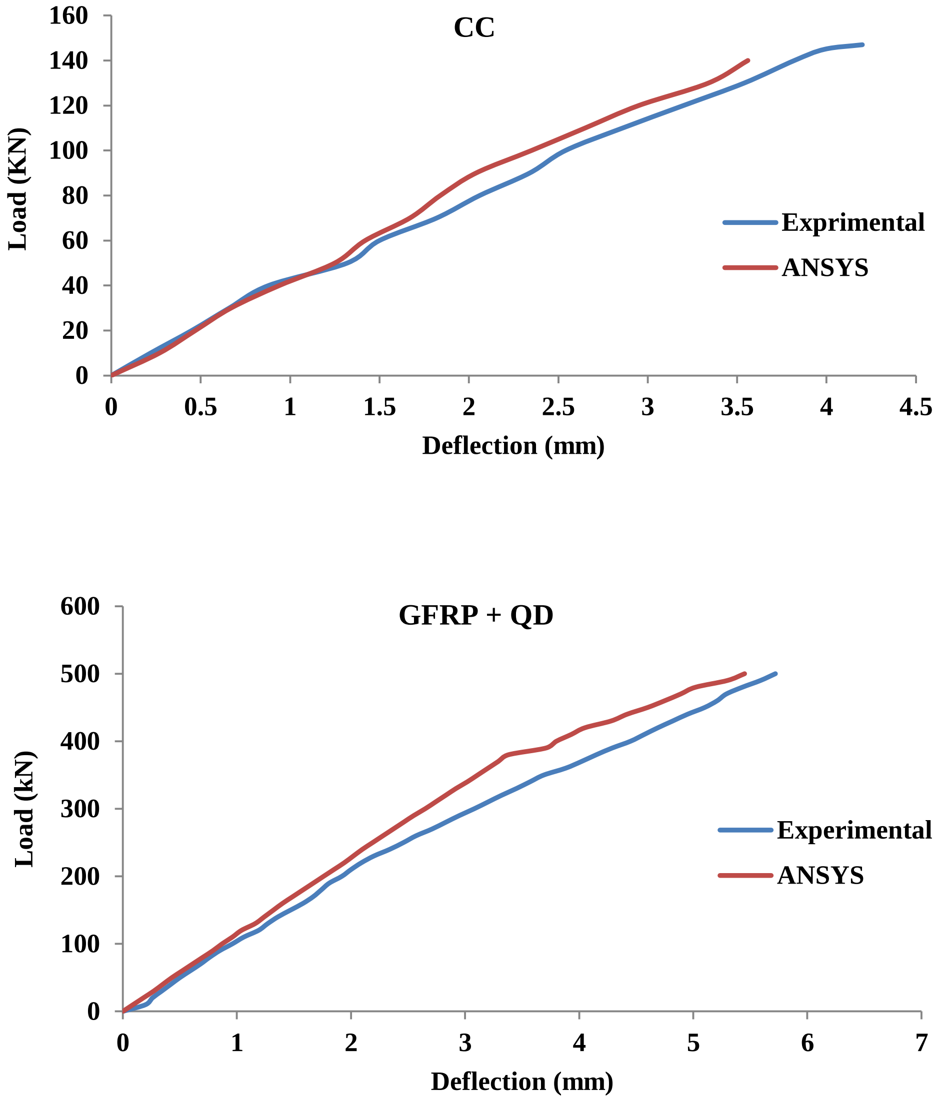


Fig. 4 Comparison of load-deflection Curve

VII. SUMMARY AND CONCLUSIONS

Based on the experimental and analytical data obtained for short column specimens, the following conclusions were made.

1. The load carrying capacity of quarry dust column was 2.28 times, GFRP column was 3.21 times and 3.57 times higher than that of the conventional column.

2. The stiffness value and energy absorption capacity of the quarry dust column, GFRP reinforced column, column replaced with both GFRP reinforcement and quarry dust were higher than conventional column in both experimental and analytical comparison.

3. The stiffness value of quarry dust column was 1.38 times, GFRP column was 2.16 times and 2.5 times higher than the conventional column.

4. The energy absorption capacity of the quarry dust column was 3.43 times, GFRP column was 5.7 times and 7.13 times higher than the conventional column.

5. From this study we could conclude column replaced with both quarry dust and GFRP reinforcement exhibit higher energy absorption capacity.

6. Corrosion of reinforcement is one of the major problem which causes durability issues. This demands effective use of corrosion resistant materials as reinforcements. By the end of the study it can be conclude that GFRP rebars effectively alternates steel rebars in compression members.

7. The study of compression behaviour of corrosion resistant GFRP bars will help to introduce the same in compression members which are exposed to aggressive environments.

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