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INVESTIGATION ON BEHAVIOUR OF FRP TUBEENCASED CONCRETE COLUMNS WITH AND WITHOUT REINFORCEMENT

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ABSTRACT

This paper presents analytical study of the Fiber Reinforced Polymer (FRP) Tubes Encased Concrete columns with and without reinforcement and comparing the results with conventional concrete. FRP encased concrete system was developed as a new structural component for masonry building and heritage structures. FRP encased concrete columns are light in weight and good in compression, flexibility and an anti-corrosion material. An analytical model has been created to forecast the axial compressive behaviour of Glass Fiber Reinforced Polymer (GFRP) columns using Finite Element software (FEM). The energy absorption capacity and stiffnesscharacteristics are determined in this investigation. This study involves 12 specimens of height 500 mm and diameter 200 mm with different thickness. The significance of different thickness on the axial compressive behaviour of GFRP Tube columns has been studied. The static and non-linear loading analysis is done the specimen. The results proved that the mechanical strength of GFRP tube columns is 30% higher than conventional concrete columns.

Keywords: GFRP tube, fiber reinforced polymer, axial compression, analytical model, tension, compression, energy absorption capacity, flexibility, concrete columns.

1. INTRODUCTION

Fibre reinforced plastic (FRP) is using widely in the industry of Civil Engineering and Technology. FRP encased concrete system was developed as a new structural component for masonry building and heritage structures. FRP can reduce the cost, time and minimise the work and manpower. In recent years it is also using as the rehabilitation material for strengthening the concrete material. FRP is very good in compression and tension, it is an environmentally friendly material with super strong and having good bonding capacity and it is a corrosion resistant material. FRP is 80% better than steel in which FRP has the least expansion and contraction with heat or cold stress. Additional research should be carried out under different load conditions such as bending and axial costs for bonding and lateral loads [1]. The results of a one-way test show that the addition of GFRP raw material to the absorptioncapacity of the energy of the particular monotonous tone is up to 487.5%. This prompted the initiation of experimental and analytical studies on the dynamic response of this absence to load exposure with the promise of excellent reaction and absorption of energy due to the added value of the GFRP tube to increase the energy required to cause damage to the sample by increasing the coefficient ratio of 1.2% and 2.4% respectively [2]. The use of FRP tubes for the confinement of the square and rectangular FRP tube can also improve the heat conduction of the shaft when the strength of the FRP tube supply is increasingly high. The radius of the tube angle has a significant impact on the performance of square and rectangular tubes FRP and increases the effect in the corner radius; in addition, the radius edge directly affects the tangent curve [3]. FRP sealed concrete raw materials can be recommended in conjunction with FRP rods to increase both fibre and thermal elasticity under eccentric axial compression as an alternative to steel RC column in areas where steel rod corrosion problem is large [4]. The FRP polystyrene composite displays low tensile strength and module, but it shows a significant drop in terms of tensile strain error than the conventional glass and carbon composites FRP, the size and scale ratio depends on the strength of the traditional point on the test cylinder [5]. Dimension and proportion measurements are not enough to affect the final force, the tension at the point of transition and variety of recent times, heterogeneous porous, natural, low strength and fragility of coral aggregates causing the failure of brittle cracks, reefs damaged by the dirty microcracks, for the aggregates of local microcracks, due to such damage, uneven ring distribution occur in compression injections and the effect of the confinement decrease [6]. Analysing the models using North American and Canadian codes ACI 440.2R-08, CSA-S6-06, and CSA-S806-02 [7]. FRP hybrids are usually small and susceptible because FRP materials have high strength and rigidity of steel reinforced concrete pillars, the results of an individual test for axial compression of a solid 7 hybrid columns displays levels 4 to 36 [8]. This thesis presents the procedure and conclusion of the testing of twelve GFRP concrete columns with and without reinforced specimens under axial and byan analysis of results and detailed outline conservation of energy absorption capacity are also presented.

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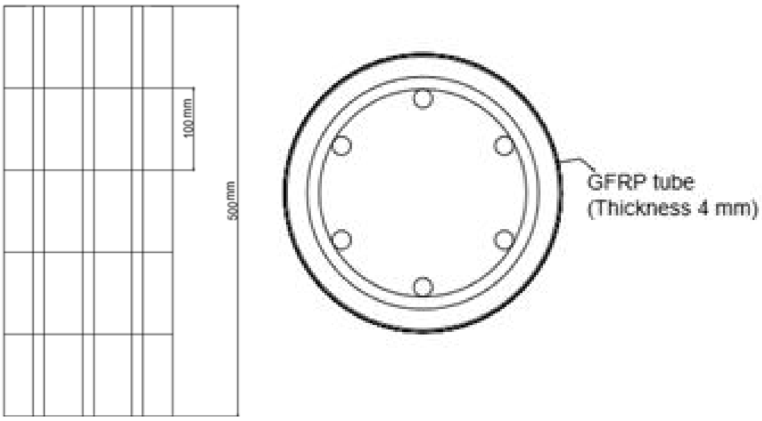

Figure-1. Specimen's reinforcement setup.

2. FINITE ELEMENT STUDY

Analytical study has been carried out to examine the influences of various thicknesses on the axial compressive behaviour of GFRP tube with and without reinforced columns. The Auto cad diagram of the GFRP model is shown in the above Figure-1. Analytical research was done using Finite element software (FEM). This product executes conditions that oversees the conduct all things considered and fathom them. These outcomes can be classified or can be displayed in graphical structures. The limited component strategy is a computational method and is utilized to get estimated arrangements of limit esteem issues. The limit condition expected and the heap is connected to the best surface of the GFRP segment which is appropriated over the full width of the segment. Precision of the outcomes in the limited component show relies on the limited component work, constitutive material model and limit conditions. Different segments, for example, GFRP tube, concrete; reinforcement bars are fit utilizing part by part premise as opposed to utilizing the global factor.

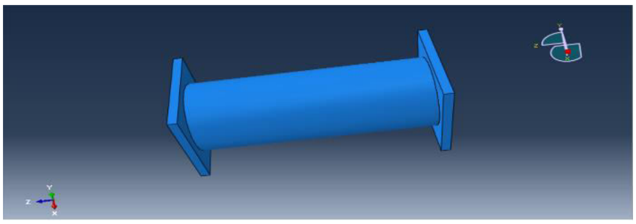

Figure-2.1. Full-scale model of GFRP tube column.

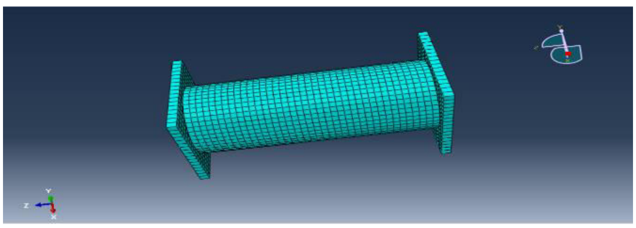

Figure-2.2. Generated mesh.

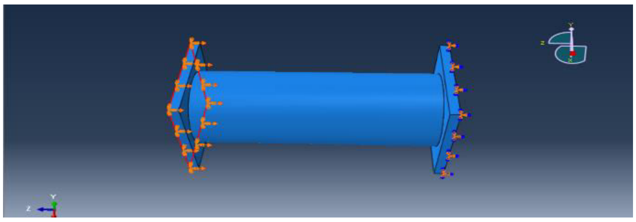

Figure-2.3. Loading Conditions.

According to the ACI 440.3R the manufacturing of FRP tube is manufactured and the manufactured report is shown in the Table-1 [10]. The initial test for GFRP is performed using ASTM D3039 and ASTM D7205, with the help of these two code books the Coupon test is performed on the GFRP tube [9]. ACI 440.2R-08 used for construction and design of FRP [11]. Various types of GFRP tube thicknesses used is 2 mm and 4 mm and 200 mm diameter are used in the present FEM study. The finite element model with lengths of 500 mm has been analysed to find the deflection parameters.

Table-1. Details of Geometry of GFRP tube.

Element	Description	Value
GFRP	Orientation angle	0°
	Height, mm	500
	Shape	circular
	Diameter of concrete cylinder, mm	200
	Process adopted	Hand layup
	Tensile strength, Mpa	30,000
	Ultimate tensile strain, Mpa	800
	Resin	Epoxy

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Table-2. Details of Geometry of composite elements.

Element	Description	Value
Concrete	Grade	M30
	Height, mm	500
	Shape	circular
	Diameter of concrete cylinder, mm	200
Steel	Number of main rods	6
	Depth, mm	500
	Spacing between main rod, mm	82
	Stirrup spacing, mm	100

3. ANALYTICAL PROGRAM

The parameters associated with the examination comprise of variety in the range length in which distinctive measurement of diameter. Concrete cylinder and the GFRP tube were modeled using four-node linear rectangular elements. Circular reinforcement were created using three-dimensional element. Contact between various parts was modeled using interaction and constraint options that represent the actual contact behaviour in test specimens. Surface to surface interaction were used to model the contacts between steel reinforcement, concrete and GFRP tube. The analysis study of the column is carried out with the material properties as mentioned earlier and the load-deflection curves was obtained for various parameters. A three- dimensional model has been proposed in which all the structural parameters associated with nonlinearities are included.

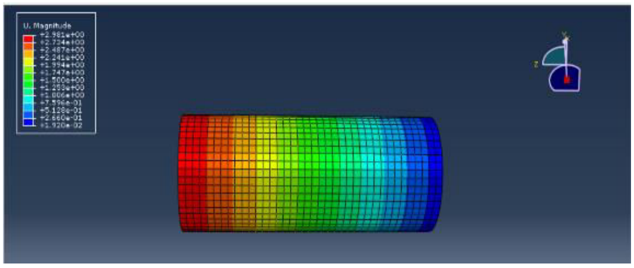

Figure-3.1. Deformed isolated GFRP tube model with and without reinforcement.

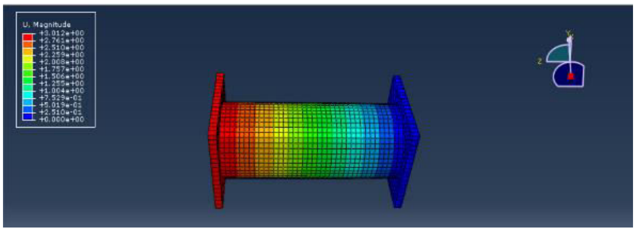

Figure-3.2. Deformed integrated GFRP full model with and without reinforcement.

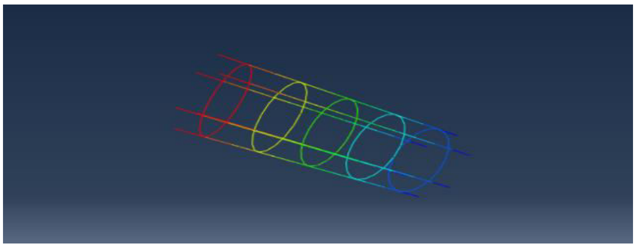

Figure-3.3. Deformed reinforcement model.

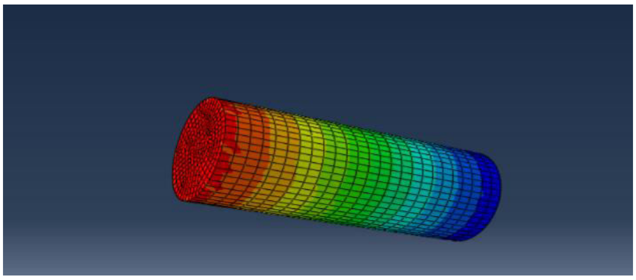

Figure-3.4. Deformed concrete model.

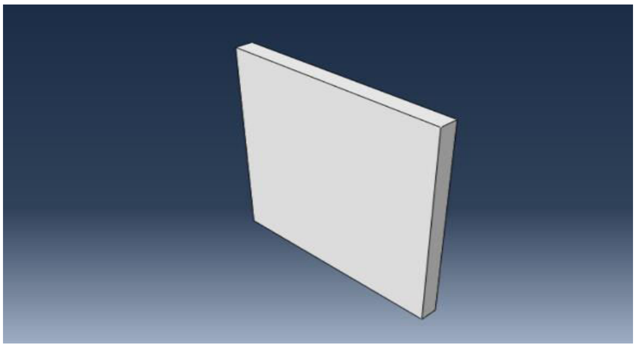

Figure-3.5. Steel plate model.

4. PROCEDURE

The modelling is done using finite element software, the components created in the software is 1) steel plates 2) GFRP tube with different thickness3) concrete cylinder 4) reinforcement. The models are created in two different thickness and the properties of GFRP tube is shown in the Table-1 according to the coupon test and manufactured report and for composite elements the properties are mentioned in the Table-2. The steel plate is created with 20 mm thickness of 300 mm square plate as shown in the Figure-3.5. GFRP tube is created with the properties mentioned in the Table1 and the dimensions of the tube is taken with different diameters and length as a constant and these tubes are mentioned with the different name according to the thickness and diameter variation shown in the Table-3, the model is shown in Figure-3.1. The circular cage reinforcement is created with 6 rods of 12 mm diameter and with the stirrup spacing of 100 mm shown in the Figure-3.3. Meshed model is shown in Figure-2.2. Contact between various parts was modeled using interaction and constraint options that represent the actual contact behaviour in test specimens. Surface to surface interaction were used to model the contacts between steel

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reinforcement, concrete and GFRP tube. The loading condition taken in this thesis is axial compression shown in Figure-2.3. The analysis study of the column is carried out with the material properties as mentioned earlier and the load-deflection curve was obtained for various parameters. A three- dimensional model has been proposed in which all the structural parameters associated with nonlinearities are included. The Table-3 and Table-4 states the results of the different types of diameters with presence and absence of reinforcement in the column with various thickness with different names in order to identify easily. Individual name has been given to the each and every specimen as described below, the term GFRP refers to the name of the specimen and 2A and 4A refers to 2 mm and 4 mm thickness of specimen A, B, C. The CCWOR refers to conventional concrete without reinforcement and CCWR refers to conventional concrete with reinforcement.

Table-3. Initial crack formation of GFRP concrete specimens without reinforcement.

S. No	Specimen	Length (mm)	Diameter (mm)	Thickness (mm)	L/d	D/t	Crack (kN)
Without Reinforcement							
1.	GFRP - 2A	500	200	2	2	100	1753
2.	GFRP - 2B	500	195	2	2.56	97.5	1720
3.	GFRP - 2C	500	190	2	2.63	95	1705
4.	GFRP - 4A	500	200	4	2	50	2800
5.	GFRP - 4B	500	195	4	2.56	48.75	2720
6.	GFRP - 4C	500	190	4	2.63	47.5	2624
7.	CCWOR - A	500	200	-	2	-	880
8.	CCWOR - B	500	195	-	2.56	-	880
9.	CCWOR - C	500	190	-	2.63	-	880

Table-4. Initial crack formation of GFRP concrete specimens with reinforcement.

S. No	Specimen	Length (mm)	Diameter (mm)	Thickness (mm)	L/d	D/t	Crack (kN)
With Reinforcement							
1.	GFRP - 2D	500	200	2	2	100	940
2.	GFRP - 2E	500	195	2	2.56	97.5	930
3.	GFRP - 2F	500	190	2	2.63	95	910
4.	GFRP - 4D	500	200	4	2	50	3726
5.	GFRP - 4E	500	195	4	2.56	48.75	3652
6.	GFRP - 4F	500	190	4	2.63	47.5	3541
7.	CCWR - A	500	200	-	2	-	2498
8.	CCWR - B	500	195	-	2.56		2397
9.	CCWR - C	500	190	-	2.63	-	2357

The above two Tables 3 and 4 refer the various speciments with different names and diameters as mentioned. The CCWR refers to Conventional concrete with reinforcement and the diameters are classified with various alphbeticals. The CCWOR refers to conventional concrete with reinforcement in the concrete columns. In this investigation we are comparing the results of GFRP tubes encased concrete columns of with and without reinforcement with conventional with and without reinforcement specimens, and the formation of initial crack in different diametes are listed. The results of different thickness are shown with the respective graphs in the results part.

5. RESULT AND DISCUSSIONS

Load-deflection curves obtained for different specimens with various diameter and thickness are shown in Figures 4 and 5 and the conventional specimen graph obtained with the same size and diameter with and without reinforcement is illustrated in Figure-5. In the below graph GFRP- 2D is having better results when comparing to remaining GFRP 2 mm thickness tubes in with reinforcement case and GFRP-2F is having the least result.

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In 4 mm thickness GFRP-4D is having good results and GFRP - 4F is having least results in with reinforcement test results. From the above Table-4 GFRP- 2A is having good results and GFRP- 2C is having least results, and in 4 mm thickness GFRP- 4A is having better result and GFRP-4C is having the least results. The comparison of GFRP tubes with different specimens are shown in the Figure-4 and Figure-5 as given below.

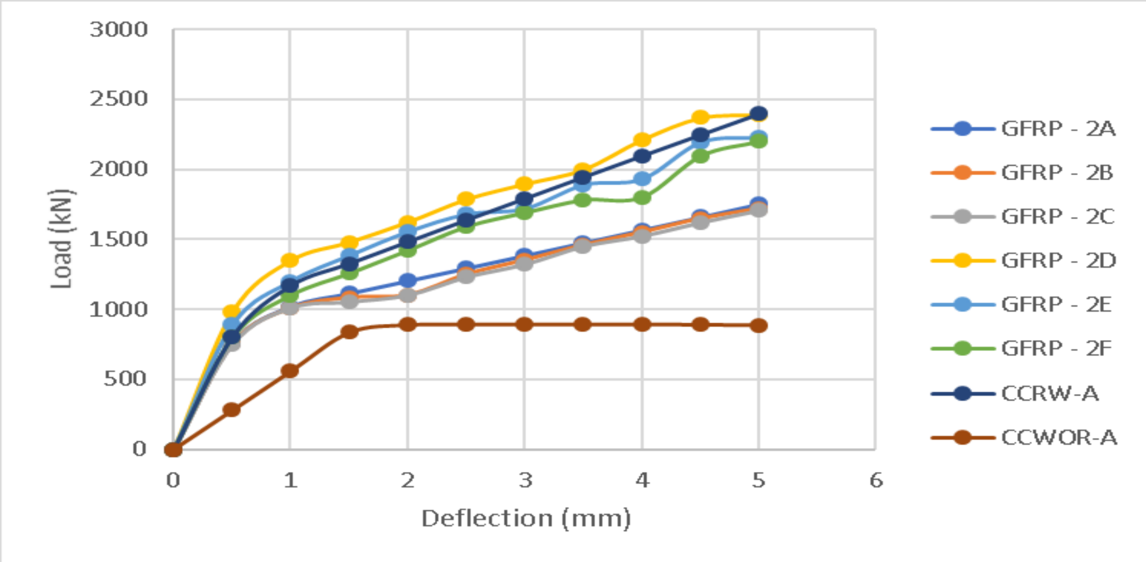

Figure-4. Load vs Displacement curves of GFRP with and without reinforcement of 2 mm thickness with conventional specimens

The above graph refers comparison of 2mm thickness of GFRP tube column encased with and without reinforcement. Here, there are three types of diameters were taken with numerical and alphabetical terms of 200 mm with tube length of 500 mm. The initial cracks formed at different loading conditions are shown in the Table-4. The static loading and axial compression test is done on the above three different diameter tubes. From the above eight specimens the more energy absorption and stiffness is carried out by GFRP - 2D.

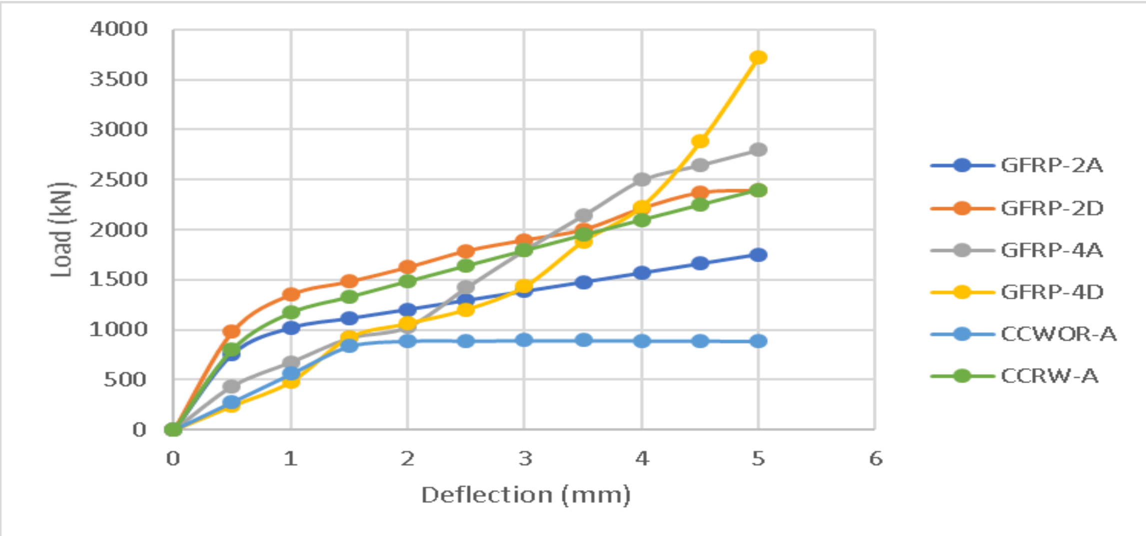

Figure-5. Load vs deflection curve of 2mm & 4mm thickness GFRP tube of with and without reinforcement.

The above graph refers with 2 and 4 mm thickness of GFRP tube column encased with and without reinforcement. Here, two types of different thickness and conventional specimens were taken with diameter of 200 mm with tube length of 500 mm. The initial cracks formed at different loading conditions are shown in the Table-4. The static loading and axial compression test is done on the above different specimens. Comparing the above six specimens, GFRP - 2D specimen exhibits more energy absorption and stiffness. Comparing GFRP-2D and CCWR-A, GFRP- 2D is 16.5% higher than CCWR-A and GFRP-2A is 49.80% higher than CCWOR- A. Comparing

GFRP- 4Dand CCWR-A, GFRP- 4D is 32.95% higher than the CCWR-A and GFRP-2B 32.95% higher than CCWOR-A. Comparing GFRP- 2D is 5.3% higher than the CCWR-B and 48.38% higher than the CCWOR-B. Comparing GFRP- 4E and CCWR-B, GFRP-4E is having GFRP-4B 34.83% higher than the CCWOR-B, GFRP- 4B is having 67.64% higher than CCWR-B. Comparing GFRP-2F and CCWR-C, GFRP-2F is having 3.6% higher than CCWR-C and 48.38% higher than CCWOR-C. GFRP-4F and conventional grade of CCWR-C GFRP-4F is having 33.4% higher than the CCWR-C and GFRP-4C 66.46% higher than CCWOR-C.

CONCLUSIONS

A numerical investigation is carried out to compare the axial compression behaviour of FRP Tubes Encased Concrete Columns with and without reinforcement in which the result obtained is as discussed below:

- In this research there is no much difference in load taking with different diameter change.
- The maximum load carrying capacity of GFRP tube column without reinforcement of 2 mm thickness obtained is 1753 kN.
- The maximum load carrying capacity of GFRP tube column with reinforcement of 2 mm thickness obtained is 940kN.
- The maximum load carrying capacity of GFRP tube column with reinforcement of 4 mm thickness obtained is 3726 kN.
- The maximum load carrying capacity of GFRP tube column without reinforcement of 4 mm thickness obtained is 2800kN.
- The deflection obtained is less for 4 mm GFRP is to 1.6 mm compared to 2 mm.
- Of the two thickness with reinforcement considering, 4 mm tube is having the optimum strength compared with 2 mm and conventional concrete and having good energy absorption capacity and stiffness.
- As the diameter of the tube increases, deflection got significantly reduced.

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