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Comparative Study of Concrete Filled Steel Tubes and R.C.C. Column under Axial Compression

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ABSTRACT

In this paper, experimental study have been conducted to study the behavior of self-compacting Concrete Filled Steel Tube CFST stub columns strengthened by Glass Faber Reinforced Polymer GFRP and CFST Columns strengthened by GFRP laminates .A total of 42 stub columns under monotonic compression load were tested in order to discover the best configuration of the GFRP for confined column system, Fourteen specimens with circular cross-sections 50 mm Diameter and another Fourteen specimens with square cross-sections 70X70 mm, Fourteen specimens with Rectangular cross-sections 95X95X50 mm and having thickness of each specimen is 3 mm. The experimental results indicated that the use of GFRP laminates to strengthen the GFST has a significant effect on the overall behavior of GFST such as enhancement on its strength. Also, the GFRP confinement delays local buckling of steel tube, prevents a sudden strength reduction caused by the local buckling of the steel tube, and increases lateral confinement of the concrete core. It is found that the best configuration of GFRP tubes system is transverse CFRP tube for circular hollow steel tube columns. Finally, from experimental investigation we have conducted that by using GFRP laminates strength has been increase consider ability for CFST columns and R.C.C columns.

Key words: GFRP, GFST, CFRP, CFST, RCC

INTRODUCTION

In the Concrete Filled Steel Tube Structural System high-strength concrete is used for filling steel tubes. These members are ideally suited for all applications because of their effective usage of construction material. In this type of composite members, the advantages of both hollow structural steel and concrete is utilized. CFST having excellent static and earthquake resistant properties and due to which, they are being used widely in real civil engineering projects. Concrete filled steel tubes possess properties such as high strength, high ductility and large energy absorption capacity. When these types of composite members are used as structural columns, especially in high-rise buildings, CFST may be subjected to high shearing force as well as moments due to wind or seismic actions. Therefore it is very important to study the behaviour of CFST columns in axial compression.

From many research studies it is observed that it gives mechanical and economic benefits when high strength concrete infill is used, which contributes greater damping and stiffness to CFST columns compare to normal strength concrete. Due to high strength concrete infill, CFST columns require a smaller cross section to withstand the load, which is appreciated by architects and building engineers. Local buckling is delayed due to interaction between concrete and steel tube and this is the main advantage of CFST, along with which steel tubes provided sufficient confining effect to concrete. The enhancement of CFST column in structural system is due to composite action between steel and concrete. The steel tube itself acts as longitudinal and transverse reinforcement. The shell also provides confining pressure to the concrete, which puts concrete under tri-axial state of stress, and concrete infill increase the stiffness of column, which prevents the inward buckling of steel tube, and increases the stability and the strength of column system, resulting in higher flexural strength. Therefore, tubes with thinner walls could reach the yielding strength before local buckling.

Under axial compression, the steel tube confines the concrete, therefore improves both axial load resistance and ductility of CFST members. Steel tubes were also used as permanent formwork and the well distributed reinforcement located at most efficient position. Due to large shear capacity of concrete filled steel tubular members, they predominantly fail in flexure in a ductile manner. Confinement effectiveness may be reduced to bit if rectangular or square tubes are filled up with high strength concrete but it provides advantage against flexure.

The advantage of CFST columns in construction is reduces the material and labour cost related with formwork and steel reinforcement. The concrete core can act to increase the stiffness and compressive strength of the hollow steel tube and to delay local buckling. The hollow steel tube acts as concrete reinforcement, resists bending moments and shear forces, and confines the concrete thereby increasing ductility.

Composite construction incorporates the adverse property of steel which has high tensile strength and ductility with the concrete having high compressive strength, excellent fire resistance and low cost. The composite construction is very often adopted in super high-rise building, long span bridges and roof structures owing to its high structural efficiency with large strength to weight ratio as well as large flexural rigidities against instability and serviceability problems. Among the composite members, the composite column is gaining importance because of its wide applications over bridge piers subjected to impact from traffic, column supporting storage tanks, columns in high rise buildings, railway decks, piles and offshore structures.

1.1 Problem Statement

The concrete filled steel tubular column plays an eminent role in the construction industry owing to its structural behaviour like large deformation and energy absorption capacity. But these members get deteriorated due to the environmental effects like corrosion and ageing. The external strengthening of using fibre reinforced polymer FRP material is emerging as a new trend in enhancing the structural performance of CFST members to counteract the drawbacks in using the past rehabilitation work. Strength and ductility gain in concrete is obtained by many confinement parameters e.g., compressive strength of concrete

1.2 Objective

1. To design concrete Mix design for M20, M30 grade.
2. To study concrete filled steel tubes CFST under axial compression loading.
3. Comparative study of concrete filled steel tubes with and without FRP.
4. Comparative study of concrete filled steel tubes with RCC column.

1.3 Scope of project

This gives a brief introduction to behaviour of concrete filled steel tube column under axial compression. It includes the comparative parametric study of square, circular and rectangular column with varying grades of concrete M20, M30 for their load carrying capacity and deformation. We are focusing on FRP the best main advantage of FRP is that it reduces corrosion as compare to CFST columns.

1.4 Description of project

The project present experimental study, a total of Nine square section, Six circular section ,Ten rectangular are to be tested. These specimen were cast with circular shape, rectangular shape, square shape. The complete load-deflection behaviour and strength of column specimen were obtained and result were discussed in the study. In addition the column specimen were analysed on an experimental result.

Table No. 1 Sizes of columns

Section	Title		
	RCC Column	**CFST Column**	**CFST with FRP**
Rectangular	95×50×300 mm	95×50×300 mm	95×50×300 mm
Circular	60 mm Dia.	60 mm Dia.	60 mm Dia.
Square	70×70×300 mm	70×70×300 mm	70×70×300 mm

LITERATURE SURVEY

This includes the review of different papers of different authors published earlier, related to the topic was done for understanding the subject in a better way. These papers include experimentation as well as theory studied by the authors related to strengthening of concrete filled tube column.

Theoretical and experimental investigations show that behaviour of hollow CFST elements was more complicated than that of solid ones, because of complex stress states none of stresses in hollow concrete core were evenly distributed through the thickness of its cross-sections. For single-layered CFST elements the triaxial stress state was achieved only at the contact surface between the concrete core and steel shell. An internal hollow concrete core of double-layered CFST elements was in the same stress state as of single-layered members, but an external layer was analysed as being in 3D stress state**.**(A. Kuranovas et.al)The deformation of the column was decreasing 10-15 percentage with increasing grade of concrete. The deformation was influenced by the shape of the CFST section. The circular section leads to better behaviour than square section due to better confinement. He concluded the deformation was in circular section was 20-25 percent smaller compared to square section. This was because circular section takes confining effect better than square section. The equivalent stress value becomes constant after achieving its ultimate strength. Deformation decreases with increasing grade of concrete, but for higher grades of concrete decreasing in deformation was less. Stress concentration was more at the edges of square column while in circular column, due to confining effect, stress concentration was equal throughout the whole section. (D. Shah et.all)

The HCFST columns subjected to bi-axial eccentric loading failed to work because of instability and showed a certain degree of ductility. The ultimate bearing capacity of HCFST subjected to bi-axial eccentric loading resulted from analysing with finite element software ABAQUS shows good agreements with the test data the numerical method was verified to be reliable in predicting the load versus deformation relationships. The simplified formula was used to calculate bearing capacity of the test specimens, and the calculation results agree well with test data. (Guo Chang Li.et.al 4)

The failure modes and bearing capacity of four connections were obtained from experimental results, which offer the basis of the structural design. The separation angle of the connections will result in different failure modes. Corner separation connection needs to be reinforced appropriately to adhere to the seismic design principle “stronger connection, weaker components” which was defined by current codes. Experimental results can be substantiated to be correct and usable by comparing to the FEA results. Finally, the obliquely crossing connections were verified necessary to design with good lateral confinement.(H.Chao.et.al, 5) A Finite element analysis was carried out to find buckling strength of Hollow Steel Tube and CFST structures. Hollow Steel Tube and CFST members were mainly used in columns of multi-story structures, bridge piers, earthquake resisting structure and other industrial applications. Initially both Hollow Tube and CFST geometries were built. Buckling analysis was carried out in both Hollow Tube and CFST domain. The stresses were very high in the small slenderness ratio of Hollow Tube region and for nonlinear analysis the stresses were very less in the high slenderness ratio of CFST. The results show the Hollow Tube buckling load carrying capacity less compared to the CFST buckling loads. Also, graphical plots were represented to find effect of thickness, diameter, and slenderness ratio on stress and buckling strength estimates. (K. Raghu.et.al. 6)

The use of CFRP laminates to strengthen the CFST has a significant effect on the overall behaviour of CFST such as enhancement on its strength and ductility. Self-compacting concrete (SCC) was an innovative concrete that does not require vibration for placing and compaction. Also, the CFRP confinement delays local buckling of steel tube, prevents a sudden strength reduction caused by the local buckling of the steel tube, and increases lateral confinement of the concrete core. It was found that the best configuration of CFRP tubes system was transverse CFRP tube for circular hollow steel tube columns, circular plain concrete columns, circular concrete filled steel tube columns and square plain concrete column with a percent of increase in ultimate load of (31.1%, 254.3%, 43.4%, and 101%) respectively, and longitudinal in the square CFST column confining pressure was high at the corners.(N. Alwah.et.al. 8) Most design engineers have treated the CFST system as an alternative to the steel system, trying to cut the cost by reducing the steel consumption. However, it was also possible to look at the CFST system as an alternative to the reinforced concrete system. In this study, three-dimensional finite element models have been developed to investigate the force transfer by natural bond and the interaction between the steel tube and the concrete core of concrete-filled steel tubes under loading. (S.Kurian.et.all 11)

EXPERIMENTAL PROGRAM

In this experimental work, it is aimed to evaluating compressive strength of reinforced cement concrete column and concrete filled steel tube column with and without FRP. For this purpose mix design of M20 and M30 is prepared and for that following process is followed:

3.1. Procurement of Materials:

Batching:

Is the process of measuring concrete mix ingredients either by volume or by mass and introducing them into the mixture. Traditionally batching is done by volume but most specification required that batching be done by mass rather than volume. Percentage of accuracy for measurement of concrete materials as follows.

Cement:

Cement used for casting of specimen was ordinary Portland cement of 53 grade. The cement was used in standard bags. The specific gravity of cement was determined and found to be A cement is a binder, a substance used for construction that sets, hardens and adheres to other materials, binding them together. Cement is seldom used on its own, but rather to bind sand and gravel aggregate together. Cement is used with fine aggregate to produce mortar for masonry, or with sand and gravel aggregates to produce concrete.

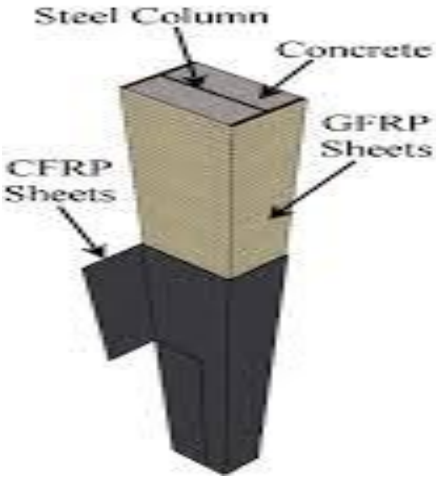
Water:
The water used for mixing and curing the concrete is the potable water from the tap. The pH of water used in mixing was 7.

Fine aggregate:
These aggregates were passed through 4.75mm sieve. The fine aggregate used for entire specimen was river sand. The specific gravity of fine aggregate used for concrete was determined and found to be 2.7. Aggregates are inert granular materials such as sand, gravel or crushed stone that are an end product in their own right. They are also the raw materials that are an essential ingredient in concrete.

Aggregates, which account for 60 to 75 percent of the total volume of concrete, are divided into two distinct categories--fine and coarse (know more about this in the next section). Fine aggregates generally consist of natural sand or crushed stone with most particles passing through a 9.5mm sieve. Fine aggregates generally consist of natural sand or crushed stone with most particles passing through a 3/8-inch sieve. Fine aggregate is natural sand which has been washed and sieved to remove particles larger than 5 mm.

Coarse aggregate:
The coarse aggregate used in the mix was crushed sand. 10mm size of aggregate was stored in separate dust proof containers. The specific gravity of coarse aggregate was determined and found to be 2.7.Those particles that are predominantly retained on the 4.75 mm sieve and will pass through 3-inch screen, are called **coarse aggregate.** The coarser the aggregate, the more economical the mix. Larger pieces offer less surface area of the particles than an equivalent volume of small pieces. Use of the largest permissible maximum size of coarse aggregate permits a reduction in cement and water requirements. Using aggregates larger than the maximum size of coarse aggregates permitted can result in interlock and form arches or obstructions within a concrete form. That allows the area below to become a void, or at best, to become filled with finer particles of sand and cement only and results in a weakened area.

GFRP:
“Glass Fiber reinforced polymers" or GFRP are a demonstrated and successful option that have various favourable circumstances over conventional reinforcement methods, giving structures a more drawn out service life. Glass Fiber Reinforced Polymers are for all time impervious to chemical acids and alkaline bases; subsequently additional concrete cover, cathodic protection, and anti-shrink additives are not needed. GFRP essentially enhances the life span of engineering structures where corrosion is a major consideration. The present project work is experimental oriented and requires preliminary investigation in a systematic way. The detailed testing on each material of column is carried out.

	
Fig.no.1 GFRP sheet	**Fig. No.GFRP Sheet Wrapping**

RESULT AND DISCUSSION

Testing on R.C.C columns

Shape of specimen	**M20**	**M30**
Rectangular	103.30 KN	123 KN
	82.55 KN	113.33 KN
	92.00 KN	119.10 KN
Square	77.30 KN	126.00 KN
	85.13 KN	102.89 KN
	105.10 KN	115.56 KN
Circular	123.37 KN	131.17 KN
	118.15 KN	129.54 KN
	132.78 KN	140.20 KN

Testing on CFST columns without FRP

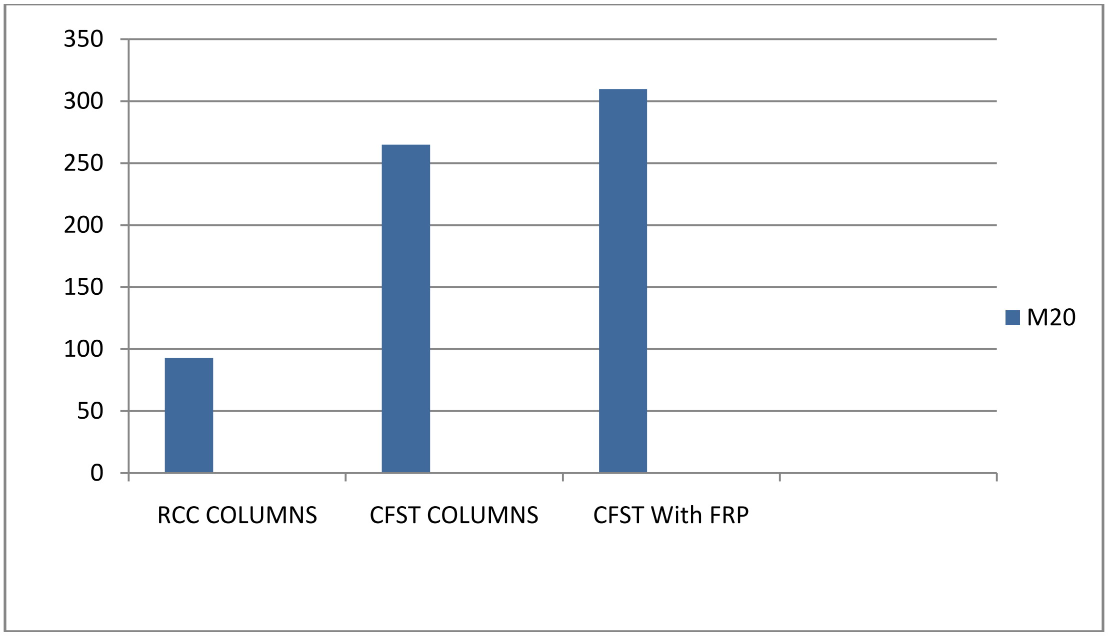
Shape of specimens	**M20**	**M30**
Rectangular	256.70 KN	279.15 KN
	267.80KN	282.34KN
	273.10 KN	286.60 KN
Square	283.95 KN	309.55 KN
	289.05KN	294.07KN
	295.10 KN	284.70 KN
Circular	332.00 KN	323.45 KN
	328.06 KN	331.13 KN
	329.80 KN	335.75 KN

Testing on CFST columns with FRP sheet

Shape of specimens	**M20**	**M30**
Rectangular	309.85 KN	314.35 KN
Square	342.00 KN	336.05 KN
Circular	362.18 KN	382.10 KN

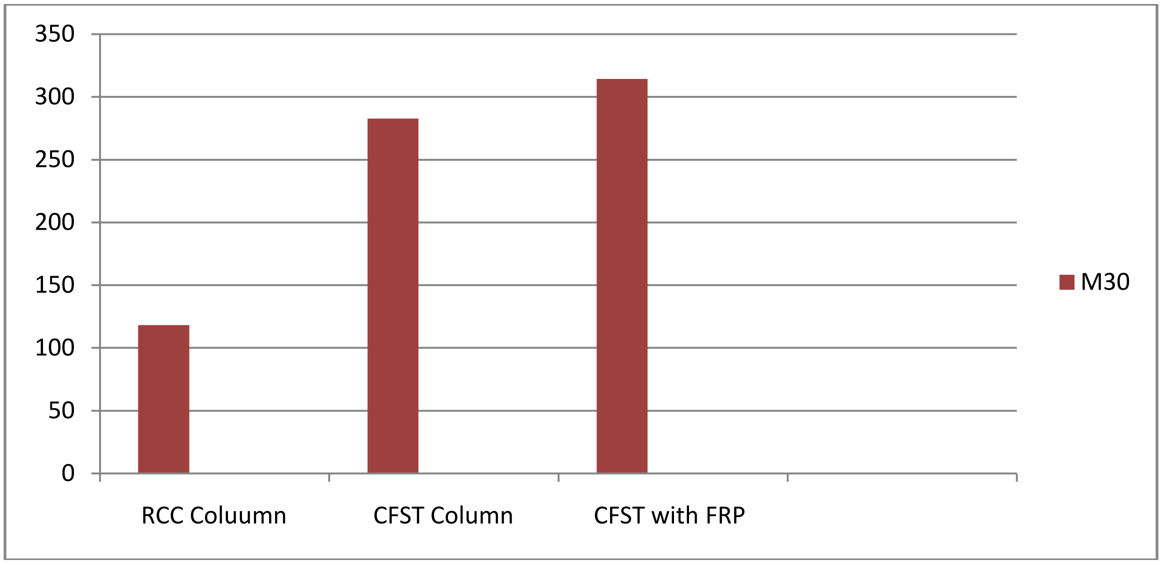
RECTANGULAR SPECIMENS
Specimen Shape: Rectangular
Specimen Type: RCC, CFST without FRP, CFST with FRP
Grade of Concrete: M20



Graph No. 1 Rectangular section M20

Observation:
It is observed that the load carrying capacity of CFST column without FRP is increased by **96.66%** and with FRP it is increased by **107.95%**.as compared to RCC columns.

Specimen Shape: Rectangular
Specimen Type: RCC, CFST without FRP, CFST with FRP
Grade of Concrete: M30

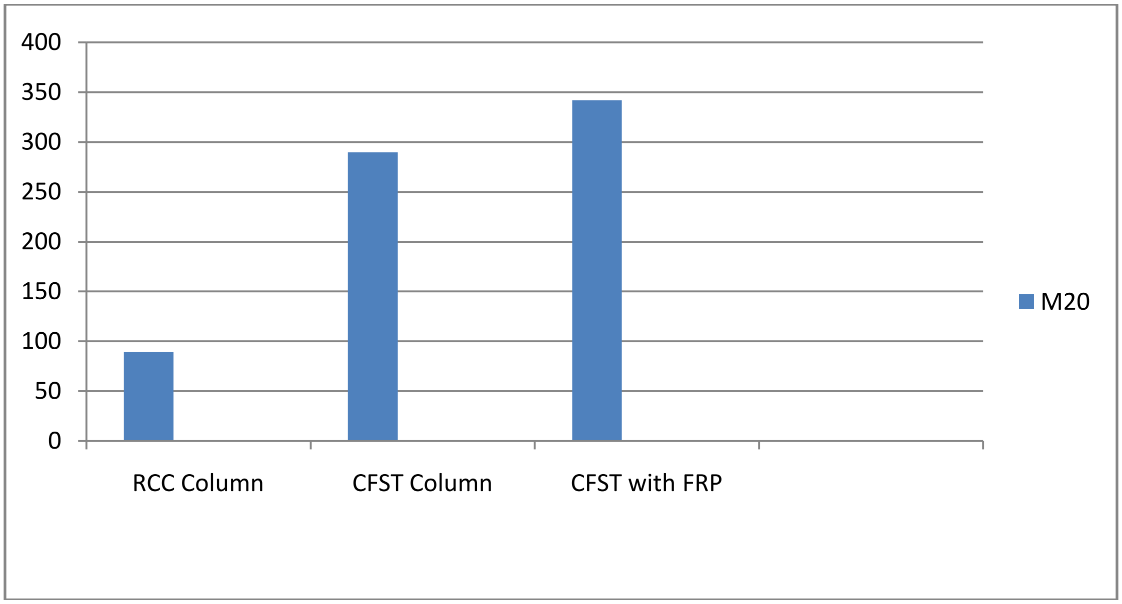


Graph No. 2 Rectangular section M30

Observation:
It is observed that the load carrying capacity of CFST column without FRP is increased by **81.87%** and with FRP it is increased by **90.51%**.as compared to RCC columns.

SQUARE SPECIMENS

Specimen Shape: Square
Specimen Type: RCC, CFST without FRP, CFST with FRP
Grade of Concrete: M20

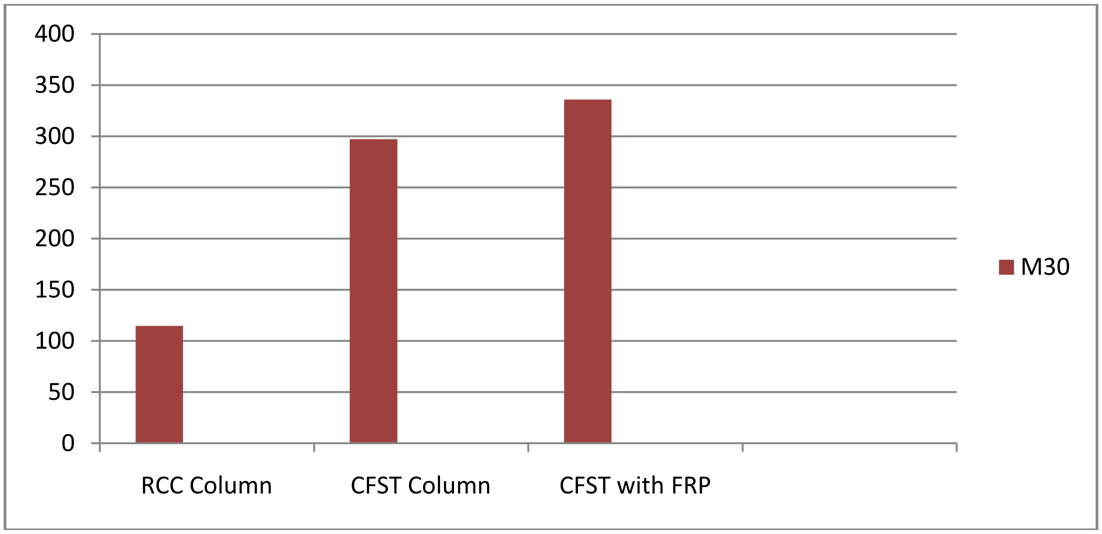


Graph No. 3 Square section M20

Observation:

It is observed that the load carrying capacity of CFST column without FRP is increased by **105.77%** and with FRP it is increased by **117.27%**.as compared to RCC columns.

Specimen Shape: Square
Specimen Type: RCC, CFST without FRP, CFST with FRP
Grade of Concrete: M30



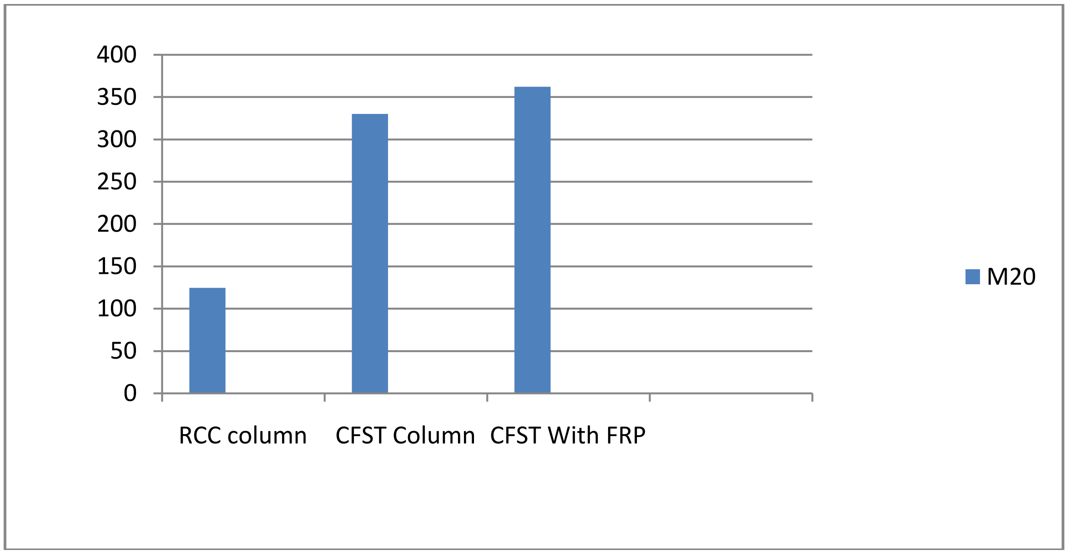
Graph No.4 Square section M30

Observation:

It is observed that the load carrying capacity of CFST column without FRP is increased by **88.23%** and with FRP it is increased by **98.14%**.as compared to RCC columns.

CIRCULAR SPECIMENS

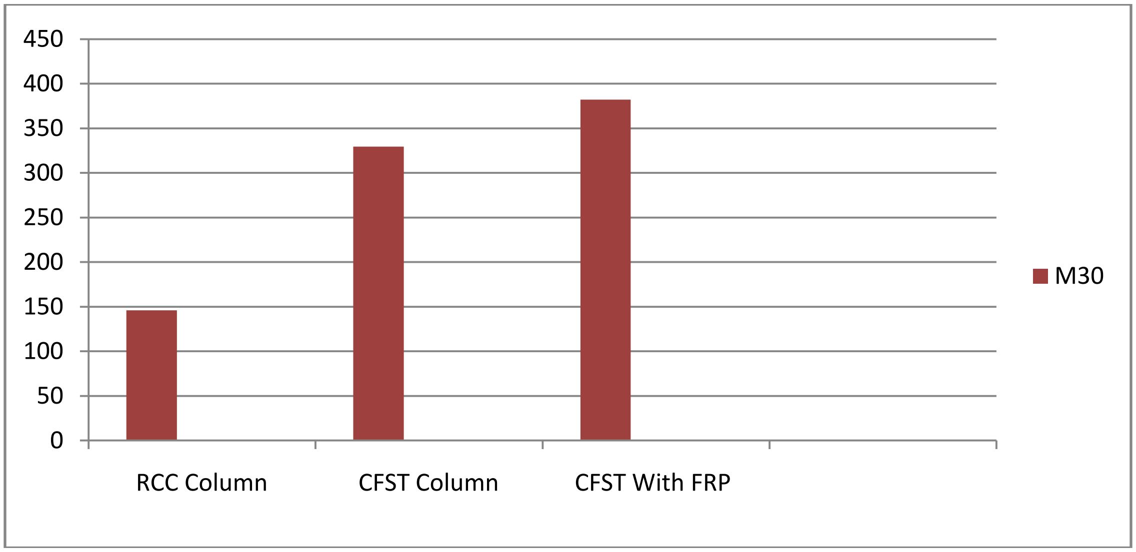
Specimen Shape: Circular
Specimen Type: CFST without FRP, RCC, CFST with FRP
Grade of Concrete: M20



Graph No. 5 Circular section M20

Observation:
It is observed that the load carrying capacity of CFST column without FRP is increased by **90.25%** and with FRP it is increased by **97.51%**.as compared to RCC columns.

Specimen Shape: Circular
Specimen Type: RCC, CFST without FRP, CFST with FRP
Grade of Concrete: M30



Graph No. 6 Circular section M30

Observation:
It is observed that the load carrying capacity of CFST column without FRP is increased by **84.73%** and with FRP it is increased by **96.35%**.as compared to RCC columns.

CONCLUSION

1. It is observed that the load carrying capacity of M20 grade concrete Rectangular CFST column without FRP is increased by 96.66% and with FRP it is increased by 107.95%.as compared to Rectangular RCC columns.
2. The load carrying capacity of M30 grade concrete Rectangular CFST column without FRP is increased by 81.87% and with FRP it is increased by 90.51%.as compared to Rectangular RCC columns.
3. The load carrying capacity of M20 grade concrete Square CFST column without FRP is increased by 105.77% and with FRP it is increased by 117.27%.as compared to Square RCC columns.
4. The load carrying capacity of M30 grade concrete Square CFST column without FRP is increased by 88.23% and with FRP it is increased by 98.14%.as compared to Square RCC columns.
5. The load carrying capacity of M20 grade concrete Circular CFST column without FRP is increased by 90.25% and with FRP it is increased by 97.51%.as compared to Circular RCC columns.
6. The load carrying capacity of M30 grade concrete Circular CFST column without FRP is increased by 84.73% and with FRP it is increased by 96.35%.as compared to Circular RCC columns.
7. The weather reaction on CFST column can be controlled by thick layer of GFST sheet & also GFRP sheet the strength of column get increased also life of column increases.

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