

Axial Performance of Geopolymer Concrete Infilled Steel Tubes

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ABSTRACT: Concrete filled steel tubular members has wide structural applications as they are a composite structural members. In present study total 24 concrete filled steel tubes were casted and tested for compression and flexure. CFST casted in two series 1 and 2 of varying L/D ratio of 2.5 and 3.5 respectively and constant D/t ratio of 50 as per the limits of EC4 and ACI 318. For infilling concrete, fly ash based geopolymer concrete and conventional concrete was used for M₂₅ grade. 12 hollow steel tubes of series 1 and 2 were separately tested and they shows significant results as expected. Results of CFST shows that L/D ratio of 2.5 will be a most feasible section as they show better strength parameters among all others. Also GPC based CFST will be a promising composite structural member for construction sector as GPC is an eco-friendly and economical alternative for OPC.

KEYWORDS: CFST, Geopolymer concrete, Compression, Flexure.

I. INTRODUCTION

Concrete filled steel tubular (CFST) members has better advantages of both steel and concrete. They composed of a steel hollow section of any shape like circular or rectangular shape filled with plain type or reinforced type of concrete. They are widely used in high-rise and multistory buildings as columns and beam-columns, and as beams in low-rise industrial buildings where a robust and efficient structural system is required. There are a number of distinct advantages related to such structural systems in both terms of structural performance and construction sequence. The prominent buckling problem related to thin-walled steel tubes is may be either prevented or delayed due to the presence of the concrete core. Furthermore, the performance of the concrete in-fill is improved due to confinement effect exerted by the steel shell. The distribution of materials in the cross section also makes the system very efficient in term of its structural performance. The steel lies at the outer perimeter where it performs most effectively intension and bending. It also provides the greatest stiffness as the material lies furthest from the centroid. This, combined with the steels much greater modulus of elasticity, provides the greatest contribution to the moment of inertia. The concrete core gives the greater contribution to resisting axial compression. The use of concrete filled steel tubes in building construction has seen resurgence in recent years due mainly to its simple construction sequence, apart from its superior structural performance. Typically, it was used in composite frame structures[1].

Sustainable advancement in concrete leads the role as it may hamper or damage the environment. For sustainable development geopolymer concrete is one of the best alternative for ordinary Portland cement which causes the carbon dioxide emission in a very harsh manner. To reduce this damage GPC is introduced. As GPC produced mainly from fly ash or GGBFS which are the byproducts or waste products of coal and steel power plant respectively, it reduces the major dumping problem for both of the product and can be effectively used. Geopolymer concrete replaces entire cement content to fly ash or ground granulated blast furnace slag. For polymerization process it needs to add alkaline activators in the mixture.

In present study hollow and concrete infilled circular sections are tested for both compression and flexure. Study used conventional concrete as well as geopolymer concrete as a filling. Total 24 concrete infilled circular steel sections were casted. Along with CFST, hollow steel tubes were tested.

II. PREVIOUS STUDIES OF CFST

Research has been carried out to find sustainable concrete infilled steel tubular members. Subhan Ahmad et al. investigated the axial performance of GGBFS concrete filled steel tubes and tested fifteen circular CFST which were filled with concrete having partial replacement of GGBS. The study concluded that axial capacities of GGBFS concrete filled CFST were higher than that of control mix [1]. Zhong Tao et al. studied Compressive Behavior of Geopolymer Concrete-Filled Steel Columns at Ambient and Elevated Temperature. The study investigated the GPC and control mix

CFST at normal and elevated temperature and concluded that mechanical properties of both the type of concrete filled CFST were similar [2]. Xin Yu et al. Studied Effect of different types of aggregates on the performance of concrete-filled steel tubular stub columns. The experimental results demonstrate the feasibility of using steel slag and/or waste glass to replace partial or all concrete aggregates; the novel composite columns have similar and in some cases even better structural behavior compared with normal CFST columns.[3]. Subhash V. Patankar et.al.studied Mix Design of Fly Ash Based Geopolymer Concrete. They designed fly ash based M_{30} concrete mix and also other mixes[4].

III. OBJECTIVES OF THE STUDY

- I. To evaluate axial performance of geopolymer concrete infilled steel tubes.
- II. To evaluate axial performance of geopolymer concrete filled steel tubes.
- III. To evaluate most feasible CFST section.

IV. LIMITATION OF THE STUDY

The study only compares among circular CFST sections and not with any other shape.

V. MATERIAL STUDY

Steel tubes were casted in two series. Series 1 and 2 having L/D ratio of 2.5 and 3.5 respectively having outer diameter 100 mm and thickness of tubes was 2mm. Length of series 1 was 250mm and of series 2 was 350mm. Total 36 specimens were tested for flexure and compression out of 12 were hollow sections[1].

A. Fly Ash

It is also called as fuel ash or pulverized fuel ash. Class F-Fly ash was collected from JINDAL coal power plant in Ratnagiri district at place Jaigad. Class F- this type is pozzolanic in nature, less than 7% lime, can form geopolymer.

Class C- In this type in addition to having pozzolanic properties, is has self-cementing properties too.



Fig. 1.Fly Ash

B. Activators

Alkaline solution like NaOH, KOH –alkaline hydroxides and Na_2SiO_3 , K_2SiO_3 – alkaline silicates required to bind the polymer material like fly ash and GGBFS.



Fig. 2.Some Alkaline Activators

C. Conventional concrete material

OPC of 53 grade was from local market was used. For fine aggregate use of natural river sand and for coarse aggregate use of crushed/ angular aggregates was done. All the properties of materials were listed in the table.

Table 1. Specification of materials

Specification	Specific gravity	Water absorption	Zone
Fine aggregate	2.30	1.06%	II
Coarse aggregate	2.78	3.06%	II
Cement	3.15	-	-

VI. CASTING AND TESTING OF CFST

Mild steel tubes were used for this project having diameter 100mm and thickness 2mm. GPC and conventional concrete placed in the cylindrical tubes by usual methods. Tamping was done by tamping rod. Then the specimens were cured. For GPC based CFST 60⁰C oven curing was applied for 24 hours and for conventional concrete water curing was done. All the concrete mixes were designed for M₂₅ grade as per IS specifications [4].

**Fig.3.** CastedCFST**VII. RESULTS AND DISCUSSIONS**

Concrete density and slump values were listed.

Table 2. Properties of concrete

Mix	Slump	Density
CC	90	22.70
GPC	85	21.85

A. Compression behavior

Compression testing was done on a CTM of 3000KN capacity. Hollow steel tubes bear relatively smaller load as compared to CFST. Previous studies regarding the geopolymer concrete indicates that compressive strength of specimen increases with increase in ages. Also the molarity of alkaline solution i.e. sodium hydroxide shows significant effect in compressive strength. As molarity increases compressive strength increases. Concrete mixtures can be designed to provide a wide range of mechanical and durability properties to meet the design requirements of a structure. The compressive strength of concrete is the most common performance measure used by the engineer in designing buildings and other structure. The compressive strength is measure by breaking cylindrical concrete specimens in a compression-testing machine. The compressive strength is calculated from the failure loaddivided



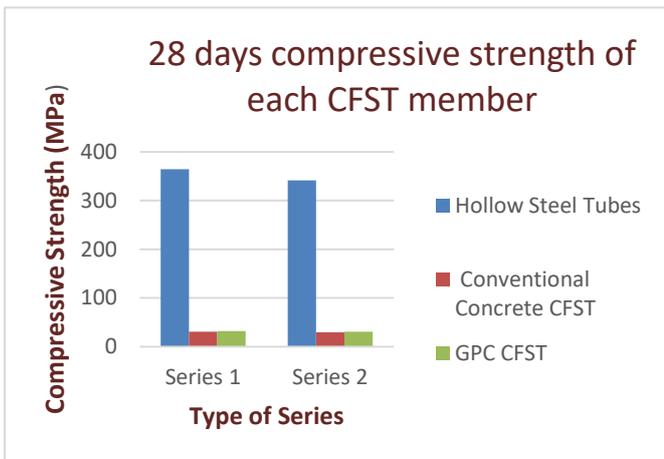
by the cross-sectional area. Concrete is primarily meant to withstand compressive stresses. CFST were placed in the middle of testing area and gradually loading was done. Failure mode and failure loads were noted and corresponding compressive strengths of each CFST were noted.

Table 3. 28 days compressive strength of CFST

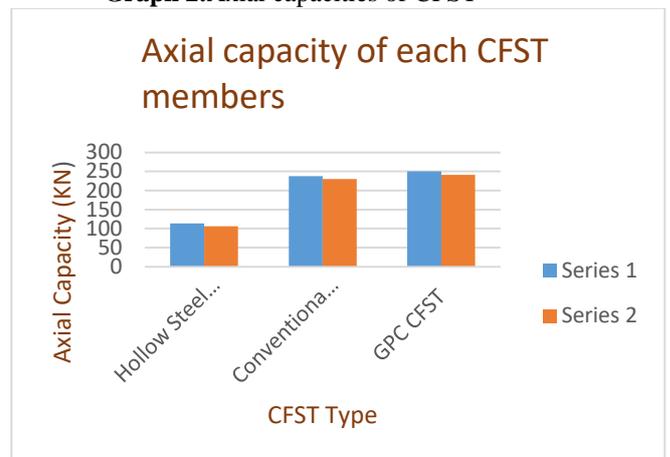
Specimen	Type	L Mm	D mm	Comp. strength MPa
Series 1	Hollow steel	250	100	364.38
	CC	250	100	30.28
	GPC	250	100	31.84
Series 2	Hollow steel	350	100	341.298
	CC	350	100	29.27
	GPC	350	100	30.68

CC- Conventional concrete GPC- Geopolymer concrete

Graph 1. Graphical representation of strength



Graph 2. Axial capacities of CFST



B. Flexural behavior of CFST

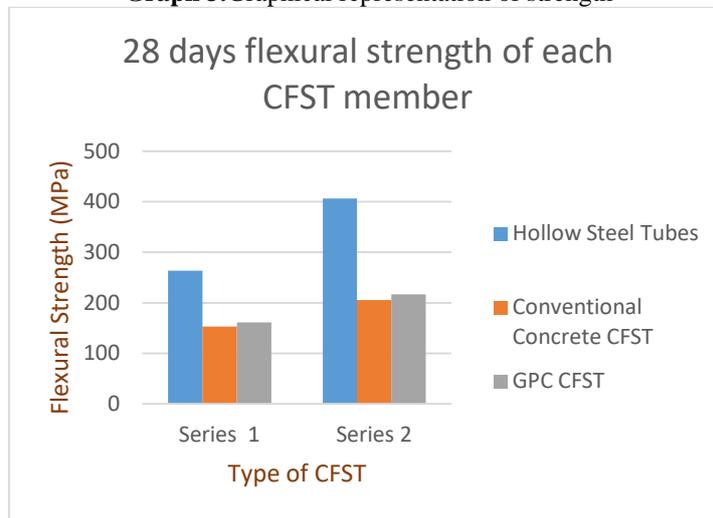
According to ASTM C293 center point loading i.e. three point bending method was applied for flexural testing of circular tubes. Specimens were tested at UTM of 400KN capacity. From the test results graphs showing flexural strengths of different CFST specimens were plotted and observed that CFST specimens showed better results as compared to the hollow sections. L/D ratio also had significant impact on flexural strength.



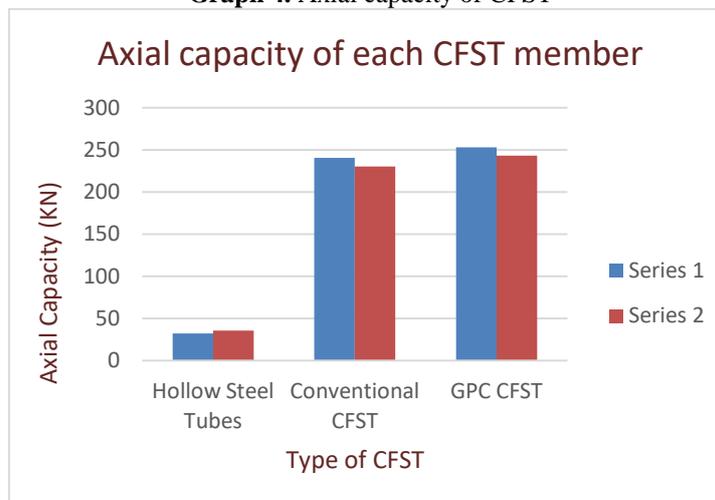
Table 4. 28 days flexural strength of CFST

Specimen	Type	L Mm	load KN	Flexural strength MPa
Series 1	Hollow steel	250	32.15	820.209
	CC	250	240.60	153.193
	GPC	250	253	161.089
Series 2	Hollow steel	350	35.35	1129.34
	CC	350	230.36	205.343
	GPC	350	243.35	216.92

Graph 3. Graphical representation of strength



Graph 4. Axial capacity of CFST



VIII. FAILURE PATTERN

Application of load resulted in the deformation of CFST specimens. When the load increased nearly up to the ultimate load, a clear crackingsound was audible and local buckling was observed on the surface of the columns. All the specimens exhibited similar local/outward folding failure due to the bulging of concrete. Generally, the failure mode

was not found to be influenced by the type of concrete. Hollow steel tubes also failed when load increased to ultimate load.



Fig.4 Behavior of CFST after testing

IX. CONCLUSION

Following conclusions can be summarized from the experimental programme conducted.

1. Steel sections obviously showed the better axial strength but carried relatively smaller axial load in both compression as well as flexural testing.
2. CFST having geopolymer concrete infilled showed slightly greater results than conventional concrete infilled CFST, so GPC infilled CFST can be effectively used as the structural members.
3. CFST member having 2.5 L/D ratio showed better compressive strength than that of 3.5 L/D ratio.
4. Circular steel sections with L/D ratio of 2.5, infilled with GPC having 13 Molarity of NaOH solution results in the better section out of all CFST sections.
5. GPC showed slightly similar workability as conventional concrete, also densities of both types of concrete showed some similarity
6. Geopolymer concrete is the best economical and environmental friendly alternative for the OPC leads to the larger amount of CO₂ emission material in the concrete industry

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