Experimental Study on High Performance Concrete Filled Tubular Short Columns

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Abstract:

Concrete filled steel tube structural system is based on filling steel tubes with concrete. The CFST structural system promots excellent structural characteristics, like strength, deformation capacity, and fire resistance for use in many fields of construction. Composite columns composed of concrete filled steel tubes have become increasingly popular in structural applications around the world. This type of columns can offer many advantages like high strength, ductility and large energy absorption capacity with possible use of simple standardized connections. The main aim of my project is to manufacture the normal M20 mix and nano silica CFST, steel fibre CFST and geo polymer concrete filled steel tubular columns under compression.

The strength improves by adding the some other material and admixtures. In preparation of nano silica CFST, cement, sand, coarse aggregate, water, nano silica, fly ash are used. The cement replaced with 10% nano silica, 30% fly ash. In preparation of geo polymer CFST, cement, sand, coarse aggregate, water, paper pulp, polypropylene are used. Sand replaced with 20% paper pulp, 20% polypropylene. Another one steel fibre CFST, cement, sand, coarse aggregate, water, steel fibre, robo sand are used. Sand replaced with 20% steel fibre, 20% robo sand. This paper presents an experimental study on different materials filled in steel tubular short columns axially loaded in compression test results and the failure mode of columns.
Keywords:-CFST Column, Nano silica CFST, Steel fibre CFST, Geo polymer CFST.

I. INTRODUCTION

1.1 Concrete Filled Steel Tube Columns

A concrete filled steel tube (CFST) column comprises steel hollow section of circular shape filled with plain concrete. The steel member shows high tensile strength and ductility on the other hand, concrete member having the advantages of high compressive strength and stiffness. If steel concrete member is designed to utilize these structural properties of both materials efficiently, than the steel concrete composite member exhibits the advantageous qualities of both materials.

1.2 Types of Concrete Filled Column

There are two main categories of composite columns, namely the concrete encased and the concrete filled columns. Encased composite column consists of structural shapes surrounded by concrete. The concrete requires vertical and horizontal bar reinforcement to sustain the encasement of the steel core. Shear connectors may be needed as well to ensure interaction and transfer between the steel shape and the concrete encasement. Filled composite columns may be the most efficient application of materials for column cross sections. Their steel shell can be a pipe or tubing or hallow section fabricated from plates. It provides forms the inexpensive concrete core and increases the strength and the stiffness of the column.

According to shapes of column.

- Circular
- Rectangular
- Square

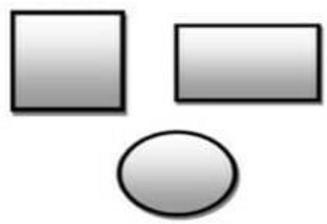

Fig.1.Section of Concrete Filled Steel Columns.

Encased column

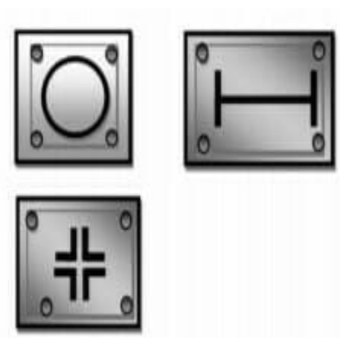

Fig.2.Section of Encased Columns.

1.3 Nano Silica, Steel Fibre and Geo Polymer Concrete

Concrete made up of cement, sand, coarse aggregate and water is brittle in nature and has some significant disadvantages. Such as low tensile and flexural strength, poor deformability and weak crack resistance in the practical usage.The tubular columns are filled with normal M20 and replaced concrete different materials of Nano silica concrete a composite material consisting of cement, sand, coarse aggregate, water and 10% nano silica, 30% fly ash which is replaced in cement. Nano silica are used to increase durability and crack resistance. In preparation of steel

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fibre concrete cement, sand, coarse aggregate, water and 20% Steel fibre and 20% robo sand which is replaced with sand. Fibres are used generally to improve the strength, ductility, post cracking resistance, toughness etc. In another sample Geo polymer concrete is 20%of polypropylene and 20%paper pulp is replaced in sand. Steel fibres (metallic fibre) and polypropylene fibre (non metallic) when added to concrete improves its properties.

1.4 Objective

- Study the load carrying capacity of steel tube columns in filled with different concretes under compression.
- Compare the compressive load capacities of normal M20 mix and nano silica CFST, steel fibre CFST and geo polymer CFST.
- The effect of steel confinement to columns and compare the failure patterns.

1.5 Literature Review

Er.Surya Ravindran, Er. Afia S. Hameed(2016), A concrete filled steel tube CFST column comprises steel hollow section of circular or rectangular cross section filled with plain or reinforced concrete. Steel confinement helps to reduce column size and confined columns posses excellent earthquake resistance and fire resistance properties. M30 design mix concrete amalgamated with 0.75% steel fibre and 0.5% polypropylene fibre was chosen as hybrid fibre reinforced concrete (HFRC) which is used as an in fill material for CFST columns. A total of 8 column specimens comprising of two normal RCC column and seven concrete filled steel box columns are tested. The paper presents an experimental study on hybrid fibre reinforced concrete filled steel tube (HFRCFST) short columns axially loaded in compression failure. Result shows that in a CFST column the steel tube acts as longitudinal and lateral reinforcement for the concrete core and play an important role in increasing the compressive strength up to 85%. Failure of CFST columns was due to local buckling of the steel tube.

Babita Kirodiwal, prof. G.R. Patil(2017), concrete filled steel tube structural system is a system based on filling steel tubes with concrete. The CFST structural system promises excellent structural characteristics, like high strength, deformation capacity, and fire resistance for use in many fields of construction. Composite columns composed of concrete filled steel tubes have become increasingly popular in structural applications around world. This type of columns can offer many advantages like high strength, ductility and large energy absorption capacity with possible use of simple standardized connections. In these days possibility to produce concretes with higher compressive strengths allows the design of more slender columns, while permits more usable floor space. The aim of my project is to improve the current knowledge of the mechanical behaviour of CFST columns to make a more efficient. In this study, different types of geometrical shapes of CFST are considered. A great deal of theoretical and experimental work has been carried out on selected sample of columns.

Richard Liew.,J.Y et al.,(2014),investigated the behaviour of tubular short columns in filled with ultrahigh strength concrete ambient and elevated temperatures. The tests were conducted for the basic mechanical properties of the high strength materials and structural behaviour of stub columns under concentric compression,beams under moment and slender beam columns under concentric and eccentric compression. High tensile steel with yield strength up to 780 Mpa and ultrahigh strength concrete with compressive cylinder strength up to 180 Mpa were used to construct the test specimens. The test values were compared with the predictions using a modified Eurocode 4. At high temperature, strength reduction in less for ultrahigh strength concrete than normal strength concrete, while more strength reduction is expected for high tensile steel compared to mild steel.

Ehab Ellobody and Mariam F.Ghazy,(2012), investigated plain and fibre reinforced concrete filled stainless steel circular tubular short column under axially and eccentric loading conditions. The column ultimate loads, load axial shortening relationship, load mid height lateral deflection relations and failure modes of the concrete filled stainless steel circular tubular columns were measured. The test ultimate loads were compared with the design ultimate loads calculated using the Eurocode 4 for composite columns. It shown that the Eurocode 4 accurately predicted the ultimate loads of axially loaded concrete filled stainless steel circular tubular columns,but were quite conservative for predicting the ultimate loads of the eccentrically loaded columns. It shown that the Eurocode 4 prediction is increased as the eccentricity is increased. The fibre reinforced concrete filled tubular columns offers a considerable increase in column ductility compared with plain concrete filled tubular columns.

Summary of Literature Review

In case of CFST columns, column capacity was significantly improved due to the concrete strength gained from the confinement provided by the steel tube. From the past studies, it is also evident that the load carrying capacities of CFST columns are more than that of hollow steel tubular columns. It has been proved that the CFST columns are applicable to high rise and long span structures because the system construction efficiency while save construction cost, time and manpower. Otherwise waste materials were utilized as a replacement of fine aggregate or cement in concrete. It is not only reduced the coast of construction but also saved large quantity of normal sand used in construction industry. The highest flexural strength and initial stiffness additions of a small fibre type had a significant influence on the compressive strength.

1.6 Methodology

- Collection of materials
- Fabrication of steel tube
- Mix design for M20 grade concrete
- Placing and pouring the steel tubular short column
- Curing of CFST specimens
- Compression test result

II. PROPERTIES OF MATERIAL

Material testing was conducted to investigate the properties of the material such has cement, fine aggregates, coarse aggregate which are used for casting the specimens various laboratory tests were performed and the test results obtained were compared with Indian standard values. The test results are listed in below tables.

2.1 Cement OPC -53 grades available in local market is used.

Table 1 Properties of Cement

Name of the property	Result	Limit
Specific gravity	3.1	3.15
Fines modulus	5%	<10%
Consistency	33%	30-35%
Initial setting time	25 min	30 min
Final setting time	<10 hrs	24 hrs

2.2 Aggregate

Table 2 Properties of Aggregate

Name of the property	Result	Limit
Fines modulus of fine	2.3	2.6-2.7
Fines modulus of coarse	2.78	6.6-8
Silt content	2.4%	5%
Specific gravity of C.A	2.78	2.5-3
Specific gravity of F.A	2.90	2.6-3

2.3 Polypropylene

Fig.3.Polypropylene

2.4 Nano Silica

- Nano technology is playing a prominent role in modern construction technology. And to Increase bond strength.
- Nano silica has properties like reduction in CO2 emission, reduction in porosity/permeability, increases durability, crack resistance and high strength.

Fig.4. Nano Silica

2.5 Steel Fibre

- Steel fibre is a byproduct in steel manufacturing industries which is used for binding material to the reinforcement bars.
- By addition of steel fibre to the concrete the durability and mechanical properties etc.
- After adding the steel fibre the bonding nature of concrete gets improved and provide greater compressive strength.

Fig.5. Steel Fibre

2.6 Fly Ash

- Fly ash is a fine powder which is a by-product from burning pulverizing coal in electric generation power plants. Fly ash is a substance containing alumina and silica material that forms cement in the presence of water. When mixed with lime and water it forms a compound similar to Portland cement.
- The reduction of cost in project.
- It increase the durability.
- Fly ash has lubricating action with reduce the water content in concrete and reduce the shrinkage.

Fig.6. Fly Ash

2.7 Robo Sand

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- Robo sand is the perfect substitute for river sand. It is manufactured by crushing granite rocks using a 3-stage crusher. It is also called as ‘manufactured sand.
- It is eco – friendly product.

Fig.7. Robo Sand

III. EXPERIMENTAL INVESTIGATION

3.1 Concrete Mix Design

Concrete mix design for M20 was done as per IS 456-2000 and 10262-2009.the mix proportions for M20 mix is given table.

Table.3. Finalized Mix Proportions for M20 Concrete.

SL.NO	Material	Quantity
1	Cement	413.33kg/m^3
2	Fine aggregates	621 kg/m^3
3	Course aggregate	1223.95kg/m^3
4	Water	186
5	Mix proportions	1:1.50:2.96

Steel fibre mix proportion 1:1.60:3.11

Geo polymer mix proportion 1:1.56:3.06

Nano silica mix proportion 1:1.67:3.2

3.2 Test Specimen Details

Failure mechanism of short circular CFST (actual model) to find out the load carrying capacity and failure mechanism of short CFST specimen, compression test is carried out, for that used compression machine. An experimental research has been planned to study the axial compressive behaviour of circular CFST short columns having 150mm*300mm*1mm size filled with different types of concrete mix such as normal M20 mix and nano silica CFST, steel fiber CFST ,geo polymer CFST. The failure of the circular CFT model takes place first at just below mid height with extensive local buckling then spreads to the bottom side. To obtain for concrete mix columns several trails were done by standard compression test.

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Table.4. Details of Test Specimen

SL. NO	Specimen	% of N ano silica	% of Fly ash	%of steel fiber	% of pape r pulp	%of P ol prop ylene	% of Robo sand
1	Normal CFST	0	0	0	0	0	0
2	Nano silica CFST	10%	30%	0	0	0	0
3	Steel fiber CFST	0	0	20%	0	0	20%
4	Geo polymer CFST	0	0	0	20%	20%	0

3.4 Test Set-Up and Test Procedure

The test specimens were placed approximately on the center of the end bearing plates of compression testing machine. Axial load was applied to the column, which is supported at the both ends. These plates were thick enough to ensure a uniform well prepared under the applied load with high of accuracy to ensure the load application to the required positions. The loading was applied from the top plate only keeping the bottom support rigid. Loss of load during the test was ensured by preventing slight movement of the specimen ends by setting the specimen exactly at the center. And initial load was applied to the test specimens and then released prior to testing. In all tests, the load was increased gradually throughout the test until failure.

Fig.8. Test Set Up

IV. RESULT AND DISCUSSION

4.1 CFST Test Result

Axially loaded columns are the one where load acts at the centroid of the column is more against buckling than eccentrically loaded columns. Load bearing capacity of a column also

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depends on the end conditions. Column with a fixed end conditions at both ends are stronger than those having both ends free. The test specimen subjected to axial compressive load and the maximum load taken by each specimen.

In the initial stages of concentric axial loading the CFST columns, both concrete in fill and structural steel will deform longitudinally. Longitudinal stress in the confining tube varies based on the transfer of forces between the concrete and steel. The failure of CFST specimens occurs as the steel reached its capacity. The common modes of failure that have been observed in the columns are local buckling &weld failure.

Table.5. Compression Strength of Different Concrete Mix Cubes

SL.NO	Concrete mix	Average of 7 days N/mm^2	Average 14 days N/mm^2	Average of 28 days N/mm^2
1	Normal	15.82	17.18	19.55
2	Nano silica	16.96	18.07	22.6
3	Steel fibre	16.88	21.23	24.3
4	Geo polymer	15	16.89	17.6

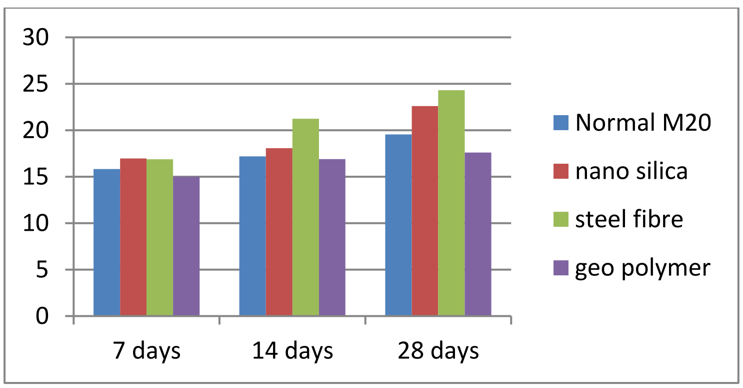

Fig.9. Compressive Strength for Different Concrete Mix Cubes

Table.6. Column Test Result

S.no	Specimen	Designation	Compressive stress N/mm^2

1	Normal CFST	C_1	19.82
2	Nano silica CFST	C_2	25.46
3	Steel fibre CFST	C_3	28.66
4	Geo polymer CFST	C_4	26.87

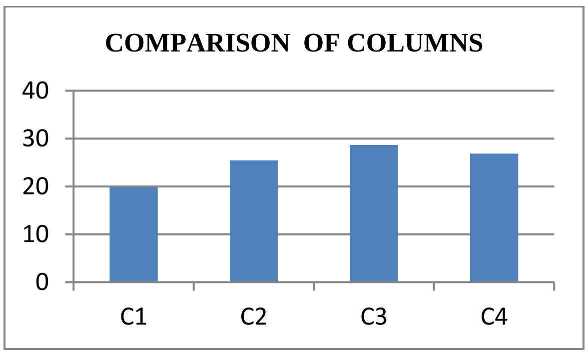

Fig.9. Compression Strength Comparison of Columns

4.2 Failure Modes of Column Specimen

When conventional or normal mix concrete columns are axially loaded, there are different modes of failure for CFST specimens based on their material and geometric configuration. However the most common mode failure of CFST columns was due to local buckling of the steel tube. The concrete infill pavements the steel tube from buckling inward and it forces the steel tube to buckle in an outward direction.

From the analysis of failure modes of CFST columns it was understood that the fibre reinforced concrete in fill has effects on the buckling of steel tube. CFST column infill with steel fibre concrete has more load carrying capacity than normal and geo polymer concrete column.

The common modes of failure that have been observed in the columns are local buckling & weld failure. Failure pattern of column specimens were shown in Fig 9-11 is most of CFST columns have an minor cracks are formed at top and bottom side.

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Fig.9.Weld Failure of Geo polymer **Fig.10.Crack Pattern of Nano Silica**

Fig.11. Failure Pattern of Steel Fibre

V. CONCLUSION

In the present study behaviour of different types of concrete filled steel tubular column has been studied. Concrete filled steel tube (CFST) columns having an L/D ratio 2 in this project.

- It is concluded that the experimental result, the steel fibre concrete filled column has more capacity than the normal, nano silica, geo polymer concrete filled columns. Normal CFST column compression strength is 19.82N/mm^2 by comparing the other columns i.e., nano silica, steel fibre, geo polymer CFST columns compression strength are 25.46N/mm^2,28.66N/mm^2, 26.87N/mm^2.
- It was found that the typical failure mode for all the tested concrete filled steel tubular columns was local buckling & weld failure.
- The steel fibre CFST column strength is slightly more than other concrete mix.

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