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Behavior of Columns with Ferro cement and Steel Tube Confinement under Axial Compression

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Abstract— **Column is the one of the most critical structural element requiring high level of care while designing. It has to carry the axial compressive load and resist moment due to eccentric loading. The following study is about Ferrocement Jacketed Column (FJC) and concrete filled tubular column (CFT) that are recently being adopted due to their various advantages over traditional column sections. In this study, a total of 20 sections of short column sections having circular and square cross section with pure confinement are experimentally tested to obtain the ultimate load carrying capacity of the short column for M40 grade concrete. The section is designed such that the core of the section is 10mm outside the confinement at the top and bottom so as to not load the ferrocement tube or steel tube longitudinally. The sections are to be tested using Universal Testing Machine. The experimental values are compared with the numerically found valued of compressive strength in each section. Also the strain increase due to confinement is analyzed. It was observed that the circular tubes provided more effective confinement as compared to square tubes. The confinement effect was higher for material with higher tensile strength and provided greater increase in load carrying capacity. The strain increase was of the order of 6 to 9 times strain of plain concrete at yield.**

Index Terms— **Triaxial Stress, Hoop stress, Tensile Strength, Confinement**

I. INTRODUCTION

In today's world, India is an developing nation with most of its 125 crore citizens living in villages in very poor condition. It is experiencing rapid economic expansion and many of its village people are expected to migrate to cities for better opportunities. Due to this for a country like India we need economically viable and durable methods of construction for a sustainable growth. Ferrocement provides an economically viable alternative to traditionally used RCC and steel construction. Being a light weight material it can highly reduce the cost of construction of certain structures. It is mostly used in fabrication of slab and wall panels. It cannot be used though in every type of structural element.
This is where steel composites come in, which have high initial cost of construction, but due to its rapid construction rate and high durability, it is cost effective over time. Concrete filled steel tube is one such composite material use to design structural members such as beams and columns.

This study explores the possibility of ferrocement and steel tube as purely confining material in concrete columns.

II. LITERATURE REVIEW

V.M. Shinde et al. (2013) - In this study, the author had made use of ferrocement tube as a outer confinement to a concrete core and analyzed with reference to number of layers and orientation of meshes. The comparison was done between confined and unconfined specimens to find the effectiveness of the confinement on the concrete specimen. By analyzing 30 specimens, the author concluded that the sharp increase in load carrying capacity of confined sections under concentric axial loading were mostly due to dimensional stability improvement and high volume fraction of mesh in the ferrocement composite. Also, the orientation of mesh from 90^o to 45^o provided increased compressive strength to the specimen.

Stephen P. Schneider (1998) - In this paper, the author has done an analytical and experimental study on the behavior of concrete filled steel tubular short columns loaded in uniaxial compression to failure. A total of fourteen Specimens out of which, three were circular, five were square, and six were rectangular steel tube shapes. These specimens were tested to ascertain the effect of shape of steel tube and wall thickness has on the ultimate strength of the composite column. Through experimental analysis, the author determined that the circular tubes provide significant post yield strength and stiffness to the composite section. This was not observed in most of square and rectangular specimens that were tested. Also, in case of square and rectangular tube walls, no significant confinement of inner concrete core was observed beyond the yield load of composite column. It was also observed by author that based on experimental results the currently available design specifications were more than sufficient to accurately predict the value of yield load of the composite section under most conditions for columns of different cross-sections.

III. AIMS AND OBJECTIVES

1. To determine the ultimate load carrying capacity of Ferrocement Jacketed Columns and Concrete Filled Steel Tubular Columns of Circular and Square cross sections for concentric loading.
2. To determine increase in load carrying capacity of Ferrocement jacketed columns and concrete filled steel tubular columns due to confinement effect.

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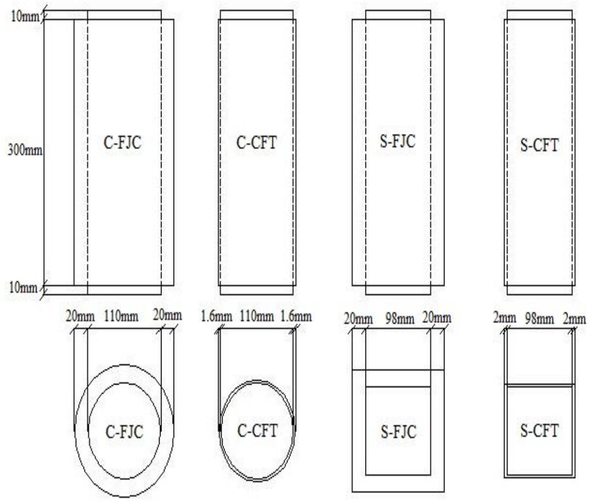

Figure 1 – Cross Section and Longitudinal Section of Each Type of Column Section

3. To calculate the strain increase due to confinement effect as compared to the maximum longitudinal strain of concrete in each type of column sections.
4. To compare the experimental results with the analytically determined values of increase in strength due to confinement in each type of column sections.

IV. Type of Specimens

In this study, four types of column sections are fabricated with 5 specimens of each to be tested. The four types of column sections and the standard concrete cube tested are as follows-

1. Pure Concrete Cube (CC)
2. Circular Ferrocement Jacketed Column (C-FJC)
3. Circular Concrete Filled Steel Tubular Column (C-CFT)
4. Square Ferrocement Jacketed Column (S-FJC)
5. Square Concrete Filled Steel Tubular Column (S-CFT)

The depth of core of all 4 types of column specimens was increased by 10mm at top and bottom to achieve pure confinement in the outer jackets without any influence of longitudinal load on lateral strength of the tube.

The pure concrete cube was standard cube of size 150mm x 150mm x 150mm tested at the age of 28 days.

The ferrocement tubes for Circular Ferrocement Jacketed Column (C-FJC) and Square Ferrocement Jacketed Column (S-FJC) were precast and cured for 15 days before the core was filled. The thickness of ferrocement tubes was kept at 20mm with 2 layer mesh in case of circular as well as square sections. The mesh had a thickness of 1.6mm and spacing of 20mm.

The steel tubes used in Circular Concrete Filled Steel Tubular Column (C-CFT) and Square Concrete Filled Steel Tubular Column (S-CFT) were of MS steel and the thickness was based on the availability in market. The circular tube with thickness of 1.6mm whereas the square tube with thickness of 2mm were used in experimental program. the dimensions of core of each section was taken such that, the cross sectional area of all section is comparable.

The cross section and longitudinal section of 4 types of column specimens are displayed in figure 1.

V. Numerical Approach

Based on properties of concrete and by making certain assumptions, a theoretical model for strength gain due to pure confinement was prepared for circular and square ferrocement jacketed columns. The theoretical model by Y. Sun was used to predict the strength gain due to confinement by steel tubes. All the formulae are based on the compressive strength of concrete and tensile strength of confining tube. The formulae are listed below for each type of section-

Circular Ferrocement Jacketed Column-

$$\sigma = fcc + 5 \times \frac{fx\ max}{\left(\frac{R^2+r^2}{R^2-r^2}\right)}$$

Square Ferrocement Jacketed Column-

$$\sigma = fcs + 10 \times \frac{fx\ max \times t^2}{br + b(b+r)}$$

Circular Concrete Filled Steel Tubular Column-

$$\sigma = \left[1 + \frac{8.2\left(\frac{D}{t}-1\right)}{\left(\frac{D}{t}-2\right)^2}\frac{f_y}{f_{cc}}\right] f_{cc} \quad \text{(Y. Sun, 2008)}$$

Square Concrete Filled Steel Tubular Column-

$$\sigma = \left[1 + \frac{46\left(\frac{B}{t}-1\right)}{\left(\frac{B}{t}-2\right)^2}\frac{t}{c}\frac{f_y}{f_{cc}}\right] f_{cs} \quad \text{(Y. Sun, 2008)}$$

Table 1 Experimentally Obtained Properties of Column Specimens

Sr. No.	Notation Used	Type of Section	Experimental Average Compressive Strength	Numerical Compressive Strength	Average Stain of Section at Failure	Average Modulus of Elasticity
1	CC	Pure Concrete Cube	42.3	-	0.002	32519
2	C-FJC	Circular Ferrocement Jacketed Column	54.01	56.39	0.0125	3754
3	C-CFT	Circular Concrete Filled Steel Tubular Column	69.68	72.08	0.015	4845
4	S-FJC	Square Ferrocement Jacketed Column	40	44.2	0.0088	4555
5	S-CFT	Square Concrete Filled Steel Tubular Column	52.86	47.19	0.0118	4854

Where,
σ - Compressive Stress
f_{cc} - Compressive Strength of Standard Concrete Cylinder
f_{cs} - Compressive Strength of Standard Concrete Cube
f_y - Yield Strength of Steel Tube
$f_{x\ max}$ - Tensile Strength of Ferrocement Element
R - Outer Radius of Circular Ferrocement Tube
r - Inner Radius of Circular Ferrocement Tube
b - Inner Width of Square Ferrocement Tube
t - Thickness of Confining Tube
h - Depth of Confining Tube
D - Diameter of Steel Tube
B - Outer Width of Steel Tube
C - Unsupported Length of Steel Tube
Experimental Approach

Figure 2 Expreimental Setup of Column Specimens

For experimental analysis, each section was placed in the UTM and deflection needle was fitted to measure longitudinal deflection. Steel cover-plates were used to
ensure the load is distributed on the entire loading surface of the test section. The compressive test was carried out by applying concentric axial compressive load on the test specimens and taking down deflection readings at every incremental load of 2 tonnes. The section was loaded until failure and few reverse readings were also taken to see how strain increases post yielding. The setup of circular ferrocement jacketed specimen is shown in figure 2.

VI. RESULTS AND DISCUSSIONS

As can be seen in Table 1, the experimental value of compressive strength of Circular Ferrocement Jacketed Column in axial compression is higher by a factor of 1.6 times the characteristic strength of standard concrete cylinder which is taken as 80% of standard cube strength. Also it was found to be very close to the analytically found value with a difference of 4.36%. The average value of strain at yield for C-FJC column is 0.0125 which is 6.25 times larger than the normal strain at yield of 0.002 in concrete. This means the column allows large deformation in longitudinal direction without failure. The average modulus of elasticity of C-FJC column is 3754 MPa which is 1/8.66 times that of concrete which was found to be 32519MPa numerically.

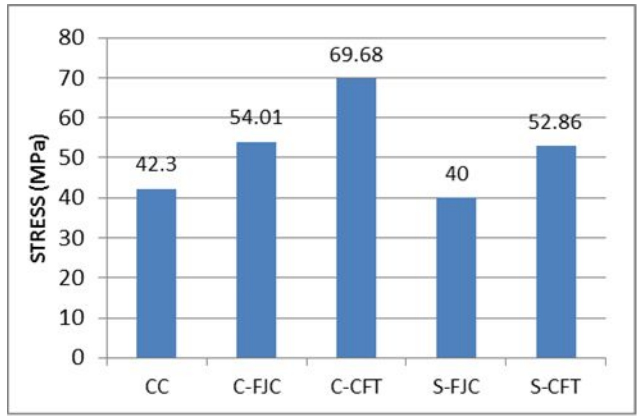

Figure 3 Comparative Compressive Strength of Each Type of Column Specimen

As can be seen in Table 1, the experimental value of compressive strength of Circular Concrete Filled Steel Tubular Column in axial compression is higher by a factor of 2 times the characteristic strength of standard concrete cylinder which is taken as 80% of standard cube strength. Also it was found to be very close to the analytically found value with a difference of 3.44%. The average value of strain at yield for C-CFT column is 0.015which is 7.5 times larger than the normal strain at yield of 0.002 in concrete. This means the column allows large deformation in longitudinal direction without failure. The average modulus of elasticity of C-CFT column is 4845 MPa which is 1/6.71 times that of concrete which was found to be 32519MPa numerically.

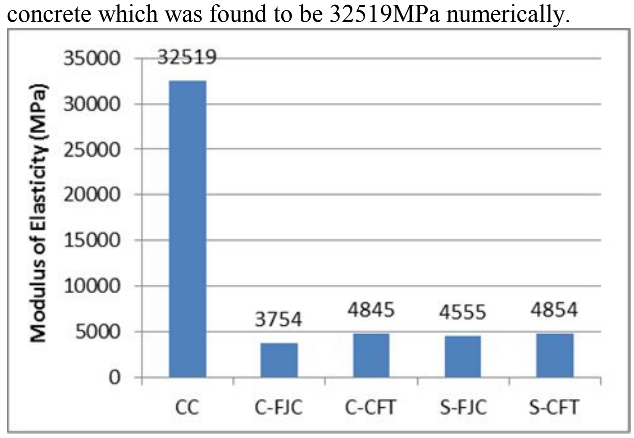

Figure 4 Comparative Modulus of Elasticity of Each Type of Column Specimen

As can be seen in Table 1, the experimental value of compressive strength of Square Ferrocement Jacketed Column in axial compression is very close to the analytically found value with a difference of 10.5%. The average value of strain at yield for S-FJC column is 0.0088 which is 4.4 times larger than the normal strain at yield of 0.002 in concrete. This means the column allows large deformation in longitudinal direction without failure. The average modulus of elasticity of S-FJC column is 4555 MPa which is 1/7.14 times that of concrete which was found to be 32519MPa numerically.
As can be seen in Table 1, the experimental value of compressive strength of Square Concrete Filled Steel Tubular Column in axial compression is very close to the analytically found value with a difference of 10.73% with analytical strength lower then experimental strength. The higher strength of this type of column above normal may be

attributed to the bond strength of steel and concrete which partially transferred the longitudinal load to steel tube by frictional action and rigid corners providing some confinement. The average value of strain at yield for S-CFT column is 0.0118 which is 5.9 times larger than the normal strain at yield of 0.002 in concrete. This means the column allows large deformation in longitudinal direction without failure. The average modulus of elasticity of S-CFT column is 4854 MPa which is 1/6.7 times that of concrete which was found to be 32519MPa numerically. Comparative charts of compressive strength and modulus of elasticity of each section type are given in Figure 3 and Figure 4.

CONCLUSIONS

The ultimate load carrying capacity of ferrocement jacketed circular column under concentric loading was observed to be significantly higher than the characteristic strength of concrete cylinder with confinement increasing the load carried by factor of 1.5 to 1.6 times in the column section. Although the circular concrete filled steel tubular column was found to be most effective with an increase in ultimate load carrying capacity by a factor of 2 as compared to characteristic strength of concrete cylinder.

Square ferrocement jacketed column did not experience an increase in load capacity as compared to characteristic strength of concrete cube, yet, negligible confinement effect was observed as the column maintained its ultimate load carrying capacity very close to characteristic strength of concrete cube. Strengthening of corners can give much better confinement and improve overall effectiveness of section.

The ultimate load carrying capacity of square concrete filled steel tubular column under concentric loading was observed to be higher by a factor 1.25 as compared to the characteristic strength of concrete cube. As the confining tube did not fail, the significant increase in stress capacity may be attributed to the transfer of some of the longitudinal stress to the steel tube due to friction between the surfaces and very small confinement offered by rigid corners.

The longitudinal strain of all the section at the ultimate load was in the order of 6 to 9 times the standard permissible strain in a concrete section.

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