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# Experimental Investigation on Steel Concrete Composite Hollow Section

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***Abstract*— In recent days, due to the expansion of cities it is required to construct high storey buildings. Composite buildings prove to be promising for multi storey building. As a result, composite columns have recently undergone increased usage throughout the world, which has been influenced by the improvement of high strength concrete enabling these columns to be considerably economized. Columns are designed to resist the majority of axial force by concrete alone can be further economized by the use of thin walled steel tube. This paper presents an experimental investigation on the behaviour of the short concrete filled steel tubular columns (CFST). The investigation is carried out on hollow steel tube (HST) & concrete filled steel tube (CFST) specimens of circular cross-section with different thickness(1.5mm,2mm,2.5mm) under axial compression. A total of 12 specimens (9 specimens were filled with concrete and 3 specimens were kept hollow). The grade of concrete used for infill concrete is M25grade of concrete. The tests on said CFST specimens are carried out with the help of compression testing machine. The axial load is applied gradually on specimens. This paper presents the details of study carried out and the conclusions arrived.**

***Keywords—component; Hollow Steel Tube(HST), Concrete-Filled Steel Tube(CFST),In filled concrete, axial load, buckling***

## I. INTRODUCTION

### A. *General*

Steel members have the advantage of high tensile strength and ductility, while concrete members may be advantageous in compressive strength and stiffness. Many researchers agree that CFST members utilize the advantage of steel and concrete. This chapter involves aim, scope, objective, need for study of the research.

### B. *Concrete filled tubes*

Steel tubular structures are being increasingly used for structural applications. This is due to the aesthetic appearance, high corrosion resistance, ease of maintenance and ease of construction. Hollow columns consisting of two concentric circular thin steel tubes with filler between them have been investigated for different applications.

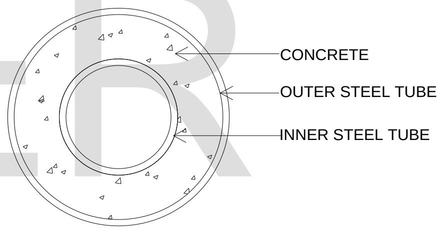


Fig 1. Typical cross section of CFT hollow

In composite construction, the concrete and steel are combined in such a fashion that the advantages of both the materials are utilized effectively in composite column. The lighter weight and higher strength of steel permit the use of smaller and lighter foundations. The subsequent concrete addition enables the building frame to easily limit the sway and lateral deflections. Hollow column has less self weight and a high flexural stiffness and hence its usage in seismic zone proves promising. It reduces requirements on labour. and construction time and maintains the construction quality.

#### a) *Applications of concrete filled tubes*

i. The CFT structural member has a number of distinct advantages over an equivalent steel, reinforced concrete, or steel-reinforced concrete member.

ii. The orientation of the steel and concrete in the cross section optimizes the strength and stiffness of the section. The steel lies at the outer perimeter where it

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performs most effectively in tension and in resisting bending moment.

iii. Also, the stiffness of the CFT is greatly enhanced because the steel, which has a much greater modulus of elasticity than the concrete, is situated farthest from the centroid, where it makes the greatest contribution to the moment of inertia.

iv. In high-strength applications, smaller column sizes may be used, increasing the amount of usable floor space in office buildings.

v. The smaller and lighter framework places less of a load on the foundation, cutting costs again. These advantages have secured an expanding role for this versatile structural element in modern construction.

b) *limitations of concrete filled tubes*

A number of factors complicate the analysis and design of concrete-filled steel tubes. A CFT member contains two materials with different stress-strain curves and distinctly different behavior.

i. The interaction of the two materials poses a difficult problem in the determination of combined properties such as moment of inertia and modulus of elasticity.

ii. The failure mechanism depends largely on the shape, length, diameter, steel tube thickness, and concrete and steel strengths.

iii. Parameters such as bond, concrete confinement, residual stresses, creep, shrinkage, and type of loading also have an effect on the CFT's behavior.

iv. Axially loaded columns and, in more recent years, CFT beam-columns and connections, have been studied worldwide and to some extent many of the aforementioned issues have been reconciled for these types of members

c) *Features of hollow column*

i. Column sections using Hollow Tube Filled with concrete can be reduced because of its high strength.

ii. Vibrations caused by earthquakes and winds can be reduced to its higher rigidity than that of steel structure.

iii. Fire-resistant coating can be reduced or omitted due to the effect of concrete filled in steel tubes.

Self-compacting concrete (SCC) is an innovative concrete that does not require vibration for placing and compaction. The SCC proves much advantageous to be used in hollow columns due to its self compacting ability. The placing of this concrete is easy and rapid.

a) *Need for hollow composite column*

i. Increased strength for a given cross sectional dimension.

ii. Increased stiffness, leading to reduced slenderness and increased buckling resistance.

iii. Significant economic advantages over either pure structural steel or reinforced concrete alternatives.

iv. Identical cross sections with different load and moment resistances can be produced by varying steel thickness, the concrete strength and reinforcement. This allows the outer dimensions of a column to be held constant over a number of floors in a building, thus simplifying the construction and architectural detailing.

v. Erection of high rise building in an extremely efficient manner.

vi. Formwork is not required for concrete filled tubular sections

## C. *Hollow composite columns*

Steel members have the advantages of high tensile strength and ductility, while concrete members may be advantageous in compressive strength and stiffness. Many researchers agree that composite members utilize the advantages of both steel and concrete. They are comprised of a steel hollow section of circular or rectangular shape filled or centrifuged with plain or reinforced concrete.

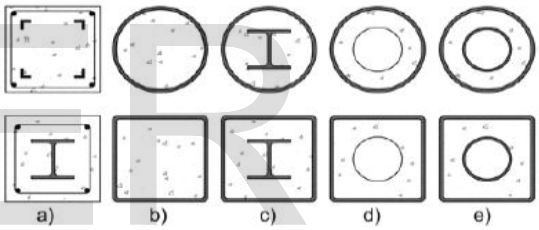


Fig 2. Various types of composite columns

Figure1.2. Shows the various types of composite columns in which (a) Concrete encased steel (CES), (b) CFST, (c) combination of CES and CFST, (d) Hollow CFST sections, (e) Hollow double skin sections

The main effect of concrete is that it delays the local buckling of the tube wall and the concrete itself, in the restrained state, and is able to sustain higher stresses and strains when unrestrained. These composite columns can be also used for the resisting outside pressure, such as ocean waves, ice; in seismic regions because of excellent earthquake-resistant properties such as high strength, high ductility, and large energy absorption capacity. Concentrically layered hollow CFST elements are more effective than ordinary hollow elements, because of the interaction between surfaces of concrete layers which appears after spinning .This interaction appears independently on the type of loading applied to such hollow CFTS element and on the increased load-bearing capacity of components.

Whilst workability is essential for quality concrete construction, all other properties are adversely affected as they are linked to the porosity of the cement paste and therefore the permeability of the concrete. The fundamental parameters which control the durability of concrete are

i. Water cement ratio.

ii. Degree of compaction.

The first parameter is controlled by the mix design, while the second one is strongly influenced by the care and the quality of the workmanship. Workability of the concrete and its homogeneity in the structure determine its durability. In 1975 "Rheoplasticity" concept was introduced. It was attributed to a concrete having the following properties:

i. High workability (slump >200 mm)

ii. Low W/C ratio (equal to that of a no slump concrete without an admixture)

iii. Little bleeding and no segregation

iv. Requires minimum of vibration for compaction

The placing of this concrete is easy and rapid. However, it still requires some manpower for the compaction. In the late '80s several researchers worked to improve the flow and segregation resistance of concrete. Terms such as "Highly Flowable Concrete", or "Super Flowable Concrete", or "High Performance Concrete", etc. was used to describe these concrete.

In 1989, Prof. Ozawaintroduced the term "Self-Compacting Concrete" at the East Asia Structural Engineering Congress in Singapore, opening new horizons in Concrete Technology. The "rheoplastic" concrete concept was improved by the self-compacting concrete, which has some particular properties such as:

i. Adequate fluidity

ii. High resistance to segregation

iii. Appropriate plastic viscosity

iv. Sufficient deformability

### *D. Concrete - its ingredients*

a) Requirements of concrete

Concrete is a mixture of Portland cement, water and inert materials put in place in a plastic conditions but hardening soon after due to the process known as the hydration of the cement. Although concrete is placed in a plastic conditions and cannot be tested for quality that may be necessary to meet the requirements of the work by proper control to the proportioning making and placing together with subsequent curing.

The fundamental requirements of hardened concrete are strength, durability and economy. Fresh concrete must be workable that is it must be of such a consistency and physical make up that it can be readily placed in the form without segregation of the materials and without requiring an excessive amount of spading to completely fill the form. Uniformity in both fresh and hardened concrete is necessary to secure economy of materials, to facilitate handing and placing and to obtain uniformity in the completed structure.

### *E. Objectives of this work*

The objective of the thesis is to utilize the properties of concrete and steel effectively as a composite column. Characteristics of steel and concrete considered in the study are,

i. Strength and Ductility for steel.

ii. Density and Compaction for concrete

iii. To study the behavior of concrete filled tube using self compacting concrete and controlled concrete.

iv. To compare the behavior of concrete filled tube using self compacting concrete and controlled concrete.

### *F. Scope of this work*

i. Hollow column has less weight and high flexural stiffness and thus can be used in seismic zones.

ii. Self weight of the members are reduced and there by permits smaller and lighter foundations.

iii. Compaction of concrete is difficult in the location of reinforcement congestion so self-compacting concrete enables compaction in such cases

iv. In case of concrete filled tube composite member reduces the cross section area of the element. Thereby increases the functional requirement of the structure.

## II. Methodology

### *A. Materials used*

Ordinary Portland Cement (OPC) is the most common type of cement in general usage. It is a basic ingredient of concrete, mortar and plaster. It consist of a mixture of oxides of calcium, silicon and aluminum. Portland cement and similar materials are made by heating limestone (a source of calcium) with clay and grinding this product (called clinkers) with a source of sulphate (most commonly gypsum). The ordinary Portland cement is classified into three grades namely 33, 43 and 53 grade cement depending upon the strength of the cement at 28 days. We have used Cement used in the investigation was 53 grade ordinary Portland cement. We got ordinary Portland cement from the alpha blue metals.

Fine aggregate is the inert or chemically inactive material, most of which passes through a 4.75 mm IS sieve and contains not more than 5 per cent coarser material. They may be classified as follows

The fine aggregates serve the purpose of filling all the open spaces in between the coarse particles. Thus, it reduces the porosity of the final mass and considerably increases its strength. Usually, natural river sand is used as a fine aggregate. However, at places, where natural sand is not available economically, finely crushed stone may be used fine aggregate.

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*B. Methodology flow chart*

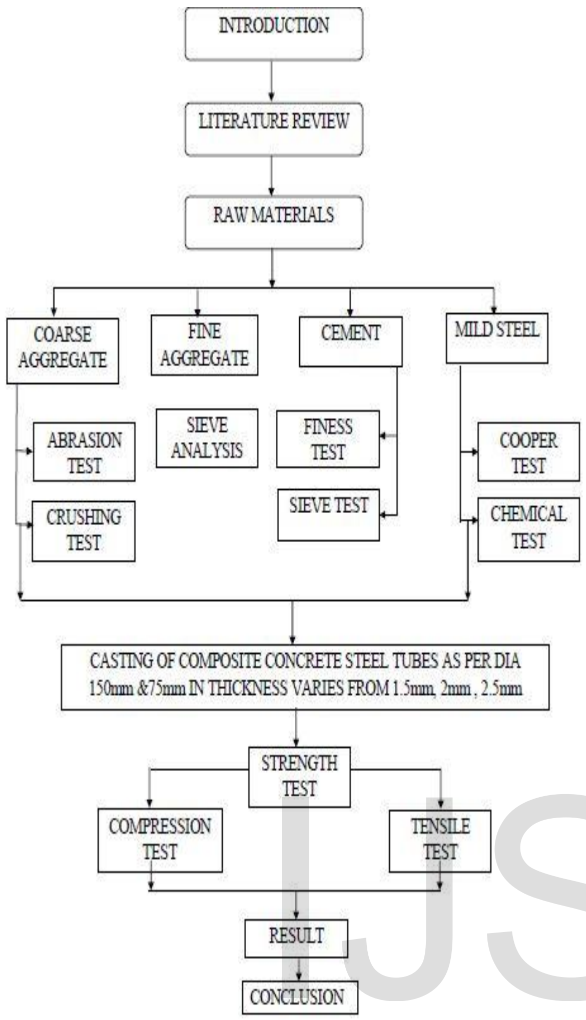



Fig 3. Methodology Flowchart diagram

## III. EXPERIMENTAL ANALYSIS AND RESULTS

*A. Testing Of Course Aggregate*

*a. Abrasion Test*

Fig 4 .Abrasion test

b. Crushing Test

Fig 5. .Crushing test

Table 1 .Properties of Coarse Aggregate

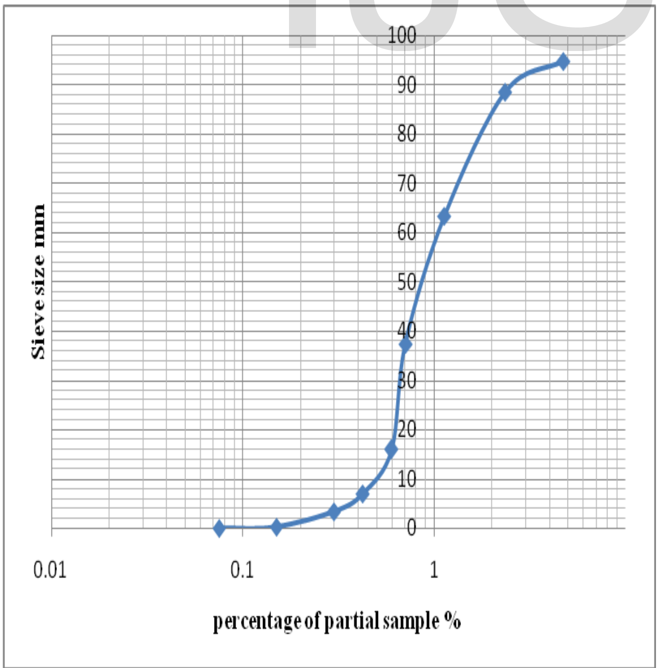
| Test | Result | As per IS 4031-1998 |
|---|---|---|
| Specific Gravity | 2.70 | 2.6-2.85 |
| Fineness Modulus | 7.3 | 6.5-8 |
| Impact | 18.18% | Strong (10-20%) |

*B. Testing Of Fine Aggregate*

A sieve analysis is a practice or procedure used to assess the particle size distribution of a granular material. The size distribution is often of critical importance to the way the material performs in use. A sieve analysis can be performed on any type of non-organic or organic granular materials including sands, crushed rock, soil, coal, down to a minimum size depending on the exact method. Being such a simple technique of particle sizing, it is probably the most common.

Table 2. Properties of Sieve Analysis

| I.S. Sieve Designa-tion | Weight of soil retained | Cumulative weight retained, $W_d$ | Soil retained as percentage of partial sample, N | Soil passing as percentage of partial sample, $N_1$ |
|---|---|---|---|---|
| Mm | G | g | $N=W_d/W_c \times 100$ | $N_1=100-N$ |
| 4.75 | 26 | 26 | 5.2 | 94.8 |
| 2.36 | 31 | 57 | 11.4 | 88.6 |
| 1.13 | 131 | 188 | 37.6 | 63.4 |
| 0.71 | 125 | 313 | 62.6 | 37.4 |
| 0.60 | 107 | 420 | 84 | 16 |
| 0.42 | 45 | 465 | 93 | 7 |
| 0.30 | 18 | 483 | 96.6 | 3.4 |
| 0.15 | 16 | 499 | 99.8 | 0.2 |
| 0.07 | 1 | 500 | 100 | 0 |




*C. Testing Of Cement*

a. .Fineness Test

Table 3..Properties of OPC

b

| Test | Result | As per IS 4031-1998 |
|---|---|---|
| Consistency | 33 | - |
| Initial setting time | 72 minutes | Not less than 30 min. |
| Final setting time | 5 hours 30 minutes | Not more than 600 min |
| Specific gravity | 3.15 | 3.15 |
| Fineness | 2.9 | - |

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*D. Testing Of Mild Steel*

*a.* Tensile Test

*b.*Chemical test

a.Tensile Test

Table 4. Properties of Steel

| COMPOSITION | Min | Actual values |
|---|---|---|
| Tensile strength in MPa | 410 | 509 |
| Yield stress in MPa | 250 | 394 |
| Elongation in GL of 5.65VA | 23% | 32% |

*b.*Chemical test

From material selection to composition verification, chemical analysis method provides accurate, in-depth results.

During chemical analysis it is our goal to ensure the safety, reliability and performance of the supplied metal.

Table 5. Properties of Steel

| COMPOSITION | Chemicals present in the CFST % | | |
|---|---|---|---|
| | Min | Max | Actual values |
| CARBON | - | 0.22 | 0.12 |
| MANGANESE | - | 1.50 | 0.65 |
| SILICON | - | 0.40 | 0.18 |
| SULPHUR | - | 0.045 | 0.016 |
| PHOSPHOROUS | - | 0.045 | 0.040 |

Table 6. Tensile Test on Steel Tube Samples

| Sl No | Samples | Compressive Load (kN) | Compressive Strength ($N/mm^2$) |
|---|---|---|---|
| 1 | Ø150 ×1.5mm Thickness | 188.90 | 14.26 |
| 2 | Ø150 ×2.0mm Thickness | 197.15 | 14.88 |
| 3 | Ø150 ×2.5mm Thickness | 397.85 | 30.03 |

*E. Tensile Test on Steel – Concrete Composite Samples*

Tensile test on steel concrete composite samplesdimensions of 150mm outer diameter and 75mm inner diameter and the thickness varies from 1.5mm, 2mm, 2.5mm respectivelv

Table 7.Compression Strength ($N/mm^2$) For 1.5mm thickness

| Days | Trial 1 | Trial 2 |
|---|---|---|
| 28 | 39 | 39.56 |
| 7 | 25.3 | 25.82 |
| Empty | 14.26 | 14.53 |

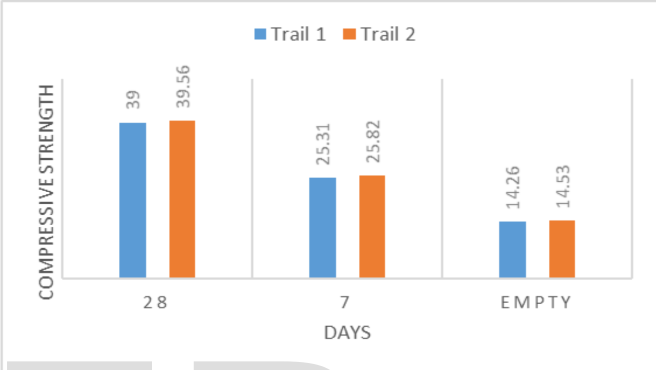



Table8.CompressionStrength($N/mm^2$)for2.0mmthickness

| Days | Trial 1 | Trial 2 |
|---|---|---|
| 28 | 34.14 | 26.95 |
| 7 | 27.81 | 28.91 |
| Empty | 14.88 | 14.53 |

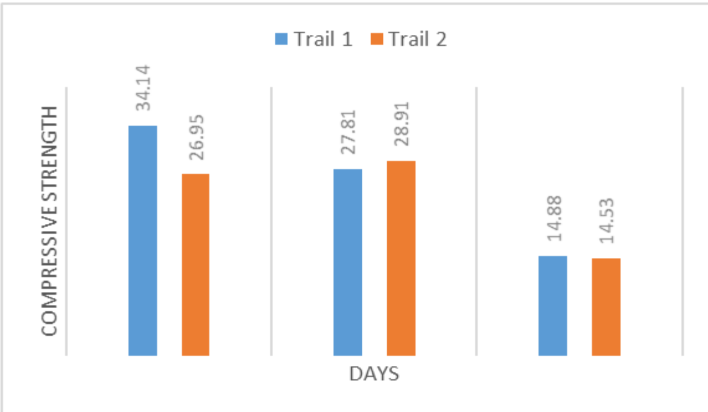
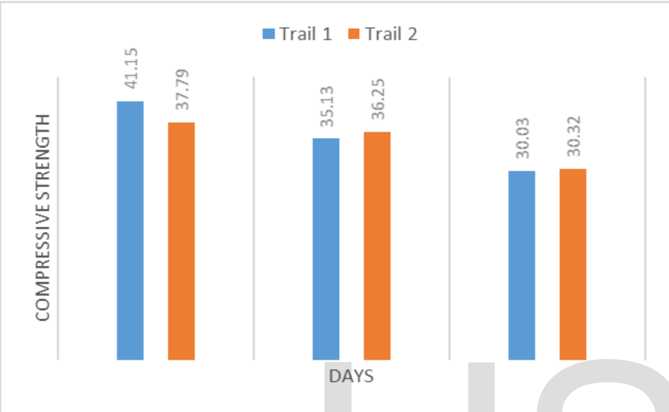


Table 9.CompressionStrength (N/mm$^2$) For 2.5mm thickness

| **Days** | **Trial 1** | **Trial 2** |
|---|---|---|
| 28 | 41.15 | 37.79 |
| 7 | 35.13 | 36.25 |
| Empty | 30.03 | 30.32 |




*F. Test on Hardened Concrete.*

Compression Strength Test Using CTM

Fig6. Test on Hardened Concrete

Fig7. Testing of cube in compression testing machine

Table 10. Properties of Steel

| **S.No** | **Specimen details** | **Average Compressive Strength (N/mm$^2$)** | |
|---|---|---|---|
| | | **7 days** | **28 days** |
| 1. | M25 grade of concrete | 5.2 | 26.3 |

*G. Mixing, Placing And Curing*

Fig8. Curing of CFT

*H. Test Setup , Instrumentation And Procedure*

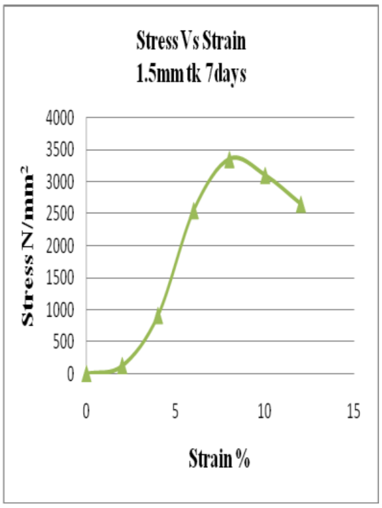
After the curing period of 28 days is over, all the columns were tested using the test setup. All the composite columns were carried out using a 2000kN load capacity compression testing machine. Compressometer were placed in the mid height of the specimen. We were note the deflection readings in the compressometerand then note the corresponding load in the Compression testing machine until to reach the ultimate load. Figure 4.7 shows the test setup for CFST with OPC and PPC respectively were discussed below.

Fig 9. Test setup for CFT columns

*I. Stress And Strain Distribution Of Steel And Concrete Composite Samples*

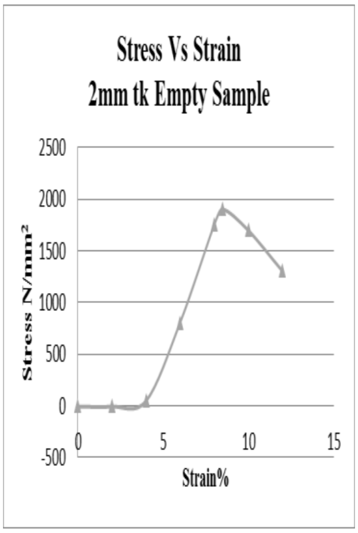
Stress Vs Strain curve for 1.5mm 7days

| Strain % (7 Days) | Stress $N/mm^2$ (7 Days) |
|---|---|
| 0 | 0 |
| 2 | 125 |
| 4 | 910 |
| 6 | 2550 |
| 8 | 3350 |
| 10 | 3100 |
| 12 | 2650 |




Stress Vs Strain curve for 2mm (Empty Sample)

| Strain % (Empty Sample) | Stress $N/mm^2$ (Empty Sample) |
|---|---|
| 0 | 0 |
| 2 | 0 |
| 4 | 62.5 |
| 6 | 875 |
| 8 | 1800 |
| 10 | 1925 |
| 12 | 1737.5 |
| 14 | 1325 |

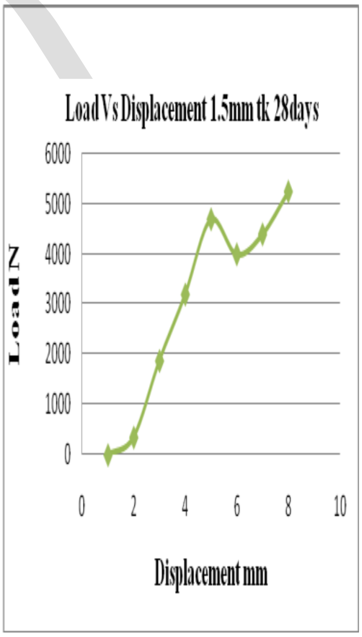



*J .Load-Displacement Curves For Different Thickness For Different Days*

Load and displacement distribution of steel and concrete composite samples dimensions of 150mm outer diameter and 75mm inner diameter and the thickness varies from 1.5mm, 2mm, 2.5mm for 28 days and 7 days of curing.

Load Vs Displacement curve for 1.5mm (28 Days)

| **Displacement mm (28 Days)** | **Load N (28 Days)** |
|---|---|
| 0 | 0 |
| 2 | 350 |
| 4 | 1875 |
| 6 | 3200 |
| 8 | 4700 |
| 10 | 4000 |
| 12 | 4400 |
| 14 | 5250 |



## CONCLUSION

In the present study, the local carrying capacity and failure pattern based on compressive strength of load displacement curve under uniaxial compression, is predicted for hollow circular concrete filled steel tube with M25 grade of conventional concrete with OPC. From the experimental investigations the following conclusions are arrived,

1. The load carrying capacity for the conventional concrete filled in steel tube with diameters of 150mm outer dia and 75mm inner dia and thickness varying from 1.5mm, 2.0mm, 2.5mm are given.
2. Load carrying capacity for composite hollow tubular section is found to be higher than tubular section without concrete.
3. Considerably concrete filled hollow tubular section having thickness 2.5mm has compressive strength of 39.47 $N/mm^{2.}$
4. This compressive strength is higher by 7% of tubular section without concrete.
5. The presence of concrete infill provided additional stability of the tube walls against the influence of local buckling mechanisms. Hence the hollow concrete filled steel tube exhibits only slight local buckling and weld failure.
6. It was also found that the typical failure mode for all the tested concrete filled steel tubular columns was the slight local buckling and weld failure mode which was in an outer direction because of the infill of concrete.
7. The stress strain curve and load displacement curve pattern shows the varying distribution of load and displacement, stress and strain of different thickness concrete filled hollow tubular section.
8. Even though adding concrete in tubular section is less economical considering the strength parameters concrete filled hollow tubular section is highly recommended in high rise buildings.

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