

# Investigation of Double Skin Concrete Filled Steel Tube Beams under Cyclic Loading

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**ABSTRACT:** In recent years, it was proposed by several researchers that concrete filled double skin steel tubes (CFDST) be studied for their strength as a column or a beam. The CFDST member is a new type of composite construction, which consists of two concentric steel tubes with concrete sandwiched between them. Thus, CFDST beams have a series of advantages, such as high strength, high bending stiffness, good seismic and fire performance, and also having a favorable construction ability. In this present investigation made an attempt to determine the flexural behavior of CFDST beams under cyclic loading. Beams with rectangular cross section of size 100 mm x200 mm and length of the span was 3000 mm were investigated. Rectangular tubular sections have an advantage over other types of sections when used as bending members, for a given cross-sectional area, they have a large uniform flexural stiffness in all directions. Filling the tube with concrete will increase the ultimate strength of the member without significant increase in overall performance of the structural elements. Self-compacting concrete (SCC) were used as infill material for CFDST beam specimens. These beams were tested up to failure by applying repeated cyclic loading to evaluate the enhancement of flexural behaviour of CFDST beams. The responses of CFDST are compared to RC beams in terms of load carrying capacity and load deflection analysis. The experimental results were validated by using finite element software ANSYS14.

**KEYWORDS:** Concrete filled Double skinned steel tube (CFDST), self-compacting concrete (SCC), Reinforced concrete beam (RC).

## I. INTRODUCTION

Composite steel–concrete construction is widely used in the construction of modern buildings and bridges, even in regions of high seismic risk. The composite construction ideally combines the advantages of both steel and concrete, namely the speed of construction, high strength, and light weight of steel, and the inherent mass, stiffness, damping, and economy of concrete. A creative innovation of composite construction is known as concrete-filled double skin steel tubes (CFDST). CFDST members have almost all the same advantages as traditional CFST members. They have better structural performance than those of bare steel or bare reinforced concrete. The steel hollow section acts as formwork as well as reinforcement for the concrete. Concrete eliminates or delays the local buckling of steel hollow section, and increases significantly the ductility of the section. CFST construction has proven to be economic in material as well as providing for rapid construction and thus additional cost savings. Moreover, they have lighter weight, higher bending stiffness, and better cyclic performance. One of the challenges in CFDST construction is to ensure proper concrete compaction. The self-consolidating concrete (SCC) has been successfully used in a variety of construction projects due to its benefits such as elimination of vibration noise, reduced cost, flow ability, filling ability and high construction ability. Therefore, the CFDST member in combination with SCC could be applied in engineering projects such as bridges, high-rise buildings, transmission towers etc. Various CFDST steel tubes profiles such as circular hollow sections (CHS), square hollow sections (SHS) or rectangular hollow sections (RHS) ions as shown in fig. 1.

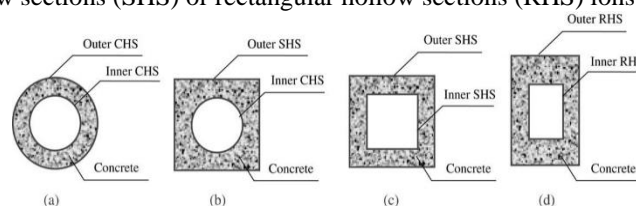


Figure 1. Various CFDST Section Profiles

The behavior of CFDST beams under cyclic loading has been experimentally investigated and the results are presented in this paper.



**II. PREVIOUS RESEARCH WORKS**

In recent years, the behavior of CFDST members has been studied by several researchers, such as Wei et al, Yagishita et al, Lin and Tsai, Elchalakani et al, Zhao and Grzebieta, Zhao et al, Han et al, and Tao et al. Reviews of these studies are given by Tao and Han and Han et al. The reviews indicate that almost all CFDST members studied in the literature were fabricated with circular steel tubes or square steel tubes. Only six preliminary tests on thin-walled rectangular CFDST stub columns were reported by Tao et al. , and no CFDST beam or beam–column with rectangular sections was investigated, which is favorable when large major-axis bending moments occur. Most of the research efforts have been made on Behavior of CFDST stub columns, Beam-columns under static and dynamic loading condition with various grades of concrete. Only few researchers reviewed the flexural behavior & fire resistance of CFDST beams (up to 1.3m), under static and dynamic loading conditions. Parameters investigated in most of the researches are Slenderness ratio, Hollow section ratio, confinement factors, d/t & b/t ratio, constraining factor, cross area of steel and concrete, type of cross section profile, Poisson's ratio , confinement effect, etc. are investigated.

**A. Observations on the Actual State of Art**

From the above review of literatures, illustrates that although substantial research has been conducted on thin-walled rectangular CFDST stub columns and few reports on CFDST beam or beam–column with rectangular sections were investigated. Many research work has been conducted on CFDST beams, columns & beam-columns in terms of flexural loading, axial compression and seismic loading. Only a few researcher made an attempt on CFDST beams (upto 1.3m span) with cyclic loading to study the flexural behavior of CFDST beams where both inner and outer tube as rectangular hollow sections.. This paper also presents the experimental and numerical investigation of RC and CFDST beam with SCC as infill material in terms of load carrying capacity and load deflection behavior.

**III. EXPERIMENTAL INVESTIGATION**

**A. Material Properties**

**1) Rectangular Steel Tube Beam**

Two types of cold-formed rectangular steel tubes (both inner and outer) of size (200 x 100 mm & 100 x 50 mm) with a measured thickness of 3.2 mm were used. The steel tubes were produced by cold rolling. The nominal dimensions and material properties for the Rectangular hollow section tubes used in the test program are shown in Table 1. SCC is used as infill materials for CFDST beam.

Table 1. Tube Dimensions and Material Properties of Steel

1) Reinforced Concrete Beam

Rectangular Tube	b	d	t	L	E	μ
	(mm)	(mm)	(mm)	(mm)	(N/mm <sup>2</sup> )	
Inner	50	100	3.2	3000	2x10 <sup>5</sup>	0.3
Outer	100	200	3.2	3000	2x10 <sup>5</sup>	0.3

The size of RC beam are 200 X100 mm and length 3000 mm respectively. M30 grade of concrete and its mix proportion is 1:1.16:2.81 with w/c ratio is 0.45 and Fe415 steel were used. 4#nos of 12mm dia rods are used as top and bottom reinforcement and 8mm dia rod are used as stirrups with spacing of 100mm c/c. The reinforcement detailing of beam specimen as shown in fig

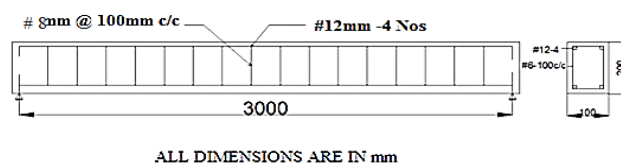


Figure 2 .Reinforcement Detailing for RC Beam

**B. Casting of CFDST and RC Beam Specimens**

Self-Compacting Concrete of mix 1:1.57:2.15 with w/c ratio of 0.45 and coarse aggregate with a maximum size of 12 mm were used for casting of CFDST a beam specimens. SCC mix design satisfies the EFNARC guidelines and fresh properties of concrete as per IS codes. The use of SCC reduce significantly the time of in-fill of the concrete between the steel tubes. For RC beams, M30 grade of concrete mix 1:2.15:1.57 with w/c ratio of 0.5 were used for casting .The companion specimens of three cubes were casted and tested for arriving at the grade of concrete. The excess spilled concrete was then neatly and gently cleaned and the specimens were cured for 28 days in controlled humid condition. After curing period specimens were wiped dry and cleaned. Painting of specimens was done for easy identification of failure pattern. Then, the specimens were subjected to testing.

**C. Test Setup and Procedure**

The tested beams supported on two roller supports at both ends and a 1,000-kN hydraulic jack bolted to an independent loading frame was used to apply loading on the beams through rigid steel spreader beam.

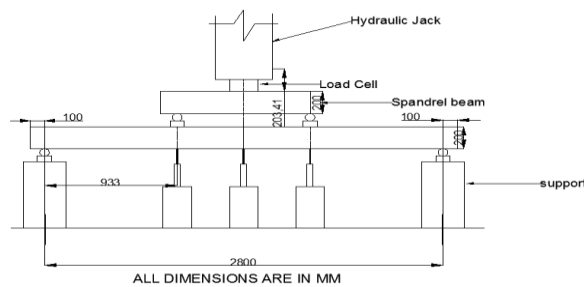


Figure 3. Test Setup Arrangements

The steel spreader beam was used to deliver two equal concentrated loads to the one third of the span. Load cells were used to measure the applied load with the help of data acquisition system. Moreover, deflection was measured by using LVDTs, at five different locations in each span such as one at midpoint, two at one third span and two at support to measure local buckling & deflection of steel tubes. The applied load, displacements, buckling of steel tubes and strain readings were electronically recorded during the test by using a data acquisition system monitored by a computer. The arrangement for testing of beams as shown in fig 3.

**D. Testing of Beams**

All the specimens were tested under two point loading condition. The specimen was loaded up to the final failure of the specimens as shown in fig 4 & 5.



Figure 4. Testing of RC Beam



Figure 5. Testing of CFDST Beam

**IV. NUMERICAL INVESTIGATION**

For many engineering problems analytical solutions are not suitable because of the complexity of the boundary conditions, the material properties and the structure. The finite element method is the representation of a body or a structure by an assemblage of subdivisions. ANSYS 14 is finite element based software which gives good results on analysis of any structural elements.

**A. Model Overview**

The structural analysis program ANSYS 16 Workbench is advance of Ansys APDL were used to construct the FE model of CFDST beam. Steel and concrete material are selected from material library and properties of the materials entered in the property section of the material .All the support conditions are pinned. A rotational degrees of freedom are free and translation Uy is free remaining Ux, Uz are restrained.

3.An two point load was applied over the top surface of the beam. The meshing and deflected of the CFDST beam by using ANSYS14 as shown in fig 6 and 7.

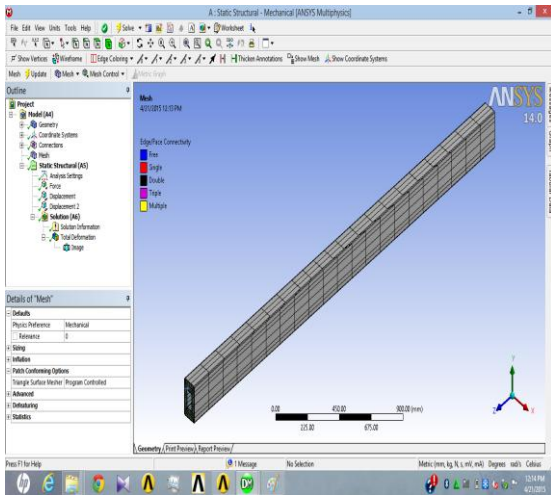


Figure 6. Meshing of CFDST Beam

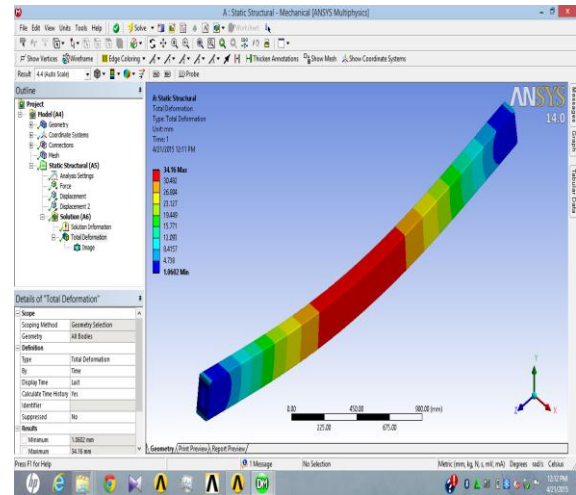


Figure 7 Deflection of CFDST Beam by using ANSYS

**V. TEST RESULTS AND DISCUSSIONS**

**A. General**

In most of the structures the behavior under flexural loading plays an important role in many applications. An experimental investigation was carried out to study the behavior of flexure RC beam and CFDST beams specimens under cyclic loading. The parameters like first crack load and ultimate load carrying capacity were observed. The results of the investigation were discussed and compared with numerical investigation.

**B. Load Deflection Behavior**

The maximum load level was increased. The beam specimen was loaded with two point loading. The specimen must be carefully aligned with the axis of loading device. The load was increased and decreased in each stage. The first crack load for RC beam was found to be 18 kN. The ultimate load carrying capacity of RC beam and CFDST beam was found to be 176 kN whereas the corresponding value for control RC beam were 48 kN. The load deflection curve for RC and CFDST beams were shown in fig 8 & 9 respectively.

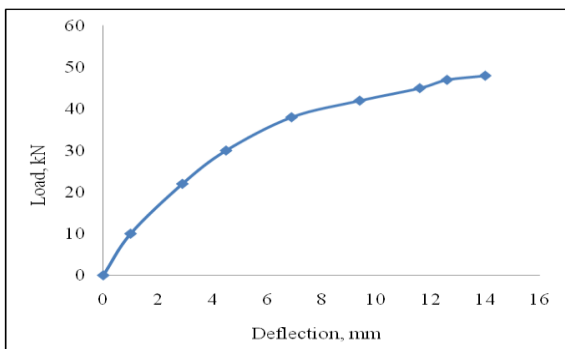


Figure 8. Midspan Deflection of CFDST Beam

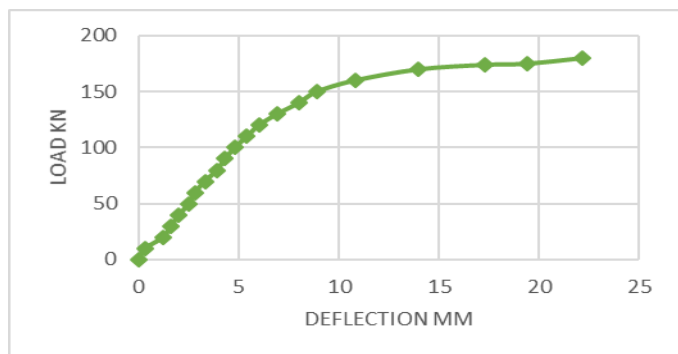


Figure 9 Midspan Deflection Of CFDST Beam

### C. Cyclic Behavior of RC and CFDST beams

The beam specimen was tested under cyclic loading condition. The load was increased and decreased in each cycles. For each cycle the load was increased up to 10kN and its decreased to 0kN. Deflection of the specimen is measured for each cycle with the help of LVDT and Data Acquisitions system monitored by computer. CFDST beams carry more number of cycles when compared to RC beams. The behavior and response of RC and CFDST beams under cyclic loading as shown in figure 10, 11 & 12.

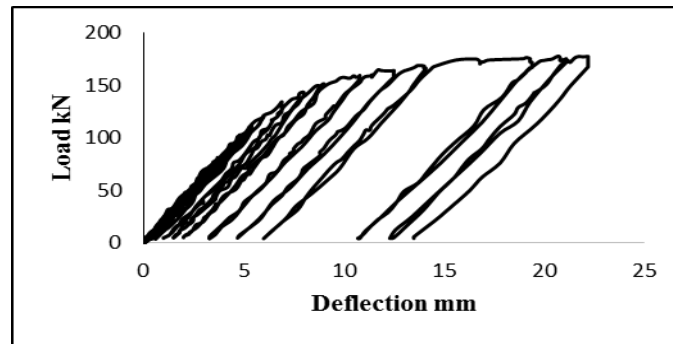


Figure 10 Cyclic Response of CFDST Beam

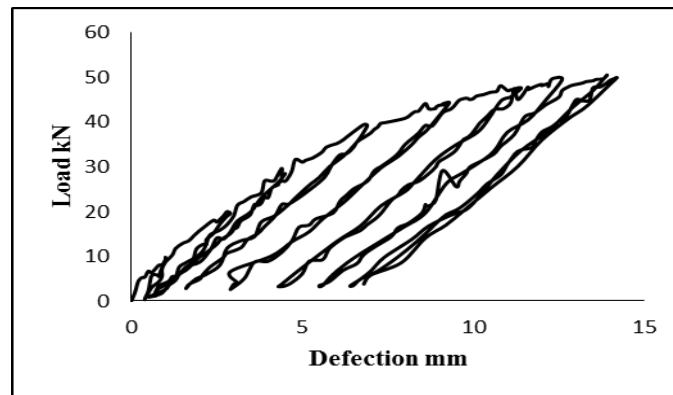


Figure 11 Cyclic Response of RC Beam

### D. Behavior and mode of failure

RC beam and CFDST beam have failed in flexure mode by yielding of steel rod and steel tubes. For RC & CFDST beams, crushing and spalling of concrete takes place after the yielding of steel in tension zone. Behavior of RC & CFDST beams under two point loading are listed below,

- 1) For RC beam maximum deflection was observed as 14mm under ultimate load of 48 kN. More number of cracks have been observed during final failure of the RC beam specimen
- 2) For CFDST SCC beam maximum deflection was observed as 24mm under ultimate load of 176 kN. Sounds for crushing of concrete was noted at a load of 156kN.
- 3) Local buckling of steel tube occurs at the CFDST beam at support area was noted at a load of 156kN.
- 4) By Numerical investigation the maximum deflection of CFDST SCC beam was observed as 34.mm under the ultimate load of 180kN and experimentally it was 24mm for 180kN.
- 6) By Experimental investigation the maximum deflection of RC beam was 14.5mm for 50kN.
- 7) Test results denotes CFDST beam suffers lesser damage as compared to RC beam specimen. The failure pattern of the RC and CFDST beam is shown in fig 13&14.





Figure 13 Failure Pattern in RC Beam



Figure 14 Failure Pattern in CFDST Beam

## VI. CONCLUSIONS

Based on the results obtained from the experimental and numerical investigation, the following conclusions are made:

- 1) The increase in ultimate load carrying capacity of CFDST mainly depends on the filler material strength.
- 2) Experimental results show that void filling increases energy absorption capacity, reduces the stiffness degradation and increases the ductility factor.
- 3) From this investigation it was observed that SCC concrete could be used as infill material for an acceptable mechanism.
- 4) Numerical results give good prediction between the experimental results.

From the above observation and test results it can be seen that CFDST beams perform well in all aspects when compared to RC beam. Hence, CFDST proves to be an effective and economic construction technique when compared to ordinary construction techniques.

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