Experimental Investigation on CFST Column Infilled with Self Compacting Concrete at Different Temperature under Compression

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Abstract: Concrete-Filled Steel Tubular (CFST) Columns have several structural and constructional benefits, such as high strength and fire resistance, large stiffness and ductility control to local buckling of the steel tube provided by the infill of concrete core, omission of formwork leading to lessening in the construction cost and time. The CFST tube were casted with different grades of SCC and tested in hydraulic compression machine at elevated temperature the CFST has following of different diameters are 26.9mm, 33.7mm, 42.4mm and different lengths are 215.8mm, 404.4mm, 678.4mm experiments are conducted on prepared specimens to find ultimate load carrying capacity at different temperatures (60º, 90º, 120º) Based On This Suitable plots were obtained Such As (Pu V/S Temp., Temp V/S Grade, Pu V/S L/D Ratio, Pu V/S Deflection). And Same Is Verified With analytical results and ASCE-29 Fire Standards.

Keywords—self compacting concrete, L/d ratio.

I. INTRODUCTION

. Concrete-filled steel tubular (CFST) laced columns are widely used as building columns and as elements in arch bridges [Bode 1976; International Association for Cooperation and Research of Steel-Concrete Composite Structures (ASCCS) 1997; Chen 2007]. Examples of such structures include the International Exhibition Center in Tianjin City in China and the 460-m span Wuxia Changjiang Bridge in Chongqing City in China In recent years, several investigations have been performed to quantify the dynamic behavior of these columns. Some researchers have focused on the deformation capacity and buckling strength of two CFST laced columns under cyclic loading (Kawano et al. 1996;Kawano and Matsui 1999). Test results showed excellent ductility, indicating that these columns have promise for a new earthquake resistant system (Kawano and Sakino 2003). However, because of the limited number of test specimens, additional experimental results are needed to quantify the static behavior, failure mode, and ultimate load-carrying capacity of CFST columns. Finally, a universal method that more accurately predicts the ultimate load-carrying capacity of four-tube CFST laced columns is proposed. The column contain elevated load bearing capability with elevated earthquake aggressive. Steel tube provide captivity toward solid fill, which here act like a bear just before the steel pipe and limited in most buckle segment and column contain an elegant form and compact part. Main compensation of CFST are it bonfire fight because of temperature effect of the concrete fill so as to delay the increase of heat within section, in concert by defensive result of the toughen pipe protect solid center since straight fire experience. The steel shell prevent falling solid, leftovers enhanced sheltered next to bonfire.

II. Maintaining the Integrity of the Specifications

Enhanced strength for the given cross sectional aspect. Improved firmness, primary to reduced slenderness and improved buckling resistance. Drying shrinkage and creep of the concrete be much minor than here usual reinforced concrete columns. The strengthen part within the CFST traverse segment is greatly superior to those into the durable concrete traverse segment. While the formwork is not involved in the technique, larger space is available for transportation and the location be clear. Man power, constructional time and cost saved because here no form and reinforce bars are used and the casting is done by pump-up method. The structures which are subjected to earthquake loadings, the CFST columns provide the enhanced ductility and load resistance even behind general concrete damage.

III. STEEL COLUMN TESTS

Test Program

A total of 20 tests on steel columns were conducted by Aasen (1985) at the Norwegian Institute
of Technology. All the columns were made from the European rolled I-section IPE 160. The average measured dimensions of the cross section are shown in Four column lengths were tested, namely 3,100, 2,210,1,750, and 1,700 mm, with slenderness
ratios about the weak axis of 169,120,95, and 92, respectively. Shorter columns were not teste,because of the limited capacity of the test rig.The columns were tested using

three different support conditions. Most of the columns were tested under pin-end support conditions, in which the column ends were free to rotate and to expand axially (unrestrained). Five columns were tested with some end-rotation restraint, by connecting the ends of the columns to restraining beams through web-cleat or end-plate connections (rotationally restrained), and two other columns were tested with the ends restrained against axial expansion (axially restrained). Various levels of axial load were applied to the columns. All columns were loaded through the centroid of the cross section except in the last two tests, in which load eccentricities of 14mm and 20 mm were introduced. The heating conditions were chosen by Aasen (1985) to give a nominal steel temperature rise rate of 20°C/min for most of the tests. For the last five tests, however, the rate was reduced to 10°C/min. Finally, complete content and organizational editing before formatting. Please take note of the following items when proofreading spelling and grammar:

GENERAL CONFIGRATION OF CFST

The authors have presented a very interesting numerical method
for the simulation of the behavior of members under different temperature conditions. This method allows a large number of phenomena to be taken into account, in fact, much more than in The application example that is produced. The discusser would Like to comment on the sentence written by the authors: "The influence of different temperature metallurgical processes such as the normalization of f.~ is ignored." 'The discussers fully agree with the approach which has Been chos~~ .to tak~ residual stresses into account, i.e. by means of mItial strams according to *(2c).* We in fact use the same approach in our own calculations (Franssen 1989), although .with the opposite convention of sign. The point we would lIke to raise is that this model of initial strains, together with the assumption that plastic strains are unaffected by changes in temperature, really makes it unnecessary to consider any variation of the residual stress during the heating and cooling process. The sentence of the authors is motivated by the experimental observation that, when a steel profile that has residual stresses is heated and then slowly cooled down, the residual stresses tend to decrease and even vanish. Is it not proof that residual stresses are affected by the temperature changes and that the model should take this into account? In fact, even a very simple stress-strain relationship as the elastic, perfectly plastic law depicted can reproduce the experimental fact of the stress normalization process when residual stresses are modeled as initial strains. What is necessary is that during the heating phase the proportional limit of the stress-strain law is decreased below the level of the initial strain, and that the hypothesis of Fig. 5 is maintained during the cooling phase. shows the evolution of the stress in a particular point of a profile where the initial strain is Eg;. The initial temperature is TI (for example 20°C) and the stress is al' When the temperature is increased to T2 > TI, and if the proportional limit of the material at this temperature becomes smaller than the initial strain, then the material yields with its stress limited to *a2* and the plastic strain *Epi* appears. During the cooling down to T3 = TI, this plastic strain is not affected by the temperature change and the stress becomes *a3* < *a*. The residual stress has indeed been reduced, but the initial strain used to model it remains unchanged. Only a plastic strain has appeared. With the evolution of the yield stress and modulus of elasticity proposed by the Australian Standard *AS4100* (1990) and with a residual stress *aT* =0.50 X 235 = 117.5 MPa, i.e. an initial strain E; = *117.5/210,000* = 0.56 10-3the stress will be reduced only if the maximum temperature exceeds 865°C, and the stress will completely vanish if the maximum temperature reaches 905°C. One must bear in mind that the *AS4100* stress strain relationship has not been established with the aim of modeling the stress relieve process but for the simulation of steel elements submitted to fire. What the discusser wanted to point out is that the modeling of initial strain has the inherent capability to represent this phenomenon. Of course, the utilization of a more sophisticated stress strain model could lead to more realistic temperatures. Consideration of a nonlinear part in the stress-strain relationship before the yield stress would reduce the proportional limit and therefore decrease the temperature level necessary to reduce the stress during the heating cooling cycle. Introduction of an explicit creep term in the material model would also have the same effect to acceleratethe decrease of the stress. Another point that the discusser would like to raise briefly is that elastic, perfectly plastic stress-strain relationships have been derived for and are applicable mainly for the calculation of members submitted to bending,

SELF COMPACTION CONCRETE:

Self compaction concrete (SCC) is an innovative building material with improved properties like superior strength, longer durability and high workability, than usual concrete. SCC be a material used during appropriate manufacture for insertion the concrete in complex conditions and in structure with crammed reinforcement with no vibration. In high rise building concrete is used in the construction which is at risk when exposed to high temperature. The word “data” is plural, not singular.

A general numerical procedure to analyze the behavior of load-bearing members under different temperature conditions has been developed (Poh and Bennetts 1995). The method accounts for combined actions of axial force and biaxial bending, external restraints, temperature variation over the cross section and along the member, material nonlinearity, geometric nonlinearity, unloading and reloading, residual or initial stress, and initial "out-of-straightness" of the member. It applies to members of any cross-sectional shape and with any different temperature stress-strain relationship for the material.

In this paper the results obtained from the numerical analysis are compared with the data obtained from a series of elevated temperature steel column tests conducted by Aasen (1985) at the Norwegian Institute of Technology..

ANALYSIS OF STRUCTURAL MEMBERS

Under compression loading.

ADVANTAGES OF SELF COMPACTION CONCRETE:

Cost of production is less due to faster construction.

better quality.
It is self-compacted here no needs to use any vibrator.

Working method is absolutely safe.

DISADVANTAGE OF SELF COMPACTION CONCRETE:

Highly capable and qualified people are necessary for manufacture of SCC.

The casting rate slows due to SCC requires high fluidity in tight joints.

It is extra pricey than some other conventional concrete.

OBJECTIVES OF PRESENT STUDY

To understand the effects of steel tubes with different L/D ratios/ different D/t ratios with different grades of Self Compaction Concrete (SCC) infill at room temperature and elevated temperature.
To study the behavior of deflection for different steel tubes filled with SCC under cyclic loading at elevated temperature
To know the failure mechanism of composite steel and hollow steel tubes at elevated temperature.

SPECIFICATIONS OF MATERIALS AND ITS PROPERTIES

CEMENT:
OPC of 53 grades from close by market is used. As per IS: 12269-1987 the physical and chemical property of cement can be determined.

cement property

Tests	**According to**	**Results**	**IS terms**
Specific gravity		3.1 <3.15	
Standard consistent (%)	IS4031 (part four)-1988	29% <30	
Initial time setting (minute)	IS4031 (part V)-1988	43 >30	
Final time setting (minute)		250	<600
Compressive strength on 7th day		38KN	
Compressive strength on 28th day		53KN	

FINE AGGREGATE
The particles passed through 2.36mm sieved are fine aggregate. River sand is used as fine aggregate for this study. Table shows characteristics of fine aggregate as per IS: 2386:1975. The sample satisfies the necessities of grade region 2 according to IS: 383-1970.
Table.. Fine aggregate Characteristics

SCC can be placed easily in dense form work and dense reinforcement.
Due its low water-cement ratio SCC is workable, it gives faster strength development, higher durability and gives

sieve no	**collective %**		**IS.383-1970 (%)**		
	Retained	**Passing**	**Zone 1**	**Zone 2**	**Zone 3**
4.75mm	3	96	90-100	90-100	90-100
2.36mm	24	88	60-95	75-100	85-100
1.18mm	42.4	78.5	30-70	55-90	60-79
600micron	62	59	15-34	35-59	60-79
300 micron	87.4	11.9	5-20	8-30	12-40
150 micron	99.1	0.99	0-10	0-10	0-10

Table. Fine aggregate physical properties

Specific gravity	2.68
Bulk density (kg/ m3)	1690
Water absorption	1%

COARSE AGGREGATE
The coarse aggregate were tested as per guideline in IS383-1970. And it confirms to the IS specification. Table shows the individuality of coarse aggregate sample for 10mm down size shows the physical properties of coarse aggregate sample.

Table. Characteristics of coarse aggregate sample.

Sieve size	Collective %		**For 20mm according to Indian standards**	
	Retain	**Passed**	**Grade**	**Single**
20.00mm	.1	100	100	100
12.50mm	2.5	97.5	90-100	85-100
10.00mm	17.1	82.7	40-85	0-45
4.75mm	90.3	9.7	0-10	0-10

CONCRETE USED IN CURRENT WORK

As per IS 10262-2009 the mix proportion of self compaction concrete of different grades were designed. The table shows the mix proportion of M 20, M 25, M 30 grade.
Table Concrete mix proportion for M 20, M 25 and M 30 grade.

Grade	M 20	M 25	M 30
Cement	323.63kg/m3	400kg/m3	445kg/m3
Fine aggregate	1074.491kg/m3	1090.958kg/m3	1015.718kg/m3
Coarse aggregate	879.129 kg/m3	857.181kg/m3	831.042kg/m3
Water	178liters	157.6liters	178liters

W/C ratio	0.55	0.45	0.4
Super plasticizers SP430 (2%of cement content)	0.00611kg/m3	0.006kg/m3	0.0070kg/m3
Mix proportion C:FA:CA	**1 : 3.320 : 2.716**	**1:2.727:2.142**	**1:2.282:1.867**

TEST ON FRESH SCC:

Some of the test conducted for SCC during organizes towards know the liberated of the concrete, i.e. workability.

SI.NO	Method	Unit	Result	Usual range	
Min			**Maxi**		
1	L -Box	h2/h1	0.96	0.8	1.0
2	T50-slump flow	Second	3	2	5
3	J Ring	Mm	7	0	10
4	Slump flow - Abram's cone	Mm	660	650	800
5	U Box	h2/h1	16	0	30

`Following figures shows the test conducted in fresh state of SCC.

Figure : L BOX

figure: U BOX

Figure : V FUNNEL

Figure : J RING

STRUCTURAL STEEL SPECIFICATION **:**

Totally there are 84 specimens were used in the current work, in which 63 specimens are filled with self compacting concrete of different grades are M20, M25 and M30. Remaining 21 specimens are hollowing tubes. Three different diameters having same thickness of steel tube were used. The material used is hot rolled steel available in 6 meters in length which are cutting into required L/D ratios. These steel tubes are having yield strength of 310MPa, elastic modulus of 210GPa and a Poisson's ratio of 0.3.

EXPERIMENTAL PROGRAMM

GENERAL:

In this experiment total of 84 specimens are used, which include 63 filled and 21 hollow tubes of various lengths and even thickness are selected for the investigation. The specimens were tested at room temperature 30°C and at elevated temperature of 60°, 90°, 120°, which are heated in the oven. The geometric properties of which are listed up in table

METHODOLOGY **:**

To know the ultimate load carrying capacity of the steel tube under cyclic loading subjected to elevated and its equivalent deflection for different lengths and for different grade of concrete. The materials used in the present study were tested according to Indian standards. The SCC in the fresh state is also tested. Total of 84 specimens where prepared according to present aim of the project and these steel tubes where cut to required lengths and cleaned to remove it from dirt and any type of grease and the edges are leveled in order to maintain the even surface. The prepared SCC filled into the steel tube and the specimen is cured for 28 days. After 28 days, steel tube be heated to different temperature and tested at cyclic composite steel machine.

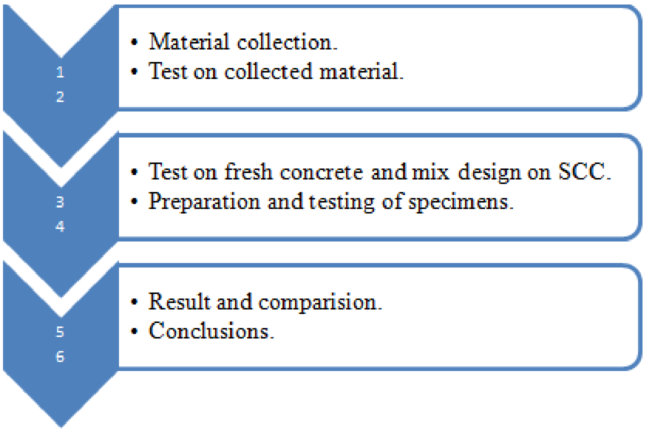


Figure : Methodology of the experiment

Table : geometric properties of specimens

Case	*L(mm)*	*D(mm)*	*t (mm)*	*L/D*	*D/t*
Hallow tube					
	215.8	26.9	3.2	8	8.40
	404.4	33.7	3.2	12	10.53
	678.4	42.4	3.2	16	13.25
M20	215.8	26.9	3.2	8	8.40
	404.4	33.7	3.2	12	10.53
	678.4	42.4	3.2	16	13.25
M25	215.8	26.9	3.2	8	8.40
	404.4	33.7	3.2	12	10.53
	678.4	42.4	3.2	16	13.25
M30	215.8	26.9	3.2	8	8.40
	404.4	33.7	3.2	12	10.53
	678.4	42.4	3.2	16	13.25

PREPARATION OF SPECIMENS:

Steel tubes are cutting into required length:

Cutting of specimens at work shop

Hollow specimens

Specimens filled with different grade of SCC

Specimens curing: Curing for twenty eight days

Curing of specimens

Specimens placed in the oven: The specimens who are heated at 30°, 60°, 90°,etc.

Specimens placed in the oven

LOADING TEST SET UP

In this experiment all the specimens are tested under cyclic loading by cyclic loading machine. The experimental aim is to determine the ultimate load for steel tube having different length and diameter at elevated temperature. The specimen geometric properties and pattern of loading should enter in the The specimen is loaded until buckling is absorbed..Shows the composite steel column machine in corporated with compression shows the experimental setup and buckle of the specimen on loading.

Deformation on loading of specimen

LOCAL BUCKLING

One of the advantages of CSFT columns is that the local bucking is delayed and sometimes prevented. This can be observed in the figures below. Figure shows the hollow steel specimen bulged at the end. The failure is characterized with buckling at the centre and bulging at the ends. Figure. shows the concrete filled steel tubes after failure. In the concrete filled steel tubes there was no bulging at the ends; failure is characterized with buckling at the centre and with slight.

local buckling in the hollow steel tube on loading

Buckling of the concrete filled and hollow steel tubes

Results obtained from experimental investigation for L = 215.8 mm.

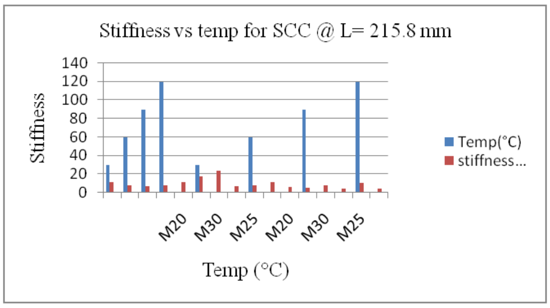
L (mm)	D (mm)	t (mm)	L/D	D/t	Case	Temp. (˚C)	Pu (kN) SCC
215.8	26.9	3.2	8	8.40	M20	30	149
					M25		169
					M30		176
215.8	26.9	3.2	8	8.40	M20	60	140
					M25		149
					M30		157
215.8	26.9	3.2	8	8.40	M20	90	133
					M25		140
					M30		151

L (mm)	D (mm)	t (mm)	L/D	D/t	Case	Temp. (˚C)	Pu (kN)
215.8	26.9	3.2	8	8.40	Hollow	30	110
						60	91
						90	83

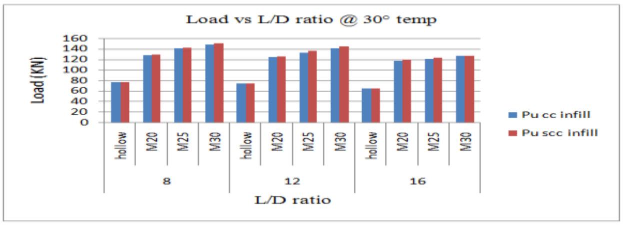
L (mm)	D (mm)	t (mm)	L/D	D/t	Case	Temp. (°C)	Pu (kN) SCC
404.4	33.7	3.2	12	10.53	M20	30	144
					M25		166
					M30		173
404.4	33.7	3.2	12	10.53	M20	60	134
					M25		139
					M30		144
404.4	33.7	3.2	12	10.53	M20	90	126
					M25		131
					M30		135

L(mm)	D (mm)	t (mm)	L/D	D/t	Case	Temp. (°C)	Pu (kN)
404.4	33.7	3.2	12	10.53	Hollow	30	102
						60	82
						90	78

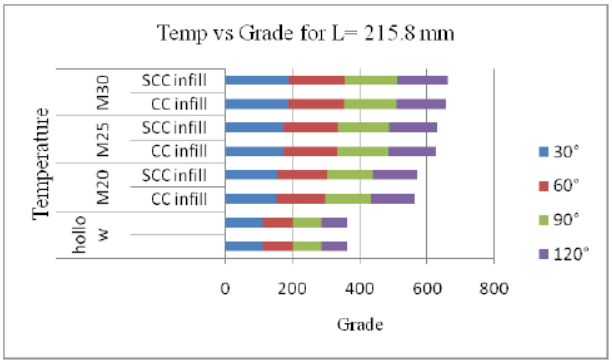
Results obtained from experimental investigation for L = 404.4 mm.



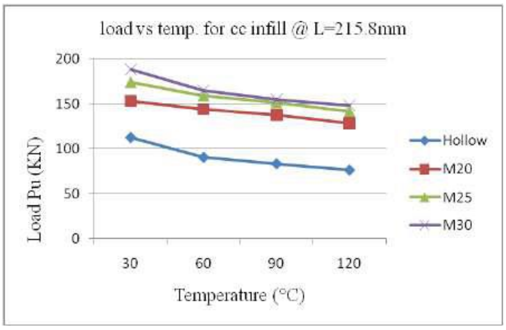
stiffness vs temperature



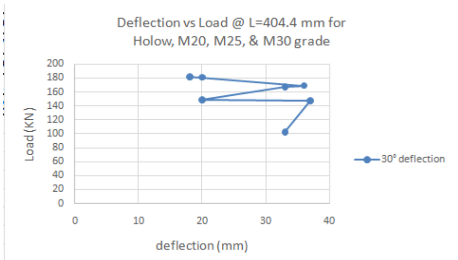
Load vs L/D Ratio



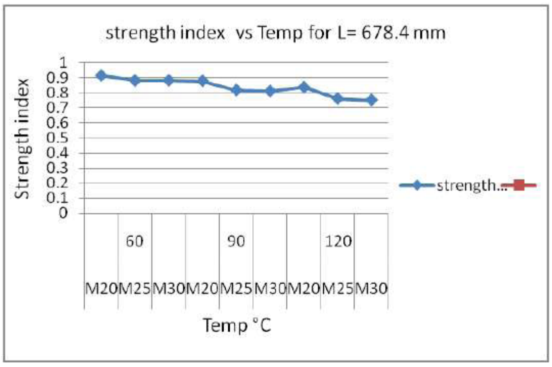
Temperature vs Grade



Load vs Temperature.



Load vs deflection



strength index vs axial load

Results obtained from experimental investigation for L = 678.4 mm.

L (mm)	D (mm)	t (mm)	L/D	D/t	Case	Temp . (°C)	Pu (kN) SCC
678.4	42.4	3.2	16	13.25	M20	30	138
					M25		156
					M30		162
678.4	42.4	3.2	16	13.25	M20	60	127
					M25		136
					M30		140
678.4	42.4	3.2	16	13.25	M20	90	121
					M25		126
					M30		129

CONCLUSIONS

The ultimate load carrying capacity of CFST is higher at room temperature than at elevated temperature 30° C, 60° C, 90° C).

For every increment of temperature the ultimate load carrying capacity of concrete filled tubes decreases by 5-10% and for hollow tubes by 10-15%.

L (mm)	D (mm)	t (mm)	L/D	D/t	Case	Temp. (°C)	Pu (kN)
678.4	42.4	3.2	16	13.25	Hollow	30	92
						60	79
						90	71

SCC filled steel tubes carry higher ultimate load than the hollow tubes when subjected to elevated temperature. The ultimate load for SCC filled steel tube is about 13-20% higher than the hollow steel tubes. [From load verses deflection curves

The local buckling is delayed in CFST compared to the hollow steel tubes.
With increase in grade of concrete the ultimate load also increases marginally by 4-5%. Thus the load verses deflection curve is shifted higher for higher grades of SCC.[from load v/s deflection curve

As L/D ratio increases, the load carrying capacity of the composite tube decreases by 4%-10%.

Stiffness of CFS tubes increases with increase in different grade of concrete.

Strength index of concrete filled steel tubes decreases with increase in Temperature

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