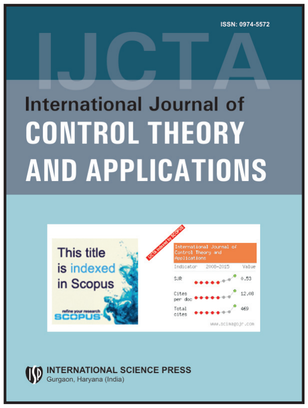

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Experimental Study on Concrete in-Filled Light Gauge Steel Hollow Sections

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Abstract: The experimental study made on the behavior of rectangular Concrete Filled Cold-formed Steel Tubes (CFCST) samples under concentric compression applied on concrete considering the confinement effect. By reviewing the recent literatures related to the present work a detailed experimental program has been planned using different sizes of light gauge steel members. Previous studies have revealed that the splitting of steel and concrete in the interfaces between them could be the dominant cause for the initiation of failure in concrete filled steel tubes (CFST). Here four different sizes of square and rectangular specimens by varying one of the cross-sectional dimensions of the cold-formed steel tubes, keeping the other constant are column tested under axial compression. The two types of column were considered one plain concrete (PC) column and light gauge steel hollow section in-filled concrete. The present study would reveal the compressive ductile behavior due to the hoop stress developed by the concrete on cold-formed steel tubes against the monotonic loads by utilizing the steel concrete composite action.

Keywords: Cold-formed Steel Tubes, Confinement, Ductility, In-fill.

1. INTRODUCTION

Concrete in-filled cold-formed steel tubes columns having strength, durability, ductility, stiffness and full usage of materials in construction industry. In a concrete in-filled column section both the steel and concrete would resist the external loading by better confinement action. The steel tube acts as permanent formwork to column. In composite column the steel provides external reinforcement, and support several levels of construction prior to concrete being pumped. However, investigation of concrete-filled cold formed steel tube columns are found in the literature. The Experiments test have been performed to investigate the strength of CFT columns by varying the depth-to-thickness ratios (D/*t*), length-to-depth ratios (L/D), corner radius, etc. The results revealed that the local buckling occurred in the circular tubes at an axial ductility of 10 or more whereas square and rectangular tubes occurred between 2 and 8. The square and rectangular specimens did not offer confinement effect beyond yield load of the composite column. [1]. The experimental program is carried for the high strength stainless steel columns were tested by Young and Lui, the surrounding steel tube will provide the confined to concrete when the local buckling occurred. [2, 3]. Hsuan-Teh Hu, M. A detailed non-linear finite element analytical study using numerical simulations of CFT columns, has shown that for circular cross-sections the confining effect was better with D/t values were less than 40. A small confining effect was observed with B/*t* value greater than 30. Also they found that the closely spaced reinforcing ties would provide better confining effects. [4]. Togay Oqbakkaloglu (2013) performed experiments on 24 specimens which included square and rectangular FRP tubes filled with Ultra High Strength Concrete. Then the same types of 24 specimens using different type of concrete. Those tests were performed by filling High Strength Concrete instead of Ultra High Strength Concrete for filling the Fiber Reinforced Polimer tubes. Both the articles reveal that sufficiently confined square and rectangular tubes filled with both Ultra High Strength Concrete and High Strength Concrete could exhibit highly ductile behavior. Also the corner radius plays a vital role in confinement effectiveness in both the studies [5, 6]. Jian C. Lim (2013) developed a database by assembling the test results of axial load tests on FRP confined to the HSC. The authors found that the model developed by them could perform significantly better than the previously developed models of FRP restrained concrete in expecting the ultimate conditions of FRP- restrained to HSC. This study could lead the present study to focus on developing models on Cold-formed Steel Tubes (CFST) filled with concrete [7]. Confinement model for normal and high load strength of concrete with FRP confinement was developed by Thong M. Pham, et. al., (2014). A new column parameter was suggested by creating a database considering confinement technique (wraps and tubes) and types of material (different Fiber Reinforced Polymers) from previous studies. The developed model performed well to expect the ultimate condition of FRP restricted concrete circular columns and also have fitted the experimental results. It was concluded in this paper the amount confinement increases with the increase in unconfined load strength of concrete and decrease in ultimate strain. This study could be a lead to the present studies on the amount of confinement by Cold-formed Steel Tubes [8]. Cenk Tort, A.M. et. al., (2010) did analytical study on composite frames consisting of Rectangular Concrete Filled steel Tubes subjected to static and dynamic loads. Finite element model was developed permitting the slip between the steel tube and concrete. It was found that the mixed-finite element model could produce results in correlation with the experimental specimens which shows good computational efficiency on the confinement effect, the surrounding steel tube local buckling, cyclic in both compression and tension under monotonic, quasistatic and pseudo dynamic loads [9].

2. EXPERIMENTAL INVESTIGATION

2.1. Test Specimens

Concrete filled cold formed steel tube section using four different sizes of square and rectangular specimens of cold-formed steel tubes, have taken for experimental investigation and it is tabulated in Table 1.

Table 1
Specimen Details

Specimen Label	*Cross Sectional Dimension (mm)*	*Length in (mm)*	*Slenderness Ratio (λ)*	*In-fill*
CC-1	80 × 80 × 2.5	500	22	P.C.C In-fill
CC-2	80 × 100 × 2.5	500	17	P.C.C In-fill
CC-3	80 × 120 × 2.5	500	14	P.C.C In-fill
CC-4	80 × 140 × 2.5	500	12	P.C.C In-fill

Specimen Label	Cross Sectional Dimension (mm)	Length in (mm)	Slenderness Ratio (λ)	In-fill
PCC-1	75 × 75	490	23	P.C.C
PCC-2	75 × 95	490	18	P.C.C
PCC-3	75 × 115	490	15	P.C.C
PCC-4	75 × 135	490	13	P.C.C
HS-1	80 × 80 × 2.5	500	16	No In-fill
HS-2	80 × 100 × 2.5	500	13	No In-fill
HS-3	80 × 120 × 2.5	500	11	No In-fill
HS-4	80 × 140 × 2.5	500	10	No In-fill

2.2. Instrumentation and Testing Procedure

The test setup for axial deformation of the concrete in-filled light gauge steel hollow section is shown in Figure 1. The deformation of the specimen is recorded with two linear variable differential transformers (LVDT). It is mounted at the 1/3rd of the specimen height with the supporting steel plates. The steel plate with 40 mm thickness is placed over the either side of the concrete. Thus entire load is applied on the concrete core, not on the steel. In order to maintain the equilibrium condition, the steel plate is provided at the bottom of the column section. Hinged – hinged supporting condition is taken before load is applied. The load is applied on the concrete core to estimate the withstand capability of the ultimate load with universal testing machine (UTM). This process is repeated for various concrete in-filled steel hollow sections. In order to obtain the material compressive strength of the plain cement concrete, the specimen is tested by removing the steel moldings as illustrated in Figure 2. Similarly the material compressive strength of the steel hollow section is obtained by having two steel plates on either side of the steel to have the uniform distribution of the forces as shown in Figure 3. Thus the load is applied on the specimen with:

1. Concrete core in the concrete in-filled column
2. Concrete
3. Steel

Figure 1: Concrete in-filled light steel gauge column

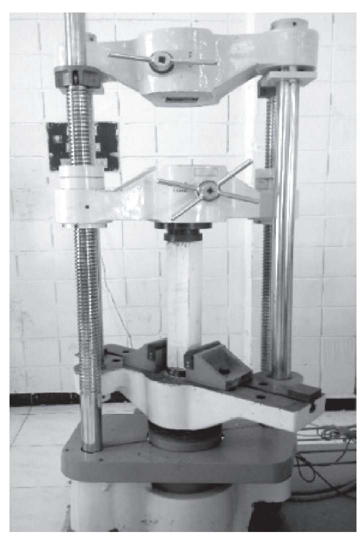

Figure 2: Plain cement concrete column

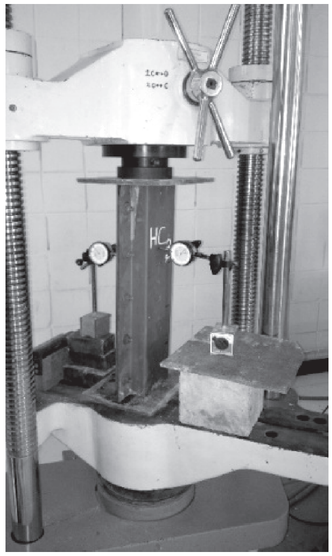

Figure 3: Light gauge steel hollow section column

3. FAILURE MODE

Figure 4 shows failure of the specimen. The load is applied on the concrete core in the CC specimen, which results in bulging at bottom of the column, thereby steel specimen withstands the ultimate load. To test the plain concrete, load is applied on the plain concrete column. When it reaches the maximum load level of 276 KN, crack is formed on the top surface of the plain concrete. With further increase in load causes the sudden failure in the top of the column. From the failure mode it's predicted that the in filled column failed after taking high load than PCC and Hollow column.

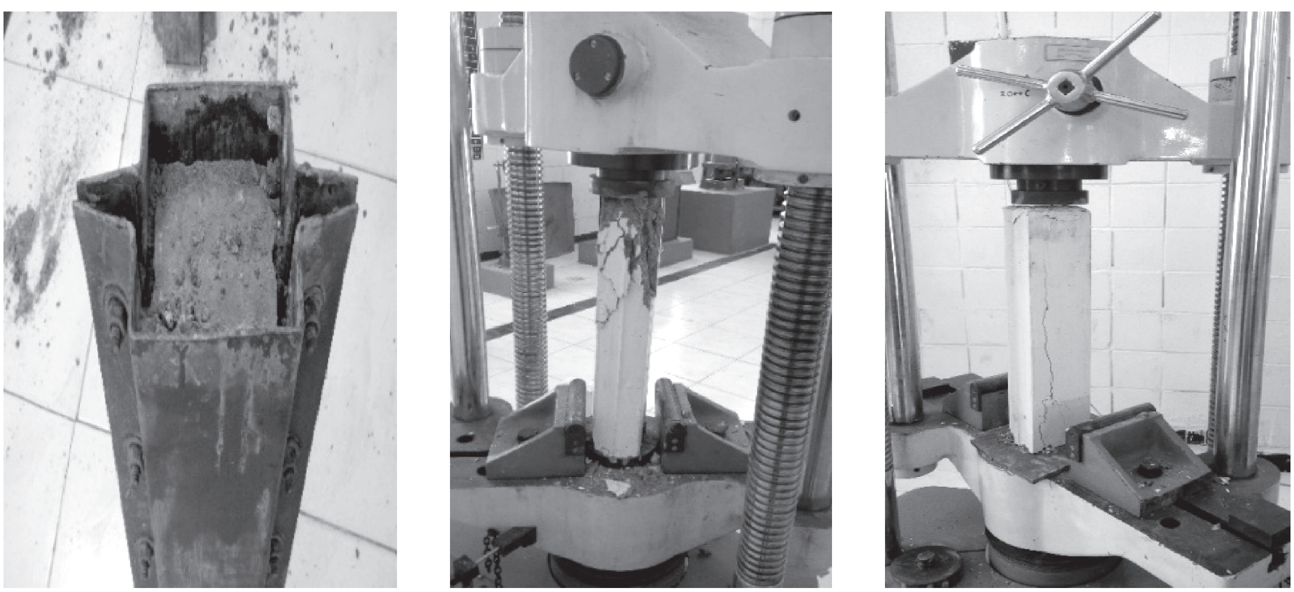

Figure 4: Failure of the specimen

4. RESULT AND DISCUSSION

The ultimate and theoretical strength load value is given in Table 2.

Table 2
Comparison of ultimate load strength and theoretical design strength

Specimen Label	*Experimental stages (KN)*	*Design as per IS 456-2000 and IS-801-1975 (KN)*	*Design as per Euro Code (EN 1994-1:2004) (KN)*
CC-1	392	-	375
PC-1	170	231	-
HS-1	161	179	-
CC-2	453	-	427
PC-2	186	260	-
HS-2	174	196	-
CC-3	510	-	478
PC-3	230	289	-
HS-3	198	212	-
CC-4	563	-	530
PC-4	276	381	-
HS-4	208	229	-

The ultimate load strength for the three types of specimens, concrete in-filled column (CC), Plain concrete column (PCC) and steel Hollow section (HS) are performed experimentally. Theoretical calculation was carried out by Indian standard (IS) code and Euro code-4 and values are tabulated in Table 2. It is inferred from the Table 2 the experimental and theoretical load values for CC is higher than the other specimens. When compared the ultimate load carrying capacity, the CC is taking more load than PCC and HS columns. The in-filled column CC is taking 50% more load than PCC column and 65% more load than HS column. Also while associating with Indian Standard (IS456-2000) design calculations, CC processes 40% higher ultimate strength and 60% more load carrying capacity with Indian Standard (IS801-1975) and 6% higher ultimate strength with European code (Euro code 4) standard design. The load vs displacement curve for all the specimens are shown in Figure 5 and 6.

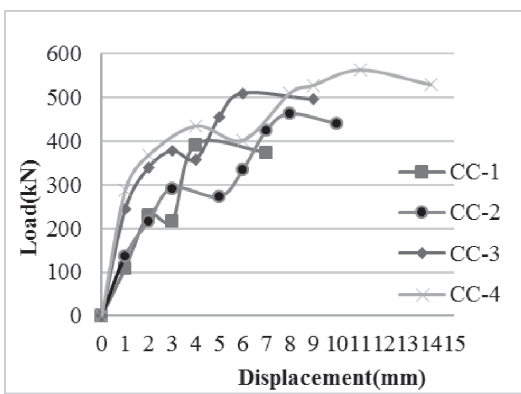

Figure 5: Load vs Displacement for concrete in-filled steel section

Figure 5 shows the load vs displacement curve of concrete in-filled steel section with varying cross sections. It is observed that the size of the column increases the load carrying capacity also increases. The axial load is applied gradually in the concrete core. Initially the failure occurs in the concrete, thereby the load decreases. As a result, steel section withstands the ultimate load. This shows in the graph a slight downward track of the line. The concrete in-filled steel section (CC-1) fails at 230 KN load, then load is automatically decreases slowly to 217 KN. Then the steel section takes the ultimate load until load reaches 392 KN, beyond which it fails. Comparing the four concrete in-filled steel specimens, CC-3 is more superior to the others. It is capable of carrying the higher load with lower displacement that is 510 KN ultimate load capacity with 6 mm displacement.

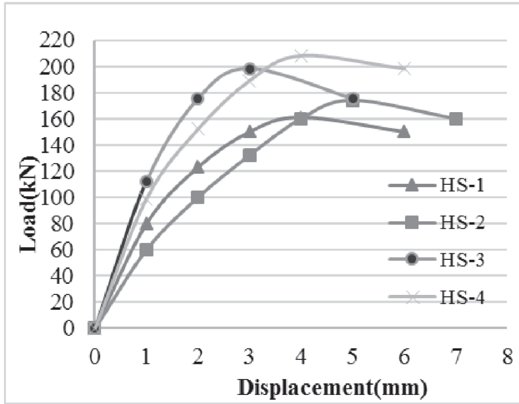

Figure 6: Load vs Displacement steel hollow section

Figure 6 shows the load vs displacement curve of hollow sections. It is concluded that the column with greater cross sectional area HS-3 has higher load carrying capacity. Hence it is capable of withstanding 198 KN load with minimum displacement 3 mm, whereas others has higher displacement.

5. CONCLUSIONS

In this experimental investigation, four different sizes of square and rectangular specimens are tested. The testing is done by varying the one of the cross-sectional dimensions of the CFST by having others constant. It has been tested under axial compression in CFST column. On the basis of these results, the following conclusions were obtained:

1. The column with greater cross sectional area has higher load carrying capacity. Comparing the axial load carrying capacity, concrete in-filled steel column (CC-3) is taking more load carrying capacity of 510 KN with 6 mm displacement.
2. Comparing to the axial load carrying capacity of concrete in-filled steel column is 50 % higher than PCC column.
3. While comparing concrete in-filled steel column with steal HS, it has 65 % more axial load carrying capacity.
4. The experimental test load strength value of concrete in-filled steel column is increased by 40% with the theoretical load carrying capacity of RCC column using Indian Standard IS 456-2000.
5. Theoretical load carrying capacity of the composite column by the guide lines given by European code (Euro code-4) has 6% lower load carrying capacity than concrete in-filled steel column.
6. The experimental test axial load carrying capacity of concrete in-filled steel column (CC) is increased by 60% with the theoretical load carrying capacity of HS column using Indian Standard IS 801-1975.

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