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STUDY OF SHORT CONCRETE FILLED TUBULAR (CFT) COLUMNS

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ABSTRACT: Concrete filled tubular column or CFT column consists of hallow steel tube filled by concrete. Concrete filled steel column is becoming popular for the earthquake resistant structures because of good ductility and high axial strength. It has been observed that structure with concrete filled steel column performs well during strong earthquake. Several codes, namely Eurocode-4,BS 5400-part-5,AISC-LRFD and Architectural Institute of Japan have their own specifications for concrete filled steel columns. In this paper various formulae stated in these codes are described in detail. Then load carrying capacity of concrete filled steel columns determined analytically using these code specified formulae. Finally the analytical results are compared with experimental data available from existing literature. Different shapes of columns are considered for the stud.

KeyWords: Composite Column, Design Codes, BS-5400,AISC-LRFD,EC-4, AIJ

.INTRODUCTION: Structural members are generally made up of either steel or concrete or both steel and concrete as composite. The steel members show high tensile strength and ductility, on the other hand, concrete members have the advantages of high compressive strength and stiffness. If steel concrete members are designed to utilize these structural properties of both materials efficiently, then the steel-concrete composite members exhibit the advantageous qualities of both materials. Like sufficient strength ductility stiffness and energy absorption capacity. The strength of steel and concrete for building structures is getting higher with the development of new high strength concrete. The cross section with high strength concrete becomes smaller, and consequently a column becomes more slender.

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Definition– composite column is a compression member comprising of concrete and steel in the form of other than reinforcing bars, composite column can be of two types: (1) concrete filled tubular columns and (2) encased columns. Concrete filled tubular columns can be divided in following two categories.(1)According to shape of column(a)Square(b)Rectangular(c)Circular and(2)According to depth of concrete filling (a) partially filled concrete steel column(b)fully filled concrete steel column

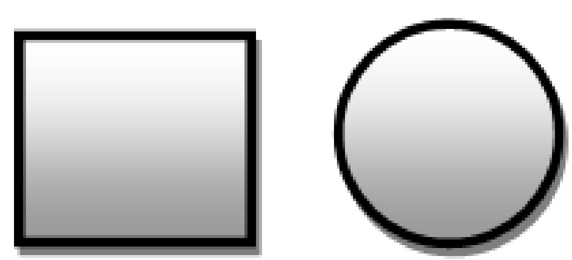

Figure 1 -concrete filled steel columns section

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ADVANTAGES OF CONCRETE FILLED STEEL COLUMN

The concrete filled steel column system has many advantages compared with ordinary steel or reinforced concrete systems. The main advantages are listed below:

(1) Interaction between steel tube and concrete: Local buckling of the steel tube is delayed, and the strength deterioration after the local buckling is moderated, both due to the restraining effect of the concrete. On the other hand, the strength of the concrete is increased due to the confining effect provided by the steel tube, and the strength deterioration is not very severe, because concrete spalling is prevented by the tube. Drying shrinkage and creep of the concrete are much smaller than in ordinary reinforced concrete.

(2) Cross-sectional properties: The steel ratio in the CFT cross section is much larger than in reinforced concrete and concrete-encased steel cross sections. The steel of the CFT section is well plastified under bending because it is located outside the section.

(3) Construction efficiency: Labor for forms and reinforcing bars is omitted, and concrete casting is done by Tremie tube or the pump-up method. This efficiency leads to a cleaner construction site and a reduction in manpower, construction cost, and project length.

(4) Fire resistance: Concrete improves fire resistance so that fireproof material can be reduced or omitted.

(5) Cost performance: Because of the merits listed above, better cost performance is obtained by replacing a steel structure with a CFT structure.

(6) Ecology: The environmental burden can be reduced by omitting the formwork and by reusing steel tubes and using high-quality concrete with recycled aggregates.

STUDY OF DESIGN CODES

In calculating the capacity of composite column member, the strength of the cross section, which is usually expressed in terms of the squash load and the ultimate moment of resistance, is a basic requirement. There is no Indian Standard specification available for the design of concrete filled steel column, several design methods for concrete-filled tubular columns have been developed in different countries and some are under development. In this paper, the design methods or recommendations of concrete-filled columns will be presented for codes from UK (Bridge Code-BS-5400-5), Load &Resistance Factor Design Specification (LRFD), Euro code (EC4). Architectural institute of Japan (AIJ).

The Bridge Code BS-5400 (2005)

A. Wall Thickness of Steel

Steel members must have a wall thickness of not less than:

$b\sqrt{f_y/3E_s}$ For rectangular hollow section

$De\sqrt{f_y/8E_s}$ For circular hollow section

Where

b: breadth of the rectangular section.

De: outside diameter of the steel hollow section.

F_y: yield strength of steel.

E_s :moduls of elasticity of steel.

B. Slenderness

The slenderness function λ is given by

$\lambda = l_e / l_E$

$l_E = \pi\ [(E_c I_c + E_s I_s) / N_u]^{0.5}$

Where,

l_e: effective length of the actual column in the plane of bending

E_s: modulus of elasticity of hollow steel section.

I_c, I_s : moment of inertia of concrete and steel about the appropriate axis, respectively.

E_c: modulus of elasticity of concrete = 450 $f_{cu,}$ where f_{cu} is the characteristic cube strength of concrete.

N_u :squash load

C. Axially Loaded Short Column

When the ratios of the effective length to the lateral dimension for axes, l_x/h, and l_y/b do not exceed 12 (h and b are the largest and the least lateral dimensions of the composite column, respectively) the column will be considered as short column.

The squash load, N_u, is defined as the ultimate short-term axial loads for a short column, and is

Given as:

$N_u = A_s F_y / \gamma_{ms} + 0.67\ A_c f_{cc} / \gamma_{mc}$

Euro Code 4 (EC-4-1994)

Euro code 4 covers concrete-encased steel sections, partially encased sections and concrete-filled sections with and without additional reinforcement. Only concrete filled sections (circular, square and rectangular) are covered in this chapter. EC4 uses limit state concepts to achieve these aims of serviceability and safety by applying partial safety factors, one set to the action (i.e. loads), and the other set to material properties. Actions include the characteristic values of load, live (imposed) and wind loads as well as imposed deformation caused for instance by temperature, shrinkage and settlement.

A. Resistance to Local Buckling (c.n.-4.8.2.4)

Resistance to local buckling is assumed to be achieved if,

$h/t < 52\varepsilon$ for rectangular hollow steel sections

$d/t < 90\ \varepsilon^2$ for circular hollow steel section

Where:

$\varepsilon = (235 / 0.91 f_y)^{1/2}$

f_y: yield strength of steel in MPa.

t: thickness of steel cross section in mm.

d: diameter of circular column in mm.

h: height of rectangular column in mm.

B. Short Column

For short column, that is column with slenderness ratio, $\lambda \leq 0.2$, capacity of column is

$$N_{plrd} = \frac{A_s F_y}{Y_{ms}} + \frac{A_s f_{cu}}{Y_{mc}}$$

American Standards: AISC -LRFD Methods:

Section 1 of the American Institute of Steel Constructions- Load Resistance Factor Design Specification for Structural Steel Buildings (1993) provides detailed requirements to cross sectional areas, wall thickness of the steel tubing, concrete strengths, and steel strength.

Design equations are developed for both the concrete encased steel shapes and the concrete filled steel tubes (CFT) with different calculations. This section attempts to provide a summary of the design requirements and calculation for CFT columns.

The general requirements limitations for CFT are listed below:

1. The total cross sectional area of the steel section may not be less than 4 percent of the

gross column area. $A_s \geq 0.04\ A_g$.

2. The specified compressive strength of normal concrete must be at least 21 MPa but not more than 55 MPa if normal concrete is used: 21MPa ≤ f_c ≤ 55MPa, and not less than 28 MPa for lightweight aggregate concrete.

3. The yield stress of the steel section and reinforcing bars used may not be greater than F_y ≤ 380 MPa

4. The minimum wall thickness of the steel tubing and pipe sections filled with concrete is as follows:

$$t \geq b\sqrt{f_y/3E_s}$$ for rectangular sections.

$$t \geq De\sqrt{f_y/3E_s}$$ for circular section.

Where:

b: width of the steel tube.

D_e: outside diameter of steel section.

E: modulus of elasticity of steel.

t: wall thickness of steel tube.

F_y: yield stress of steel.

Capacity of column is$N_d = \Phi P_n = 0.85\ f_{cr} A_s$

Architectural Institute of Japan

The Architectural Institute of Japan specification provides the method of design of concrete filled steel columns based on ultimate limit state which is explained in this section.The specified yield stress of steel tubes ranges from 235MPa (215 if plate thickness t > 40mm) to 355MPa (335 if t > 40mm) in accordance with several steel grades which contain high-strength steel.The limiting values of the width-to-thickness ratio for a rectangular tube and the diameter- to-thickness ratio for a circular tube are as follows.

B = flange width of a rectangular tube

D = depth or diameter of a circular tube

t = wall thickness of steel tube

F = standard strength to determine allowable stresses of steel, smaller of yield stress and 0.7 times tensile strength (MPa)

These values are relaxed to 1.5 times those of bare steels based on the research of the restraining effect of filling concrete on local buckling of steel tubes. The long-term allowable bond stress between the filling concrete and the inside of the steel tube is 0.15MPa for a circular tube and 0.1MPa for a rectangular tube. The bond stress does not depend on the strength of the concrete. The values for the short-term stress condition are 1.5 times those for the long-term condition.

The maximum effective length l_e of a CFT member is limited to:

For a compression member $l_e / D \leq 50$

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For a Beam column $l_e / D \leq 30$

where,

l_e effective buckling length of a member.

D minimum depth of a cross section. And capacity of column is

$N_{cu1} = {}_cN_{cu} + (1+\eta)\, {}_sN_{cu}$

NUMERICAL EXAMPLES BASED ON CODES

Concrete filled steel columns of circular and square cross sections are studied analytically and the analytical results are compared with experimental values. Experimental data have been taken from available literature [Almadini (2011) and Gupta P.K. (2010)].

Table-1 Comparison of code specified results for short CFT column with experimental data by Almadini (2011)

Sr No	Shape	Section properties		Material properties (N/mm²)		Squash load Experimental (kN)	Squash load (analytical) (kN)			
		D/t ratio	L_e/D	f_c	f_y		BS-5	EC-4	AISC/ LRFD	AIJ
1	Circular	39.75	2.51	71.25	360	1800	1380	1488	1508	1785
2	Circular	39.75	2.51	45.42	360	1400	1039	1129	1178	1227
3	Square	35.25	2.83	71.25	360	1750	1023	1241	1327	1531
4	Square	37.5	3.33	71.25	360	1945	1195	1722	1740	1803

Table-2 Comparison of code specified results for short CFT column with experimental data by P.K. Gupta (2010)

Sr No	Shape	Section properties		Material properties (N/mm²)		Squash load Experimental (kN)	Squash load (analytical) (kN)			
		D/t ratio	L_e/D	f_c	f_y		BS-5	EC-4	AISC/ LRFD	AIJ
1	Circular	32.59	3.80	30	360	612	430	413	419.5	481.8
2	Circular	32.59	3.80	40	360	665	446	458	471	494
3	Circular	38.94	3.02	30	360	730	522	549	581	603
4	Circular	38.94	3.02	40	360	822	623	612	661	709

DISCUSSION AND CONCLUDING REMARKS

The results lead to the conclusion that as the characteristic strength of concrete increases the load carrying capacity of the CFT column increases. Another observation is that when Le/D ratio decreases and D/t increases load carrying capacity increases.The analytical results using four codes show that the squash load is less in BS-5 case and maximum in AIJ case. All analytical values are much less than an experimental value, which shows the reserve strength in the columns, designed as per code specified formula. BS-5and EC-4, give more conservative results compared to AISC/LRFD and AIJ codes. It can be concluded that concrete filled steel columns can be effectively used as structural members. However to determine suitability of CFT columns in a particular structure, more detail investigation and experimental work is necessary.

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