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Structural behavior of concrete filled steel tubular sections (CFT/CFSt) under axial compression

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ABSTRACT

In this study, compressive strength, modulus of elasticity and steel tensile coupon tests are performed to determine material properties. Sixteen hollow cold formed steel tubes and 48 concrete filled steel tube specimens are used for axial compression tests. The effects of width/thickness ratio (b/t), the compressive strength of concrete and geometrical shape of cross section parameters on ultimate loads, axial stress, ductility and buckling behavior are investigated. Circular, hexagonal, rectangular and square sections, 18.75, 30.00, 50.00, 100.00 b/t ratio values and 13, 26, 35 MPa concrete compressive strength values are chosen for the experimental procedure. Analytical models of specimens are developed using a finite element program (ABAQUS) and the results are compared. Circular specimens are the most effective samples according to both axial stress and ductility values. The concrete in tubes has experienced considerable amount of deformations which is not expected from such a brittle material in certain cases. The results provide an innovative perspective on using cold formed steel and concrete together as a composite material.

1. Introduction

Tension and compression stresses occur at different regions according to the loads and load conditions in structural members. It can be seen that the optimum resisting section against these stresses in the same member is the reinforced concrete which has had a composite structure since the 1850s. However, recent studies concerning concrete filled steel tubes (CFST) have become important in the area of structural engineering.

Structural members have enough bearing capacity against internal forces according to dead loads and live loads caused by external effects in normal conditions. However, extra shear forces and moments created by seismic movements or dynamic vibrations during earthquakes force the capacities of members. Conventional reinforced cross sections might be of higher dimensions than required during the design stage because of this. Concrete filled steel tubes have a high ductility and bearing capacity. This system provides for rapid construction without removing any formwork. Steel members prevent lateral expansion of concrete as seen with stirrups. Steel tube performs both longitudinal and lateral reinforcement as well as it is used in formwork. A concrete core resists axial force, at the same time preventing the buckling of steel in an inward direction on a tube. The main design criteria of Turkish Earthquake Codes, based on the human life sustainability during earthquakes, can be easily provided by the ductility behavior of CFST members easily. The use of steel walled composite cross sections is becoming widespread in civil engineering.

The main purpose of using CFST members is to provide maximum bearing capacity prior to possible buckling modes. Local buckling is expected in the case of the inadequate confinement effects by steel tube or inadequate concrete core strength in a composite section. The confinement effect is called the radial pressure created by steel tubes. It operates in the same manner as stirrups and alters the buckling mode. Slenderness is also an important effect on the buckling mode determined using the dimensions of members.

Most researchers have focused on the strength, ductility, deformation, buckling and confinement effects created by the change of cross section areas and shape, the interaction of composite materials, the strength of materials, strengthening bars, and member lengths and width (or diameter)/thickness ratios (b/t) under normal load or bending moment conditions. Hu et al. [1] investigated the confinement effects on 24 circular, square and strengthened square sectioned specimens with a range of 17–150 b/t ratio under compression. The maximum confinement effects

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were seen on circular specimens ($b/t < 40$). Little confinement effects were observed on square sections ($b/t > 30$). Other experimental tests were performed on composite stub columns produced with b/t ratio values between 15 and 59. The results indicate that circular shaped specimens produced three dimensional inclusive confinement effects on core concrete (Knowles and Park [2]). An experimental study was performed on elliptical concrete filled tubular specimens with a range of 69–160 b/t ratio under centric loading (Uenaka [3]). They showed that the axial load capacity of elliptical CFST columns can be estimated by the equation including confinement effect of smaller diameter direction. Gupta et al. [4] showed that lower b/t ratios provide higher confinement effects on the test results of 81 specimens having the ratios of between 25 and 39. Hu et al. [5] investigated the interaction and confinement effects on CFT columns under a combination of axial compression and bending moment. More lateral confinement pressure was observed in strengthened circular specimens with an increasing axial loading ratio. The behavior of stub CFT column under concentric loading on 11 specimens was studied by Sakino et al. [6]. Chitawadagi et al. [7] demonstrated that the most effective parameter is the diameter of a steel tube related with the ultimate axial load and axial shortening on highly slender CFTs. Elchalakani et al. [8] performed a series of bending tests on circular hollow sections. They showed that the effects of nonlinear bending properties and the regulation of existing slenderness criteria are required for circular hollow sections. Yang et al. [9] investigated the ultimate bearing capacity and buckling mechanisms on 28 cold formed steel specimens having the high tensile strength (550 MPa) and the b/t range between 13 and 119. An approximate six percent difference between the experimental and the analytical results was observed according to the finite element model. The buckling and ultimate strength behavior of cold formed steel mid-length columns was investigated on 16 innovative specimens by Narayanan and Mahendran [10].

Ductility behavior and buckling behavior are the other results of this study. Ductility is the total deformation capacity measurement up to an ultimate point. Serious deformation might occur when the strength of the material is approximately constant throughout the ductile structure. Ductility is an important parameter for the dissipation of energy during earthquakes or blasting

Table 1
Amount of materials for 1 m^3 concrete mix design.

Material	Estimated compressive strength values of concrete		
	10 MPa	20 MPa	30 MPa
Cement (kg)	240.0	313.0	400.0
Water (kg)	238.6	237.1	236.9
0–5 mm aggregate (kg)	808.9	781.6	749.1
5–15 mm aggregate (kg)	529.7	511.8	490.6
15–22 mm aggregate (kg)	441.3	426.3	408.6

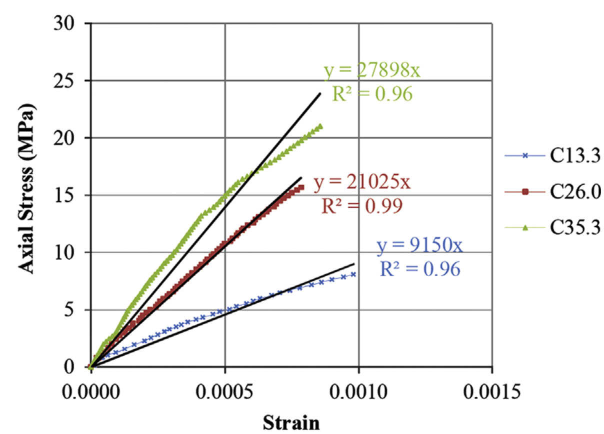

Fig. 2. Modulus of elasticity results for concrete specimens.

Fig. 1. Concrete compression test equipment.

Fig. 3. Steel tension coupon test equipment.