Construction and Building Materials 168 (2018) 715–731

Contents lists available at ScienceDirect

Construction and Building Materials

journal homepage: www.elsevier.com/locate/conbuildmat

Code based assessment of load capacity of steel tubular columns infilled with recycled aggregate concrete under compression

Ihsan Taha Kadhim [a,b,*], Esra Mete Güneyisi [a]

[a] Department of Civil Engineering, Gaziantep University, 27310 Gaziantep, Turkey
[b] Building and Construction Department, University of Technology, Baghdad, Iraq

HIGHLIGHTS

- A parametric study on circular concrete filled steel tubular short columns was performed.
- Ultimate strength of the columns were assessed by various design codes.
- Effect of different parameters on the behavior of these columns was discussed.

ARTICLE INFO

Article history:
Received 31 July 2017
Received in revised form 13 January 2018
Accepted 14 February 2018

Keywords:
Composite column
Concrete
Design code
Predicted load
Recycled aggregate concrete
Steel tube

ABSTRACT

In this study, a comparison and code evaluation for the load carrying capacity (Pu) of recycled aggregate concrete (RAC) filled steel tubular short columns under axial compression are presented. For this, a total of 1600 Pu results were assessed using four different international design codes (Eurocode 4, ACI, AIJ and DL/T). The relations as well as the proposed formulas extracted from the study were discussed. For the composite column, the properties of the steel tube such as outer diameter (D), wall thickness (t), length (L) and yield strength of steel (f_y) as well as the properties of core concrete such as single and combined used of recycled coarse and fine aggregates, substitution level and compressive strength were considered as the investigation parameters. Moreover, the strength of the recycled aggregate self-compacting concrete was adopted from an experimental study reported in the literature. It was found that Eurocode 4 had revealed better results in terms of randomness and scatter of data; whilst the strength values calculated via ACI had relatively more variation than other codes. In addition, the analysis of the results indicated a shortcoming especially in ACI due to not considering the benefit of the confinement between the steel tube and infill. The effect of the yield strength of steel tube was observed to be varied based on D/t ratio. Furthermore, in all tested codes, the incorporation of recycled aggregate adversely affected the concrete strength which in turn decreased the predicted Pu of the columns.

1. Introduction

In recent years, the use of concrete filled steel tubular (CFST) columns are widely increased for multiple construction members. In general, CFST structural element consists of concrete (plain or reinforced) in the core restricted by steel tube forming a kind of steel-concrete structures. The wide spread of CFST structure, particularly in columns, attributes to the combined advantages of steel and concrete together. Indeed, the strength of the confined concrete considerably increases due to surrounding it by steel tube; also, the inward buckling of the steel tube is delayed or prevented via the presence of concrete core [1]. Steel tube not only contributes to the strength of element but also borders the concrete, which eliminates the formwork of concrete; thus, reduces the time of construction [2]. Hence, the term " composite column" or " CFST column " includes any compression member in which steel and concrete contribute to the strength of structure; where the element of steel acts compositely with concrete [3]. The remarkable increase in the axial load capacity (Pu) of CFST columns leads to reducing the cross-section area of elements as well as providing the distinct performance in the earthquake-resistant characteristics [4]. Therefore, the usage of these columns expands to include various types of structures such as tall buildings, bridges and subway platforms, etc. [5–8].

In CFST columns, concrete core represents 75–98% of total cross-sectional area. For this, concrete is a pivotal factor controlling

* Corresponding author at: Building and Construction Department, University of Technology, Baghdad, Iraq.
E-mail address: ihsantahak@yahoo.com (I.T. Kadhim).

https://doi.org/10.1016/j.conbuildmat.2018.02.088
0950-0618/

the strength of the output columns. Hence, the concrete type must be determined by taking into account the multiple designs as well as the availability of concrete materials. In this regard, recycled aggregate concrete (RAC) could offer a reasonable choice to utilize it in the field of such columns particularly in countries where the natural materials are exhausted [9]. The use or application of RAC in the steel tubular members as an infill material could be a convenient way to save the natural resources and environmental preservation by consuming it rather than disposal in landfills or depletion the virgin resources. Moreover, as reported in the literature, the scarcity of natural materials in the metropolitan environments as well as the long distance between the source of materials and construction sites compels the constructors to substitute the natural aggregate (NA) by the recycled materials [10–13]. In the case of natural disasters such as earthquakes, about 50% of the construction and demolition waste is obtained from solid wastes in urban areas compared with 13–29% in normal situations [14]. Hence, the recycling of old concrete and demolition waste can provide a cost-effective method for the construction industry.

In effect, the theoretical analysis and experimental investigation of the maximum Pu of CFST columns have a significant role in the research and engineering practices. For this, several studies related with the field of circular CFST columns were conducted in the last few years [2,15–20]. Previous literatures investigated the strength aspects as well as diameter-to-thickness (D/t) ratios of circular CFST columns. For stub CFST columns, the failure occurred either in compressive yielding of steel or crushing of concrete core; while the local buckling occurred in high D/t ratio columns [7]. Hence, the engineering properties such as D/t ratio, length, confining coefficient and slenderness of columns are deemed as crucial and critical [15,21]. For this, in the literature, the composite columns with different D/t ratios and combinations of various material properties were studied. For example, Goode [22] documented a series of databases and compiled 1819 CFST columns test results in order to conduct a comparison of these databases of circular stub columns. In similar way, Güneyisi et al. [4] compared 314 comprehensive experimental data samples extracted from the previous studies and prepared a data set for testing the proposed model. Lu and Zhao [2] also summarized a total of 250 experimental data of axial capacity for CFST stub columns. The authors applied the design codes (ACI, AISC, AIJ, Eurocode 4 and DL/T) as well as existing empirical models proposed by the previous researchers to calculate Pu value of circular CFST stub columns.

However, the aforesaid literatures were mainly undertaken the structural behavior of steel tube columns filled with conventional concrete (CC). In comparison with this type of concrete, limited research has been conducted to examine the effect of RAC on the predicted axial capacity of CFST columns. Moreover, the studies dealing with full recycled aggregate replacement level are limited. In this regard, Dong et al. [23] prepared an experimental study to investigate the structural response of normal and RAC filled steel tube columns. The authors concluded an interesting result that the ultimate strength for steel tube columns filled with RAC showed slightly higher values than for the corresponding columns with CC. Yang and Han [24] reported that the typical failure modes of RAC columns were similar to those of CFST columns filled with CC; however, RAC columns revealed slightly low results in term of Pu and ductility. Konno et al. [25] concluded that the ultimate strength of the composite column filled by RAC was smaller than those of the confined CC columns; further, the fractures progressed faster. However, Chen et al. [26] stated that the failure process of RAC filled-circle steel tube columns was similar to CC ones; also, Konno et al. [27] emphasized that there was similar deformational behavior between the confined RAC and CC columns in spite of low Young's modulus of RAC.

In the present paper, a parametric study based on the design code equations for evaluating the axial load capacity of the steel tubular columns infilled with RAC was performed. The capacity of the columns was assessed according to four different international codes (Eurocode 4, ACI, AIJ and DL/T) [28–32]. The effects of the key parameters on the aforementioned property was studied and discussed comparatively.

2. Details of the study

Basically, the test of ultimate axial load of CFST columns considered several important geometric and material properties taken as predictive parameters such as D/t ratio, the strengths of the concrete and steel tube. The compression test of circular CFST columns is schematically depicted in Fig. 1 in which the steel tube is loaded simultaneously with the concrete core. In the current study, four widely used international design codes were followed to determine the capacity of the composite columns. For each tested code, the specimens had fixed steel tube thickness of 3 mm and length to diameter ratio (L/D) of 3 while they had 5 different D/t ratios (20, 40, 60, 80 and 100) and 5 different yield strengths of steel tube (185, 235, 275, 355 and 450 MPa). For the concrete core, the details of mix proportion as well as compressive strength of concrete were obtained from the experimental studies of Kadhim [33] and Gesoglu et al. [34]; in which totally 16 self-compacting concrete (SCC) mixtures with and without recycled aggregate (RA) were manufactured and tested. In their studies, the concretes were produced by utilizing NA and/or RA at specific proportions; in which they were classified into four series. Each series consisted of four mixes. In series I, mixes included 100% NA, while series II mixes included recycled coarse aggregate (RCA) and natural fine aggregate (NFA). Series III was made with natural coarse aggregate (NCA) and recycled fine aggregate (RFA). Finally, series IV was produced with a 100% RA (RFA + RCA). Moreover, the concrete properties were enhanced by adding silica fume (SF) as an admixture for the mixtures to clarify the effect of this material in SCC. In this regard, the concretes were designed at two different water/binder ratios (w/b) of 0.30 and 0.43. It was noted that the compressive strength of the reference series of SCC tested by 150 mm cube samples, Series I, varied from 66.6 to 81.4 MPa. However, the compressive strength of recycled aggregate self-compacting concrete (RASCC) recorded lower values than those of reference mixtures by about 11.8–16.9%, 15.8–26.9%, and 27.0–30.9% for Series II, III and IV, respectively.

In this study, the effect of abovementioned parameters on the Pu results were observed, compared and discussed in detail. For this, the possibility of using RASCC as a concrete core for CFST column was numerically investigated. The capacity (totally 1600 Pu test results) for five different D/t ratio and yield strength of steel tube as well as 16 different compressive strength of concrete core

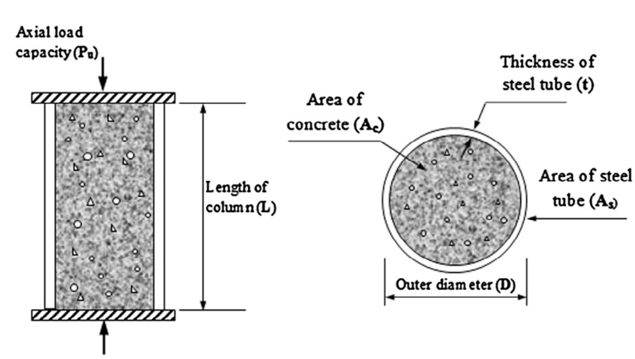

Fig. 1. Testing detail and cross-section of circular CFST columns.