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Simulation of seismic behavior of square recycled aggregate concrete – filled steel tubular columns

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HIGHLIGHTS

- A computer program for the nonlinear analysis of square RACFST columns was developed.
- CFST structures can realize the economic savings by working with high RCA contents.
- Strengthening measures need to be developed to ensure the ductility of 1:1-scaled square RACFST columns.

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ABSTRACT

Concrete-filled steel tubes can improve the mechanical behavior in terms of strength, stiffness, ductility and energy dissipation for the initial deficiencies of recycled aggregate concrete compared with natural aggregate concrete. The firsthand seismic performance indices on recycled aggregate concrete-filled steel tubular (RACFST) structural members are very limited due to the rare experimental results reported in the literature. To this end, a computer-assisted program for the nonlinear analysis of square RACFST columns was developed by employing SeismoStruct Software, to emphasize the effect of recycled coarse aggregate (RCA) content on the behavior of recycled aggregate concrete and the confinement effect provided by outer tubes on core concrete. Concerning the hysteretic curves, load carrying capacity and ductility, comparisons between simulation results and existing experimental ones were made to examine the rationality of numerical square RACFST model. The analysis results show that the numerical model can well simulate and predict the seismic behavior of square RACFST columns. To obtain more structural performance indices, the parametric study was performed to investigate the effects of RCA content and pre-wetting, steel yield strength, length-diameter ratio, diameter-thickness ratio, axial load ratio and structural size ratio on the hysteretic characteristic, initial lateral stiffness, ultimate lateral load and ductility of cyclic bended square RACFST columns. Both the measurement and simulation results demonstrate that concrete-filled steel tubular columns employing recycled coarse aggregates have laudable seismic behavior, and it is feasible to apply and promote the recycled aggregate concrete into concrete-filled steel tube structures in anti-seismic regions.

1. Introduction

Recycled aggregate concrete (RAC) has been recognized as a cleaner production in construction activities from the viewpoint of recycling and reuse of waste concrete [1]. A lot of experimental investigations have demonstrated that it is feasible and sufficient to use recycled aggregate concrete as a structural concrete in Civil Engineering, even though the initial deficiencies of recycled aggregate concrete can reduce its mechanical behaviors (eg. lower strength, elastic modulus, energy dissipation, durability but larger peak strain, Poisson's ratio, shrinkage and creep), compared with natural aggregate concrete (NAC, also known as normal concrete) [2–11].

With regard to popularizing RAC materials, many efforts were made to enhance the mechanical behavior of RAC structures.

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Partially and fully confined concrete structural members can be an effective solution to strengthen the imperfection of recycled aggregate concrete (see Fig. 1). Ma et al. [12,13] adopted H-shaped steel to partially restrict the dilation of RAC under cyclic loading, and the experimental results showed that the bearing capacity, stiffness, ductility and energy dissipation of steel reinforced recycled aggregate concrete columns were much better than those of reinforced recycled aggregate concrete columns. As for the fully confined RAC, many researchers such as Xiao et al. [14], Chen et al. [15], Zhao et al. [16], Xie and Ozbakkaloglu [17] and Teng et al. [18] performed static experimental studies on the properties of FRP-confined recycled aggregate concrete columns under compression, and the test results collectively demonstrated that the compressive strength and the ductility of recycled aggregate concrete were improved due to the wrapping of FRP. In addition, Xiao et al. [19] carried out a series of tests on the compressive behavior of recycled aggregate concrete-filled steel tubular (RACFST) columns and FRP-confined recycled aggregate concrete columns to evaluate the confinement effects provided by steel tubes and FRP wraps, respectively. A finding can be concluded from the comparative results that the comprehensive mechanical behavior of RACFST is superior to that of FRP-confined recycled aggregate concrete. Based on this philosophy, Chen et al. [20], Yang and Han [21], Yang and Ma [22], Shi et al. [23], Wang et al. [24,25] and Zhao et al. [26] accomplished a mass of experimental researches to investigate the influence of recycled coarse aggregate (RCA) content on the compressive behavior of RACFST columns. From these tests, Chen et al. [27] summarized the compressive strengths and proposed a strength prediction model by considering the influence of RCA content. Moreover, a basic conclusion can be made from Chen et al. [27]: (1) for the pre-wetted recycled coarse aggregates, an increase of RCA content leads to reduce the compressive strength of RACFST; (2) for the no pre-wetted recycled coarse aggregates, an increase of RCA content leads to enhance the compressive strength of RACFST.

In order to reveal the seismic failure mechanism of RACFST, Yang et al. [28] firstly conducted the experimental work on the performance of recycled aggregate concrete-filled steel tubular columns under cyclic loading beam-tests. It should be pointed out that the recycled coarse aggregates used in Yang et al. [28]'s study were pre-wetted before fabricating the specimens. With respect to the no pre-wetted recycled coarse aggregates, Zhang et al. [29] and Chen et al. [30] tested sixteen cantilever RACFST columns subjected to a constant load and cyclic bending loads. The cyclic load carrying capacities of RACFST affected by RCA content and pre-wetting are similar to the before-mentioned static compressive strengths of RACFST. In addition, Wu et al. [31,32] performed cyclic tests on thin-walled steel tubular columns made from demolished concrete blocks or lumps with fresh concrete to investigate the effects of replacement percentages of the demolished concrete blocks and the thickness of steel tubes on their seismic behavior.

In spite of the extensive studies of RACFST members in the literature, the topics on the seismic behavior of RACFST columns still have not been fully addressed; and the amount of these composite square column specimens is quite limited to obtain the firsthand seismic performance indices and to establish the design method for RACFST columns. The primary objective of this paper is to develop a computer-assisted program for the nonlinear analysis of square RACFST columns subjected to a constant axial load and cyclic bending loads. A secondary objective is to carry out the parametric study to investigate the effects of RCA content and pre-wetting, steel yield strength, length-diameter ratio,

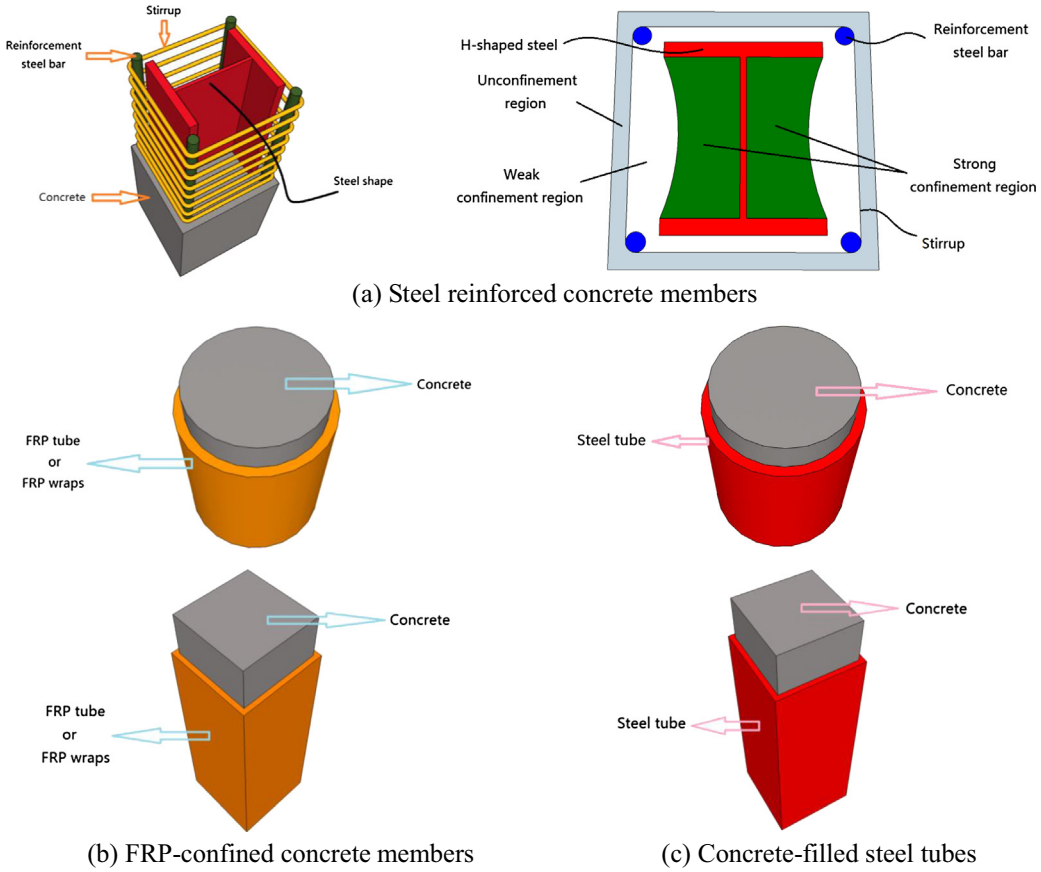

Fig. 1. Sketches of partially and fully confined concrete structural members.