Construction and Building Materials 126 (2016) 641–660

Contents lists available at ScienceDirect

Construction and Building Materials

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

Review

Recycling and reuse of construction and demolition waste in concrete-filled steel tubes: A review

Zongping Chen [a,d], Jinjun Xu [b,*], Yuliang Chen [a], Eric M. Lui [c]

[a] College of Civil Engineering and Architecture, Guangxi University, 530004 Nanning, China
[b] College of Civil Engineering, Nanjing Technology University, 211816 Nanjing, China
[c] Department of Civil and Environmental Engineering, Syracuse University, NY 13244-1240, Syracuse, USA
[d] Key Laboratory of Disaster Prevention and Structural Safety of Ministry of Education, Guangxi University, 530004 Nanning, China

HIGHLIGHTS

- Bond behavior between recycled aggregate concrete and steel tubes was reviewed and discussed.
- Static behavior and long-term performance of RACFT members were summarized.
- Performance of recycled aggregate concrete-filled steel tube members and frames under cyclic loads were described.
- Strength prediction model of recycled aggregate concrete-filled steel tubes was proposed.

ARTICLE INFO

Article history:
Received 23 April 2016
Received in revised form 8 August 2016
Accepted 17 September 2016

Keywords:
Recycled coarse aggregate (RCA)
Natural aggregate concrete (NAC)
Recycled aggregate concrete (RAC)
Concrete-filled steel tubes
Bond behavior
Cyclic performance

ABSTRACT

This paper presents a summary review of research performed on the mechanical behavior of concrete-filled steel tube members and frames made from recycled aggregate concrete (RAC). The paper begins with an introduction of some research progress made on the bond behavior between RAC and steel tubes. Discussion is then turned to the static behavior of recycled aggregate concrete-filled steel tube (RACFST) members, including the flexural performance of beams, concentric and eccentric load carrying capacities of stub columns and long-term performance of columns. Research findings on the performance of RACFST columns and RACFST plane frame under cyclic loads are then presented. The paper concludes with a presentation of a prediction model for the strength of RACFST by considering whether the recycled coarse aggregates have been pre-wetted or not before fabrication of the structural members. Based on these research results, it can be concluded that with proper design and construction, the application of RAC as a structural material in concrete-filled steel tube structures is feasible and safe.

Contents

* Corresponding author.
E-mail address: jjxu_concrete@163.com (J. Xu).

http://dx.doi.org/10.1016/j.conbuildmat.2016.09.063
0950-0618/

1. Introduction

The construction industry is an important economic sector that has a large environmental impact in terms of natural resources extraction, energy consumption, pollutants release, greenhouse gases emissions and amount of waste generated [1]. Hence, promoting and practicing sustainability in construction can help preserve the planet's ecosystems, conserve natural resources and improve the environmental conditions of all living organisms on earth. Recycling and reuse of construction and demolition wastes is one such attempt to achieve this goal. Processing construction and demolition wastes and reintroducing them as recycled aggregates in new concrete, referred to as recycled aggregate concrete (RAC), can be an effective way to develop and implement "green" concrete for new construction.

A review of existing literature [2–9] has shown that much effort has been devoted to the investigation of the mechanical properties and durability of RAC. Thereupon, a basic consensus is that the compressive and tensile strengths, elastic modulus and durability of RAC are in general lower than those of natural aggregate concrete (NAC), but the strain that corresponds to the peak stress, shrinkage and creep of RAC are to a certain extent higher when compared with NAC. Many investigators have demonstrated that the existence of residual mortar lumps adhering to the recycled aggregates as well as the formation of micro-cracks during the crushing process in recycled aggregate production can reduce strength and increase deformation in RAC materials. Regardless of the technical level, the labor costs and additional energy consumption may be enlarged when crushing the construction and demolition waste and producing the recycled aggregates. In addition, common people are lack of confidence on RAC. Therefore, the development and applications of RAC in structures are somewhat restricted due to the above-mentioned shortcomings.

Confining concrete in steel tubes has long been recognized as an effective means to improve the behavior of concrete not only because confinement increases the compressive strength of concrete and helps suppress crack development, but the core concrete is sealed from moisture exchange with the surroundings and its lateral deformation is significantly restricted by the steel tubes [10,11]. Konno et al. [12] were the first to put forth the idea of placing recycled aggregate concrete in steel tubes, with the aim toward improving the mechanical properties of RAC. The resulting structural member is called recycled aggregate concrete-filled steel tube (RACFST). Since then, other researchers have conducted studies to evaluate the effective use of construction and demolition wastes as recycled aggregates in various types of steel tubes, including carbon steel tubes, stainless steel tubes and carbon steel tubes strengthened with fiber reinforced polymers.

In fact, the greatest distinctive feature of RCAs compared to NCAs is their higher water absorption capacity, due mainly to adhered mortar [13,14]. In other words, the additional absorbing moisture of RCA can reduce the actual water-cement ratio (w/c) in concrete when RCAs are not pre-wetted, which means that there is a curing effect on the concrete strength. This finding has been confirmed by Chen et al. [15]. However, many researchers launched the investigations on mechanical properties of RAC by the way of pre-wetting the RCAs, so that the workability of RAC can be improved during the construction process [16–18]. Hence, it is not difficult to understand that the strength of RACFST can be varied depending on whether the RCA are presoaked or not.

The primary objective of this paper is to summarize some important findings on the behavior of RACFST when used as isolated flexural and compression members and as members of a frame. A secondary objective is to provide a knowledge basis for further studies on the use of recycled concrete in structural and construction applications.

2. Bond behavior between RAC and steel tubes

One of the most important requirements for concrete-filled steel tube (CFST) construction is the integrity of the bond between concrete and steel. Using pushout tests as shown in Fig. 1, Chen et al. [19] studied the bond behavior between the core RAC and the outer steel tubes without surface preparation. The main information about the specimens is given in Table 1 and the results are shown in Fig. 2.

It can be seen from Fig. 2 that the bond strength in general increased with an increase in RCA replacement percentage, except for cases when the recycled aggregate concrete-filled circular steel tubes have replacement percentages of $r = 75\%$ and 100%. It is worth noting that in the study of Ref. [13], the recycled coarse aggregates used in manufacturing RACFST were not pre-soaked,

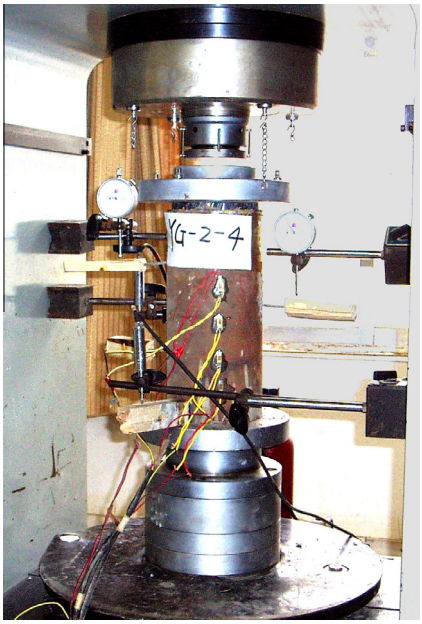

Fig. 1. Push-out test set-up (Chen et al. [19]).