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A review of experimental results of steel reinforced recycled aggregate concrete members and structures in China (2010-2016)

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Abstract

A series of investigations on the structural performance of Steel Reinforced Concrete (SRC) members and frame structures realized employing Recycled Aggregate Concrete (RAC) have been performed in China from 2010 to 2016. The research achievements on Steel Reinforced Recycled Aggregate Concrete (SRRAC) structures are sufficient to review and share with investigators from other countries. This paper begins with an introduction of some research progress made on the bond behavior between RAC and I-steel. Discussion is then turned to the static behaviors of SRRAC members, including the flexural and shear performances of beams and concentric and eccentric compressive properties of columns. Finally, research findings on the performance of SRRAC columns and the corresponding beam-column joints and frames under cyclic loads are presented and analyzed.

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Keywords: Recycled aggregate concrete; steel reinforced concrete; bond behavior; static and cyclic performance

1. Introduction

Processing Construction and Demolition Wastes (CDW) 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 environmental sustainable concrete for new constructions [1-3]. A review of existing literatures [4-8] has shown that much effort has been devoted to the investigation of mechanical properties and durability of RAC. A basic

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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). 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 the strength and increase the deformation in RAC materials [9-13]. Therefore, the development and applications of RAC in civil engineering applications are somewhat restricted due to the above-mentioned shortcomings.

Steel embedded into concrete structural members, also named Steel Reinforced Concrete (SRC, see Figure 1), can make full use of the properties of steel and concrete. As a kind of composite structures with higher carrying capacities and better seismic behavior, SRC structures have been widely used in high-rise buildings with good economic benefits [14-18]. It can be seen from Figure 1 that the reduced mechanical properties of RAC can be made equivalent or partially higher to NAC by employing steel shapes embedded into concrete. Hence, SRC members can be recognized as an effective mean to improve the mechanical behavior in terms of strength, stiffness, ductility and energy dissipation for the initial RAC deficiencies compared with NAC. These composite structures combining the material science and SRC structures have been developed for seven years in China from 2010 to 2016, and the concept of Steel Reinforced Recycled Aggregate Concrete (SRRAC) structures was firstly proposed by Cui [19].

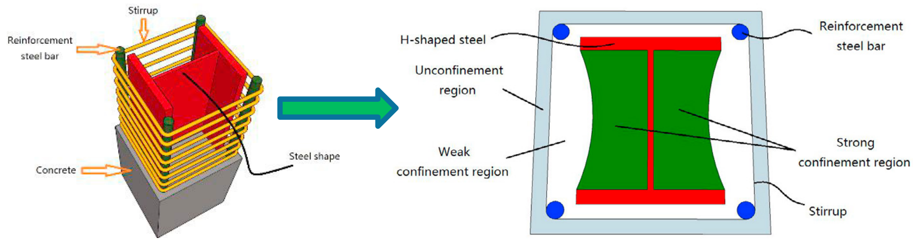

Fig. 1. The details of different elements in Steel Reinforced Concrete members

In this context, a carefully review of the current knowledge on SRRAC members and the corresponding structures is needed in order to identify the field of research that reached a sufficient knowledge for practical application and implementation in Standards and Code of Practice. On the other hand, being this topic a relatively new one, it is important to point out the need for further research.

The objective of this paper is to summarize some important findings on the behavior of SRRAC members and the corresponding structures. In Section 2, with the aim to define the interfacial force transmission mechanism, it is reviewed the bond behavior between RAC and I-steel under push-out tests by considering different influencing variables such as RCA content, maximum RCA size, thickness of the protective layer and stirrup ratio. Then, the static performances of SRRAC beams (Section 3) and SRRAC columns (Section 4) are analyzed. Finally, the cyclic properties of SRRAC columns and the corresponding joints and frames are addressed in Section 5, Section 6 and Section 7, respectively.

2. Bond behavior between RAC and I-steel

Bond is an important structural behavior of Steel Reinforced Concrete and refers to the adhesion between steel shape and surrounding concrete which is responsible for transfer of axial force between these two elements thereby providing strain compatibility and composite action of concrete and steel. By push-out tests, Chen *et al*. [20] and Zheng *et al*. [21] studied the bond behavior between RAC and I-steel without surface preparation. Variables reported in their tests are the RCA content (r=0, 10%, 20%, 30%, 40%, 50%, 60%, 70%, 80%, 90% and 100%), maximum size of RCA (20 mm and 32 mm), thickness of the protective layer to I-steel flange (40 mm, 50 mm, 60 mm and 70 mm) and stirrup ratio. It should be pointed out that the recycled coarse aggregates used in their studies were not pre-soaked, and the design water-cement ratios (w/c) were kept constant for all the specimens. Some critical experimental results of describing the bond strengths include the bond at initial slip (τ_s), bond at ultimate point (τ_u) and bond at residual point (τ_r). These bond strengths presented in Figure 2 show that: the relative bond stresses, including $\tau_{s,r}/\tau_{s,0}$, $\tau_{u,r}/\tau_{u,0}$ and $\tau_{r,r}/\tau_{r,0}$, are generally improved as the increasing of RCA content, and this