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Axial compressive behaviour of steel-jacket retrofitted RC columns with recycled aggregate concrete

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HIGHLIGHTS

- Axial compression tests on steel-jacket retrofitted columns with RAC were undertaken.
- Variable Poisson's ratio of material was considered in the finite element model.
- Developed an axial load capacity design model for the retrofitted columns.

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ABSTRACT

It is an effective solution to strengthen structural column by using steel jacket and infill concrete for reinforced concrete (RC) structure retrofitting. In this research, the recycled aggregate concrete (RAC) is adopted as an infill concrete instead of using the normal concrete, in order to reduce the carbon footprint of construction. Fifteen columns including twelve steel-jacket strengthened columns, one unstrengthened column and two concrete filled steel tube (CFST) columns are tested to investigate the axial compressive behaviour of steel-jacket retrofitted RC columns with RAC. The variables among the tested specimens include the recycled coarse aggregate replacement ratio, RAC strength, steel tube thickness and preload of original column. Experimental results illustrate that using steel jacketing approach for retrofitting could significantly improve the strength, stiffness and ductility of the columns. The axial compressive strength of the steel-jacket retrofitted column with RAC is slightly lower than the one with normal infill concrete, but the influence of recycled coarse aggregate replacement ratios is negligible. The peak strengths of steel-jacket retrofitted columns can be significantly enhanced by increasing the thickness of steel tube. The performances of the steel-jacket retrofitted columns are similar to that of the CFST columns. The effect of the preload of original column on the ultimate strength of steel-jacket retrofitted column is limited. A finite element (FE) model is also developed by using ABAQUS software to simulate the performance of steel-jacket retrofitted columns. The accuracy of the model is validated through comparing with the experimental results. By using the developed FE model, the mechanical behaviour of the column is further discussed in details and extended parametric studies are undertaken to elucidate the effects of various influencing factors on the behaviour of the column and its components. The design methods for predicting the axial compressive strength of the retrofitted column with RAC are suggested.

1. Introduction

The steel jacketing approach is a commonly used retrofitting solution for reinforced concrete (RC) structural column, with high retrofitting effectiveness and economic efficiency, as well as ease of construction. In this method, a steel jacket is added outside the RC column, while the space between the tube and the original column is filled with concrete for integration purpose. Several experimental results on the steel jacketing approach with normal infill concrete have been reported. Chai and Priestley [1–4] firstly studied the influence of the circle and ellipse steel jacketing on the lateral response of circular bridge columns, and found great

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enhancement on the lateral strength, shear strength, resistance of lap splice and ductility of the columns after being retrofitted by steel jacket. Aboutaha [5] examined the effectiveness of the rectangular solid steel jackets and partial steel jackets on improving the ductility and strength of the columns that had inadequate shear resistance. Xiao et al. [6,7] conducted a series of tests on the columns with a square or rectangular section retrofitted by partially stiffened steel jackets and indicated the effectiveness of the method. Other types of steel jackets have also been proposed, e.g. corrugated steel jacket [8] and octagonal steel jacket [9]. It was shown that the strength, stiffness and deformation capacity of the retrofitted column could be significantly improved due to the confinement effects on the core concrete provided by the steel jacket. The steel jacketing construction process is also quite efficient since the steel tube could act as permanent formwork.

In the conventional approach of steel jacket retrofitting, normal aggregate concrete is often used as padding to fill the gap between the original column and the steel jacket. However, in recent years, a new type of concrete named recycled aggregate concrete (RAC) was introduced. In RAC, the natural coarse aggregates are partially or entirely substituted by the recycled coarse aggregates. The application of RAC is considered as alternative solution for processing and recycling demolished concrete. Accordingly, this paper presents a structural column retrofitting technique by using RAC. The proposed method is based on the steel jacketing approach, while the RAC is adopted as an infill concrete to replace the normal concrete. Fig. 1 shows the typical cross-sections of the steel-jacket retrofitted columns with RAC. This method not only can serve the propose of the building or bridge retrofitting in order to avoid reconstruction, but also take full advantage of using recycled aggregated concrete, which therefore help the reduction of carbon dioxide emission.

Unfortunately, RAC used to be described as a kind of green materials but with low strength and elastic modulus, bad workability, high water infiltration and high shrinkage and creep comparing to normal concrete [10–13]. However, from the ongoing research, it has been found out that confining RAC is an effective way to enhance their mechanical properties not only because confinement increases the compressive strength of concrete and suppresses the 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 [14–16]. Chen et al. [16] present a summary review on the bond behaviour, the static and cyclic performance of recycled aggregate concrete-filled steel tubes members and frames. It was found the axial compressive strength and deformation capacity of RAC are significantly improved under the confinement of steel tube. Yang et al. [17,18] conducted a series of tests on RAC filled steel tubes and RAC filled stainless steel tubes. The test results showed that the RAC in-fill columns had slightly lower but satisfactory ultimate strength compared with the specimens filled with normal concrete. Xiao et al. [19] undertook a series of tests on RAC that was confined by steel tubes, which found out that both the strength and deformation capacity of RAC are greatly increased. The results also indicated that the peak load decreases with the increase of the recycled aggregate replacement percentage. Wang et al. [20] investigated the compressive behaviour of RAC filled steel tubes. It was mentioned that there was about 10% or less reduction on the compressive strength of RAC filled steel tube columns than the normal concrete filled steel tube columns due to the inferior performance of recycled coarse aggregates, and clarified that the source of recycled coarse aggregates had little effect. In summary, most of the research conducted on RAC has mainly been concerned with implementation of structural components. However, the applications of RAC on structural retrofitting have not received much attention.

Although the cross-section of steel-jacket retrofitted column with RAC is similar as that of RAC filled steel tube column, some distinct characteristics of steel-jacket retrofitted column with RAC need to be identified. Firstly, two types of concrete exist in the steel tube of retrofitted column. The strength, elastic module and shrinkage properties of the concrete in the original column could be different from the infill RAC, which may lead to stress redistribution on the core concrete. Secondly, there is discontinued interface between the original column concrete and the infill RAC, which may influence the axial compressive strength of the column. Thirdly, during the retrofitting construction in practice, most of the pre-existing RC columns are subjected to preloads arising from the existing live and permanent loads from the upper floors or substructure. The stress and deformation induced by the preloads might inevitably affect the structural performance of the retrofitted columns [21], which was often overlooked in previous research [1–9].

The purpose of this paper is to present a comprehensive study on the axial compressive behaviour of steel-jacket retrofitted RC columns with RAC. The effects of the steel tube thickness, recycled coarse aggregate replacement ratio, RAC strength and axial preloading level are considered. Tests on fifteen columns are reported and the experimental results are discussed. A finite element model verified by comparing the experimental results is also implemented and extended for further investigation. A design model for predicting the ultimate strength of the column is proposed.

2. Experimental program

2.1. Test specimens

Fifteen columns including twelve steel-jacket retrofitted columns (A1 ~ A12), one unstrengthened RC column (A0), two concrete filled steel tube (CFST) columns (E1 ~ E2) were fabricated and tested. The CFST columns consisted of one normal concrete filled steel tube column (E2) and one RAC filled steel tube column (E1). The cross-sectional dimensions of the specimens are shown in Fig. 2. The diameters D of steel jackets of all the specimens were the same as 320 mm. Details of the specimens are shown in Table 1.

The recycled coarse aggregates were produced from a concrete recovery plant in Guangzhou with the aggregate size from 5 ~ 20 mm and the water absorption of 9.37%. The crush index of the recycled coarse aggregates was 9.4%. The bulk density and apparent density were 1245 kg/m^3 and 2656 kg/m^3 respectively. For the infill concrete, the river sand, tap water and the ordinary Portland cement with a 28 day compressive strength of 42.5 MPa

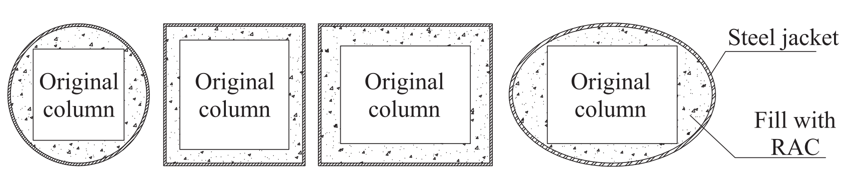

Fig. 1. Various sections of steel-jacket retrofitted column with RAC.