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Behavior of slender square steel tubular columns filled with fresh concrete and demolished concrete lumps

Bo Wu[a], Wei-Feng Li[a], Xin-Yu Zhao[a,*]

[a]State Key Laboratory of Subtropical Building Science, South China Univ. of Technology, Guangzhou 510640, P. R. of China

Abstract

Adding large-size demolished concrete lumps (DCLs) into the core of concrete-filled steel tubes (CFTs), a proposal by the authors and co-workers, has been demonstrated to be a practicable alternative means for old concrete recycling. This paper reports preliminary results of an experimental campaign newly implemented concerning the structural behavior of slender square steel tubular columns filled with DCLs and fresh concrete (FC). The replacement ratio of FC by DCLs and the load eccentricity were chosen as the two primary variables. The presented research focuses on the evaluation of the ultimate strength of the aforementioned columns. Design provisions in current codes of practice specified for conventional CFTs were used to check their applicability to the columns studied. The experimental outcomes indicate that: (1) the encasement by the outer square steel tube and the inherent cohesion between DCLs and FC ensured the integrity of inner concrete, thus the failure mode of the columns filled with FC and DCLs was similar to their counterparts filled with FC alone; (2) the initial stiffness, peak load, and post-peak response of the specimens appeared to be influenced only to a rather limited extent by the addition of DCLs; (3) the ultimate strengths of the concentrically and the eccentrically loaded specimens incorporating DCLs can be satisfactorily estimated by the design code Eurocode 4: 2004 and GB 50936-2014, respectively.

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Keywords: Concrete-filled steel tubes; demolished concrete lumps; ultimate strength; design code

* Corresponding author. Tel.: +86-135-7037-3755
E-mail address: ctzhaoxy@scut.edu.cn

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1. Introduction

Extensive efforts have been made around the world aiming at reducing the construction sectors' enormous demand for energy and raw materials. One significant fraction of these efforts is dedicated to exploring the potential of recycling waste concrete generated either from construction or demolition. To create a solid basis for such recycling, substantial research has been done on evaluating the mechanical properties of the recycled aggregate concrete (RAC), made by crushing and sieving concrete debris to replace natural aggregates in new concrete [1-3]. Despite these impressive endeavors, RAC is still largely limited to low-value applications such as pavement base. One of the many causes for this situation may be ascribed to the fact that producing quality recycled aggregates is often cumbersome and costly, making it less energy-saving and economical in actual practice.

In a distinctly different way, the authors and co-workers have proposed a new recycling method with which old concrete can be reused more straightforwardly. After being coarsely crushed, the resulting demolished concrete lumps (DCLs) with a considerably larger size (60~300 mm) than conventional recycled aggregates (often <30 mm), are allowed to be placed alternately with fresh concrete (FC) into a hollow steel tube, thereupon forming a new composite member referred to as the steel tubular columns filled with DCLs and FC. Of late years much work has been done by the first author's group, including numerous experimental evaluations and several dozen in-situ applications [4-10]. An accumulated knowledge gained over these years illustrated that old concrete disintegrated in the form of DCLs can be reliably incorporated into structural elements, constituting a viable alternative to the extant recycling method (i.e. through the application of RAC).

In the presented research, structural behavior of slender square steel tubular columns filled with DCLs and FC was experimentally investigated. This was done because previous experiments dealt merely with stub square steel tubular columns containing DCLs, and the slenderness effects in such columns was not adequately examined. Comparing to their counterparts of circular shape [7, 11], there is an increasing need to understand the behavior of slender square steel tubular columns containing DCLs. This is not only because columns with square/rectangular shape are more common in practice, but the square tube is expected to provide substantially weaker confinement to concrete core as compared to the circular one, in particular for slender columns where the concrete confinement is further reduced due to the presence of tensile stress at cross section. As such, an immediate concern arises about the potential compromise in the element's ultimate strength when the slender square tubular columns containing DCLs will to be used. To address this concern, a comparative experimental program involving such column specimens was conducted. The structural response of the columns was recorded and compared, and the preliminary findings are described in this paper.

2. Test program

2.1. Material properties

All test columns had the same geometry with an outer width (B) of 240 mm and an effective buckling length (l_k) of 2720 mm; l_k being the center-to-center distance between the two pin supports linked to the column ends. FC used was actually ready-mix concrete from one batch. The mix proportion of FC is shown in Table 1. 150 mm cubes were cast along with the specimens to obtain the FC's compressive strength in accordance with the Chinese standard [12]. The measured compressive cubic strength of FC was 50.2 MPa. DCLs were obtained by crushing waste concrete members obtained from a demolition site in Guangzhou city. Core tests were conducted to identify the compressive strength of DCLs, and their equivalent 150-mm cube strength was 35.2 MPa, measured as per the CECS 03-2007 [13]. The size of DCLs was in the range of 60 mm to 90 mm, as shown in Fig. 1a.

Table 1. Mix proportion and measured compressive strength of FC.

Water (kg/m^3)	Cement (kg/m^3)	Fine aggregate (kg/m^3)	Coarse aggregate (kg/m^3)	Fly ash (kg/m^3)	Slump (mm)	$f_{cu,FC}$ (MPa)
172	407	639	1116	66	170	50.2