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Experimental behaviour of concrete-filled steel tubular members under lateral shear loads

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A B S T R A C T

This paper deals with an experimental investigation on the shear behaviour of concrete-filled steel tubular (CFST) members. A total of 38 specimens with either circular or square cross-sections were tested. Among these specimens, four were subjected to shear and the rest were subjected to combined axial compression and shear. The main parameters considered were the axial compression ratio ($n = 0$–0.75), shear span-to-depth ratio ($m = 0.075$–0.75), concrete strength ($f_{cu} = 31.9$ or 57.4 MPa), steel ratio ($\alpha_s = 0.070$ or 0.108) and steel yield stress ($f_y = 338.3$ or 415.7 MPa). The test results showed that, all the CFST specimens exhibited ductile characteristics. The influences of the parameters on the failure mode, load vs. deformation relationships, shear capacity, and strain development of the tested specimens were investigated. Finally, an existing simplified model for predicting the shear capacity of CFST members under combined compression and shear was also assessed.

1. Introduction

Concrete-filled steel tubular (CFST) members have been widely applied in bridges and buildings over the past few decades [1]. In the past, there has been extensive research on the behaviour of CFST members subjected to axial compression [2–5], axial tension [6–9], and more complex loading conditions [10–15]. Compared with the conducted research in the above fields, relatively little work [16–19] has been reported on the shear behaviour of CFST members.

As a CFST member is composed of the core concrete and outer steel tube, it is expected that the shear behaviour of CFST members is more complex than that in either pure concrete or steel members. Han et al. [16] conducted a finite element analysis of CFST members under shear and constant axial compression. The influence of different parameters on the ultimate strength of CFST members was investigated, and formulas were proposed for the prediction of the ultimate strength. Abdullah et al. [17] developed a nonlinear finite element model to investigate the behaviour of square tubed reinforced concrete (RC) and steel reinforced concrete (SRC) short columns under combined axial compression and shear. Xiao et al. [18] tested 58 specimens to study the shear behaviour of circular CFST columns. The concrete cube compressive strength ($f_{cu} = 30$–50 MPa), steel yield stress ($f_y = 345$–445 MPa), shear span-to-depth ratio ($m = 0.14$, 0.4, 0.5, or 1.0), and axial compression ratio ($n = 0$, 0.2, or 0.4) were set as the main research parameters. Ikeda et al. [19] conducted cyclic tests on short CFST columns with constant axial compression loading. Three circular CFST specimens were involved in the test program and the parameters considered were the shear span-to-depth ratio ($m = 1.7$ or 3.0) and diameter/thickness ratio ($D/t = 64$ or 117).

The above literature review indicates that, research on shear behaviour of CFST members is still limited, especially for CFST members with square cross-section, which have been widely used in engineering practice. Furthermore, no research has been conducted on CFST members with a shear span-to-depth ratio smaller than 0.14 or an axial compression ratio higher than 0.4. To address these research gaps, more experimental and analytical studies need to be conducted. It should be noted that although CFST columns with a shear span-to-depth ratio (m) smaller than 0.14 may be rare in practice, the investigation of these columns will help to fully understand the influence of m on the shear behaviour of CFST members. This paper is intended to carry out an experimental study on the shear behaviour of CFST members under constant compression and shear. The purpose of the research is threefold: (1) to provide new test data pertaining to the shear behaviour of CFST members over a wider parameter range; (2) to study the influence of different parameters on the shear strength of CFST members; and (3) to evaluate the accuracy of an existing simplified model in predicting the shear capacity of CFST members.

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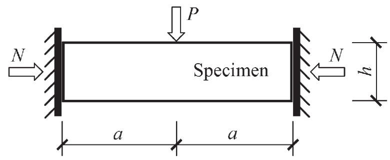

Fig. 1. Schematic of loading and boundary conditions of the specimen.

2. Experimental program

2.1. General description

In the investigation of shear behaviour of RC members, the shear span-to-depth ratio is always considered as one of the most important parameters, because it affects both the failure mode and the shear capacity of a RC member [20]. Similarly, the shear span-to-depth ratio is proved to affect the shear behaviour of a CFST member [18]. Meanwhile, in real structures, CFST members are often under combined loading conditions. For example, when short CFST columns are subjected to seismic action, the columns may be under a combination of axial compression, bending and shear. As a result, the effect of axial compressive load on the shear behaviour should be considered.

A total of 38 CFST specimens, including 4 specimens subjected to pure shear and 34 specimens subjected to combined axial compression and shear, were tested in this program. Two types of cross-sections were studied, i.e., the circular and square cross-sections. The overall diameter (D) of the circular steel tubes and overall width (B) of the square steel tubes were both set as 120 mm. Other test parameters included:

- axial compression ratio ($n = 0, 0.25, 0.5, 0.6$, or 0.75);
- shear span-to-depth ratio ($m = 0.075, 0.15, 0.5$, or 0.75);
- concrete cube compressive strength ($f_{cu} = 31.9$ or 57.4 MPa);
- steel ratio ($\alpha_s = 0.070$ or 0.108, corresponding to a tube thickness of 2 or 3 mm, respectively) and steel yield stress ($f_y = 338.3$ or 415.7 MPa).

The specimens were tested under fixed-ended conditions, so the shear span-to-depth ratio (m) in this paper is defined as:

$$m = \frac{M}{Vh} = \frac{a}{2h} \tag{1}$$

where M and V are the moment and shear force acting at the end cross-section of a fixed member, respectively; a is the length of the shear span; and h is the depth of the specimen, as illustrated in Fig. 1.

The axial compression ratio (n) is defined as:

$$n = \frac{N}{N_u} \tag{2}$$

where N is the applied axial compressive load; and N_u is the axial compressive strength of the specimen, determined using the EC4 code [21].

The steel ratio (α_s) is defined as:

$$\alpha_s = \frac{A_s}{A_c} \tag{3}$$

where A_s and A_c are the cross-sectional areas of the steel tube and core concrete, respectively.

Fig. 2 shows a schematic of the specimen, and a summary of the test information is given in Table 1. In Fig. 2 and Table 1, t is the wall thickness of the steel tube; and L is the specimen length. Two identical samples were tested under each condition to confirm the reliability of the results.

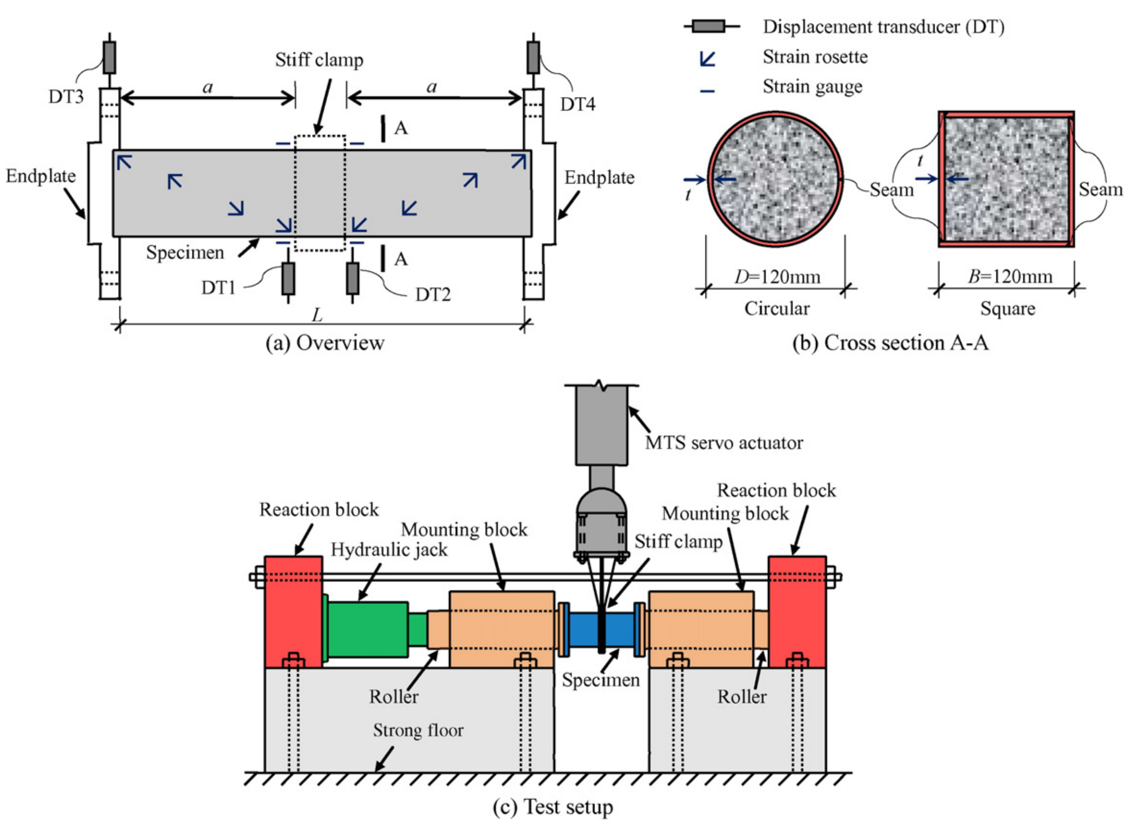

Fig. 2. Schematic of test setup and instrumentation layout.