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Developments and advanced applications of concrete-filled steel tubular (CFST) structures: Members

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ABSTRACT

Concrete-filled steel tubular (CFST) structure offers numerous structural benefits, and has been widely used in civil engineering structures. This paper reviews the development of the family of concrete-filled steel tubular structures to date and draws a research framework on CFST members. The research development on CFST structural members in most recent years, particularly in China, is summarized and discussed. The current design approaches from various countries are examined briefly. Some projects in China utilizing CFST members are also introduced. Finally, some concluding remarks are made for CFST members.

1. Introduction

The concrete-filled steel tubular (CFST) structure offers numerous structural benefits, including high strength and fire resistances, favorable ductility and large energy absorption capacities. There is also no need for the use of shuttering during concrete construction; hence, the construction cost and time are reduced. These advantages have been widely exploited and have led to the extensive use of concrete-filled tubular structures in civil engineering structures.

China has seen a great deal of research and use of concrete-filled steel tubular structures in practice. There are numbers of books published in public domain in recent years [1–6]. Some codes of practice and local specifications were developed to provide design guidance as well. This paper reviews the state-of-the-art for concrete-filled steel tubular structures, especially some the most recent developments in China. Current design approaches from various countries are examined briefly. Some practical projects using CFST members are presented, and the development trends are discussed.

2. Component behavior

Fig. 1(a) depicts three typical column cross-sections, where the concrete is filled in a circular hollow section (CHS), a square hollow section (SHS) or a rectangular hollow section (RHS), where D and B are the outer dimensions of the steel tube and t is the wall thickness of the tube. It is noted that the circular cross section provides the strongest confinement to the core concrete, and the local buckling is more likely to occur in square or rectangular cross-sections. However, the concrete-filled steel tubes with SHS and RHS are still increasingly used in construction, for the reasons of being easier in beam-to-column connection design, high cross-sectional bending stiffness and for aesthetic reasons. Other cross-sectional shapes have also been used for aesthetical purposes, such as polygon, round-ended rectangular and elliptical shapes, as shown in Fig. 1(b).

It is well know that the compressive strength of concrete is much higher than its tensile strength. Furthermore, the compressive strength is enhanced under bi-axial or tri-axial restraint. For the structural steel, the tensile strength is high while the shape may buckle locally under compression. In concrete-filled steel tubular members, steel and concrete are used such that their natural and most prominent characteristics are taken advantage of. The confinement of concrete is provided by the steel tube, and the local buckling of the steel tube is improved due to the support of the concrete core. Fig. 2 shows schematic failure modes for the stub concrete-filled steel tubular column and the corresponding steel tube and concrete. It can be seen that both inward and outward buckling is found in the steel tube, and shear failure is exhibited for the plain concrete stub column. For the concrete-filled steel tube, only outward buckling is found in the tube, and the inner concrete fails in a more ductile fashion. Fig. 3(a) shows a comparison of the measured results between a steel stub column, a reinforced concrete stub column and a concrete-filled steel tubular stub column without steel reinforcement, where D and t are the outer diameter and the wall

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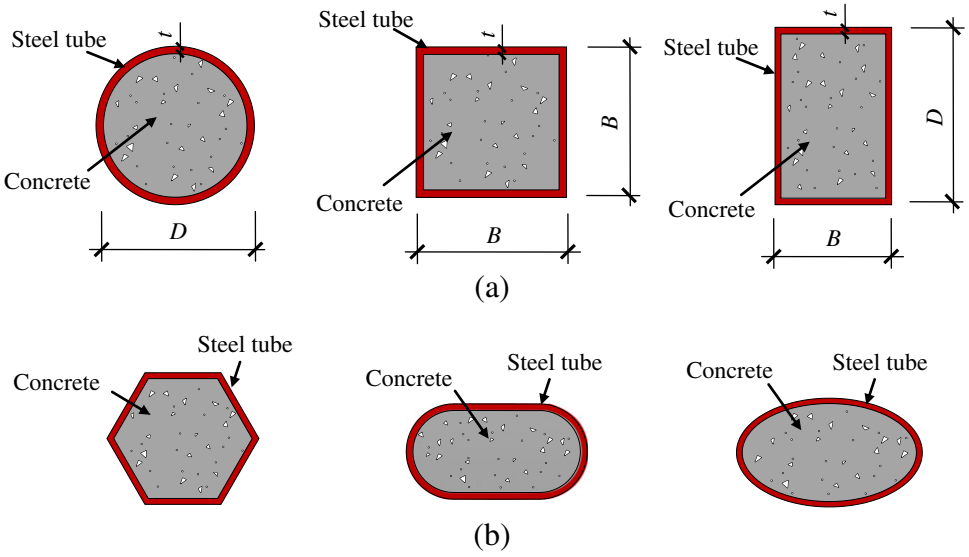

Fig. 1. Typical concrete-filled steel tubular cross sections.

thickness of the circular steel tube, respectively; f_y is the yield strength of the steel; f_{cu} is the compressive strength of the concrete cube. The geometric dimension of the circular hollow steel section is the same as in both steel column and composite column, and also the same for the concrete parts in both the reinforced concrete column and the composite column. The term "steel tube + RC" in Fig. 3 indicates the summation of the ultimate strength of the steel tube and the reinforced concrete (RC) specimens. It clearly shows that the ultimate strength for a concrete-filled steel tube is even larger than the summation of the strength of the steel tube and the RC column, which is described as "1(steel tube) + 1 (concrete core) greater than 2 (simple summation of the two materials)" [2]. Fig. 3(b) shows a schematic view of the load versus deformation relationship of the hollow steel tube, the concrete stub column by itself and the concrete-filled steel tube. It can be seen that the ductility of the concrete-filled steel tube is significantly enhanced, when compared to those of the steel tube and the concrete alone.

3. Development of concrete-filled steel tube family

Apart from the common concrete-filled steel tubes shown in Fig. 1, there are other types of "general" member designation in the CFST family. Some of them are shown in Fig. 4, i.e. concrete-filled double skin steel tubes (CFDST), concrete-encased concrete-filled steel tubes as well as reinforced and stiffened concrete-filled steel tubes. The characteristics of these "general" CFST members are as follows: 1) they consist of the steel tube(s) and the filled concrete; 2) the concrete and the steel tube(s) sustain the axial load together.

The CFDST consists of inner and outer tubes, and the sandwiched concrete between two tubes, as shown in Fig. 4(a). The concrete-steel-concrete sandwich cross-section has high bending stiffness that avoids instability under external pressure [7]. Research results have shown that the inner tube provides effective support to the sandwich concrete, and the behavior of the composite member is similar to that of the concrete-filled steel tube. The outward buckling of the outer tube and the inward buckling of the inner tube was observed after beam and column ultimate strength tests. The steel tubes and the concrete can work together well and the integrity of the steel-concrete interface is maintained. This composite column could also have higher fire resistance than the regular CFST columns, due to the inner tubes being protected by the sandwiched concrete during fire. The CFDST could be a good option when designing members with large cross-sections. The thickness of the steel tube wall can be reduced significantly when compared to the steel tube member by itself, and the self weight is less when compared to the concrete-filled steel tube. Another advantage of the CFDST is that both the outer and the inner steel tubes can act as primary reinforcement and permanent formwork, which is convenient for construction. At the same time, different materials can be utilized for the inner and outer tubes in order to have the additional advantages of esthetics as well as corrosion resistance. Thus, an outer stainless steel tube and an inner carbon steel tube has been described as one option [8].

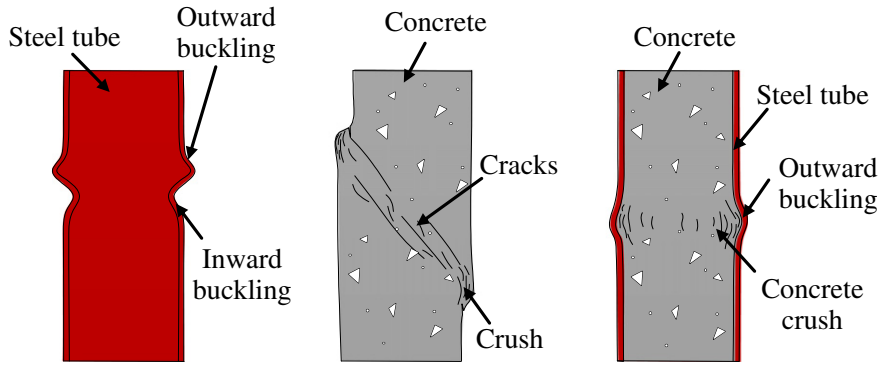

Fig. 2. Schematic failure modes of hollow steel tube, concrete and CFST stub columns.