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Development in Concrete-Filled Steel Tubular Structures

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Abstract: CFST is the member with concrete filled into steel tubes. It is a new structure that evolved and developed based on SRC Structures, spiral stirrup structures and steel tube structures. Concrete-filled steel tubular (CFST) structure offers numerous structural benefits, and has been widely used in civil engineering structures. This report reviews the development of the family of concrete-filled steel tubular structures up to date and effectively presents a detail study 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.

Keywords: Concrete, Steel Tubes, CFST, Spiral Stirrup, Development.

I. 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. Some codes of practice and local specifications were developed to provide design guidance as well. This report 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.

II. LITERATURE REVIEW

Shankar Jagadesh in May 2014, Concrete-filled steel tubes are gaining increasing prominence in a variety of engineering structures, with the principal cross-section shapes being square, rectangular and circular hollow sections. The study about the behavior and the characteristics of CFST columns is the prime need of the hour. This review paper outlines the important contributions on CFST columns contributed in the recent years. This paper presents the innovative experimental investigations conducted on CFST columns and the load deflection response characteristics of columns are also addressed. A comprehensive summary of various analytical and numerical studies on modeling of CFST members is portrayed in this paper. The design specifications and standards by AIJ, Eurocode-4, ANSI/AISC and AIK are addressed.

Lin-Hai Han, Wei Li, Reidar Bjorhovde in June 2013, 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.

Baochun CHEN in July 2008, The Concrete Filled Steel Tubular (CFST) structure has been applied prevalently and rapidly to arch bridges since 1990 and this trend is continued with more and more long span CFST arch bridges been built since 2000. This paper briefly introduces the present situation of CFST arch bridges, their five main structure types and the construction methods. Many selected CFST arch bridges built since 2000 and some still under construction are presented.

BaoChun Chen in 2009, this paper briefly introduces the present situation of concrete filled steel tube (CFST) arch bridges in China. More than 200 CFST arch bridges were investigated and analyzed based on the factors of type, span, erection method, geometric parameters, and material. Some key issues in design calculation were presented, such as check of strength, calculation of section stiffness, and joint fatigue strength. It will provide a comprehensive reference of CFST arch bridges for the bridge designers and builders.

LinHai Han, ShanHu He, LianQiong Zheng, Zhong Tao in March 2012, A series of tests on curved concrete filled steel tubular (CCFST) built-up members subjected to axial compression is described in this paper. Twenty specimens, including 18 CCFST built-up members and 2 curved hollow tubular built-up columns, were tested to investigate the influence of variations in the tube shape (circular and square), initial curvature ratio (β, from 0 to 7.4%), nominal slenderness ratio (λ, from 9.9 to 18.9), section pattern (two main components, three main components and four main components), as well as brace pattern (battened and laced) on the performance of such composite built-up members. The experimental results showed that the ultimate strength and stiffness of CCFST built-up specimens decreased with increasing βr or. Different load-bearing capacities and failure modes were obtained for the battened and laced built-up members. A simplified method using an equivalent slenderness ratio was suggested to calculate the strength of CCFST built-up members under axial compression.

III. COMPONENT BEHAVIOUR

A. Component Behaviour

Fig1(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. It is well known 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.

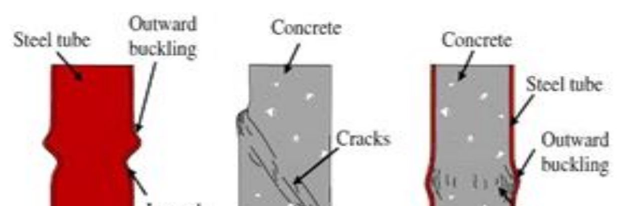

Fig.1. Schematic failure modes of hollow steel tube, concrete and CFST stub columns.

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 CFST, only outward buckling is found in the tube, and the inner concrete fails in a more ductile fashion.

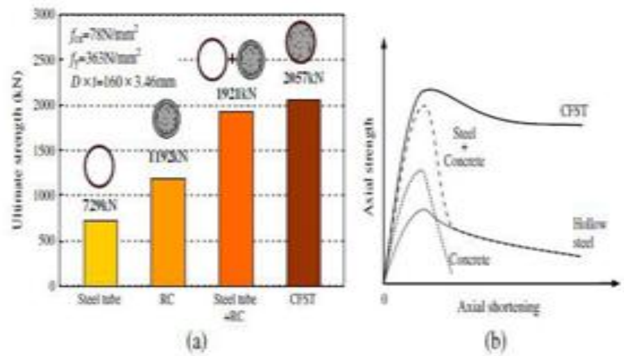

Fig.2. Axial compressive behavior of CFST stub column.

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)". Fig2(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.

IV. DEVELOPMENT OF CFST FAMILY

Apart from the common concrete-filled steel tubes shown in Fig3, there are other types of "general" member designation in the CFST family. 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.

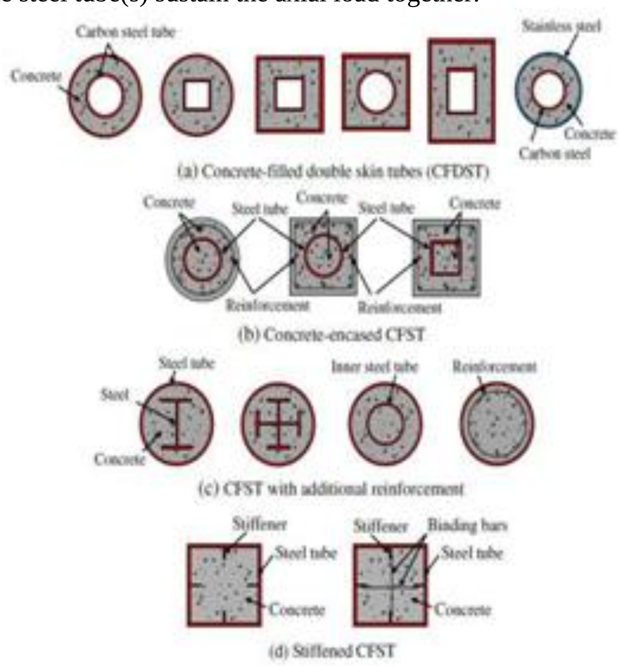

Fig. 3. General CFST cross sections.

The CFDST consists of inner and outer tubes, and the sandwiched concrete between two tubes, as shown in Fig. 3(a). The concrete-steel- concrete sandwich cross-section has high bending stiffness that avoids instability under external pressure. 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.

V. CONCLUSION

With the rapid development of research and application of concrete- filled steel tubular structures in China and all over the world in the past decades, the scope of “concrete-filled steel tube” has been extended greatly by researchers and engineers. The characteristic of these concrete-filled steel tubular members is that the structural properties can be improved due to the “composite action” between steel tube and filled concrete. Some typical applications of concrete-filled steel tubular members are in buildings, bridges, high towers and other few structures. The concrete-filled steel tubular structure can be treated as an alternative system to the steel or the reinforced concrete system. Some questions on the feasibility of the CFST system should also be fully evaluated for its widely expanded application. The thorough comparison of advantages and disadvantages of the CFST system with the steel and RC system, the space truss structural system, the connection system, the hybrid system using high performance and sustain- able materials as well as the life-cycle performance evaluation should be conducted in the future.

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