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Finite element modelling of concrete-filled double-skin short compression members with CHS outer and SHS inner tubes

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ABSTRACT

Composite steel-concrete construction utilising the benefits of both materials has extensively been used in structural engineering with the ability to be used in onshore and offshore applications. One of these elements is the concrete-filled double-skin tubes (CFDST) which is a concept that has been developed in recent years. In this column, the steel tubes can support considerable amounts of loads while providing permanent formwork to the concrete. Likewise, the steel tubes add confinement to the concrete whereas the concrete infill delays the local buckling of the steel tubes. This paper provides the behaviour of CFDST short columns under concentric compressive loads. The specimens studied consist of an outer skin, which is a circular hollow section (CHS), and an inner skin, which is a square hollow section (SHS), with the annulus filled with concrete while the inner tube is completely empty. A finite element (FE) analysis is generated in order to analyse the performance of such columns. Therefore, to assure the accuracy of the modelling of these specimens, FE models with concentric axial loads are developed and compared against results from past experiments. In view of this, different stress-strain curves for structural steel and concrete infill are identified, and those that provided the best curve fittings were selected for the parametric study. Accordingly, the best combination of the constitutive models of both the steel (suiting the cold-formed tubes) and the concrete (filled in double-skin tubes) is found based on previous research and considered herein. The study aims at examining the effect of various diameter-to-thickness (D_o/t_o) ratios, width-to-thickness (B_i/t_i) ratios and material properties such as nominal compressive strength and nominal yield strength on the fundamental behaviour of CFDST. In the parametric study, high nominal compressive strengths are tested, and the steel tubes are cold-formed from different design yield strengths. Overall, this paper provides important conclusions for current circular CFDST short columns with an inner SHS and an outer CHS.

1. Introduction

1.1. General

Historically, the concept of "double-skin" arose from the use of composite structures in submerged tube tunnels (Zhao and Han

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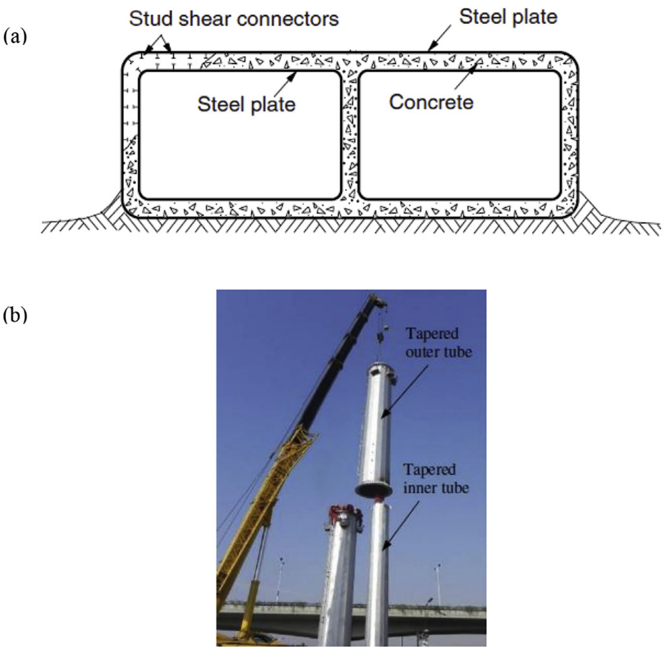

Fig. 1. Example of double-skin cross-sections.

[1]). Fig. 1(a) shows an example of a double-skin composite structure as a submerged tube tunnel. This cross-section was used for the first time in Kobe Minatojima Submerged Tunnel in Japan (Kimora et al. [2]). Recently, concrete-filled double-skin tubular (CFDST) columns have been under consideration as load bearing elements in construction and off shore projects [3]. CFDST columns are composed of two concentric steel cylinders with a concrete fill in-between them; see Fig. 1(b). Currently, CFDST columns are used as structural members because of their several advantages over conventional concrete-filled tubular (CFT) columns, reinforced concrete and/or structural steel columns (Ho and Dong [4]).

1.2. CFDST columns

The combination of the steel tubes and the annulus filled with concrete may provide several advantages over CFT such as high ductility, high bending stiffness, reduction of the structure self-weight, high local permanence due to the interaction of the three components, high global permanence due to the increase in section modulus and good cyclic performance [1]. There are four types of CFDST sections in which circular hollow sections (CHSs) and square hollow sections (SHSs) are combined as outer and/or inner tubes, as can be seen in Fig. 2. Extensive research was under taken to investigate the behaviour of the CFDST columns by researchers in past experiments. Research results have shown that CFDST offer several advantages such as integrity of the steel-concrete interface since the steel tubes and the concrete work well together. These specimens provide stability under external pressure since they have high bending stiffness. Also, owing to the protection the concrete offer to the inner tube, these composite members have higher fire resistance when compared to regular CFT. Moreover, these specimens offer a convenient method of construction because the steel tubes can be utilised as permanent formwork as well as primary reinforcement (Han et al. [3]). Experimental campaigns conducted on CFDST stub columns under static loading have indicated that the ultimate load carrying capacity and ductility increased significantly when compared to that of relevant outer steel tube. In addition to this, CFDST members have been shown to provide an increase in energy absorption up to five times [1]. However, it is clear from the literature evaluation that there is little information regarding the combination under study (CHS outer and SHS inner) as most of the research conducted on CFDST has been focused on other combinations of CFDST.

1.3. Innovation and scope of the paper

The combination under this investigation is denoted as “CHS + SHS” which refers to a CHS as the outer tube and a SHS as the inner tube. This combination has seldom been experimentally investigated in literature, whereas no finite element (FE) modelling available of it. Accordingly, this paper explores the behaviour of CFDST short columns under concentric compressive loads in order to better understand the behaviour of such specimens. To understand and predict the performance of these specimens, an FE analysis was generated by using Abaqus program [5]. Stress-strain curves for both structural steel and concrete infill were identified and selected for the materials in the Abaqus models. The innovation of this paper may be summarised in finding the best combination of the utilised constitutive material models for the steel and concrete components forming the current double-skin columns. This is done, opposite to most available investigations on the double-skin columns (see for example Hassanein and Kharoob [6]), by firstly