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Pull-out performance of a novel anchor blind bolt (TubeBolt) for beam to concrete-filled tubular (CFT) column bolted connections

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ABSTRACT

The utilisation of beam to concrete-filled tubular (CFT) column bolted construction remains limited due to the severe slippage of bolts, column surface deformation and low moment-resisting capacity. This study proposes a novel blind bolt, known as the TubeBolt, for beam to CFT column connections. Ten pull-out test specimens were evaluated under tensile monotonic loading. Bolt type, bolt diameter, end anchor member, hollow tube wall thickness and bolt hole diameter were varied for the test. The failure modes, anchorage performance, load-carrying capacity, strength, slippage and elongation of the bolts were analysed. The behaviour of the TubeBolt specimens was compared with that of the Extended Hollo-bolt specimens under the same condition. Experimental results indicated that the novel TubeBolt in concrete-filled tubes exhibited excellent anchorage performance, higher strength and less slip and elongation until the failure state was reached.

1. Introduction

The utilisation of concrete-filled tubular (CFT) columns has opened new horizons in the construction of high-rise buildings in seismic zones [1–4]. The efficiency of tubular columns is better than that of open columns under a compressive load, and the load-carrying capacity of CFTs can be increased remarkably [4,5]. However, bolting a beam to the hollow column surface using standard bolts is nearly impossible. To overcome this problem, the blind bolt was proposed to connect a beam to a hollow column face. This type of bolts can be inserted and tightened from one side of the tube. The Lindapter Hollo-bolt (HB), Ajax bolt, Flowdrill bolt and Molabolt are currently the most commonly used bolts. Nevertheless, these types of blind bolts are not developed for moment-resisting connections and are restricted to the construction of shear-resisting connections because of their difficulties in achieving sufficient tensile strength and moment-resisting capacity. The concept of a long-headed bar anchor bolt was presented in an earlier study [6]. Thereafter, this idea was applied to the HB blind bolt, known as the Extended HB (EHB), and the headed stud anchored blind bolt (HABB) to facilitate the on-side bolting of CFT column connections and enhance the anchorage performance of the HB and Ajax bolts, respectively [7–10]. The modified Ajax bolt, known as the headed stud anchored blind bolt, was also developed [10–13] as a fastener for CFT column bolted connections. The anchorage element of this type of blind bolt is a nut at the end of the long shank, which is similar to EHB. Another study [14,15] proposed a modified version of the headed stud anchored blind bolt with two nuts at the end of the shank and between the end nut and the nut bearing on the tube wall, respectively to enhance the anchorage performance of the bolt. The application of semi-rigid connections is currently limited [16,17] due to the lower bond strength between the bolt and the concrete [18,19], substantial column face deformation and bolt slippage within the concrete [20–24]. Given the aforementioned reasons, an ideal beam to CFT column connection, particularly for CFT bolted connections, is continuously being researched [4,9,21,22,25–35]. At present, beam to CFT column welded connections are widely used as rigid connections [4]. However, the fabrication of CFT welded connections is generally difficult and costly in terms of time and money. The introduction of an ideal CFT bolt connection has many advantages, such as easier and faster fabrication and design, lower cost and higher stability compared with CFT welded connections.

The current study proposes a novel type of blind bolt known as the TubeBolt. This bolt was designed based on the concept of the long-headed bar anchor bolt to improve the performance of existing blind bolts for CFT column connections. The main parts of the TubeBolt are two expandable sleeves and an end anchor member, as shown in Fig. 1. The TubeBolt can be inserted through the bolt hole and tightened easily from one side. The first sleeve clamps the beam onto the column face, whereas the second sleeve and the end anchor member prevent bolt slippage inside the concrete core. The second sleeve is provided to enhance the anchorage performance of the bolt. Hence, the TubeBolt is expected to provide better tensile strength and stiffness. The proposed TubeBolt solves the aforementioned problems and exhibits a remarkable capability to distribute tensile load into the concrete and reduce sliding and elongation. The introduction of the TubeBolt can expand the

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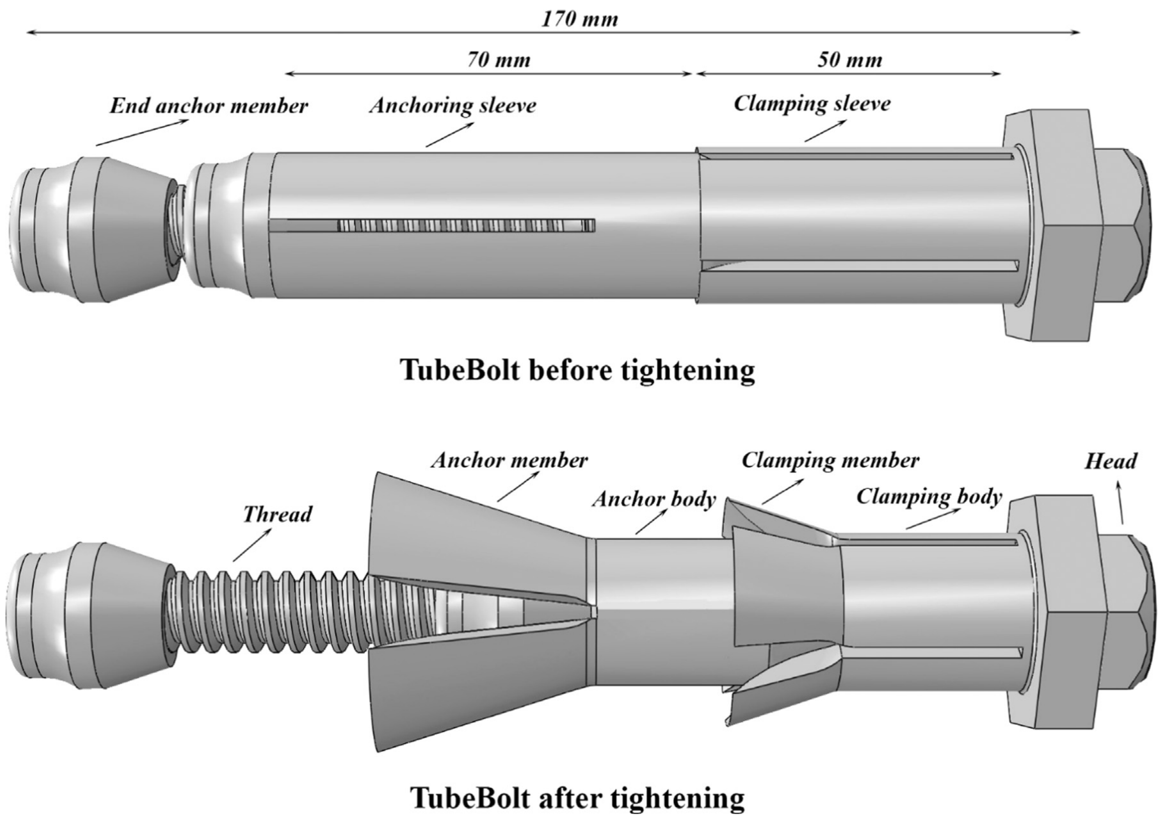

Fig. 1. Detail components of the Tubebolt.

adoption of beam to CFT column bolted connections in seismic zones due to its excellent anchorage behaviour, easy and fast fabrication process and economical properties.

In the current study, 10 pull-out specimens were tested under tensile loading to examine the anchorage performance of the proposed TubeBolt. The experimental results were compared with those of EHB specimens to investigate the TubeBolt behaviour. The failure modes, anchorage performance, load-carrying capacity, strength, slippage and elongation of the bolts were presented and evaluated.

2. Description of the proposed TubeBolt

A novel double sleeve TubeBolt is proposed for connecting a steel open beam to a CFT column. The features of the TubeBolt are shown in Fig. 1. The TubeBolt is an all-in-one bolt that can be quickly and easily inserted through a bolt hole. The shank comprises the threaded portion, which is formed on the outer surface, for tightening the fastener to connect the beam to a CFT column. The TubeBolt has three separate sections: a clamping sleeve member, an anchoring sleeve member and an end anchor member. The two sleeves are simultaneously expandable during tightening. The clamping and anchoring sleeves expand whilst the fastener is being tightened. The novel fastener is designed with a remarkable shape, mechanical properties and double sleeves to enhance the anchorage performance of the TubeBolt within the limited space of the bolt hole. The anchor sleeve considerably prevents the sliding and elongation of the bolt during loading. Moreover, The TubeBolt can be available in different size, shank length and anchoring sleeve location.

In the connection between the beam and the tubular column, the end plate and the hollow column are clamped together by the TubeBolt, and then, the hollow column is filled with concrete as illustrated in Fig. 2. The interaction, bonding and bearing between the embedded parts (i.e. the shank, clamping sleeve, anchoring sleeve and end anchor member) and the concrete prevent bolt slippage, bolt elongation and column face deformation failure modes.

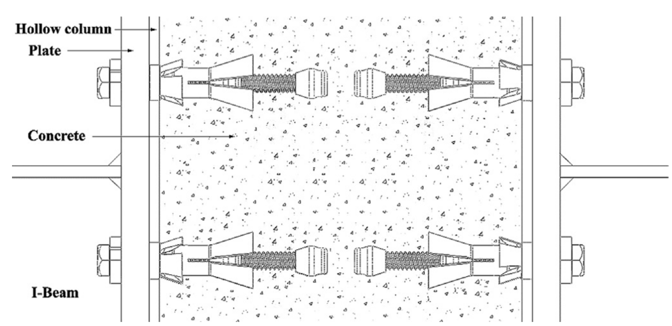

Fig. 2. Side view of the Beam to CFT column TubeBolt connection.

3. Monotonic tensile pull-out test

A total of 10 pull-out tests were performed under tensile monotonic loading to evaluate the strength, stiffness, ductility and bond and anchorage mechanisms of the TubeBolt in the concrete compared with the EHB component. Three repeated tests were conducted for each type of specimen to confirm the reliability of the test results. The main objective of the program was to examine the load transfer mechanism and performance of the TubeBolt. Its performance was then compared with that of EHB in terms of failure modes, anchorage, strength, slippage and elongation.

3.1. Test specimens

The specimens were labelled as POT1 to POT10, where POT denotes pull-out test. Test specimens were designed using commercial steel square hollow tube sections that measured 200 × 200 × 8 mm and 200 × 200 × 6 mm. The length of the steel tube in all the specimens was 650 mm. The configuration of the specimens is shown in Fig. 3. The TubeBolt connects the circular plate to the CFT tube. The diameter and