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Numerical investigation on strength and failure modes of thread-fixed one-side bolted T-stubs under tension

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ABSTRACT

The failure mechanism of thread-fixed one-side bolted T-stubs under tension was investigated by a finite element model to provide basic knowledge for its potential application in bolted beam-column endplate connection. The finite element model was verified through experimental results by considering four possible reference issues: the T-stub deformation, the force–displacement curve, the failure mode and the yield strength. Studied parameters included the bolt diameter (d), the bolt spacing (s) and the T-stub plate strength (f_y). Based on numbers of plastic hinges in the T-stub flange, the failure modes were divided into three categories: Mode 1, complete flange yielding; Mode 2, flange yielding accompanied by bolt failure or hole thread failure; and Mode 3, bolt failure or hole thread failure. Furthermore, modified design equations integrating the potential hole thread failure were proposed to analyze the failure mode and the yield strength of the T-stub connection. Theoretical and numerical analyses showed that the thread hole could provide enough clamping force to fix the high strength bolt, which assured that the one-side bolted T-stub connection would not fail caused by pre-mature thread failure.

1. Introduction

The steel tube in a Concrete Filled Steel Tube (CFT) provides confinement to the in-filled concrete and thus increases the strength and ductility of concrete; while additionally the in-filled concrete retards the potential local buckling of the steel tube. However, compared with the H-section column, connecting a beam to a CFT through bolted endplate connection becomes very difficult, as there is no access to the inside of the tube to install bolt nut. So various one-side bolts, which could be tightened from outside of the tube, were developed to be used in the bolted endplate connection [1]. Currently available one-side bolts could be classified as four types, including (1) the through-column bolt, (2) the sleeve anchored bolt, and (3) the toggle anchored bolt, and (4) the thread-fixed bolt. Fig. 1(a) was the traditional high strength bolt that assembled through a nut; Fig. 1(b) indicated a beam-column connection using the type 1 one-side bolt (through-column bolt); Fig. 1(c) showed three types of type 2 one-side bolt, which were the Reverse Mechanism Hollobolt (RMH), the Hollobolt and the Extended Hollobolt; Fig. 1(d) presented the type 3 one-side bolt: the toggle fixed one-side bolt; and Fig. 1(e) was the type 4 one-side bolted connection that fixed through hole thread, which would be investigated in this paper.

For the tubular column with wall thickness less than 12.5 mm, the thread hole could be manufactured using flow drilling technique [2,3], which allowed a thread to be incorporated into relatively thin plate by locally displacing the plate and increasing the plate thickness to permit tapping of a longer thread. France et al. [2] carried out experiments to investigate the bending moment capacity and rotational stiffness of simple joints bolted to tubular columns using flow drill connectors. Test results showed that the connections behaved in a manner suitable for use as either pinned or semi-rigid connections for simply designed braced steel frames.

The equivalent bolted T-stubs originally introduced by Zoetemeijer [4] are regarded as a fundamental approach for the idealization of the performance of the tension zone of the bolted endplate joint. The bending of the column flange and the endplate can be described using equivalent a bolted T-stub model [4–7].

Liu et al. [8] had carried out tests to investigate the behavior of thread-fixed one-side bolted T-stub connections and conducted parametric studies including the bolt pretension force and the thickness of the T-stub target flange. Two failure modes considering thread failure and the corresponding design methods were proposed. It can be concluded that the bolt pretension force can improve the initial stiffness of the connection; however, it could not increase the ultimate tension strength of the connection. On the other hand, the conclusions were limited within the scope of experiment results, which meant more proofs should be provided to validate the applicability of the thread-fixed bolted connection.

A Finite Element Model (FEM) was developed using ABAQUS to

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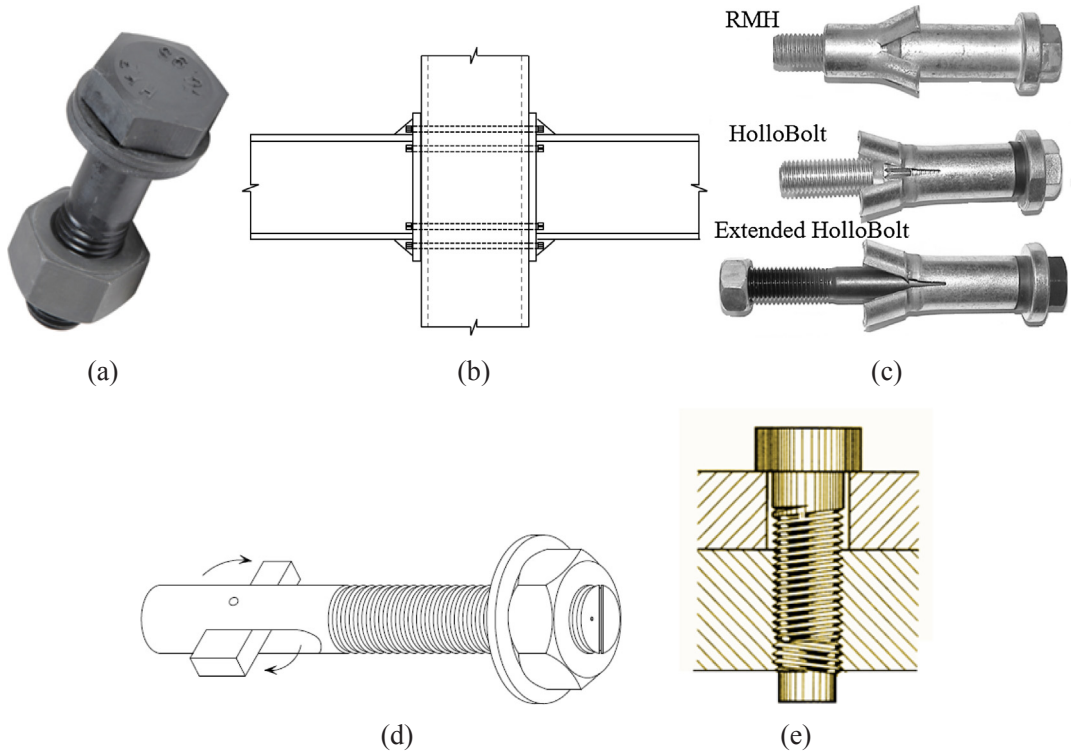

(a) The traditional High strength bolt; (b) Type 1 the through-column bolt; (c) Type 2 The sleeve anchored bolt; (d) Type 3 The toggle anchored bolt; (e) Type 4 The thread-fixed bolt

Fig. 1. The traditional bolt and four types of one-side bolts.

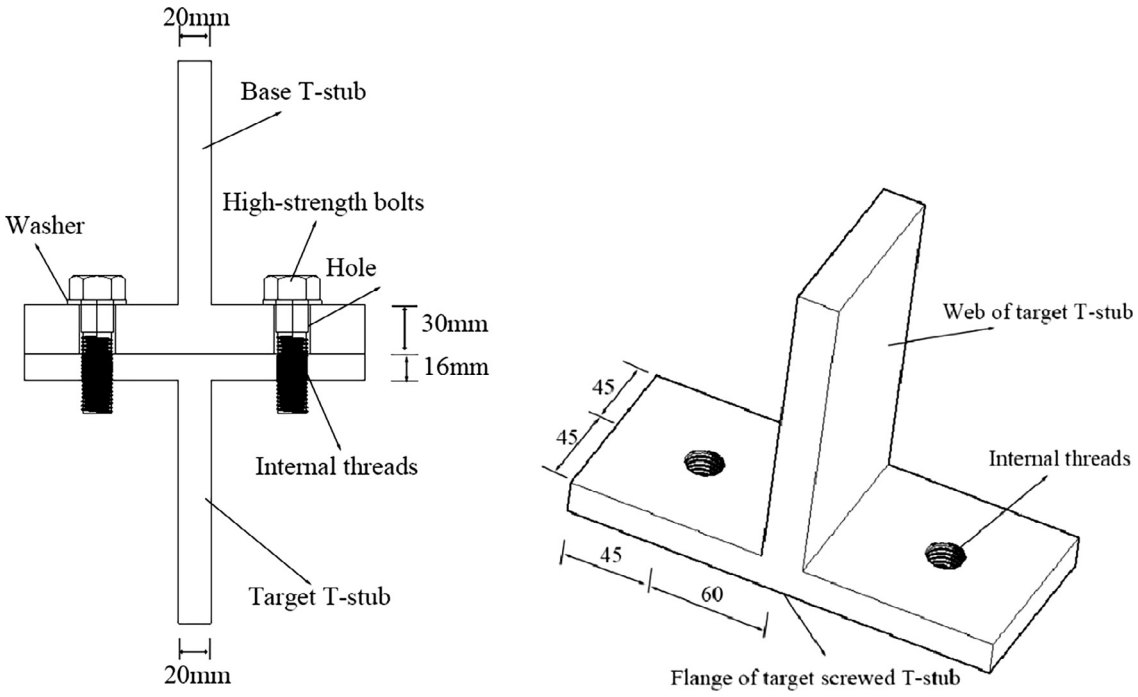

Fig. 2. Sketch of one-side bolted T-stubs.

investigate the behavior of thread-fixed one-side bolted T-stubs, which was fully validated by test results reported by Liu et al. [8]. The development of the stress and the strain contour, which could help understanding the failure mechanism of different failure modes, could be easily revealed in a FEM simulation. The location of plastic hinges, the sequence among the bolt failure, the flange failure, the hole thread failure, the companion failure of flange and bolt, and the companion failure of the flange and hole thread, all could be easily illustrated through a FEM. Effects of the bolt diameter (d), the bolt spacing (p) and the T-stub plate strength (f_y) on the behavior of the thread-fixed bolted