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Mechanical properties of right-angle couplers in steel tube–coupler scaffolds

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ABSTRACT

The mechanical property of right-angle couplers has a significant effect on the load bearing properties and stability of steel tube–coupler scaffolds. This paper presents a systematic and comprehensive experimental study on slipping and rotational stiffness in the right-angle coupler connection. Different influencing factors, such as bolt tightening torques, condition of components (new or old), different coupler combinations, and loading patterns, were considered. The failure modes and slipping or rotational stiffness were discussed and compared. Several conclusions were obtained. First, the anti-slipping capacity and rotational stiffness of various right-angle coupler connection styles are key parameters for the future design of steel tube–coupler scaffolds. Second, the slipping resistance and rotational stiffness of right-angle couplers increase with bolt tightening torque. However, with a high tightening effect, such couplers are likely to experience fracture failure. Third, the multi-coupler connecting method effectively strengthens slipping resistance. An old tube or old coupler degrades the overall performance of the scaffold connections. Fourth, a right-angle coupler connection demonstrates a semi-rigid performance, and an old coupler has weaker rotational stiffness than new ones. Lastly, fracture mostly occurs in the bolt connecting region and at the boundary between the cover plate and base plate, as revealed by slipping and rotational stiffness tests. These areas require special care during actual application.

1. Introduction

The steel tube–coupler scaffold is widely utilized as a temporary structure to support workers, materials, and structural members during construction. The steel tube–coupler scaffold is a simple steel frame that consists of steel tubes and couplers, but its mechanical property is highly complicated because of the semi-rigid coupler joint, complex initial defect, numerous connection and constraint forms, and many loading transfer paths. Therefore, structural failure of steel tube–coupler scaffolds (Fig. 1) usually occurs in construction sites because of inadequate design.

Steel tube–coupler scaffolds may be categorized as support or access depending on their use. The load on support scaffolds is transferred to the vertical members directly by a U-head, as shown in Fig. 2(a). The load on access scaffolds is transferred to the vertical members from the top horizontal members by steel coupler connections, as shown in Fig. 2(b). The mechanical properties of steel couplers, including rotational stiffness, slipping stiffness, and anti-slipping capacity, have a significant effect on the ultimate loading capacity of steel tube–coupler scaffolds.

Many disastrous incidents of scaffold collapse have occurred in several countries. Thus, the safety of scaffolds during construction has been questioned. Many studies have been conducted recently on door-type modular steel [1–9], insert-type [10–11], cuplock-type [12–15], and steel tube–coupler scaffolds. Beale [16–18], Ao [19], and Yue [20] conducted systematic studies on the stability capacity and design method for single- or double-span steel tube–coupler scaffolds; these studies provided a reliable design method in practice. Liu [21–23] conducted several experimental and theoretical studies on multi-span steel tube–coupler scaffolds.

The mechanical properties of scaffold joints are the key factors that affect the ultimate loading capacity of various scaffolds. Insert-type, cuplock, and coupler joints (Fig. 3) are the three main types of joints. Pienko [10] studied the mechanical behavior of the insert-type scaffold joint by numerically considering the nonlinear material and the interaction among particular joint elements. Chandrangsu [24] experimentally studied the rotational stiffness

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Fig. 1. Collapse of a steel tube–coupler scaffold during construction.

of the cuplock scaffold joint. Prabhakaran [25] experimentally investigated the rotational stiffness of a steel right-angled coupler manufactured according to British standards.

A few studies have been conducted on the mechanical properties of steel couplers in steel tube–coupler scaffolds manufactured according to Chinese standards; these properties exert a significant effect on the structural behavior of steel tube–coupler scaffolds. Consequently, a systematic experimental investigation was conducted on the mechanical properties of steel couplers, such as number of couplers, tightening torque, new–old degree, and connection styles, under various conditions. This investigation may serve as an important reference for the improvement of the national standards for steel tube–coupler scaffolds in China [26] and other countries.

2. Experimental study on the slipping stiffness of a right-angle coupler

Steel tube–coupler scaffolds are mainly composed of vertical and horizontal members connected by right-angle couplers. The mechanical property of right-angle couplers has a significant effect on the load bearing characteristics and stability of steel tube–coupler scaffolds. The vertical loads of steel tube–coupler scaffolds are mainly transmitted from horizontal to vertical members through slippery friction between the right-angle couplers and steel tubes. Previous studies have shown that slipping stiffness is closely related to bolt tightening torque and material properties. The "Technical code for safety of steel tubular scaffolds with couplers in construction (JGJ 130-2011)" [26] requires tightening torques to be approximately 40 N·m. However, the tightening torque in actual construction sites cannot reach 40 N·m, and the scaffold materials are likely to experience degradation after several times of usage. A means to address this situation is to adopt multiple couplers in each connection to indirectly improve connection safety and stiffness. The slipping characteristic can be adjusted by using various connected couplers and arranging them. Then, systematic experimental studies can be performed on the slipping behaviors of different right-angle coupler connections.

2.1. Connecting styles and test setup

Traditional scaffolds generally have only one coupler to connect one-way horizontal members. Many couplers were used in this study to form a multi-coupler connecting design that could strengthen slipping resistance and stiffness. According to the number of couplers, multi-coupler connections were classified as single-coupler (S — single), double-coupler (D — double), and three-coupler (T —triple) connections. The connection styles and coupler arrangements are shown in Fig. 4.

The single-coupler connection has one coupler with varying factors, such as tightening torque and new and old conditions of connected members or couplers. The double-coupler and three-coupler groups were mainly studied for the effect of coupler number and combination methods. D1 and D2 have one coupler to connect the members and adopt an additional coupler as sub-support to strengthen slipping stiffness. However, D1 has two couplers arranged on the same side, whereas

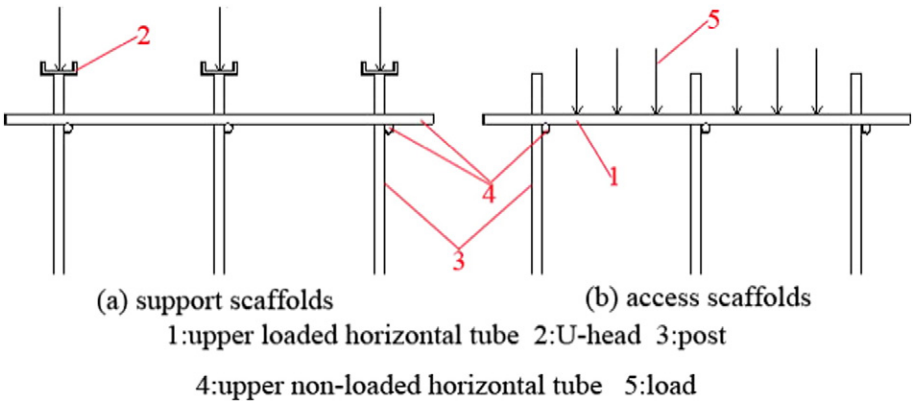

Fig. 2. Two typical load transfer paths of steel tube–coupler scaffolds.