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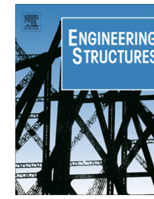

Cyclic behavior of a prefabricated self-centering beam–column connection with a bolted web friction device

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ABSTRACT

A prefabricated post-tensioned (PT) self-centering beam–column connection using a bolted web friction device (PSC connection) has been proposed. This connection is different from a common self-centering connection using a bolted web friction device (SC connection) in that the beam of a steel frame with a PSC connection is divided into three parts connected with a vertical plate and PT strands, and the beam, including the gap opening feature, can be treated as a normal single beam on site. Eight PSC connections were designed with various combinations of design parameters, which include the initial PT forces, friction bolt forces and loading histories. Low-cycle loading experiments were conducted to study the seismic behavior of the PSC connections and to investigate the effects of the initial PT force and the friction bolt force. Additionally, relevant theoretical analyses were conducted, and the results indicated that the maximum PT force at 5% radians drift with the PSC connection did not exceed the yield force, and the average loss of the PT force was within 10%. The residual rotations of all the specimens were minimal, which indicated that the PSC connection had the same robust self-centering behavior compared to that of the SC connection. Simultaneously, the PSC connection does not require on-site aerial tension in high-rise buildings because the post tensioning can be introduced on the ground or in the factory. The theoretical double-flag models match the experimental results notably well and can be applied in the analysis and design of prefabricated self-centering steel frames.

1. Introduction

To achieve a good seismic performance of steel frame beam–column connections [1] and be protected from unexpected weld fractures under seismic hazards, a variety of modified connections were designed, such as widened beam section (WBS) [2] and reduced beam section (RBS) connections [3], which could effectively move the plastic hinge from the face of the column such that the ductility, as well as the energy dissipation, could be improved. However, dissipating energy under the designed earthquake can induce yielding and correlative damage in critical regions of the primary structural members, which can result in a large residual drift after the earthquake and a high cost of seismic rehabilitation. Thus, post-tensioned self-centering beam–column connections were developed. The design principle is to enable the connection to develop a gap opening at the beam–column interface, and the PT force enables the connection to self-center upon unloading. Thus, the energy dissipation occurs in special devices designed for the beam–column connection regions. The first experimental study on self-centering steel moment resistant frames (SC-MRFs) was conducted in 1997 [4]. Afterwards, SC-MRFs consisting of post-tensioned moment connections with top-and-seat angles were proposed and validated extensively by, for example, Ricles et al. [5], Ricles et al. [6] and Garlock [7], Garlock et al. [8], Garlock et al. [9], Garlock et al. [10]. Kim and Christopoulos [11] used PT friction-damped connections placed on the top and bottom beams in the SC-MRF. Iyama et al. [12] used two types of friction devices: a PT friction damped connection placed on the top and bottom of the beam flanges and a bottom flange-only friction device. In the same year, Wolski et al. [13] designed seven specimens with beam bottom flange friction devices (BFFD), and the experimental results indicated that the BFFD provided energy dissipation to the SC beam–column connection and avoided interference with the floor slab. George et al. [15] proposed a new self-centering steel post-tensioned connection which uses high-strength steel

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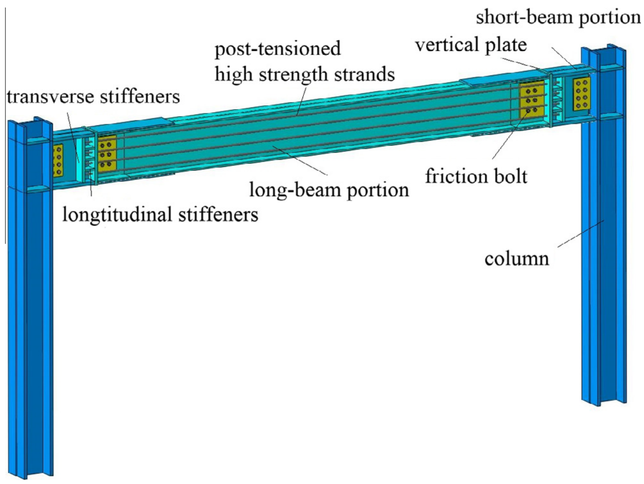

Fig. 1. PSC plane frame details.

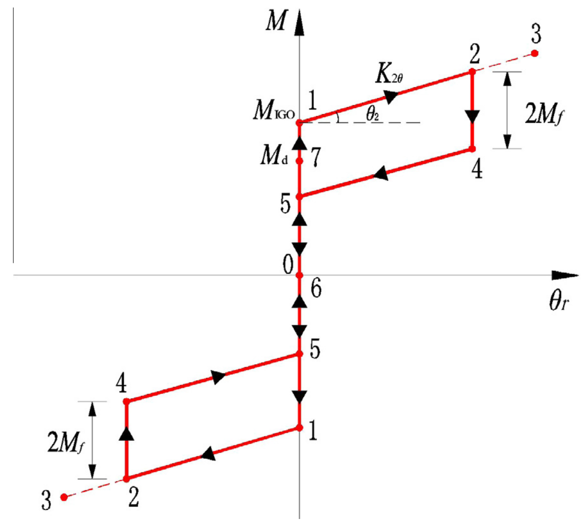

Fig. 3. Ideal M–θ_r behavior.

post-tensioned bars to provide self-centering behavior and steel energy dissipation elements that consist of cylindrical pins with hourglass shape to provide enhanced deformation capacity. Lin et al. [16,17] used web friction devices (WFDs) on beams for energy dissipation in the SC-MRF and conducted hybrid simulations and experiments to investigate the seismic performance of SC-MRFs under the design basis earthquake (DBE) and the maximum considered earthquake (MCE) [19]. Karavasilis et al. [14] conducted a parametric study on the seismic response of highly damped single-degree-of-freedom systems with self-centering flag-shaped or bilinear elastoplastic hysteresis. However, this type of structural system requires on-site aerial tension in high-rise buildings. A PSC connection with WFDs has been proposed for high-rise buildings, which is suitable for different types of columns, and the beams are post-tensioned to a short connecting element at each end. This assembly is subsequently erected similar to a traditional beam, which avoids the potential issues of aerial PT operations [18]. In this report, eight PSC connections were designed with different combinations of design parameters. These design parameters were initial PT forces and friction bolt forces as well as loading histories. The low-cycle loading experiments were presented to study the seismic behavior of the PSC connections for the life safety and collapse prevention levels compared to that of the SC connection and investigate the effects of the initial PT forces and friction bolt forces.

2. PSC connection details

2.1. Detailed description

The PSC plane frame with WFDs is illustrated in detail in Fig. 1. The beam of the steel frame designed with the PSC connection is divided into three parts: a long-beam portion and two short-beam portions at both ends. These parts are connected with a vertical plate, and PT high-strength strands run parallel to the beam. Brass plates are sandwiched between the webs of the beam and the friction plates to achieve reliable friction and dissipate energy. The requirements for maximum beam rotation determine the size of the oversized circular bolt holes on the long-beam web. The transverse and longitudinal stiffeners are built up to strengthen the two short-beam portions. The entire assembly is connected to the column similar to a traditional beam.

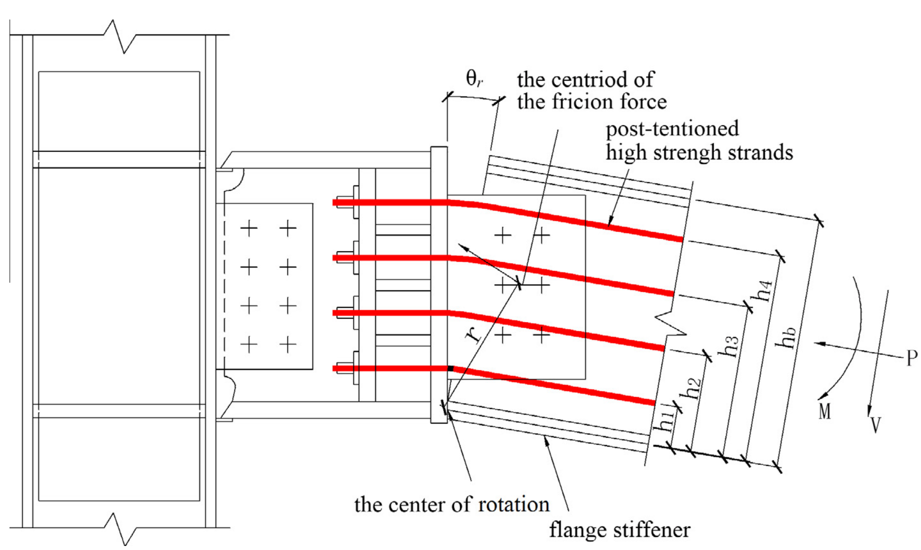

Fig. 2. Schematic figure of PSC connection gap opening.