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Development of the self-centering Sliding Hinge Joint with friction ring springs

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ABSTRACT

The Sliding Hinge Joint (SHJ) is a low-damage beam–column connection used in steel moment-resisting frames. It allows large beam–column rotation with minimal damage through sliding in asymmetric friction connections. It is however, subject to elastic strength and stiffness degradation and potential residual deformations under earthquake shaking and inelastic action. This paper describes the development of the self-centering SHJ incorporating ring springs installed to the beam bottom flange to improve the dynamic re-centering properties and reduce strength degradation. Five 10-storey frames with ring springs generating up to 50% of joint moment capacity were studied analytically using a suite of 10 earthquake records. Ring spring contribution of 40% improved the self-centering properties, resulting in residual drifts less than 0.1% under design level shaking. They also reduced strength degradation.

1. Introduction

Beam-to-column flange welds in conventional rigid welded connections in steel moment resisting frames (MRFs) suffered premature brittle fracture in the 1994 Northridge and 1995 Kobe earthquakes. Improved welded connections have since been developed which typically force plastic hinges to form in the beams away from the column face to dissipate energy (e.g. [1,2]). While effective in providing safety and collapse prevention, these systems are usually associated with irrecoverable plastic deformation and residual drifts, potentially causing significant economic losses in the building closure and post-disaster repair or replacement.

In order to mitigate these effects, low damage alternatives to welded systems incorporating self-centering capabilities have since been developed for use in steel MRFs. Ricles et al. [3], Christopoulos et al. [4], and Garlock et al. [5] applied the post-tensioned steel tendon (PT) system. This involves running high strength steel strands anchored to the exterior columns of the frame to pre-stress the beam ends against the columns. The tendons close the gaps which open between the beam and column face thereby providing static self-centering. Wolski et al. [6], Chou and Lai [7] and Iyama et al. [8] proposed incorporating energy dissipating friction devices in the top or bottom flange of the beam. Experimental studies showed that these systems provide good self-centering and energy dissipation properties [6]. However, because joint rotation is characterised by "gap-opening" of the beam-to-column interface, this leads to undesirable frame/slab interaction, which changes the self-centering behaviour of the joint and causes slab damage and increased column demands [9]. Consequently, Garlock and Li [10] studied collector beam systems to accommodate gap opening. King [11], and Chou and Chen [12,13] proposed fixing the floor slab to one bay and allowing sliding in the other bays, or using a discontinuous slab near the column face to limit the effects of gap-opening. These systems were tested showing good self-centering results. Clifton [14] also investigated the PT joint, but considered it impractical due to the effects of gap-opening, requirements for beam strengthening to carry the high internal compression forces developed in the beam flange, and the minimum tendon lengths required for the tendon to remain elastic with gap-opening in the design range.

Researchers have also proposed using the unique properties of shape memory alloys (SMAs) in low damage connections. SMAs in their austenitic state display superelastic properties, allowing them to undergo up to 8% recoverable strain. In their martensitic state, SMAs display shape memory effect, which allows strain recovery upon application of heat. Ocel et al. [15] and Sepúlveda et al. [16] tested nickel titanium SMAs (nitinol) and copper based SMAs respectively in steel beam–column connections. DesRoches et al. [17] and Ellingwood et al. [18] analytically studied the effects of austenitic and martensitic SMAs in structures. They showed that structures

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