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Analytical model validation and influence of column bases for seismic responses of steel post-tensioned self-centering MRF systems

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ABSTRACT

The first generation for the post-tensioned (PT) self-centering (SC) system, which incorporates the PT technology to beam-to-column connections, exhibits good seismic performance with small residual deformations except for the first floor. Instead of using the fixed column base, the column PT to the base affects the seismic performance of frames, especially for residual deformations. Recently, the seismic response of a SC frame subassembly, which applied the PT technology to the connection and column base, was verified in shake table tests. In this paper, a three-dimensional analytical model with rotational springs in the PT connection and PT column base was introduced to capture shake table test results of the frame subassembly. The same modeling approach was adopted to one MRF and three SC frames to study the effects of column bases on the seismic responses of frames under the design-based and maximum-considered earthquakes. The monotonic, cyclic pushover, and time–history analyses were conducted for these frames. Analytical results showed that (1) the residual drift of the first floor could be significantly minimized by using the PT column base but the maximum interstory drift in the SC frame increased with decreasing fixity at the column base, (2) the largest maximum interstory drifts of the SC frames were larger than those of the MRF due to the low-to-medium structural period and high yield strength, and (3) the SC frame with the PT column base effectively decreased column restraining forces to the first floor compared to that with the fixed column base.

1. Introduction

A post-tensioned (PT) self-centering (SC) moment frame that uses post-tensioning steel to compress steel beams against columns has been developed as an alternative to the steel welded moment-resisting frame (MRF). The welded MRF is expected to develop inelastic deformations in the beams and at the column bases during a moderate or severe earthquake, which results in large residual deformations. The SC frame, which maintains elastic responses in the beams, develops large drifts with small residual deformations through gap opening, closing responses at the beam-to-column interfaces. Repair costs following an earthquake are relatively inexpensive since inelastic deformations of the SC frame are limited to energy dissipating devices, which are easily replaced compared to buckled beams in the MRF [1,2]. Many researchers have experimentally validated a Flag-Shaped (FS) hysteresis of the PT connection with good energy dissipation added to the post-yield range as well as negligible stiffness and strength degradation [3–9]. More recently, large-scale steel SC frame tests demonstrated good FS responses [10–12]. Beam buckling, which is a major mechanism for dissipating seismic energy in the MRF, was completely eliminated in the SC frame even after several cyclic loading tests [11,12].

To investigate the seismic behavior of the SC frame, Ricles et al. [13] designed six-story, six-bay MRFs with either welded connections or PT connections. Time–history analysis results of these frames subjected to the same earthquake records showed that in terms of the maximum interstory drifts and residual drifts, an MRF with PT connections exceeded the performance of an MRF with welded connections. In Kim and Christopoulos [14], six-story, three-bay MRFs with welded connections or PT connections were designed and analyzed to compare their seismic responses. Analytical results showed that the maximum interstory drifts of the SC frame were similar to or less than those of the MRF, and the SC frame almost eliminated residual deformations except for the first floor. Although the experimental and analytical studies demonstrate the superior seismic performance of the SC frame compared to the MRF, two major issues to overcome for the

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