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Seismic behavior of post-tensioned column base for steel self-centering moment resisting frame

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ABSTRACT

This paper presents experimental and analytical investigation of cyclic response of a post-tensioned column (PT) base connection. The PT column base connection is designed to eliminate structural damage at column bases in self-centering moment resisting frames (SC-MRFs) under seismic loading; the softening behavior at the connection is provided by gap opening and elongation of PT bars rather than yielding in the column. Additional shear resistance is provided by bolted keeper plates; additional energy dissipation is provided by buckling restrained steel (BRS) plates. To investigate the cyclic behavior of the PT column base connection, a series of PT column base connection subassemblies were subjected to axial load and cyclic lateral displacements. Test parameters included initial post-tension force, initial axial force in column (constant or varying), column size and loading history. Limit states investigated for the PT column base connections included PT bar yielding and fracture of BRS plates. The test results demonstrated that properly designed PT column base connections were able to undergo lateral displacement up to 4% interstory drift while the columns and grade beams remained elastic. Also, the BRS plates showed good energy dissipation capacity by yielding in tension and compression without fracture. Structural damage at column bases was limited to the replaceable fuse BRS plates. In addition, analytical models were developed to predict the moment–rotation relationship of the PT column base connection and showed good correlation with the experimental data.

1. Introduction

Current design philosophy for conventional steel moment resisting frames (MRFs) in high seismic regions is that the frames should not collapse for major earthquakes. However, significant structural damage and residual drift (i.e., out-of-plumbness) due to inelastic deformations in beams and columns may cause loss of building occupancy or operation after major earthquakes. The 2020 Vision for Earthquake Engineering Research promotes the concept of resilient structures, which have the capacity to return to normal operation quickly after a significant seismic event [1]. To provide higher resiliency and overcome the issues (i.e., significant inelastic deformation and residual drift) of conventional steel MRFs, self-centering moment resisting frames (SC-MRFs) have been developed and studied experimentally and analytically by researchers [2–8]. The beam-column connections in the SC-MRF are constructed by use of post-tensioning. The softening behavior at the beam-column connections is achieved by gap opening (i.e., separation of beams and columns) instead of plastic hinging of beams, thus eliminating structural damage to beams.

Ricles et al. [2] (Garlock [8]) designed a 6-story, 6-bay prototype SC-MRF building located on stiff soil in the Los Angeles area. Only four interior bays were used as moment-resisting frames, so as to avoid bi-axial bending of the corner columns. The 6-story, 4-bay SC-MRF had PT beam-column connections, but continuous columns into the basement (i.e., moment resistance due to continuity at grade level). Dynamic time-history analyses of the prototype SC-MRF indicated that the SC-MRF would return to its original position with negligible residual drift after major earthquakes if significant residual deformation did not occur at the column bases.

This study focuses on the development and experimental evaluation of the PT column base connection for use in the 6-story, 4-bay SC-MRF. In the experimental program, the cyclic behavior of the proposed PT column base connection is investigated primarily for the strong axis direction, with limited study of the weak axis direction. Limit states of the PT column base connection are identified for each drift level. Also, the effects of PT column base design parameters are investigated. In addition, the performance of the energy dissipation device (i.e., buckling restrained steel plate) is examined.

A couple of contemporary, almost concurrent, studies have confirmed the viability of post-tensioned column bases for eliminating structural damage and allowing SC-MRFs to self-center. Ikenaga and Nakashima [9,10] proposed a PT column base connection to reduce the residual deformation of the SC-MRF. While there were some similar details as compared to this study, Ikenaga and Nakashima based their research on a shorter (3-story) prototype building, using relatively short PT bars, and testing mostly to a lower interstory drift level (3% or 0.03 rad) than in this study. Furthermore, the levels

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