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Experimental results of a NiTi shape memory alloy (SMA)-based recentering beam-column connection

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ABSTRACT

A half-scale interior beam-column connection incorporating superelastic nickel-titanium shape memory alloy (SMA) tendons was designed, fabricated, and tested to assess the feasibility of such a connection in a moment-resisting frame. This connection was compared to three other connections utilizing tendons made of steel, martensitic nickel–titanium, and superelastic nickel–titanium paralleled with aluminum. The connections with steel and martensitic nickel–titanium tendons rapidly lost their stiffness after being cycled beyond their elastic drift levels. The two tests with the superelastic nickel–titanium tendons showed significant recentering capabilities; they recovered a large portion of the post-elastic drift and showed promise for a material-based recentering moment connection. This novel connection was intended as a proof of concept that can be further developed in terms of practicality, ease of installation, and cost.

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1. Introduction

Earthquakes continue to expose deficiencies in today's infrastructure and call for engineers to continue to explore new ways to create resilient structures. The 1994 Northridge earthquake exposed numerous vulnerabilities in fully restrained (FR) moment-resisting connections. As a result, several research initiatives have been undertaken to create connections that have more robust performance under seismic loads, including a reevaluation of partially restrained (PR) connections. Research has shown that properly detailed PR connections have good seismic performance and should be considered as a viable alternative to FR connections [1–4]. One class of PR connections that has drawn considerable interest is the post-tensioned (PT) connection, because of its ability to recenter after a seismic event [5–7]. This research investigates the use of superelastic nickel–titanium (NiTi) shape memory alloys (SMAs) to induce the recentering force on the connection with the goal of creating a simplified ductile recentering system.

The SMA-based, partially restrained connection proposed and tested in this research was designed to provide good strength, stiffness, and ductility for a connection in a low-rise building. Additionally, the connection was designed to recenter under large drift demands to fully exploit the unique ability of NiTi to spontaneously recover up to 8% strain. This spontaneous strain recovery, a product of the diffusionless martensite-to-austenite phase transformation [8], is the key characteristic that has drawn numerous researchers to investigate the use of SMAs in seismic applications [9–13].

Four experimental tests were carried out to investigate the behavior and validate the performance of such a connection. *Test A* was performed using ordinary steel tendons to set a benchmark to compare performance. *Test B* was performed using martensitic NiTi tendons, which do not revert to their initial shape until heat is applied. *Test C* was performed using superelastic SMA tendons, which revert to their initial shape spontaneously. *Test D* was performed using superelastic SMA tendons in parallel with low-strength aluminum bars. The aluminum bars were added to provide additional energy dissipation. Both *Test C* and *Test D* displayed significant recentering behavior under large drift demands.

2. Background

Recentering PT connections have been investigated by numerous researchers as an alternative to other PR moment connections [7,14–18]. Several researchers have looked at recentering in a

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