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Advanced Shape Memory Alloy-Based Smart Isolation Systems for Post-Earthquake Damage Mitigation and Resilience Enhancement in Steel Structures

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ABSTRACT

Steel structures are widely used in seismic-prone regions because of their high strength, ductility, and ease of construction. However, strong earthquakes can still induce significant structural and non-structural damage, resulting in residual deformations, prolonged downtime, and substantial repair costs. Conventional seismic isolation systems are effective in reducing earthquake-induced forces, but they often exhibit limited self-centering capability, leading to permanent displacements after severe seismic events. Shape Memory Alloys (SMAs), owing to their unique superelasticity and shape memory characteristics, provide an innovative solution by offering both energy dissipation and self-centering capabilities. This study presents an advanced SMA-based smart isolation system designed to enhance post-earthquake recovery and minimize damage in steel structures. The proposed system integrates SMA components with conventional isolation mechanisms to improve seismic performance while reducing residual drift and structural damage under strong ground motions. Numerical modeling and nonlinear time-history analyses are employed to evaluate the effectiveness of the smart isolation system under a suite of recorded earthquake ground motions. Key performance indicators, including inter-story drift, base displacement, floor acceleration, residual deformation, and energy dissipation, are used to assess structural behavior. Furthermore, the study investigates the influence of SMA design parameters, such as stiffness, damping characteristics, and re-centering capacity, on the overall seismic resilience of steel structures. Comparative analyses with conventional isolation systems demonstrate the superior performance of the proposed SMA-based smart isolation approach in enhancing structural safety, reducing repair requirements, and enabling rapid post-earthquake functionality. The findings provide valuable insights into the development of next-generation resilient infrastructure and support the practical implementation of smart seismic isolation technologies for earthquake-resistant steel structures.

Keywords: *Shape Memory Alloy, Smart Seismic Isolation, Steel Structures, Post-Earthquake Recovery, Seismic Resilience.*