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SAP2000 Analysis of Seismic Reinforcement Using Carbon Fiber Reinforced Polymer and Textile Reinforced Mortar Jacketing

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ABSTRACT

Many global structures, not initially designed to endure seismic forces, necessitate seismic strengthening. Existing research has explored diverse strengthening methodologies and assessed the seismic performance of these solutions. In the present study, a comparative analysis of a structure's seismic behavior before and after strengthening the building's columns was conducted using nonlinear time-history analysis. Two reinforcing techniques, Textile Reinforced Mortar (TRM) and Carbon Fiber Reinforced Polymer (CFRP) jacketing, were applied to a reinforced concrete building. Both techniques aimed to achieve full composite action (full bond) between the jacketing material and the existing concrete columns. The SAP2000 software was employed, strictly adhering to the Federal Emergency Management Agency (FEMA) 356 specifications for beams and column hinges. The analysis treated beam and column elements as nonlinear frame components, defining plastic hinges at their respective ends to simulate their behavior. Specifically, the beams were modeled to only possess moment (M3) fiber hinges, while columns were designed to accommodate axial load and biaxial moment (PMM) fiber hinges. The numerical findings indicated an average increase of 8% and 5% in base shear for buildings strengthened with CFRP and TRM jackets, respectively, when compared to non-strengthened buildings. Maximum story displacement increased by 9% and 4% correspondingly when the building was enhanced with CFRP and TRM jackets, compared to the original structure. It is noteworthy that both methods required a similar number of columns to be strengthened, yet the total cost of CFRP was found to be approximately 35% higher than that of TRM.

1. INTRODUCTION

It has been observed that numerous old buildings, constructed according to previous design code standards, are prone to seismic damage. This fact becomes increasingly evident with each occurrence of a major earthquake, as similar patterns of damage repeat themselves. Previous earthquakes have revealed that many substandard structures do not manage to withstand significant seismic events, indicating that vulnerability is not limited to a few specific building types. Factors such as building design, size, local ground conditions, and construction quality have all been proposed as potential explanations. Unlike conventional structural design that primarily considers gravity loads, seismic design takes into account the possibility of building damage following a substantial earthquake. Building codes mandate that structures possess sufficient strength to withstand both strong earthquakes and minor seismic activities without collapsing [1]. The structural design must combine fundamental lateral-force resistance strength with suitable structural details and sufficient ductile connections between the structural elements to achieve this purpose [1]. Many personal homeowners, and significant industries, including government organizations, have chosen to rehab existing buildings rather than construct new ones due to the high cost of new construction and the historical significance of old structures. Governmental organizations have responded by adopting a law that requires seismic strengthening. There is a need for specific evaluation and strengthening standards for existing buildings. As evidenced by the designers' awareness of potential damage and according to their knowledge and experience, there is a high possibility of damage in older, non-code-compliant buildings, which sometimes perform not so well in significant earthquakes. As a result, it has become important to strengthen buildings in numerous ways. Using Carbon Fiber polymer in different forms is one of the simplest, quickest, and most cost-effective ways to do this. In a study conducted by Youm et al. [2] in 2007, it was observed that the utilization of Glass Fiber Reinforced Polymer (GFRP) wrapping significantly improves the ductility, capacity, and energy dissipation of reinforced concrete (RC) columns. Additionally, the seismic performance of RC columns with insufficient lap splices was enhanced through the application of GFRP wrapping. The study presented by Pantelides et al. [3] in 2008 showed that it is possible to improve the seismic behavior of beam-column joints of insufficient seismic features using CFRP jacketing. This solution demonstrated that improving joint shear strength and inelastic rotation capacity leads to enhanced structural performance in seismic events. On the other hand, it was observed that GFRP exhibited greater ductility compared to CFRP. In a study conducted by Bournas et al. [4] in 2009, it was found that Textile Reinforcement Mortar (TRM) jacketing is highly effective in enhancing the cyclic deformation ability and dissipation of energy for old type