Seismic performance of post-mainshock FRP/steel repaired RC bridge columns subjected to aftershocks

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A R T I C L E   I N F O

Article history:
Received 20 October 2014
Received in revised form 4 December 2014
Accepted 5 December 2014
Available online 13 December 2014

Keywords:
A. Carbon–carbon composites (CCCs)
A. Hybrid
C. Finite element analysis (FEA)
C. Numerical analysis
Repair and retrofit

A B S T R A C T

This study compares the performances of three types of repair jackets on mainshock (MS) earthquake-damaged RC bridge columns subjected to aftershock (AS) attacks. These repair jackets include fiber reinforced polymers (FRP), thick steel, and thin steel wrapped with prestressing strands. Results obtained from incremental dynamic time history analyses on refined numerical finite element bridge models were utilized to evaluate the efficacy of different repair jackets application on the post-MS collapse safety of RC bridges subjected to AS attacks of various intensities. Numerical results indicated that the three repair jackets can effectively improve the bridge collapse capacity by approximately 20% under severe MS-severe AS even though they cannot restore the initial stiffness of damaged columns. Repair jackets for the severe MS-damaged columns were ineffective under moderate AS events and thus not required. Steel repair jackets exhibited higher energy dissipation under MS–AS sequences than FRP jackets. In the case of FRP jackets, bidirectional fiber wraps are recommended for plastic hinge confinement of MS-damaged bridge columns subjected to aftershocks.

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1. Introduction

Bridges are required to withstand a disastrous earthquake without collapses, and retain sufficient capacity along emergency routes prior to/during potential aftershocks in order to promptly dispatch emergency vehicles to the impacted area [1]. In seismically active areas, bridges are subjected to the combined effect of a mainshock (MS) and a series of aftershocks. For example, the March 2011 Tohuku, Japan, earthquake with a moment magnitude ($M_w$) of 9 was succeeded by hundreds of aftershocks with at least thirty of them greater than $M_w$ 6 [2]. Compared to the MS, the aftershocks may have significant intensity with a longer effective duration, and different spectral shape, energy content and specific energy density [3]. Since the structural condition of damaged bridges immediately after the MS is often unknown due to strong motion variations and their propagation to structural behaviors [4], predicting the load-carrying capacity of repaired bridges during an aftershock (AS) becomes even more uncertain and challenging. While prediction of the post-earthquake load-carrying capacity of damaged structures is a challenging task [4] (still topic of extensive ongoing research!), it becomes even more onerous when the inelastic structural response under the aftershock (AS) event is considered [5].

Rapid repair of the damaged bridge columns after the MS event is essential for post-earthquake functionality and collapse prevention of the bridges under subsequent aftershocks. Usually due to close occurrences of MS and AS events, there is typically limited time for repair application. Different forms/types of fiber reinforced polymer (FRP) materials have been extensively studied for rehabilitation and new constructions in various structures [6,7]. Retrofit and repair of reinforced concrete (RC) columns with FRP wraps, prestressed FRP belts, post-tensioned FRP shells, continuous composite fiber ropes, thick steel jackets, RC jackets, prestressing strands and shape memory alloy (SMA) wraps have also been investigated in extensive studies [8–31].

Bridge columns are one of the most vulnerable structural elements during seismic events [18–31]. The post-mainshock load carrying capacity of earthquake damaged bridges depends on the