Rapid Repair of Earthquake-Damaged RC Columns with Prestressed Steel Jackets

Mostafa Fakharifar, S.M.ASCE1; Genda Chen, Ph.D., F.ASCE2; Chenglin Wu, S.M.ASCE3; Anoosh Shamsabadi, Ph.D., M.ASCE4; Mohamed A. ElGawady, Ph.D., M.ASCE5; and Ahmad Dalvand, Ph.D.6

Abstract: In this study, a lightweight prestressed steel jacket (PSJ) was proposed and developed for rapid and cost-effective repair of a severely damaged circular reinforced concrete column. The PSJ is composed of several prestressed strands, and a thin steel sheet is restrained by these strands, which can be manually wrapped around and jointed to form a jacket on the column as part of a 12-h repair job by two workers. The prestressed strands restrain the thin sheet from buckling, while the steel sheet in turn prevents the strands from cutting into cracked concrete and thus preserves the prestressing forces. The PSJ was validated with cyclic (reversed) testing of two large-scale columns with lap-splice deficiency under incrementally increased displacements every three cycles. The ultimate strength and displacement ductility of the damaged column were restored to 115% and 140%, respectively, of those of the as-built column. The initial stiffness of the damaged column, however, was restored to only 84% of that of the as-built column because the PSJ was designed to restore the strength and ductility only. By connecting the damaged column to its footing through anchored dowel bars, the levels of restoration in ultimate strength, initial stiffness, and displacement ductility were all increased by at least 20%. DOI: 10.1061/(ASCE)BE.1943-5592.0000840. © 2016 American Society of Civil Engineers.

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Introduction

Recent earthquakes have demonstrated catastrophic failures of buildings and bridges under a single mainshock or a series of mainshock-triggered events, such as aftershocks, explosions, and tsunamis. In 1 month, the March 11, 2011 Tohoku, Japan earthquake [moment magnitude ($M_w = 9.0$)] was succeeded by at least five aftershocks stronger than $M_w = 6.5$ (USGS 2012). When a major earthquake occurs, the chance that aftershocks will cause damage can be significant (Di Sarno 2013). For example, the February 22, 2011 Christchurch earthquake ($M_w = 6.3$), following the Canterbury earthquake ($M_w = 7.1$) on September 4, 2010, caused significant damage to Christchurch buildings. The August 5, 2008 aftershock ($M_w > 6$) (USGS 2012), following the Wenchuan earthquake ($M_w = 7.9$) on May 12, 2008, contributed to the collapse of many structures that sustained damage from the mainshock (Yang 2009). Because of frequent occurrences of mainshock and aftershocks, damaged bridges along an emergency route must be rapidly repaired between multiple strong events to ensure safety of the bridges and enhance the resiliency of the transportation network for postearthquake response and recovery.

Bridges built prior to 1971 are seismically deficient as a result of (1) lack of confinement associated with sparsely spaced transverse reinforcement in columns, and (2) short lap splices at potential plastic hinge locations (Laplace et al. 2005). Deficient columns can be retrofitted with passive and active external confinement in the plastic hinge regions (Caltrans 1996; Priestley et al. 1996; Buckle et al. 2006; Ying et al. 2006; Yarandi and Saatcioglu 2008; ElGawady et al. 2009; Andrawes et al. 2010; Fakharifar et al. 2014, 2015). Passive confinement can be provided by steel, RC, and fiber-reinforced polymer (FRP) jackets (Chai et al. 1991; Priestley and Seible 1995; Silva et al. 2007). The level of passive confinement is completely determined by the dilation of the column. Active confinement can be provided by prestressed strands and shape memory alloy (SMA) spirals (Saatcioglu and Yalcin 2003; Yarandi and Saatcioglu 2008; Andrawes et al. 2010), which can be changed by the initial pressure induced by mechanical prestressing and thermally induced stressing, respectively. Here, the term retrofit refers to upgrading of an undamaged existing column, in contrast with the term repair for rehabilitation of a damaged column.

Conventional thick steel and RC jackets were among the first and most widely applied retrofit techniques for RC columns (Priestley et al. 1996). They are labor-intensive and time-consuming, and often require heavy-lifting equipment during on-site installation.

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