Seismic Performance of Exterior RC Beam–Column Joints Retrofitted using Various Retrofit Solutions

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Abstract: Beam–column joints in existing concrete buildings might not satisfy the design requirements for seismic reinforcement details specified in current seismic design codes. Thus, in this study, various retrofit solutions for existing exterior beam–column joints with non-seismic details were developed: head re-bars anchoring, carbon fiber reinforced polymer (CFRP) wrapping, haunch retrofit element, and steel jacketing with various shapes and sizes. To investigate the seismic performance of exterior joints strengthened with the proposed retrofit solutions, seven half-scale exterior reinforced concrete beam–column joints including one control specimen and six retrofitted specimens were fabricated and tested under cyclic loading simulating earthquake loading. The test results showed that the proposed retrofit solutions could partially enhance the seismic capacity of the beam–column joints: steel jackets could increase deformation and load-carrying capacities; steel haunch elements could increase the load-carrying capacity, stiffness, and dissipated energy; and head re-bar anchoring and CFRP wrapping did not significantly effect on the seismic capacity of the beam–column joints.

Keywords: seismic retrofit, exterior concrete beam–column joints, head re-bars, carbon fiber reinforced polymers, haunches, steel jackets.

1. Introduction

The moment resisting frame is one of the most widely used structure systems in reinforced concrete (RC) buildings subjected to gravity and/or seismic loading. From a structural point of view, while beam–column joints that connect main structural members (i.e., beams and columns) are the weakest components, they are the most complicated components as they transfer internal forces between the structural members. In many developing countries (e.g. Korea), existing concrete buildings constructed before the 1980s were designed to resist mainly gravity loads. Thus, in the past, many reinforced concrete buildings in developing countries collapsed during severe earthquakes (including those in Costa Rica in 1991 (Al-Tarazi 2000), in Nicaragua in 1992 (Kanamori and Kikuchi 1993), and in Egypt in 1995 (Suarez et al. 1995)). It was found that in many cases the collapse of such reinforced concrete buildings was caused by inadequate reinforcement details of beam–column joints.

According to a previous investigation (the Korea National Emergency Management Agency 2011) in Korea, concrete beam–column joints designed without consideration of earthquake load have certain material and geometrical characteristics: low concrete strength; plain steel re-bars; inadequate or no transverse reinforcement in beam–column joints; and insufficient anchorage detailing leading to lack of concrete confinement (Santersiero and Masi 2015; Pampanin et al. 2002; Engindeniz et al. 2005). When such concrete buildings are subjected to earthquake loading, the beam–column joints (in particular, the corner and exterior joints) could fail in brittle manner, which might trigger partial or entire collapse of the buildings (Rashidian et al. 2016; Petrone et al. 2016). Thus, the rehabilitation of such beam–column joints is a prerequisite to resist seismic loads.

To develop retrofit techniques for external beam–column joints with non-seismic details, a number of studies have been performed. Shafaei et al. (2014) strengthened four non-seismically detailed RC beam–column joints with steel angles, which were mounted using prestressed cross-ties. With the use of the retrofit technique, slippage was prevented by increasing the joint area of the beam bottom reinforcement, the plastic hinge was relocated far from the column face, and the shear strength, stiffness, energy dissipated, and ductility capacity were also significantly increased up to 50, 120, 220, and 220%, respectively.

El-Amoury and Ghobarah (2002) investigated the seismic performance of the joints retrofitted with glass fiber-reinforced polymers (GFRP). The proposed rehabilitation schemes consist of two systems: the first system is used for upgrading the shear strength of the joint with two U-shaped GFRP layers, and the second system is used for upgrading the bond-slip of the steel bars. The use of GFRP jacketing significantly enhanced the ductility and the load-carrying