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Experimental study of a replaceable steel coupling beam with an end-plate connection

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ABSTRACT

In order to enhance the post-damage repair capability of the hybrid coupled shear wall systems, a different type of replaceable steel coupling beam with end-plate connection was investigated. Different from conventional configurations, the coupling beams were not embedded into the walls to minimize the post-event repair/replacement difficulties and expenses. To assess the seismic behavior and post-damage replaceability of the coupling beam, a two-stage experimental program was performed to test the full-scale specimens, each utilizing coupling beams with different strength and stiffness. The results of the first specimen indicated a ductile failure with a concentration of inelastic deformation at steel web and thus exhibited desirable deformation and energy absorption capacities with minimum damages to the shear wall. Again, on the minimum repaired wall-pier, the second specimen via the proposed connection, with improved characteristics such as strength and stiffness, was installed and tested. The results demonstrated excellent stiffness, strength, and ductility characteristics of subassemblages under cyclic loading, with considerable energy dissipation concentrated in the coupling beam web. Although the second specimen failed from the threaded area of the tensile bolts, due to increased coupling beam strength, the specimens were able to sustain large nonlinear displacements without significant damage in the connection to the wall pier regions; representing that this connection configuration would require little repair, if any, after a severe earthquake.

1. Introduction

Coupled wall systems that consist of separate structural walls linked together by coupling beams are employed as an efficient structural system to resist lateral forces for medium- and high-rise buildings. Coupling beams are expected to endure inelastic deformations under design-level earthquakes. Thus, the overall seismic responses of a coupled wall system largely depend on the type and details of the coupling beams used. To improve the seismic behavior of conventional coupling beams, some efforts have been made by providing special reinforcement layouts, or using steel and steel–concrete composite coupling beams as substitutes in recent years.

The concrete coupling beam has some common shortcomings, including heavy self-weight, low bearing capacity, insufficient ductility, limited energy dissipation capacity and difficult post-earthquake reconstruction [1,2]. To enhance the seismic response of conventional coupling beams, some efforts have been made by providing special reinforcement layouts [3–5].

As viable substitutes for reinforced concrete coupling beams, the use of steel coupling beams and composite coupling beams have also been investigated by several researchers [6–15]. Their experimental results revealed good energy dissipation in steel coupling beams under reversed cyclic loadings.

Because the most important issue is the connection of steel coupling beams to wall-piers, various experimental programs were conducted to monitor the behavior of the connection. Typically, the focus of these studies was on embedding the beam into the wall-pier. These experimental studies were primarily concerned with the inelastic cyclic behavior of steel coupling beams or hybrid coupled shear wall systems and did not look in detail at the connection strength. Thus, Shahrouz et al. [12] categorized the coupling beam-to-wall connections as moment connection, the outrigger beam-to-wall shear connection, and the outrigger beam-to-wall moment connection. For the coupling beam-to-wall moment connection, an embedment length was suggested to develop the adequate capacity and dissipated energy. For the outrigger beam-to-wall shear connection, the main design configuration was in providing shear studs, and for the beam-to-wall moment connection, utilization of embedded plates with headed studs was recommended.

However, special configurations of beam-to-wall connections are usually required and significant damage of the connections and coupling beams leads to very costly post-event repair. To further improve the

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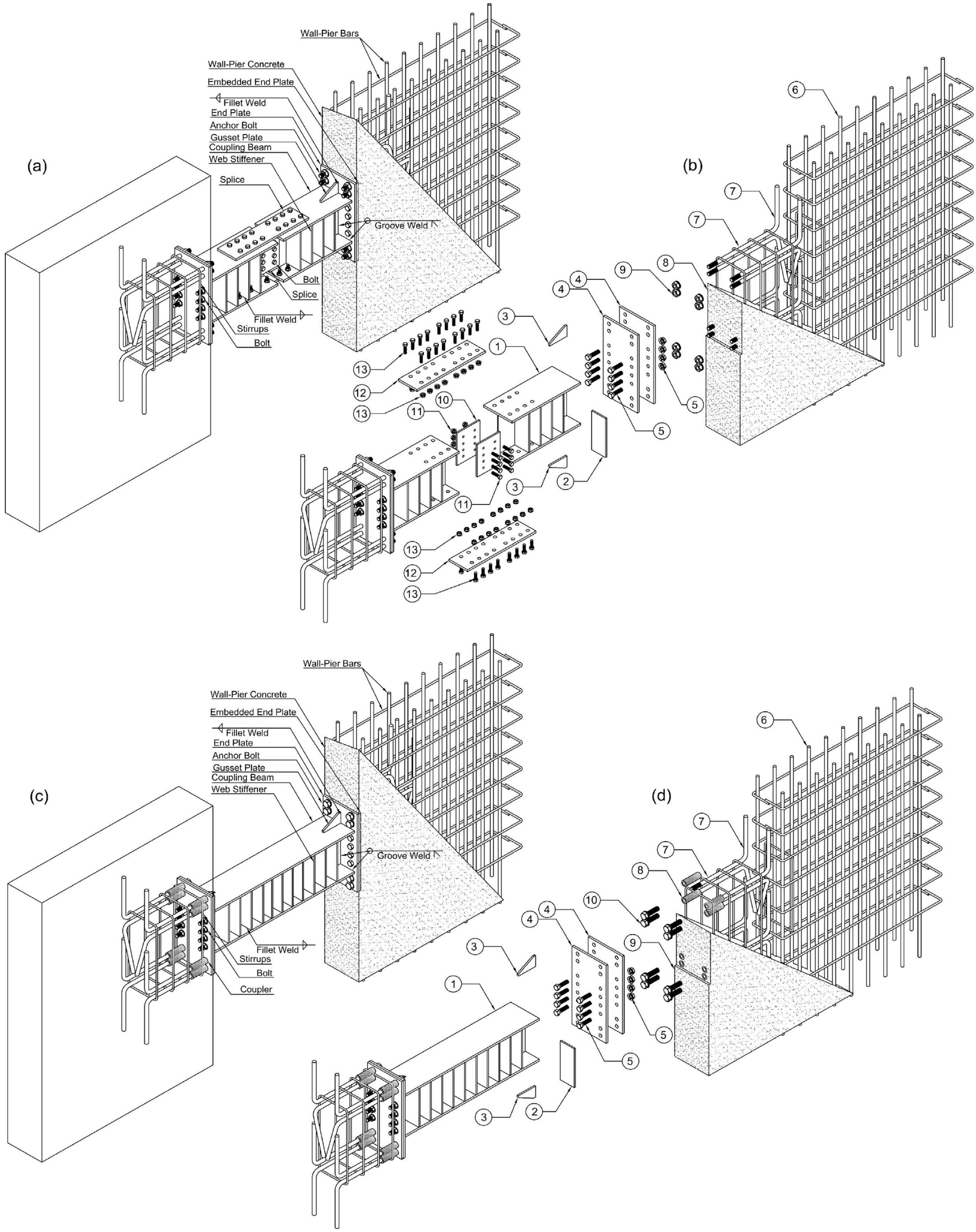

Fig. 1. The coupling beam-to-wall-pier connection for two alternatives: (a) and (c) Complete configuration and (b) and (d) step-by-step fabrication process (by assembly sequence number).