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Finite Element Modeling and Analysis of Reinforced Concrete Coupled Shear Walls Strengthened with Externally Bonded Carbon Fiber Reinforced Polymer Composites

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Abstract : Reinforced concrete (RC) coupled shear walls (CSWs) are very effective structural systems in resisting lateral loads due to winds and earthquakes and are particularly used in medium- to high-rise RC buildings. However, most of existing old RC structures were designed for gravity loads or lateral loads well below the loads specified in the current modern seismic international codes. These structures may behave in non-ductile manner due to poorly designed joints, insufficient shear reinforcement and inadequate anchorage length of the reinforcing bars. This has been the main impetus to investigate an appropriate strengthening method to address or attenuate the deficiencies of these structures. The objective of this paper is to twofold: (i) evaluate the seismic performance of existing reinforced concrete coupled shear walls under reversed cyclic loading; and (ii) investigate the seismic performance of RC CSWs strengthened with externally bonded (EB) carbon fiber reinforced polymer (CFRP) sheets. To this end, two CSWs were considered as follows: (a) the first one is representative of old CSWs and therefore was designed according to the 1941 National Building Code of Canada (NBCC, 1941) with conventionally reinforced coupling beams; and (b) the second one, representative of new CSWs, was designed according to modern NBCC 2015 and CSA/A23.3 2014 requirements with diagonally reinforced coupling beam. Both CSWs were simulated using ANSYS software. Nonlinear behavior of concrete is modeled using multilinear isotropic hardening through a multilinear stress strain curve. The elastic-perfectly plastic stress-strain curve is used to simulate the steel material. Bond stress–slip is modeled between concrete and steel reinforcement in conventional coupling beam rather than considering perfect bond to better represent the slip of the steel bars observed in the coupling beams of these CSWs. The old-designed CSW was strengthened using CFRP sheets bonded to the concrete substrate and the interface was modeled using an adhesive layer. The behavior of CFRP material is considered linear elastic up to failure. After simulating the loading and boundary conditions, the specimens are analyzed under reversed cyclic loading. The comparison of results obtained for the two unstrengthened CSWs and the one retrofitted with EB CFRP sheets reveals that the strengthening method improves the seismic performance in terms of strength, ductility, and energy dissipation capacity.

Keywords : carbon fiber reinforced polymer, coupled shear wall, coupling beam, finite element analysis, modern code, old code, strengthening
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