World Academy of Science, Engineering and Technology
International Journal of Mathematical and Computational Sciences
Vol:14, No:12, 2020

Seismic Reinforcement of Existing Japanese Wooden Houses Using Folded Exterior Thin Steel Plates

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Abstract : Approximately 90 percent of the casualties in the near-fault-type Kobe earthquake in 1995 resulted from the collapse of wooden houses, although a limited number of collapses of this type of building were reported in the more recent off-shore-type Tohoku Earthquake in 2011 (excluding direct damage by the Tsunami). Kumamoto earthquake in 2016 also revealed the vulnerability of old wooden houses in Japan. There are approximately 24.5 million wooden houses in Japan and roughly 40 percent of them are considered to have the inadequate seismic-resisting capacity. Therefore, seismic strengthening of these wooden houses is an urgent task. However, it has not been quickly done for various reasons, including cost and inconvenience during the reinforcing work. Residents typically spend their money on improvements that more directly affect their daily housing environment (such as interior renovation, equipment renewal, and placement of thermal insulation) rather than on strengthening against extremely rare events such as large earthquakes. Considering this tendency of residents, a new approach to developing a seismic strengthening method for wooden houses is needed. The seismic reinforcement method developed in this research uses folded galvanized thin steel plates as both shear walls and the new exterior architectural finish. The existing finish is not removed. Because galvanized steel plates are aesthetic and durable, they are commonly used in modern Japanese buildings on roofs and walls. Residents could feel a physical change through the reinforcement, covering existing exterior walls with steel plates. Also, this exterior reinforcement can be installed with only outdoor work, thereby reducing inconvenience for residents since they would not be required to move out temporarily during construction. The Durability of the exterior is enhanced, and the reinforcing work can be done efficiently since perfect water protection is not required for the new finish. In this method, the entire exterior surface would function as shear walls and thus the pull-out force induced by seismic lateral load would be significantly reduced as compared with a typical reinforcement scheme of adding braces in selected frames. Consequently, reinforcing details of anchors to the foundations would be less difficult. In order to attach the exterior galvanized thin steel plates to the houses, new wooden beams are placed next to the existing beams. In this research, steel connections between the existing and new beams are developed, which contain a gap for the existing finish between the two beams. The thin steel plates are screwed to the new beams and the connecting vertical members. The seismic-resisting performance of the shear walls with thin steel plates is experimentally verified both for the frames and connections. It is confirmed that the performance is high enough for bracing general wooden houses.

Keywords : experiment, seismic reinforcement, thin steel plates, wooden houses
Conference Title : ICSRD 2020 : International Conference on Scientific Research and Development
Conference Location : Chicago, United States
Conference Dates : December 12-13, 2020