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Design Optimization of the Bolted Connection Loaded Parallel to the Timber Grain for Masonry Building Retrofits

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Abstract—The experimental results of timber bolted connection tests for the purpose of optimizing the use of current design standard are presented. The test was conducted to investigate the structural performance of bolted connections loaded parallel to the timber grain. Both ductile and brittle failure modes were investigated to identify the governing parameters that affect the types of failures. The Meraka hardwood was chosen because it was found to be commonly used in the construction of the structural components of floor and roof diaphragms in Malaysia unreinforced masonry (URM) buildings. From this study, a wood database can be established for assisting the design engineers in developing the retrofitting technique of the building, especially the timber diaphragm joint part of the wall-diaphragm connections. Eighteen characteristics of steel-wood-steel (SWS) with a single row bolted joints were tested in tension, whereas ten specimens were prepared for each connection group. From the results obtained, it can be observed that the current timber design code is far too conservative compared to the optimized design proposed in this paper.

Keywords—bolted timber connection, optimized design, retrofitting technique, SWS joint.

I. Introduction

UNREINFORCED masonry (URM) building constructions can be found in Malaysia as early as 1650, during the European and British colonization, which is the Stadthuys in Malacca [1] that was used as the official residence of the Dutch Governors. Now, it is the most popular landmarks that the tourists never miss to visit. According to Ho et al. [2], many unreinforced masonry buildings still exist in town area, that being used as residential from one to two-storey heights. There are also many of these buildings being operated as business or commercial purposes in Melaka town [3]. Similarly, the unreinforced masonry buildings can be found in other states in West and in East of Malaysia that were built between 1800 and 1948 [4]. Based on the data reported by Kamal et al. [4], in Sarawak alone, the total of unreinforced masonry buildings is 1,010. From the author's observations in the Kuching town area, there are many of them still exist and are of commercial use. A retrofit implementation of wall-diaphragm connections can be seen clearly from the visible wall anchors (double-C-shape) on the exterior masonry walls of the buildings. Most of the anchors were applied to laterally restrain the wall at the roof level with a wide spacing. Very few unreinforced masonry buildings were observed to have the wall anchors at both floor and roof levels, where the majority of the buildings found to have the wall anchors the at roof level only. The diaphragm connection details were unable to be identified as the underneath of the roof and floor diaphragms was covered by the ceiling panels. However, the author strongly believed that similar bolted connection features are applied to the floor timber joists or roof timber rafters as mentioned in published literature [5, 6, 7] due to the similarity of the local building characteristics in comparison to other countries such as the United States and New Zealand.

The lack of connections between masonry walls and timber diaphragms in unreinforced masonry buildings has long been identified causing the out-of-plane failures of masonry walls, gables and parapets during earthquakes. Bruneau [8, 9] reported that many out-of-plane wall failures were observed in