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Shake table testing of a full-scale seven-story steel–wood apartment building

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ABSTRACT

In July 2009, a full-scale mid-rise light-frame wood apartment building was subjected to a series of earthquakes at the world's largest shake table in Miki, Japan. The test program consisted of two major phases: the building tested in the first phase consisted of a single-story steel special moment frame (SMF) with six stories of wood on top, and the second phase consisted of locking down the steel story and testing the six-story light-frame wood building by itself. This paper focuses on the test results for the seven-story steel–wood building tested to earthquakes having return periods of 72 and 665 years. The objective of this phase of the test program was to investigate the performance of a mid-rise light-frame wood building with a first-story moment frame when subjected to a major earthquake, essentially providing a landmark data set to the seismic engineering research community. The building consisted of 225 square meters for retail space at the first story and 1350 square meters of multi-family residential living space with 23 apartment units above. The building was instrumented with just over 300 sensors and 50 LED optical tracking points to measure the component and global responses, respectively. In this paper the seven-story test specimen is described and the resulting seismic response and behavior is summarized. Detailed damage inspection was performed following each of these tests, and representative images are presented and discussed. The building was found to perform excellently, with very little damage following an event that was slightly larger ($\times 1.16$) than the design-level event for the city of Los Angeles, California. The peak global drift at roof level was 166 mm, and the peak inter-story drifts were approximately 1.3%.

1. Introduction

Light-frame wood buildings provide an economical solution for single-family and multi-family residential buildings, and they have performed well in earthquakes with regard to life safety. A light-frame wood structure can be combined with other structural types (e.g. steel and concrete frame) as the bottom story to incorporate large open retail spaces and satisfy fire requirements in certain jurisdictions. Steel moment frames are not used as commonly as concrete pedestals, but are shown here to be a viable alternative. Full-scale seismic tests on a building with a steel moment frame base and multiple light-frame wood stories above have never before been carried out. In fact, full-scale system-level shake table tests on light-frame wood buildings have only been completed a handful of times. During the CUREE Caltech Woodframe project, Filiatrault et al. [1] tested a rectangular two-story house with an integrated one-car garage. The building was subjected to two 1994 Northridge recordings, i.e. from the Canoga Park and Rinaldi stations. In 2006, as part of the NEESWood project, [2,3] conducted full-scale triaxial tests of a two-story three-bedroom 160 m^2 (1800 ft^2) townhouse with an integrated two-car garage utilizing the twin shake tables at the State University of New York at Buffalo's SEESL laboratory. The benchmark structure performed relatively well by seemingly protecting life safety of would-be occupants, but suffered substantial costly damage. Filiatrault et al. [3] were also able to validate the earlier conclusion that non-structural elements such as gypsum wall board (GWB) and unweathered exterior stucco significantly increase the strength and stiffness, thereby contributing to the seismic performance of wood frame buildings. In 2002, a three-story apartment building with a tuck-under garage was tested as part of the CUREE-Caltech Woodframe project [4]. The results of that series of tests confirmed that these types of structure were prone to torsional response and subsequent soft story collapse mechanisms.

This paper presents the results of two shake table tests on a seven-story building which consisted of a first-story steel special moment frame (SMF) and six stories of light-frame wood for stories two through seven. The test building was constructed over a four-month period in Miki, Japan, and lifted onto the world's largest shake table, where it stayed for four weeks. Testing consisted of two phases. Phase I was testing of the seven-story mixed-use

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