SEISMIC RISK REDUCTION FOR SOFT-STORY WOODFRAME BUILDINGS: THE NEES-SOFT PROJECT

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ABSTRACT: As early as 1970, the structural engineering and building safety community recognized that a large number of two-, three- and four-story woodframe buildings designed with the first floor used either for parking or commercial space were built with readily identifiable structural system deficiencies, referred to as a “soft story”. Thus, many multi-story woodframe buildings are susceptible to collapse at the first story during earthquakes. The majority of these older multi-story woodframe buildings have large openings and few partition walls at the ground level. This open space condition results in the earthquake resistance of the first story being significantly lower than the upper stories. This paper introduces a U.S. National Science Foundation (NSF) – funded, five-university multi-industry three-year project to (1) experimentally validate economical retrofit concepts for these types of buildings; and (2) develop and experimentally validate performance-based retrofit of these types of at-risk structures.

KEYWORDS: Light-frame wood; soft-story building; performance-based retrofit; collapse

1 INTRODUCTION

Many older multi-story woodframe buildings (built prior to 1970s) are susceptible to collapse at the first story during earthquake events under this type of scenario. The majority of these older multi-story woodframe buildings have large openings and few partition walls at the ground level. Figure 1 shows a soft-story collapse in Christchurch, New Zealand taken in 2011. This open space condition results in the lateral stiffness of the first story being significantly lower than that of the upper stories. These buildings, known as soft story buildings, are prone to collapse during major and potentially even moderate earthquake events. The results of this behaviour, as was observed after the Loma Prieta and particularly the Northridge earthquake, are the destruction of the property and in some cases loss of life. Most cities and counties in the United States recognize this as a disaster preparedness problem and have been actively developing various types of ordinances and mitigation plans to address this threat. Some of the most visible efforts include San Francisco, Los Angeles, San Jose and other major metropolitan high earthquake hazard areas in California.

Figure 1: Soft-story woodframe collapse in Christchurch, New Zealand (Photo credit: John W. van de Lindt)

In 2008, the San Francisco Department of Building Inspection and the Applied Technology Council initiated a Community Action Plan for Seismic Safety (CAPSS) project with the main goal of identifying possible action plans for reducing earthquake risks in existing buildings. According to the CAPSS study, 43 to 80 percent of the multi-story woodframe buildings will be deemed unsafe after a magnitude 7.2 earthquake and a quarter of these buildings would be expected to collapse. These soft story buildings...
buildings are primarily rental apartments and rental houses with an estimated 58,000 people residing in these buildings. It is anticipated that thousands more could be displaced from their homes and many could lose their lives should a major earthquake occur before a retrofitting plan can be implemented. This is a problem throughout all of California and has substantial direct applications in many other areas of the U.S. and around the world. One component of the NEES-Soft project is to provide experimental verification of the ATC 71.1 approach to retrofitting many of these soft-story buildings.

2 TESTING

Two major tests are occurring within the NEES-Soft project in 2012 and 2013. The first test is a full-scale three-story woodframe building having a two-bedroom apartment floors 2 and 3, and parking at floor 1. The test setup is shown in Figure 1. In phase I, story 1 will consist of pin-pinned steel columns and eight different retrofits will be numerically modelled using slow pseudo-dynamic (hybrid) testing. These will be both ATC 71.1 style retrofits and performance-based retrofits that achieve owner-desired performance levels under a prescribed hazard level. The best two candidates will be selected and story 1 constructed with these retrofits in place. A series of tests on these two retrofitted buildings will make up phase II.

Figure 2: Test building setup for slow hybrid testing at full-scale

Full-scale collapse testing including several retrofit strategies will be performed in 2013 on the outdoor shake table at the University of California NEES test facility. These tests will be performed using two nominally identical specimens with the same configuration as the hybrid test described above.

3 NUMERICAL MODELING

Nonlinear time history analysis models are being improved within the NEES-Soft project. In past studies models assumed a rigid floor diaphragm which was shown in full-scale shake table tests to lead to inaccurate boundary conditions. A new model which is capable of capturing the behaviour of the building all the way to collapse, as shown in Figure 3, has been developed.

Figure 3: Soft-story modelling using 3-D collapse model developed within the NEES-Soft project

4 SUMMARY AND NEXT STEPS

The NEES-Soft project is experimentally validating retrofit methodologies at a minimal level needed to provide life-safety to building occupants and at performance-based retrofit levels which provide additional building performance as well as life-safety to the building occupants. Once the numerical models are validated and retrofit selection methods selected as best practices, logical codified retrofit approaches will be developed and applied.

ACKNOWLEDGEMENT

The material presented in this paper is based upon work supported by the United States National Science Foundation under Grant No. CMMI-1041631 (NEES Research). Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation. In addition to the PI’s listed on the title of the paper, the following senior personnel and students are acknowledged for their contributions and work on the NEES-Soft Project: Andre Filiatrault, David V. Rosowsky, Gary Mochizuki, Ioannis Christovasilis, Douglas Rammer, David Mar, Pouria Bahmani, Robert McDougal, Jingjing Tian, Chelsea Griffith, Mizanur Rahman, and Wang Yue.