EXPERIMENTALLY VALIDATED RETROFIT SOLUTIONS
Shake-table testing of securing solutions for face-loaded unreinforced masonry walls

Dr D. Dizhur and Prof J. Ingham (Flagship 3, Project No. 16058)

QuakeCoRE
NZ Centre for Earthquake Resilience

THE UNIVERSITY OF AUCKLAND
Te Whare Wānanga o Tāmaki Makaurau
NEW ZEALAND

Introduction

One of the most critical deficiencies of historic clay brick unreinforced masonry (URM) buildings [1] is the out-of-plane failure mechanism induced by lateral earthquake loads [2-4]. This failure mechanism is inhibited via the addition of adequate wall-diaphragm and wall-to-wall connections. However, in high and moderate seismic zones the sudden and unstable out-of-plane failure of walls mainly located at the upper building levels can result in extensive damage and potentially catastrophic collapse, posing a significant life-safety hazard to both building occupants and nearby pedestrians.

Examples of out-of-plain failures observed after the 2010-2011 Canterbury sequence

A number of studies have been previously undertaken to investigate the performance of as-built URM walls when subjected to out-of-plane loads [5-7] and comparatively small number of studies were undertaken on the dynamic behaviour of retrofitted URM walls and validation of retrofit techniques. The study presented herein focuses on developing and experimentally validating simple, practical, cost-effective, aesthetics, minimally-invasive and reversible seismic securing techniques for URM walls when loaded out-of-plane, with a main focus on practical applications in existing vintage buildings.

Methodology

Stage 1: Background research on the existing out-of-plane retrofit methods – experimental researches and adopted techniques.

Examples of out-of-plain wall retrofit adopted in New Zealand

Stage 2: In lab replication of double-leaf clay brick solid walls based on the observation of existing buildings [1-6].

Stage 3: Test frame design, fabrication and installation.

Stage 4: Installation of the instruments and shake-table testing of as-built and retrofitted URM solid walls.

The first retrofit technique that will be tested consists of innovative system of strong-backs. In particular, the vertical framing that is typically a non-structural support of the inner wall lining will be used as retrofit solution and fixed to the wall with steel brackets and mechanical screw-ties in order to form a strong-back.

Retrofit technique using timber strong-backs

Experimental program

Solid brick double-leaf walls are H3300 × W1200 × T220 mm and closely simulated in-situ conditions. To reproduce the low compressive strength of original lime-based mortar a 1:3 (lime:sand) mortar mix was used.

The test set-up was designed to replicate common in-situ boundary conditions for a single-story wall portion of a upper storey perimeter load-bearing solid-wall fixed at the base for continuity with the lower walls or foundation and allowing rotation and vertical displacement at the top based on typical seating arrangements observed at the roof level.

Test set-up and wall construction

Harmonic motion will be applied with acceleration increasing every 15s and constant amplitude at 50 mm. Each test will be conducted up to the point of wall cracking, and the initiation of rocking will be considered to correspond to the onset of wall instability. A second non-instrumented test will be then performed up to collapse of the wall.

References

1. Russell, A. P., Ingham, J. M. (2010). 'Prevalence of New Zealand's Unreinforced Masonry Buildings'. Bulletin of the New Zealand Society for Earthquake Engineering, 43(3), pp. 182-201.
2. Moon, L., Dizhur, D., Griffith, M., Ingham, J. M. (2011). 'Performance of unreinforced clay brick masonry buildings during the 22nd February 2011 Christchurch earthquake', Journal of the Structural Engineering Society of New Zealand, 24(2), pp. 59-84.
3. Dizhur, D., Ismail, N., Knox, C., Lumantarna, R., Ingham, J.M. (2010). 'Performance of Unreinforced and Retrofitted Masonry Buildings during the 2010 Darfield Earthquake', Bulletin of the New Zealand Society for Earthquake Engineering, 43(4), pp. 321-339.
4. Ingham, J. M., Griffith, M. C. (2010). 'The Performance of Unreinforced Masonry Buildings in the 2010/2011 Canterbury Earthquake Swarm', Commissioned report to the Royal Commission of Inquiry into Building Failure Caused by the Canterbury Earthquake, http://canterbury.royalcommission.govt.nz/documents-by-key/20110920.46
5. Penner, O., (2014) Out-of-Plane Dynamic Stability of Unreinforced Masonry Walls Connected to Flexible Diaphragms. Doctor of Philosophy Thesis. The University of British Columbia.
6. Derakhshan, H., Dizhur, D., Griffith, M. C., Ingham, J. M. (2014) 'In-situ out-of-plane testing of as-built and retrofitted unreinforced masonry walls', ASCE Journal of Structural Engineering.
7. Derakhshan, D., Dizhur, D., Griffith, M., and Ingham, J. (2014) 'Seismic Assessment of Out-of-Plane Loaded Unreinforced Masonry Walls in Multi-Storey Buildings'. Bulletin of the New Zealand Society for Earthquake Engineering, 47(2)

Further progresses & Dissemination

The first test will be undertaken on the as-built wall which will serve as reference for improvement level of the following retrofitted samples.

First stage of tests will be completed by the end of October. Data analysis, report and dissemination of the results will be completed in November.