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ILEE-QuakeCoRE collaboration: Low-damage concrete wall building test

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ABSTRACT

Implementation of low-damage concrete buildings has highlighted a number of challenges when considering the response of the entire building, including detailing for displacement compatibility during seismic response. In order to provide essential evidence to support the development of low-damage concrete structures, a system level shake-table test of a full-scale low-damage concrete wall building implementing state-of-art design concepts was conducted on the multi-functional shake-table array at Tongji University as part of an international collaborative project. The test building was designed to represent systems implemented in New Zealand buildings and used post-tensioned (PT) precast concrete walls and precast concrete frames with slotted beam connections. Different floor systems and wall-to-floor connections were incorporated to investigate alternative design concepts and detailing. A number of alternative energy dissipation devices were located at the wall base and beam-column joints, including yielding steel fuses, lead-extrusion dampers, and non-linear viscous fluid dampers. The building was subjected to approximately 40 separate earthquake ground motions, with different combinations of wall strength, energy dissipating elements, shaking direction, and ground motions. Overall, the building performance was excellent, sustaining repeated tests at both design and maximum consider earthquake intensities with only minor damage to the wall toes and minor cracking to the floor slabs. The test is of a scale not common in a New Zealand context and has provided a rich dataset to verify design procedures, detailing practice, and numerical models.

1 INTRODUCTION

The damage caused to conventional modern buildings during major earthquakes often leaves them requiring either costly repairs or demolition. The increasing need to reduce damage and downtime of modern buildings has led to the development of a low-damage design philosophy, where the earthquake loads can be resisted with damage confined to easily replaceable components. A number of different low-damage technologies have been developed and implemented that are suitable for different structural systems and building applications. Post-tensioned (PT) precast concrete systems that behave in a jointed manner were originally developed during the PRESSS research program (Priestley et al. 1999). Unbonded PT wall systems have been implemented in a number of buildings in New Zealand (Henry 2018).

To verify the seismic response of a low-damage concrete wall building implementing state-of-art design concepts and practical construction details, a joint research project between the International Joint Research Laboratory of Earthquake Engineering (ILEE) and the New Zealand Centre for Earthquake Resilience (QuakeCoRE) was proposed. The project included a shake-table test of a two-storey PT wall building. The test building incorporated state-of-art research and practice in the design and detailing. The building was recently tested on the ILEE multi-functional shake-table array located at the Jiading campus of Tongji University and preliminary findings are presented.

2 TEST BUILDING

The test building was assumed to be used for general office purpose and located in Wellington, New Zealand. The two-storey test building had plan dimensions of 5.4 × 8.95 m. The total height of the building from foundation surface was 8 m with each storey 4 m high. The building structural system consisted of a perimeter frame and two exterior PT walls in both directions. The four PT walls are designed to primarily resist seismic loads in both directions. The perimeter frame was designed to primarily carry gravity loads and used a slotted beam detail (Muir et al, 2012; 2013). The Level 1 floor system consisted of a long-span precast concrete double tee and a steel tray composite floor was used in level 2 in a short span configuration. A secondary steel beam is aligned through the longitudinal center of the floor to reduce the span of composite floor. The building design is described in detail by Lu et al. (2018) and the constructed building is shown in Figure 1.

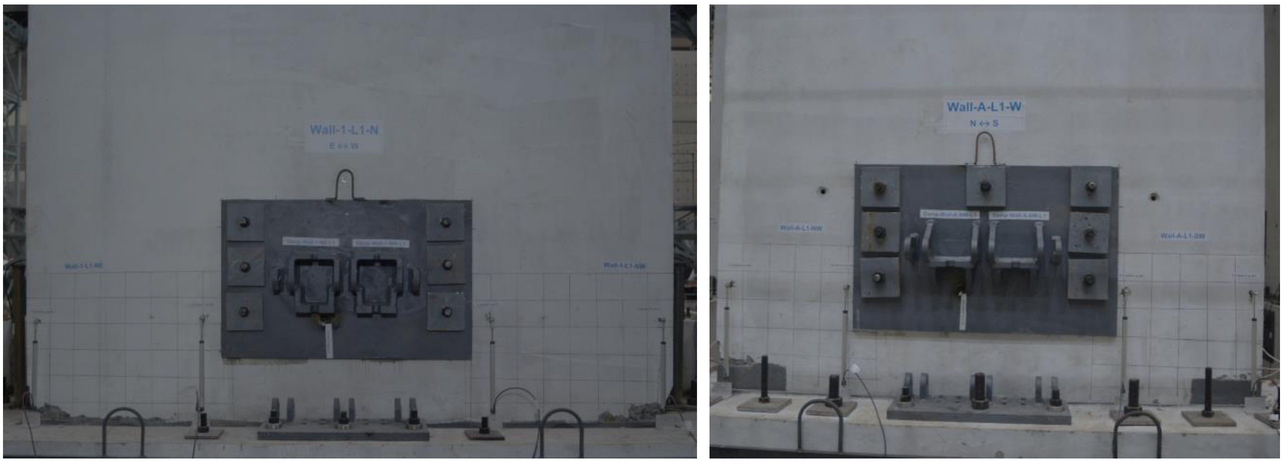
Figure 1: The test building on the shake-table array at Tongji University's Jiading campus.

The building used detailing consistent with that implemented in buildings in New Zealand. Key features included:

- Two alternative wall base details, consisting of a grouted joint detail with no shear dowels in the long-span direction and a recessed steel pocket detail in the short-span direction.
- Two alternative wall armouring approaches, consisting of a small steel angle in the long-span direction and a larger armoured end toe region in the short-span direction.
- Three alternative wall-to-floor connection approaches, consisting of a flexible link slab on level 1 of the long-span direction, flexible composite floor on level 2 of the long-span direction, and isolated steel tongue connection on both levels in the short-span direction.
- Various combinations of dissipating devises installed at both the wall based and slotted beam joints, including steel fuses (Liu et al, 2018), HF2V lead dampers (Rodgers, 2009) and non-linear viscous dampers.

3 PRELIMINARY RESULTS

The building was subjected to approximately 40 separate ground motions, consisting of five structural design configurations with different energy dissipating devices and combinations of ground motions including an SLS record, far field and a near fault ULS records, and short and long duration MCE records. The structure was subjected to both long-span and short-span unidirectional shaking, as well as bi-directional horizontal shaking. The building sustained all of these tests with only minimal damage. Minor spalling occurred at the wall toes during larger intensity shaking, as shown in Figure 2. Both wall base details performed well, with no significant wall sliding or out-of-plane walking. The flexible wall-to-floor connections accommodated the wall deformations as intended, with some resulting cracking in the floors. The isolated wall-to-floor connection was successful at preventing any unintended demands on the floor with no cracking observed around these connections. The slotted-beam connections performed well, minimising beam-elongation (frame dilation) demands on the floors which resulted in only modest residual crack widths.



a) A long-span wall utilising a grouted joint detail and a small steel angle for amouring

b) A short-span wall utilising a recessed steel pocket detail and armoured end toe region

Figure 2: Wall condition at the end of testing

Overall, the full-scale, system-level testing was considered a success, withstanding a range of uni-directional and bi-directional shaking with only minimal damage. Due to the recent completion of the testing, the test results are still being processed and analysed, with detailed results expected to be published shortly. The results will be used to validate the building design process, detailing recommendations, and numerical models.

4 ACKNOWLEDGEMENTS

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