ILEE-QuakeCoRE Shake-Table Test of a Low-Damage Concrete Wall Building

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Introduction

QuakeCoRE has given New Zealand researchers the opportunity to access some of the world's top earthquake engineering facilities. A system level shake-table test of a full-scale low-damage concrete wall building has been conducted on the multi-functional shake-table array at Tongji University as part of the ILEE-QuakeCoRE international collaborative research project. The test aimed to verify the seismic response of a low-damage concrete wall building implementing state-of-art design concepts and practical construction details that are currently being used in New Zealand buildings.

Test building

The overview of the test building is shown in Figure 1. The test building is a two-storey building with plan dimensions of 5.4 x 8.95 m. The total height of the building is 8 m with each storey 4 m. The building consists of:

- Two exterior post-tensioned walls in each direction to resist lateral loads.
- One perimeter frame with slotted beams to carry gravity loads.
- Level 1: Long-span precast concrete double tees with concrete insitu topping.
- Level 2: Composite floor with ComFlor steel decking as permanent formwork and concrete topping.

Table 1 Design configurations

Test	B-C joints	Wall base	Design Drift
1a	Steel fuse	Steel fuse	1%
1b	Steel fuse	Viscous damper	1%
1c	HF2V	Viscous damper	1%
2	Steel fuse	n/a	2%
3	n/a	n/a	3%

Key features of the building

- Two wall armouring approaches: small steel angles and larger armoured end region.
- Three wall-to-floor connection approaches: link slab, flexible composite floor and isolated steel tongue connection.
- Two wall base details: a grouted joint detail with no shear dowels and a recessed steel pocket detail.
- The building were designed for three lateral drift targets with different wall strength and energy dissipating devices. The three design cases are listed in Table 1.

Figure 1 Building overview

Preliminary Test Results

Overall response

The building was subjected to 39 tests with a range of intensity ground motions, incorporating both unidirectional and bi-directional testing on the structure with different combinations of wall strength and energy dissipating devices. The test building performed extremely well, withstanding a range of uni-directional and bi-directional shaking only minor damage resulting.

Wall base

The two alternative wall base details both performed well, with no significant wall sliding or out-of-plane walking. Figure 3 shows examples of the condition of the wall toes for wall 1 (conventional grouted connection) and wall A (steel pocket connection) after tests D1a-100%, D2-100% and D2-180%. No spalling occurred at the wall toes during earthquake of D1a-100% and only minor spalling occurred at the wall toes during larger intensity shaking of D2-100% and D2-180%.

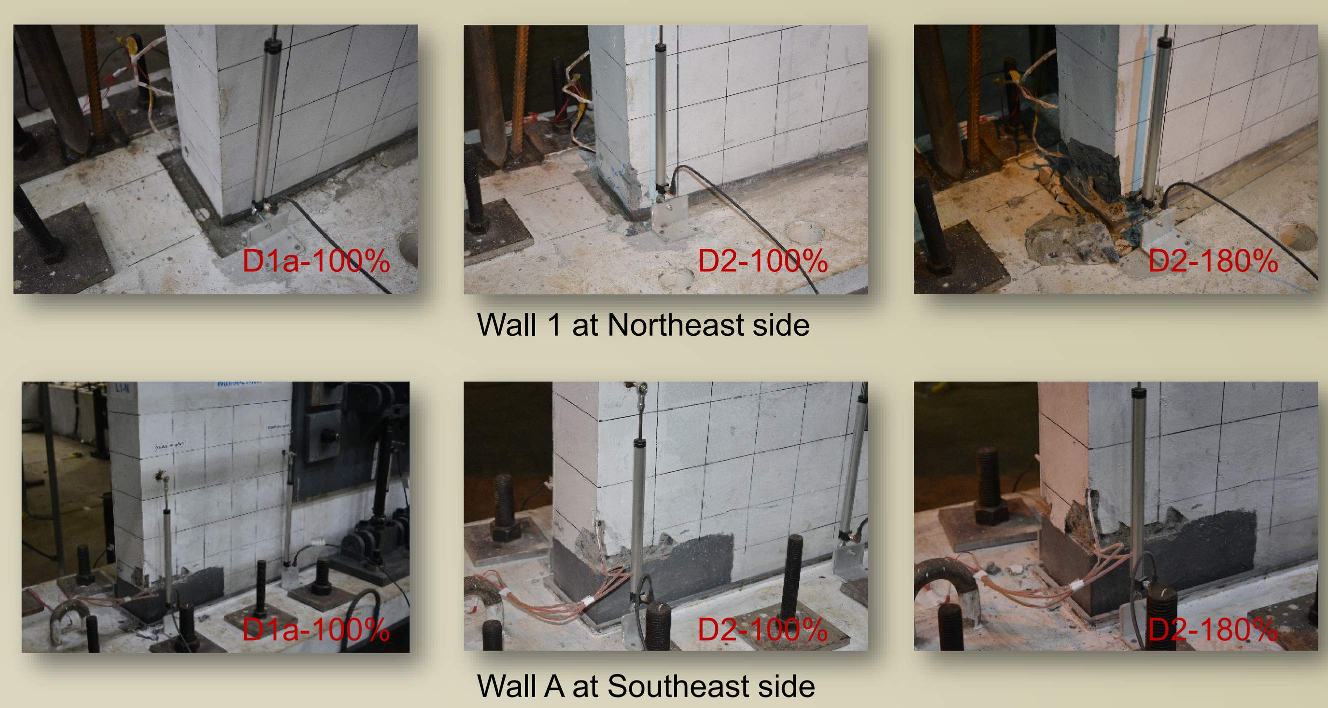

Figure 3 Wall condition after different intensity earthquakes

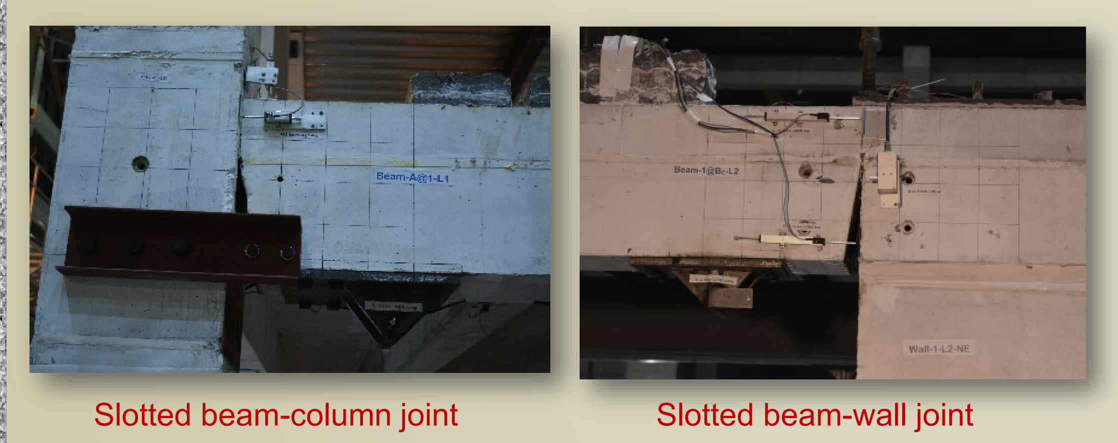

Figure 4 Final condition of slotted beam joints

Frame

The slotted-beam connections performed well, minimising beam-elongation (frame dilation) demands on the floors and limiting residual crack widths. Figure 4 shows examples of the damage progression for the slotted beam joints. Only 1-2 diagonal cracks extended from the top of slot to the floor surface with maximum residual crack widths less than 1 mm.

Wall-to-floor connection

The flexible wall-to-floor connections accommodated the wall deformations as intended, resulting in only minor cracks in the floors. For level 1, the floor cracks mainly concentrated within the two link slabs. The crack map photo of link slab at both top and bottom of the floor at the end of the test is shown in Figure 5. The cracks were evenly distributed along the length of the link slab with a maximum residual crack width of approximately 1 mm.

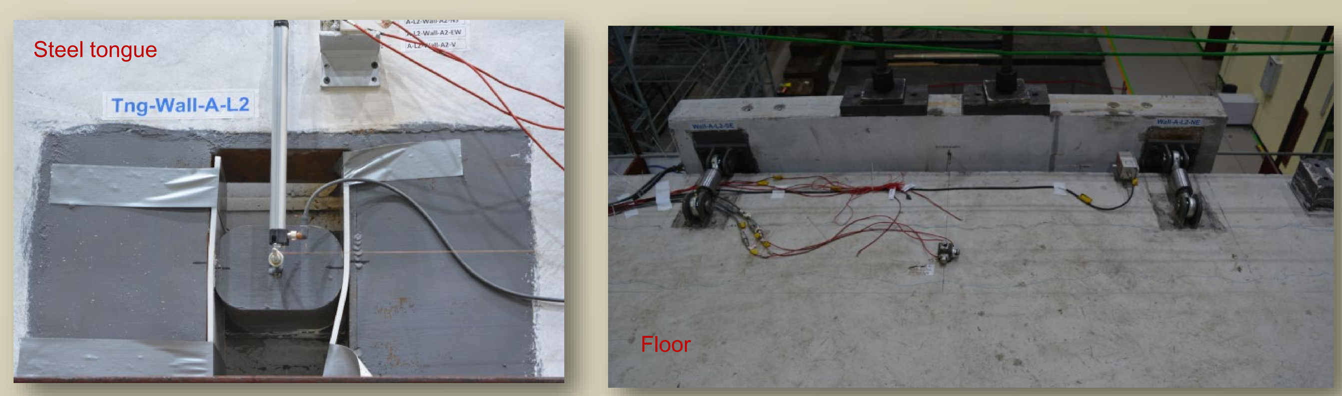

Figure 6 Final condition of isolated wall-to-floor connection

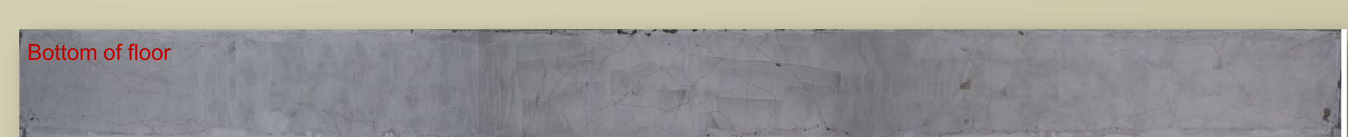

Figure 5 Crack map of link slab at end of test

The isolated wall-to-floor connection was successful at preventing any unintended demands on the floor with no cracking observed around these connections. The steel tongue performed well with only minor delamination and bending of the shims between steel tongue and armouring. The corresponding floor only had a minor crack parallel to the wall along the interface between the beam and the floor.

Building Construction

The construction was separated into two phases that were precast component construction and assembly construction. The precast component construction was conducted in a precast factory in Shanghai, China and the building was assembled on the shake-table at the ILEE lab using a construction process similar to that used in New Zealand building construction. Chinese materials were used for the precast component construction in Shanghai.

Figure 2 Building construction

Conclusion

The building performed extremely well during the intense series of tests, providing confidence the new low-damage concrete buildings are an excellent low-damage building solution. The building exhibited only minor damage, with distributed cracking in the floors and cosmetic spalling in the wall toes that could be easily repaired.

Acknowledgements

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