LIGHTLY REINFORCED CONCRETE WALLS

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Introduction

A number of concerns were raised regarding the design and construction of reinforced concrete (RC) walls following the 2010/2011 Canterbury earthquakes. A lack of distributed cracking was observed in several modern lightly reinforced concrete walls, such as the Gallery Apartments. The potential issues with lightly reinforced panels combined with examples of poor detailing and panel fixings also lead to renewed concerns around the seismic response of precast concrete wall buildings. Lastly, the potential non-ductile response of older lightly reinforced concrete walls was also a contributing factor to the collapse of the PGC building.

Objectives

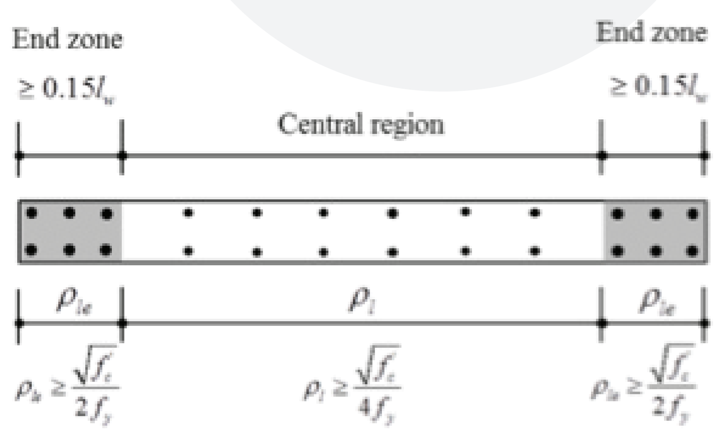
A series of experimental tests and numerical modelling will be used to verify the behaviour of existing wall designs, as well as to investigate improved design procedures and details.

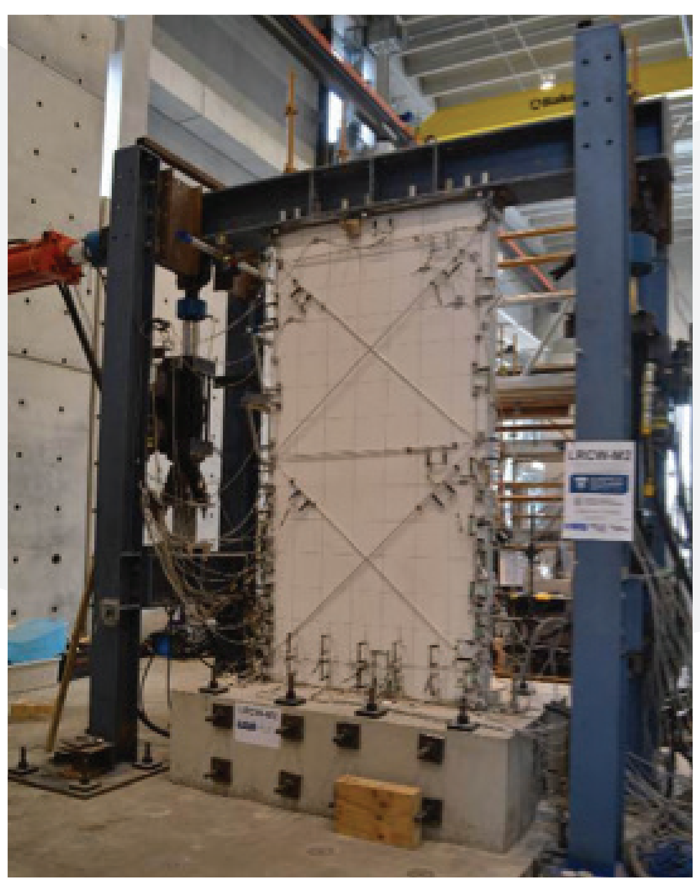
The detailed research objectives are:

- Determine minimum reinforcement requirements and deformation capacity of lightly reinforced walls
- Determine the deformation capacity of older singly reinforced walls
- Evaluate the capacity of precast walls with grouted connections and identify improved connection details
- Evaluate out-of-plane deformation capacity of base connections for singly-reinforced walls, including bi-directional loading

Minimum reinforcement limits

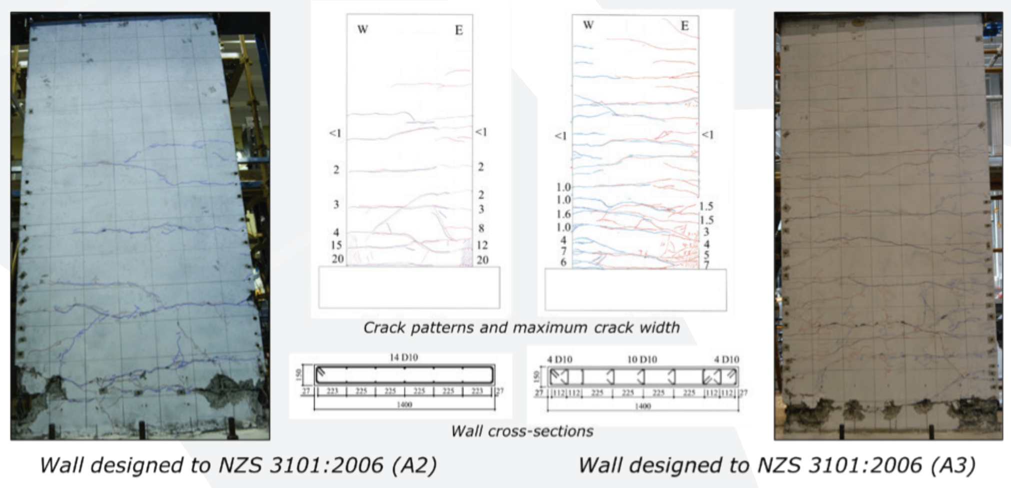
A total of eleven half scaled walls were tested. Six walls were designed with minimum distributed vertical reinforcement in accordance with the existing NZS 3101:2006 (A2) and an additional five test walls were designed in accordance with the proposed amendments to minimum vertical reinforcement requirements for ductile RC walls in NZS 3101:2006 (A3).





The behaviour of six phase I test walls designed in accordance with NZS 3101:2006 (A2) was controlled by 1-3 large flexural cracks at the wall base. The experimental results confirmed that current minimum vertical reinforcing limits in NZS 3101:2006 (A2) are insufficient to ensure that a large number of secondary cracks form and are only suitable for walls designed for low ductility demands.

The five phase II test walls designed in accordance with NZS 3101:2006 (A3) were controlled by a large number of primary and secondary cracks over the wall height that allowed the reinforcement strains to be more evenly distributed over the plastic hinge region. The additional vertical reinforcement limits proposed for the end region of ductile walls in NZS 3101:2006 (A3) were found to be adequate to ensure the secondary cracks occurred in the plastic hinge region.



Results from lightly reinforced wall tests

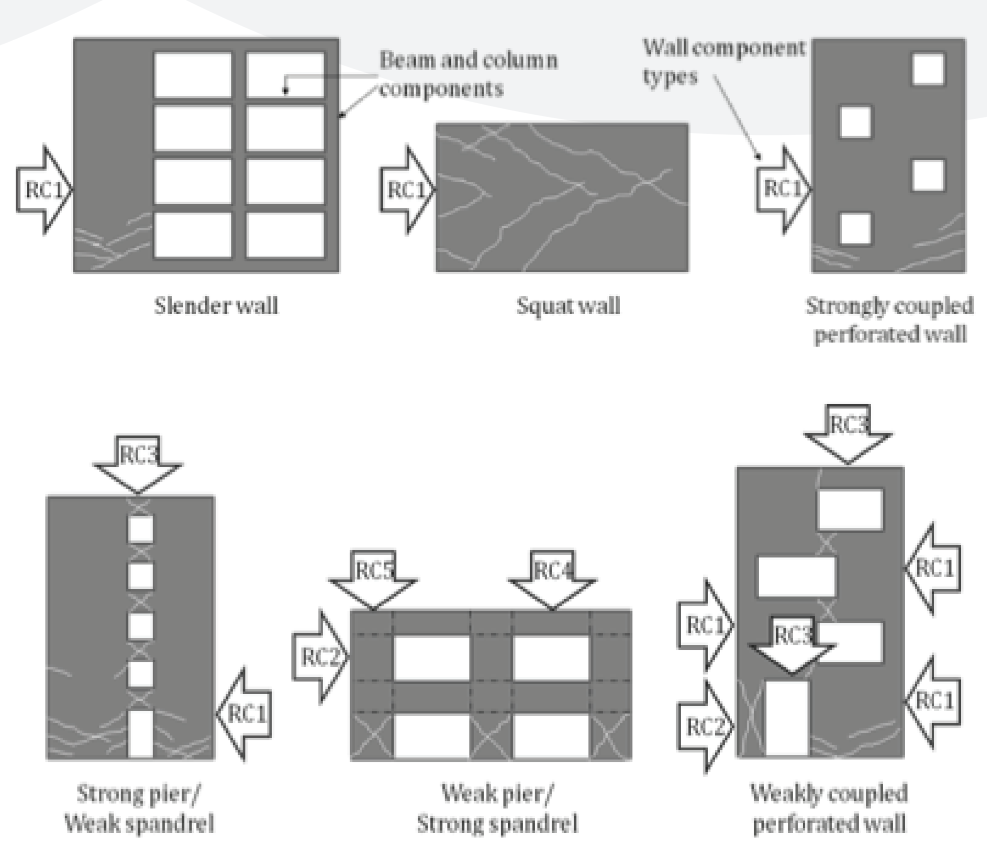
Output: Recommendations to NZS 3101 committee on minimum reinforcement requirements

Assessment of existing walls

Older concrete walls often have vertical and horizontal reinforcement that is less than the minimum required by current design standards. In addition, the single layer of reinforcement makes them particularly vulnerable to non-ductile failure modes, such as that observed in the PGC building.

Credit: 3 News

Experimental testing and modelling will be completed in 2016-2017 to identify failure modes and to refine seismic assessment procedures for older singly reinforced concrete walls in multi-storey buildings.



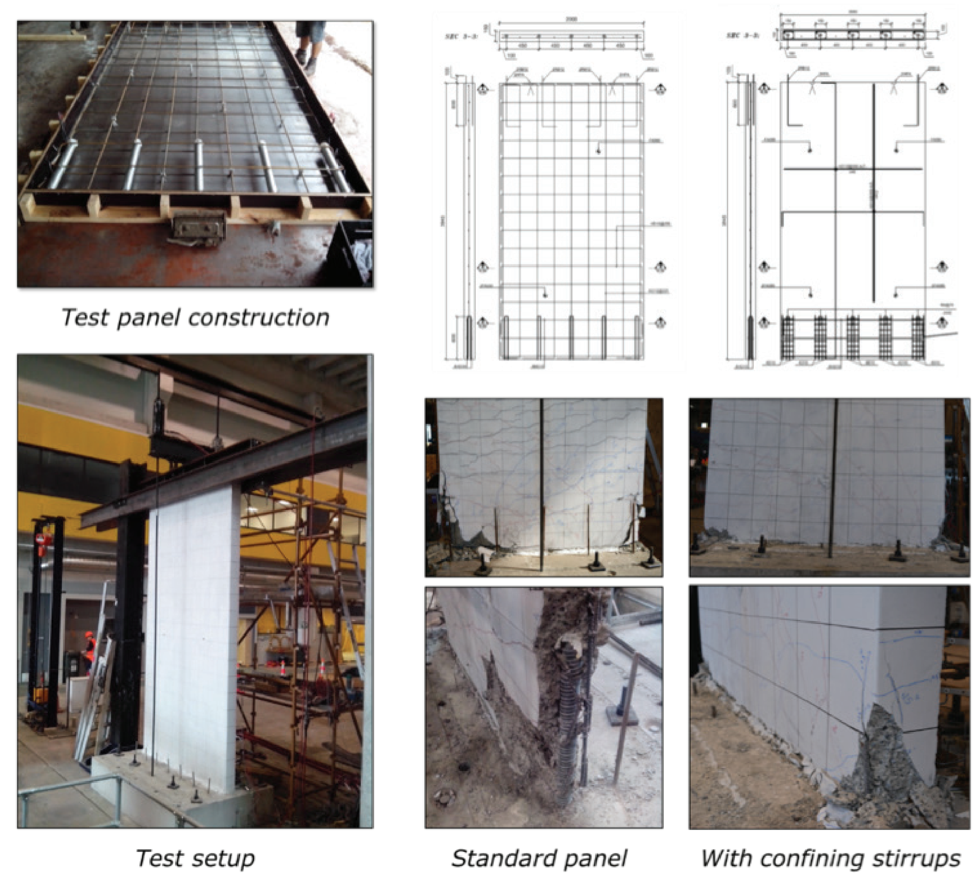
Failure modes of older walls

Output: Recommendations to NZSEE assessment guidelines for existing concrete walls

Precast wall connections

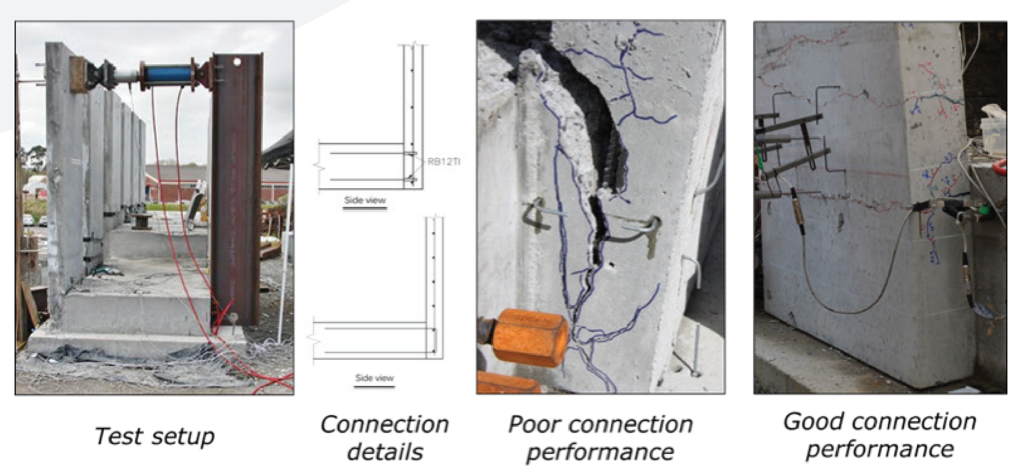
Experimental tests are currently underway to assess the in-plane and out-of-plane response of precast wall panel connections. A review of manufactured precast concrete panels was undertaken in order to develop a comprehensive understanding of the common typologies for connections between precast concrete panels and foundations.

An experimental programme was developed to assess the seismic behaviour of precast concrete panels connected to the foundation using grouted connections. Two in-plane tests of larger precast panels with grouted connections were conducted in 2016. The panels were 2 x 4 m and included both existing connection detailing and with the use of transverse confinement reinforcement around the splice, as recommended by SESOC. The results of experiments demonstrated that the use of confinement significantly improved the behaviour of the precast panel connections. The panel without connection confinement failed due to metal duct pull out, however the transverse reinforcement minimise the damage to the wall panel and was loaded until reinforcement fracture. Additional experiments are ongoing by constructing and testing a corner of the panel and applying the cyclic axial force to them.



Results from in-plane tests on grouted panel connections

A series of panel tests were completed to investigate both the monotonic and cyclic out-of-plane response of typically constructed threaded insert wall-to-foundation connections. Test panels incorporating existing detailing with shallow embedded inserts did not perform well with the flexural cracks in the panel propagating vertically into the joint region behind the back of the inserts and the connection started acting like a pin. In many cases the panel did not reach its full flexural capacity prior to the onset of this failure mode. A further series of out-of-plane tests was completed to investigate improved connection designs. Connection details were developed with the input of stakeholders such that proposed designs not only met their targeted performance, but were also feasible in practice. The majority of the alternative connections succeeded in protecting the joint from damage and forcing hinging in the panel above the foundation.



Results from out-of-plane tests on dowel connections

Bi-directional tests on both grouted and dowel connections will be performed at the MAST facility in Swinburne University in Melbourne in late 2016. These will investigate the vulnerability of the connections subjected to severe seismic loading.

Output: Draft guidelines on low-rise precast wall panel connection detailing

Acknowledgements

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