MODELLING AND PERFORMANCE OF REINFORCED CONCRETE WALLS DESIGNED FOR DUCTILITY

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The problem

Reinforced concrete (RC) ductile walls are commonly used to resist lateral earthquake loads in multi-storey construction.

The series of earthquakes hitting the Canterbury region between 2010 and 2011 resulted in unexpected failure of several RC walls as pictured below.

Following the earthquakes, SESOC and CERC recommended several changes to the design provisions in the New Zealand Concrete Structures Standard (NZS 3101:2006) that will soon be published under the third amendment. As these were based on professional judgement, these have had insufficient literature and experimental validation.

Crushing and global instability

Web and end region crushing failures

Axial crushing failure

Web crushing failures

Proposed NZS3101:2006 amendments of interest

1) Axial load limitation on walls
2) Increased confinement length used in the end region
3) Anti-buckling cross-ties required in the web region

The objective

This project will validate and further develop the improved detailing provisions in NZS3101:2006 for ductile RC walls such that the severe failures presented in the photos above are minimised in future earthquake events.

The objective can be broken down into the following deliverables:

1) Compile a database of tests comprising ductile RC wall tests from around the world [complete]
2) Identify gaps in testing data and ductile wall performance understanding [complete]
3) Identify the typical New Zealand design and construction practice used in walls [complete]
4) Develop and conduct a test programme to address the gaps [in progress]
5) Propose a set of recommendations to NZS3101:2006 relating to the above amendments

The benefits

1) Research-backed facts and guidance to aid informed decision making by the NZS3101:2006 committee
2) Improved codified design methodology for RC walls to be used by practising engineers
3) Predictable performance of RC walls to guarantee life safety in new buildings
4) Increased global understanding on performance of ductile walls and wall buildings in earthquakes

As this topic is of international interest, the findings from this project will be shared internationally to be considered for implementation into other major standards such as the United States, Japanese and Chilean building codes.

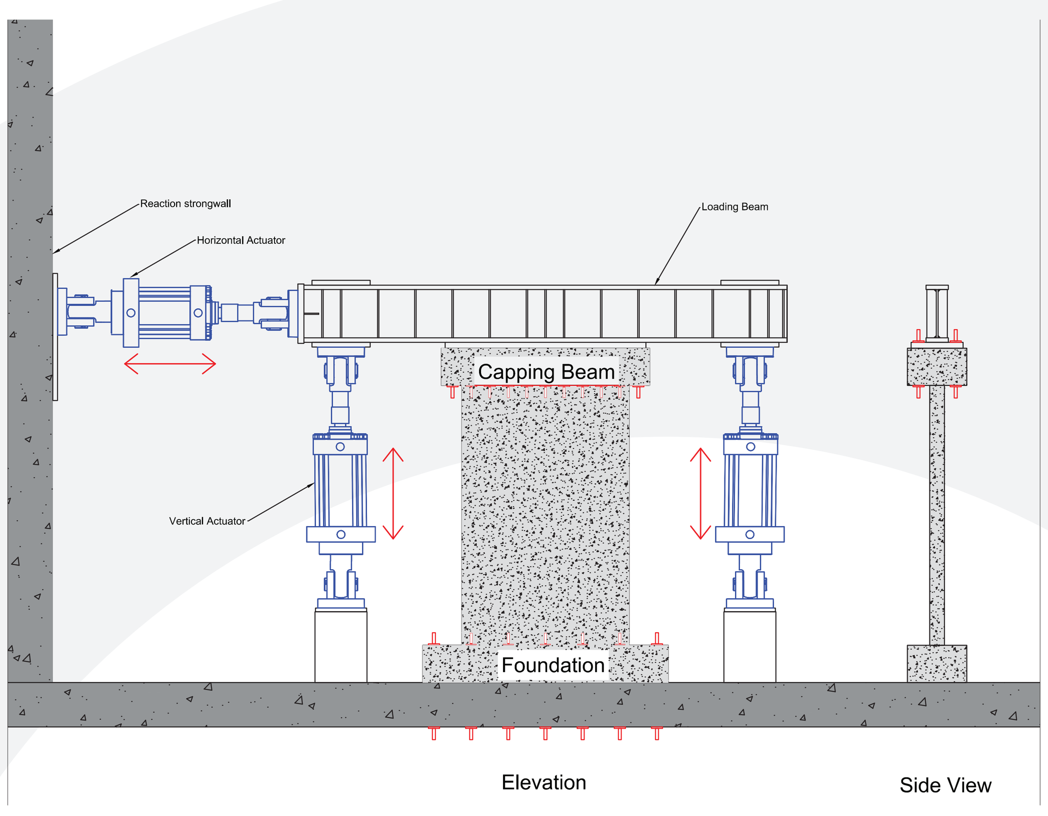
Improved wall resilience

The research outputs from this project are geared towards improving wall design such that the building not only guarantees life safety but sustains minimal structural damage, making it safe to reoccupy soon after the event.

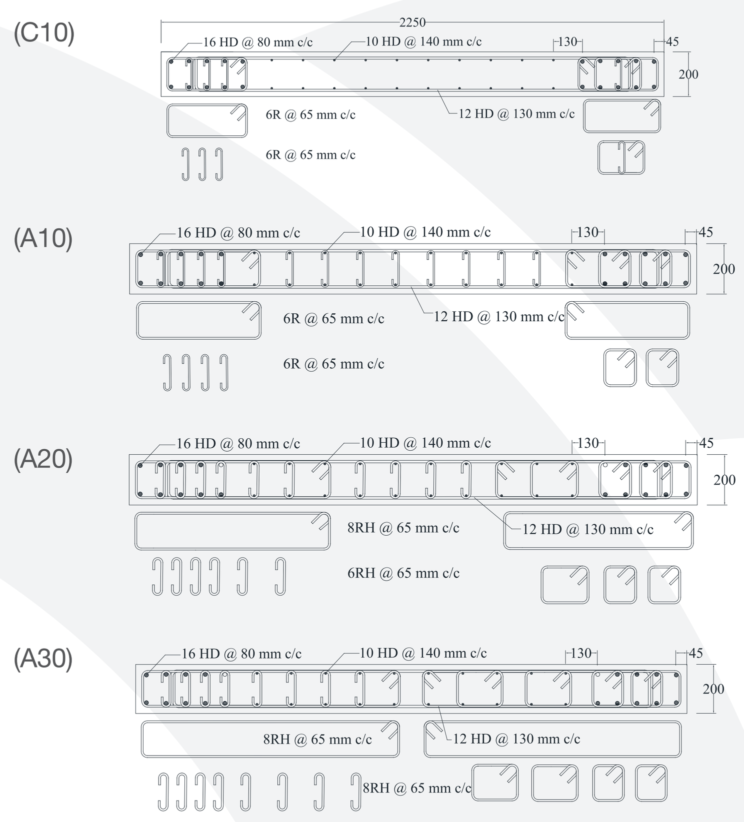
Large-scale testing of ductile RC walls

Four half-scale test specimens are being tested at the University of Auckland. These have been designed with typical detailing and geometry expected for an 8-storey idealized prototype building located in Wellington, New Zealand. The testing set up and the wall cross-sections are pictured below. These are the largest wall tests conducted in New Zealand.

Experimental set up used for testing each wall



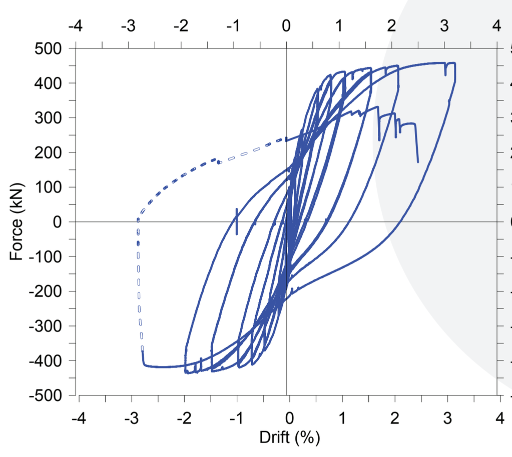
Cross-sections of each of the four specimens



Test results

Presented below are the force-displacement curves for the three tests and the final state of each wall at failure. Initial observations indicate excellent ductility characteristics of walls designed to the current and amended NZS3101:2006 provisions.

(C10)



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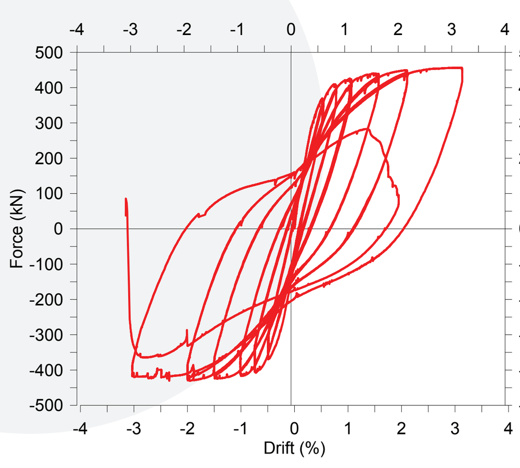

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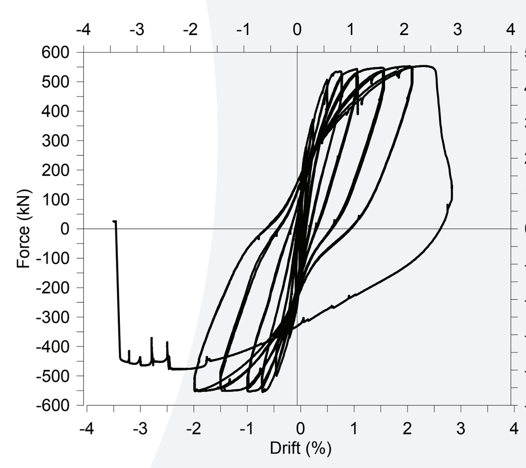

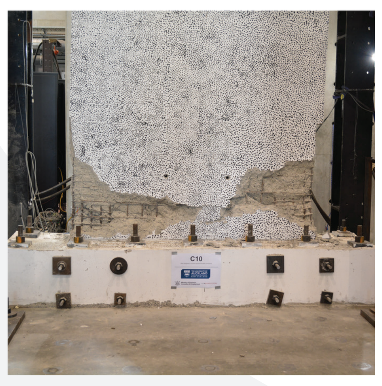

Fig.1

Fig.2

Fig.1

Fig.2

Fig.1

Fig.2

Project timeline

1) Test program complete: November 2016
2) Preliminary results summary report submitted: December 2016
3) Analysis of test data: December 2016 – April 2017
4) Modelling of parameters outside the scope of the experiments: March 2017 – October 2017
5) Modelling results summarised and final recommendations proposed to NZS3101:2006 October 2017 - December 2017

Acknowledgements

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1st, 2nd and 4th photo courtesy of Rick Henry and 3rd courtesy of Dunning Thornton Ltd