SEISMIC BEHAVIOUR OF RECTANGULAR DOUBLY REINFORCED CONCRETE WALLS UNDER BI-DIRECTIONAL LOADING

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Statement of the problem

The recent earthquakes in Chile and New Zealand led to a significant number of wall failures (Kam et al., 2011). Some of these failure modes involved out-of-plane displacements, which could potentially be affected by directional excitation.

Failure modes observed in the 22 Feb 2011 Canterbury earthquake (Kam et al. 2011)

There is a global concern on the contribution of bi-directional loading on these failure modes. So far, the effect of bi-directional loading on the design/assessment of rectangular shear walls is ignored.

Purpose of research

- Identify the key parameters influencing the seismic performance of rectangular RC shear walls under bi-directional loading.
- Assess if bi-directional loading can change the damage/failure mode expected in uni-directionally loaded walls, and, if yes, what are the likely changes.
- Improve the understanding of the traditional distinction between columns vs. wall.
- Investigate load path effects on rectangular shear walls.
- Simulate the possible failure mode(s) that can be activated in shear walls due to bidirectional loading in the lab.

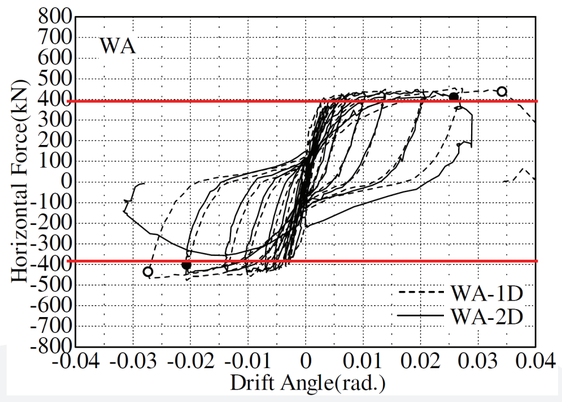
Project outputs

- Develop a simplified analytical/mathematical method to predict the drift capacity of rectangular RC shear walls taking into account the effect of bi-directional loading.
- Verify the reliability of current (national and international) code-based design requirements for walls subject to more realistic cyclic loading regimes.
- Suggest recommendations/guidelines (based on experimental and analytical/numerical evidences) to improve current practice (taking into account bidirectional loading/response) for both the design of new walls and the assessment of existing ones, to assist engineers in their daily practice.

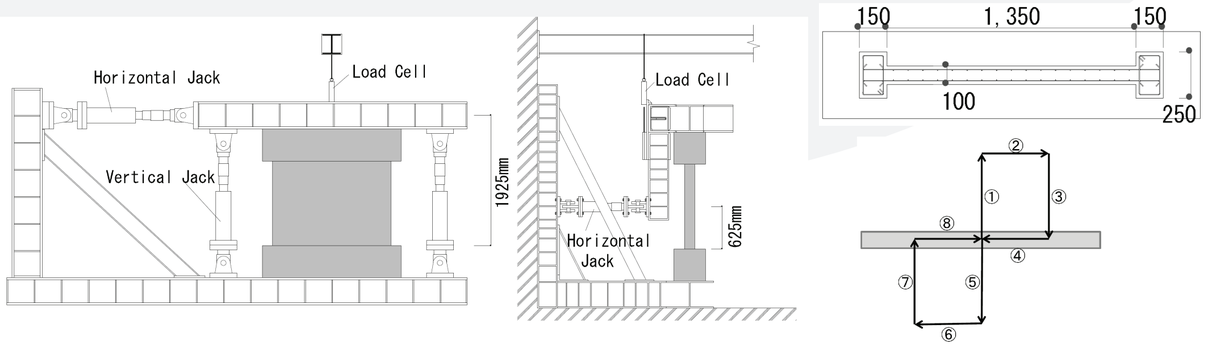
Previous studies

There is limited study on rectangular RC shear walls under bi-directional loading.

- Reduction in plastic deformation capacity
- Reduction in ductility
- Reduction in hysteretic energy dissipation capacity
- Higher axial strain in the boundary elements
- Heavier damage rates in terms of crack widths and cover concrete crushing



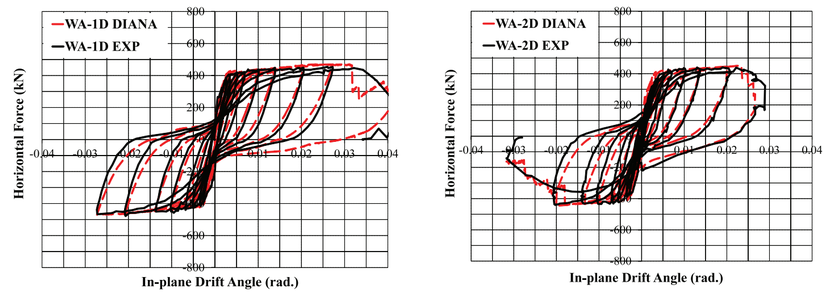
Force – displacement curve of the shear wall under uni- and bi-directional loading (Kabeyasawa et al. 2014)



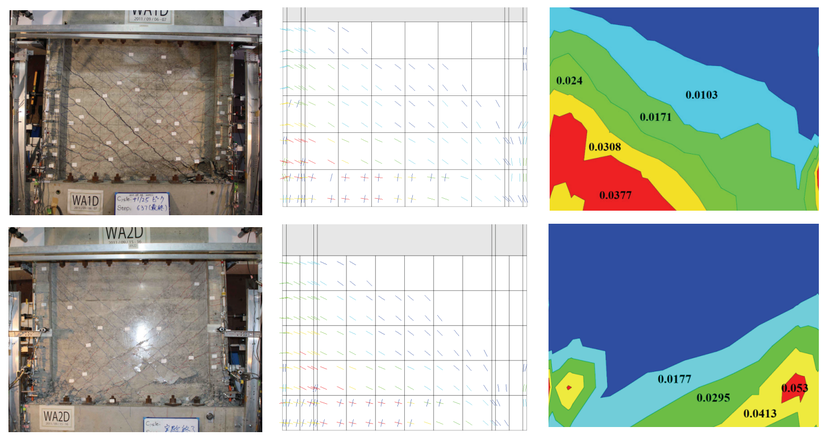
Numerical study

Numerical study is performed using Finite Element (FE) Analysis by DIANA and has three steps:

1) Verify the FE model with the experimental results (both under uni- and bi-directional loading)
2) A parametric study with the purpose of identifying the key parameters influencing the seismic performance of rectangular RC walls under bi-directional loading and to design the specimens for the experimental phase.
3) Blind predictions of the wall specimens planned to be tested in the lab with possible failure modes that can be activated due to bi-directional loading.

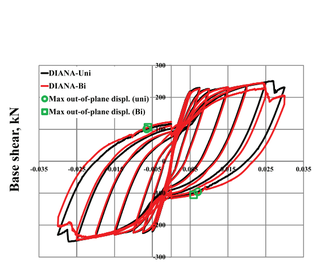


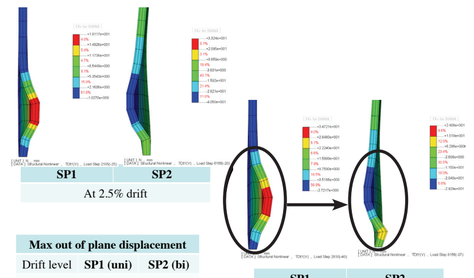
Force-displacement curves, FE analyses vs experiment (Kabeyasawa et al. (2014), (a) uni-directional and (b) bi-directional loadings



Crack pattern *Equivalent Von Mises strain contours*

Failure pattern, experiment (Kabeyasawa et al. 2014) vs FE analysis





SP1	SP2
At 2.5% drift	

Max out of plane displacement		
Drift level	SP1 (uni)	SP2 (bi)
2.5%	18.1 mm	40.5 mm
3%	34.7 mm	53.37 mm

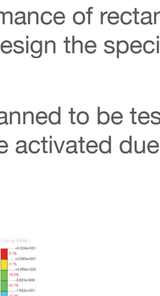
SP1	SP2
At 3% drift	

Experimental study

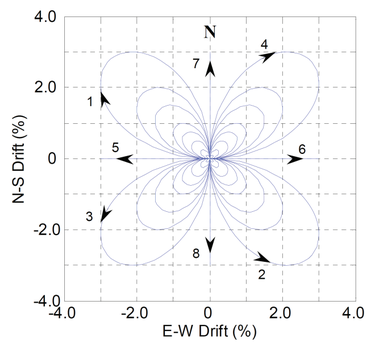
The main purpose of the experimental study is to observe the possible type of failures that can be activated by bi-directional loading.

1) Test specimen's matrix

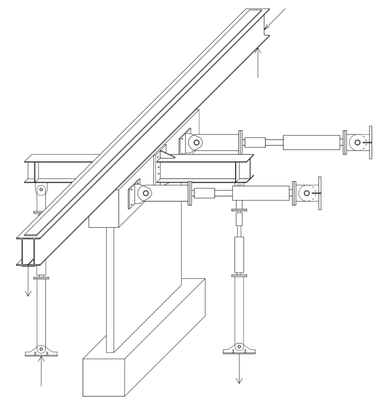
Specimen name	Scale	Shear span ratio [1]	Axial load ratio [2]	$H_w \times L_w \times t$ (mm)	Total longitudinal reinforcement ratio [3]	BZ transverse reinforcement ratio [4]	Web shear reinforcement ratio [5]	Loading pattern
SP1	1:2	3.7	6.3%	2200x1600x125	2.29%	0.0061	0.0086	Uni-directional
SP2								Bi-directional- clover leaf 01
SP3								Bi-directional-clover leaf 02
SP4		>3		Needs the numerical parametric study results on rectangular slender walls				Uni-directional
SP5								Bi-directional
SP6				Needs the numerical parametric study results on rectangular slender walls				Uni-directional
SP7								Bi-directional



2) Test setup and loading pattern



bi-directional loading pattern



Test set up for the bi-axially loaded walls

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