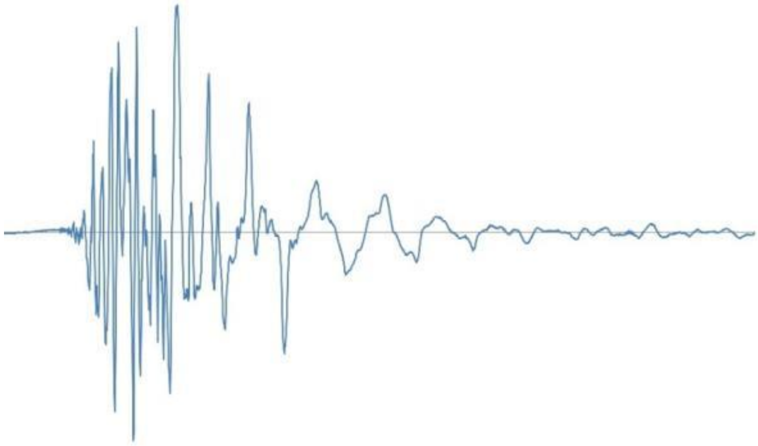
SEISMIC PERFORMANCE OF WEDGE WALL PANEL CONNECTION SYSTEMS



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UNIVERSITY OF CANTERBURY

Te Whare Wānanga o Waitaha

CHRISTCHURCH NEW ZEALAND

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1 INTRODUCTION

After the recent earthquake sequence in Canterbury initiated in 2010 (e.g., September 2010, December 2010, February 2011, June 2011 etc) partition walls have repeatedly shown to be amongst the most susceptible elements to suffer damage during an earthquake. Furthermore they represented a significant economical burden, due to both direct and indirect losses associated to business interruption, as in many cases they needed to be repetitively repaired if not completely replaced after each major aftershock.

Often the damage suffered by these walls is cosmetic only and/or could impact with fire safety considerations.

Wedge Interior Systems Ltd has developed a new connection detailing such that architectural/finishing panels could be attached on existing drywalls. This new detailing incorporates sliding-type connections that enable the architectural panels to deform according to the deflected shape of the underlying partition wall.

As part of an investigation on the seismic performance of these solutions, two full scale prototype walls have been tested in the structural laboratory of the University of Canterbury under quasi-static cyclic loading using a specifically designed non-structural wall testing set-up.

In this report the results of these tests are presented.

2 TEST SETUP

In order to test the cyclic performance of infill wall typologies of various nature, a unique test setup has been developed at the University of Canterbury. The setup (Figure 2.1) comprises two precast columns and two precast beams connected by 40 mm diameter post tensioning bars in order to achieve a rocking /re-centring behaviour at the beam column connections, without structural damage, as peculiar of a PRESSS-technology system (Pampanin et al., 2010).

Due to the characteristics of the test setup, it is possible to test a number of infill walls specimens inserted within this unique RC frame, without causing any damage to the structural frame. Moreover, the behaviour of the infill wall could be closely monitored and extracted from the global behaviour of the bare frame plus infills since the bare frame behaviour remains basically in the linear elastic range at each test.

This ad-hoc testing apparatus has been utilized to test the seismic performance of the two wedge wall panel jointing systems.

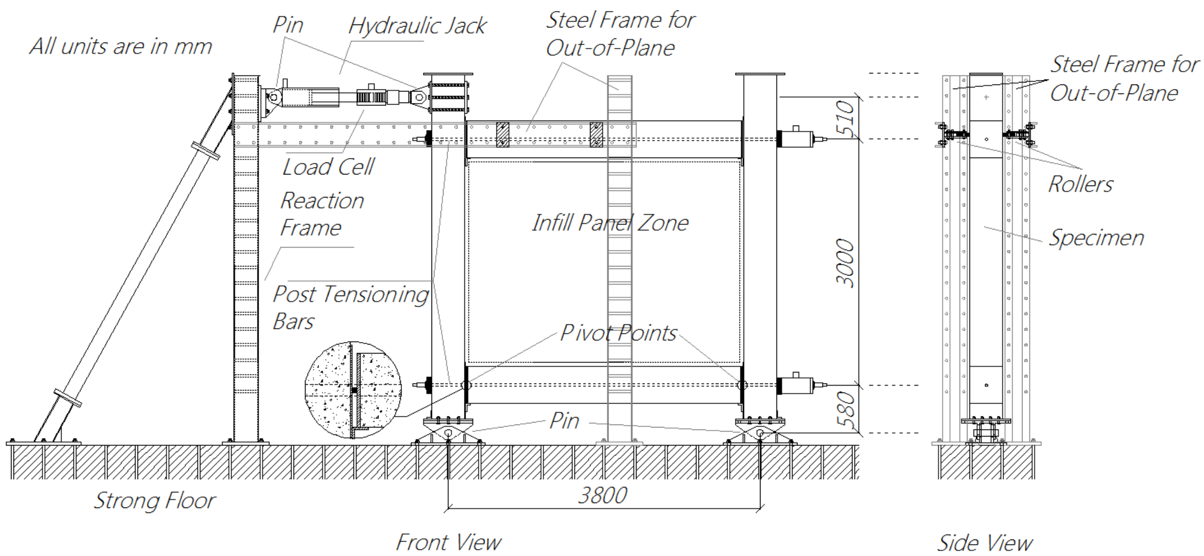


Figure 2.1a)

Figure 2.1b)

Hydraulic jack capacity	: 1000 kN
Reaction frame allowable load	: 500 kN
Post tensioning bars	: 40 mm Macalloy 1030
Load cell capacity (Connected to hydraulic jack)	: 1000 kN
Post tensioning load cell capacity	: 700 kN

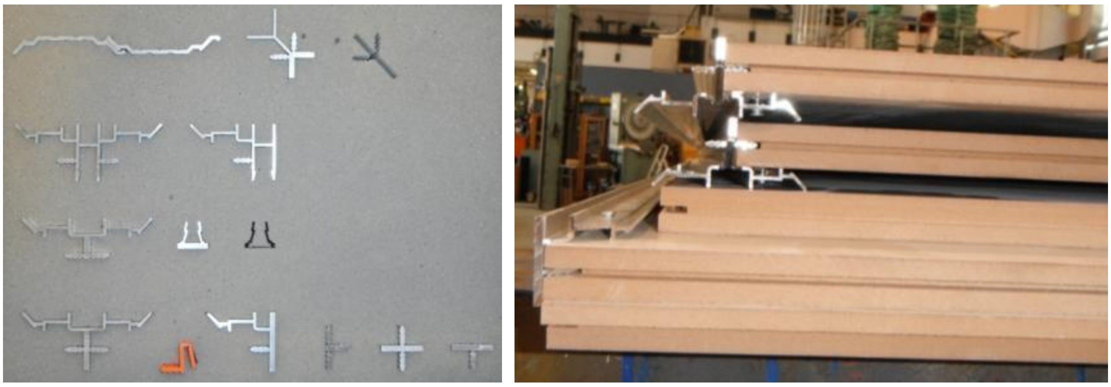
Figure 2.1. a) Schematics of the test setup, b) Photographic view of the test setup

3 MATERIALS

In order to simulate standard construction practice, the Wedge panel connection systems were installed on a typical partition wall skeleton, consisting of a light gauge steel studded drywall partition. Therefore, steel studs, tracks and gypsum wallboards (Figure 3.1a, Figure 3.1b) were required for the construction of the drywall. Overall, the Wedge panel connection system consist of the wedge panel connectors and the architectural/finishing wall panels (Figure 3.1c, Figure 3.1d).

Figure 3.1a)

Figure 3.1b)



c) d)

Figure 3.1. a) Steel studs and tracks of 90 mm height, b) Standard gypsum plasterboard, c) Aluminium Wedge panel connectors, d) Timber panels

Acknowledgment should be given to the following companies for providing the materials:

Wedge Interior Systems (NZ) Ltd

Supplied:

- Wedge Wall Panel Connector System Aluminium profiles.

Contact: Philip Shand

Laminex

Supplied:

- 18mm Melteca Panels
- 13mm Gib board

Contact: Tony Reid – Laminex South Island Sales Manager

Forman Commercial

Supplied:

- Rondo Steel Batten framing
- Installed Rondo framing & Gib board.

Contact: Mark Andrews – Forman Commercial Interiors

McKechnie Aluminium

Supplied:

- 31.75 x 31.75 x 3.0mm Aluminium Angle

Contact: Phil Taylor - McKechnie Aluminium.

JB Joinery

Supplied:

- Labour to install Wedge Wall Panel Connectors onto test bed.

Contact: Stuart Cowen – JB Joinery

4 TEST SPECIMENS

Two test specimens were tested, in this report referred to as WEDGE 01 (Standard System) and WEDGE02 (Seismic system). The basic solution of both specimens is the same, with two minor but important variations in the construction details to allow for high lateral deformations with limited or negligible damage.

In the following paragraphs a description of the two specimens will be given.

In Appendix A, the full set of construction drawings is reported.

4.1 WEDGE 01 (Standard System)

The details of the WEDGE01 specimen (Standard System) are shown below in Figure 4.1.

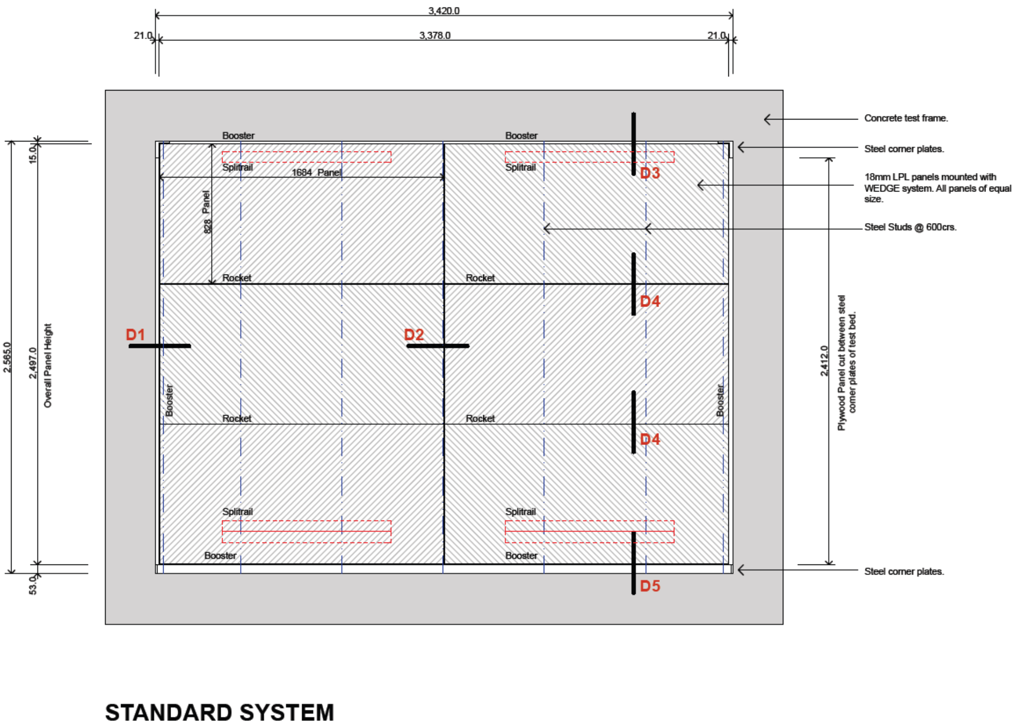


Figure 4.1a) Elevation view

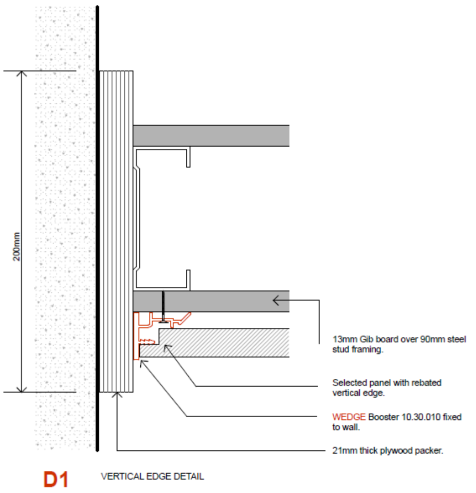


Figure 4.1b) Detail D1

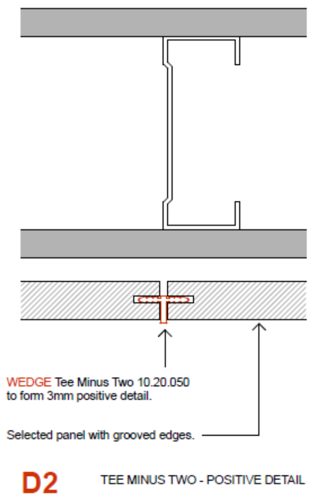


Figure 4.1c) Detail D2

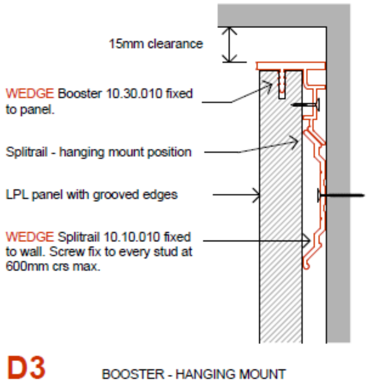


Figure 4.1d) Detail D3

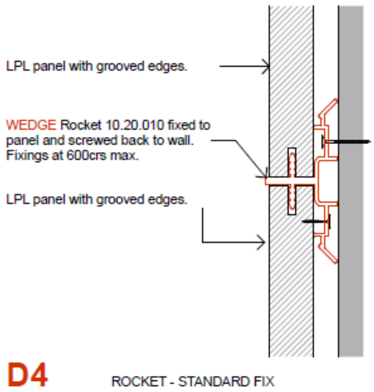


Figure 4.1e) Detail D4

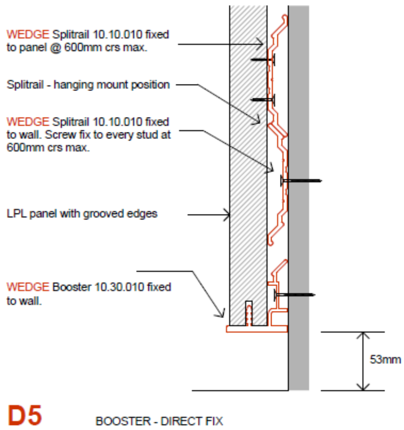
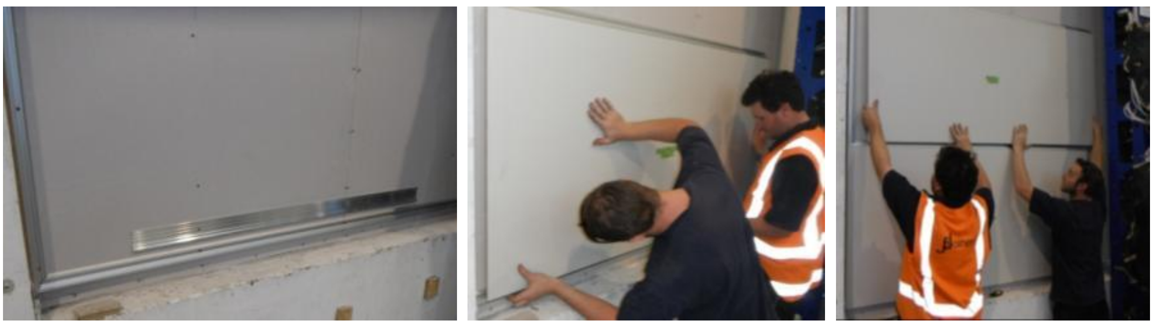


Figure 4.1f) Detail D5

Figure 4.1. Sample connector types used in WEDGE 01 (Non-seismic installation, for clearer details refer to the Appendix)

In the specimen WEGDE01 (Standard), the connections of the wall panels were made using the most basic connection typology in order to test its performance. Snapshot of the construction process are shown in Figure 4.2. It should be noted that the lowest horizontal aluminium member was made of only one length spanning along the total length of the beam. This, as suggested by Wedge Interior Systems Ltd is not the desired practice, but was intentionally used for the test as worst case scenario.



a) b) c)

Figure 4.2. WEDGE 01 specimen a) Sliding aluminium connectors are installed on the wall and the panels, b) The panels are vertically inserted to the sliding connectors and the slider connector on top is attached to the drywall, c) The upper panel is vertically inserted to the upper slider connector of the lower panel.

4.2 WEDGE 02 (Seismic System)

The details of the WEDGE02 specimen (Seismic System) are shown below in Figure 4.3.

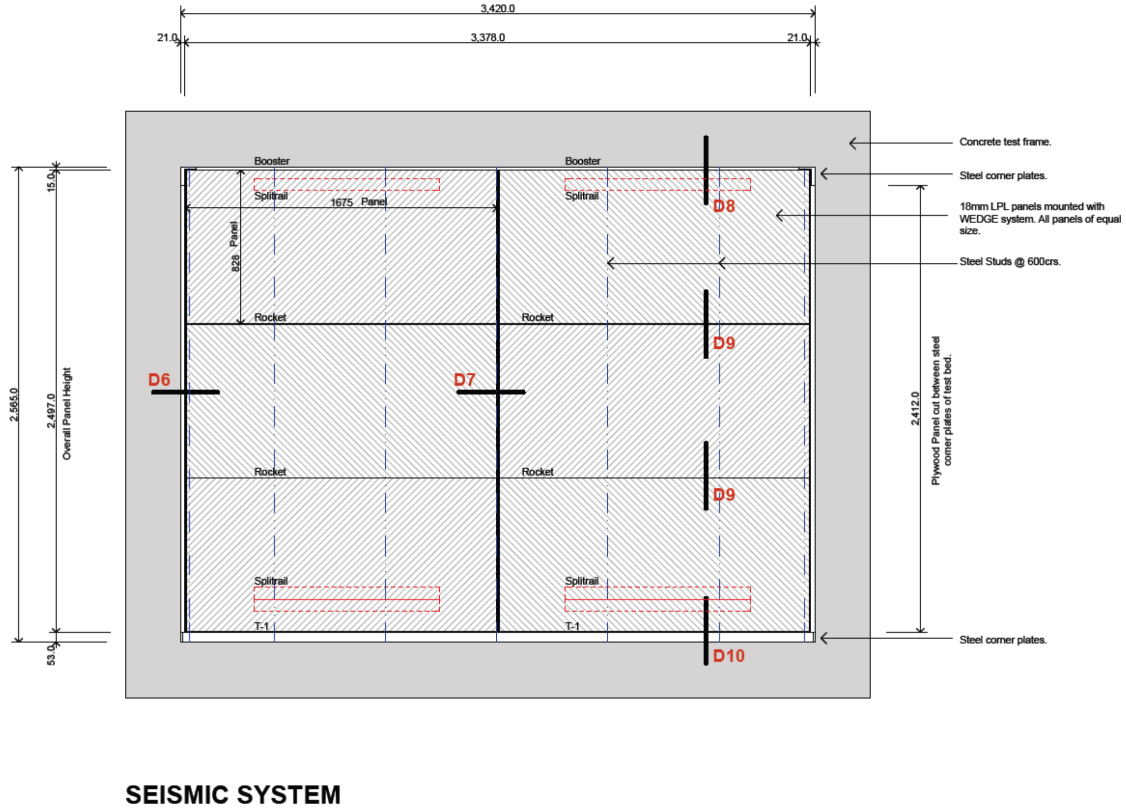


Figure 4.3a) Elevation view

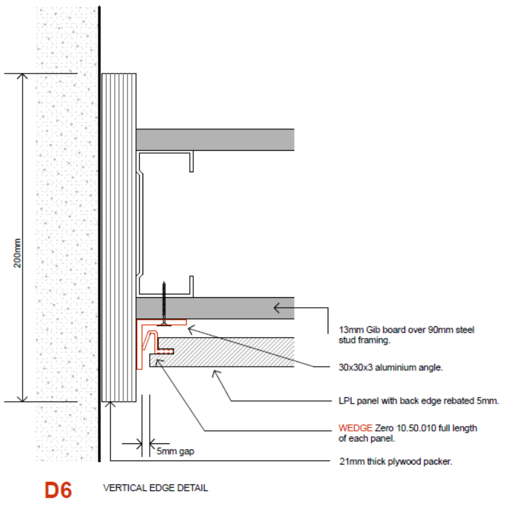


Figure 4.3b) Detail D6

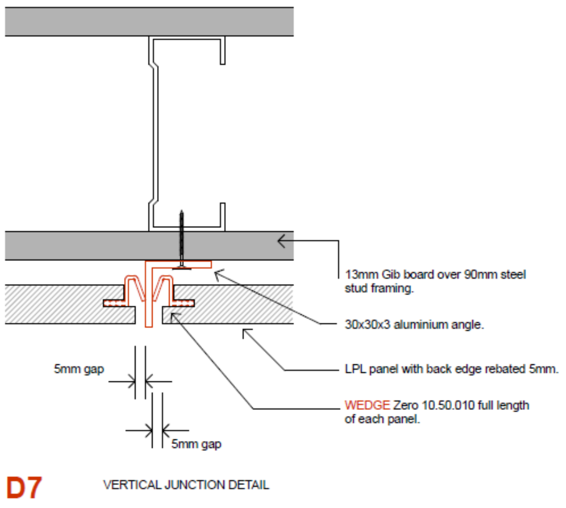


Figure 4.3c) Detail D7

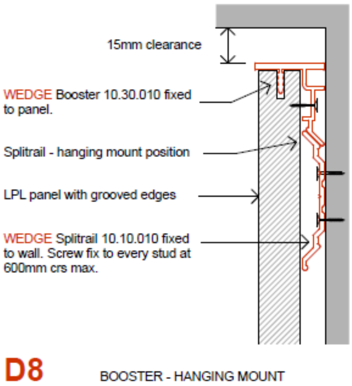


Figure 4.3d) Detail D8

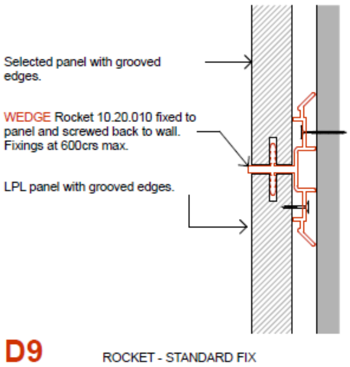


Figure 4.3e) Detail D9

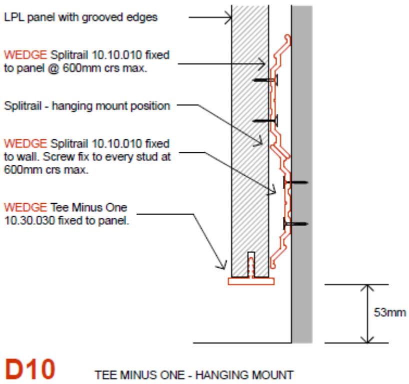


Figure 4.3f) Detail D10

Figure 4.3. Sample connector types used in WEDGE 02 (Seismic installation, for clearer details refer to the Appendix)

The specimen WEDGE02 (Seismic) had same basic type of connections with two different construction details. The lowest horizontal aluminium member was made of two separate pieces located under each respective panel. Moreover, plastic jointing elements were used in between the vertical gaps to provide a bumper effect. The rest of the installation procedure is the same as per the standard WEDGE 01 system

Figure 4.4. WEDGE 02 Specimen. Plastic vertical jointing elements located in the vertical gaps.

5 TESTING PROTOCOL AND TEST RESULTS

The tests were carried out by following the displacement regime given by acceptance criteria for moment frames based on structural testing and commentary (ACI374.1-05, 2005). ACI374 requires the following criteria to be applied for the selection of applied drift levels:

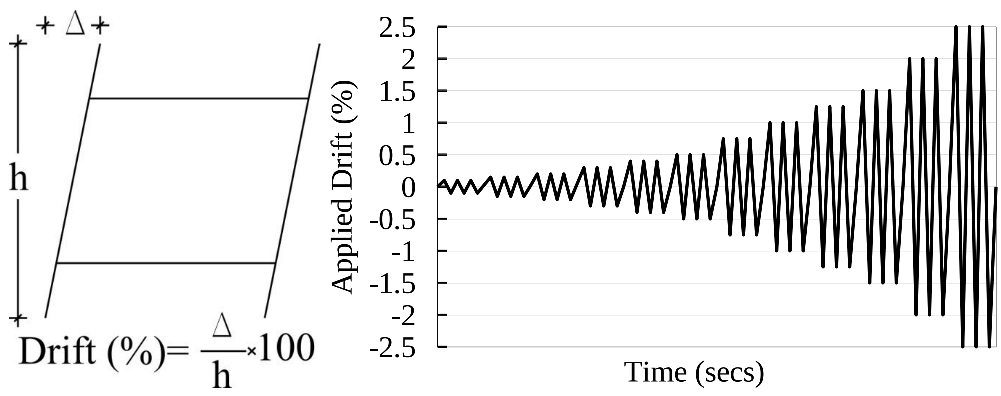
$1.25D_i \leq D_{i+1} \leq 1.5D_i$

where D_i = *Previous drift amplitude*

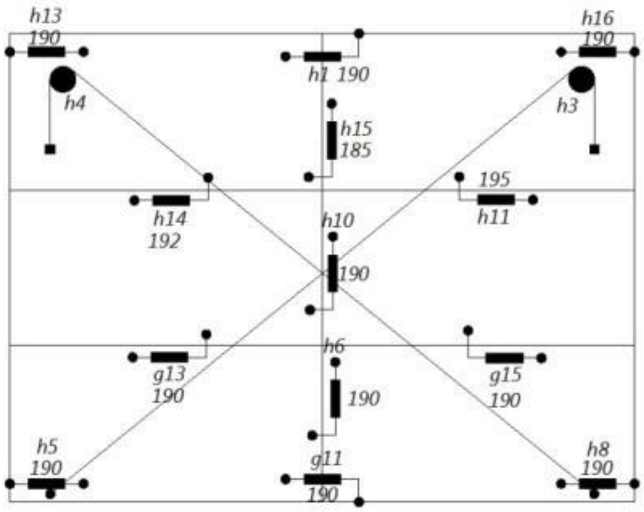
D_{i+1} = *Next drift amplitude*

The mathematical definition of the interstorey drift (%) and the displacement history loading protocol to be applied on the frame in accordance with the ACI 374 guidelines, are shown in Figure 5.1a.

The specimens were instrumented in accordance with the instrumentation scheme shown in Figure 5.1b.



a) Applied drifts (%): 0.10, 0.15, 0.20, 0.30, 0.40, 0.50, 0.75, 1.00, 1.25, 1.50, 2.00, 2.50



b) Instrumentation

Figure 5.1. a) Applied displacement history (0.1, 0.15, 0.2, 0.3, 0.4, 0.5, 0.75, 1.0, 1.25, 1.5, 2.0, 2.5% are the drift levels applied), b) Instrumentation scheme of the specimens

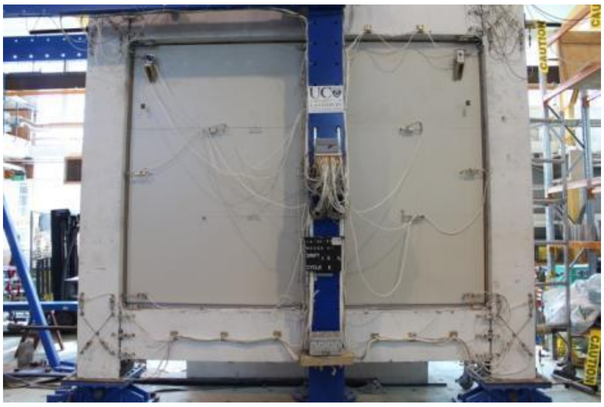
In this section of the report, the test results for the two WEDGE specimens are reported (WEDGE 01, WEDGE 02)

5.1 Performance of WEDGE 01 (Standard System)

Overall, no overall damage was observed to the panel specimen throughout the test up to 2.5% drift. The only damage was imposed on the lower horizontal aluminium element. It showed deflection and resulting shearing of the fasteners, which was caused by the rocking motion of the panels. The sequential images and the deflection imposed on the aluminium element have been given in Figure 5.2.

The experimental results of the test are given in Figure 5.3. The specimen behaved very similarly to a bare frame with thus negligible effect/interaction on the structural behaviour. However, it is worth noting that any interaction would mostly be due to the steel studded drywall itself infilled within the structural system, with no or negligible structural contribution by the panels attached by the Wedge connection system. The structural behaviour of the tested wall is summarized in Figure 5.3 (i.e. hysteresis curves, envelope curves).

For similar considerations, the energy dissipation comes from the drywall infill skeleton which is thus expected to have sustained damage in the back of the Wedge Wall system regardless of the performance of the Wedge Wall system.



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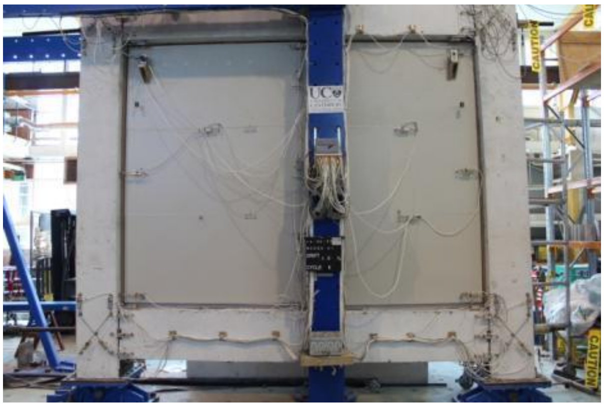

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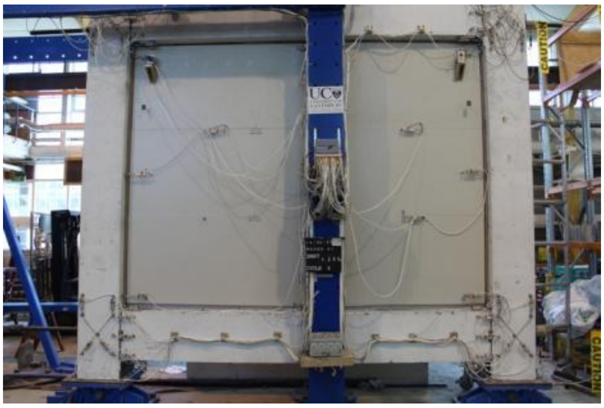

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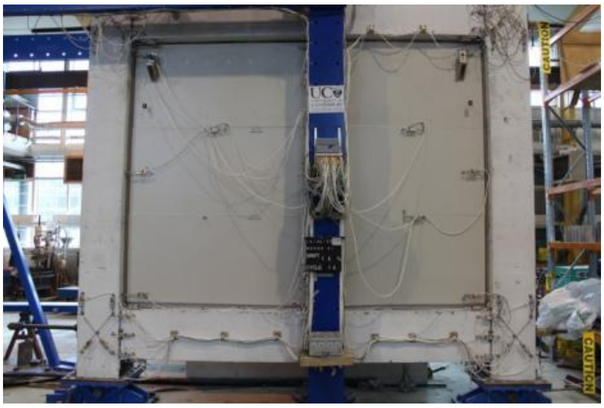
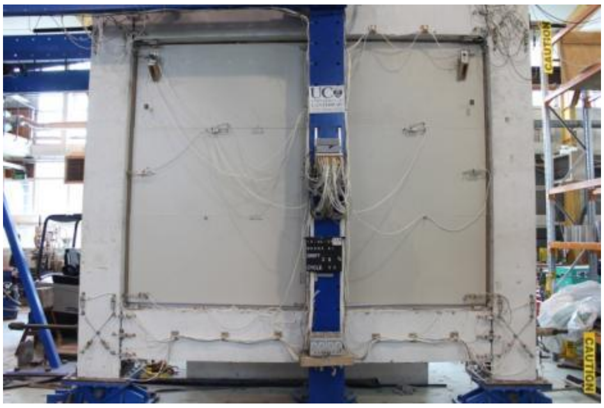
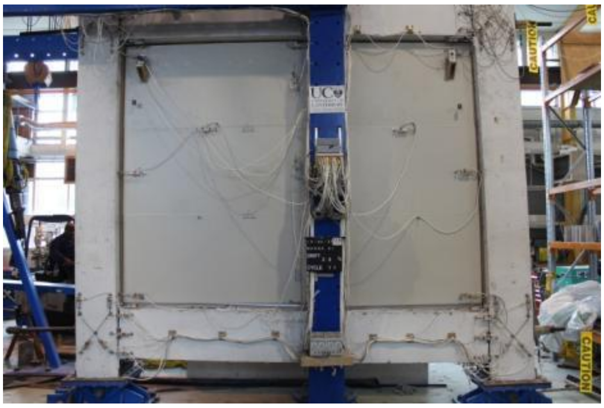


+1.5% -1.5%





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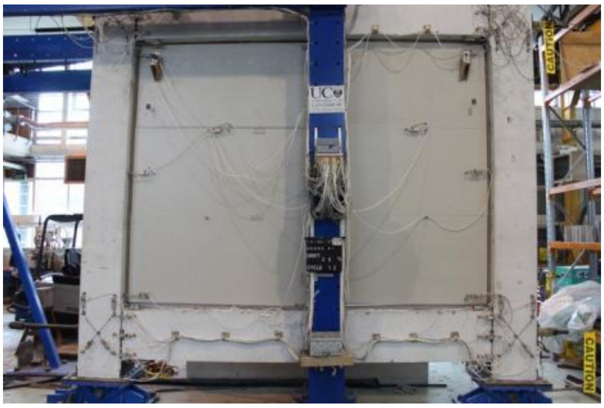


+2.5% -2.5%

The deformation imposed on the horizontal aluminium element at -2.5% drift

Figure 5.2. The sequential images of WEDGE 01 during the test.

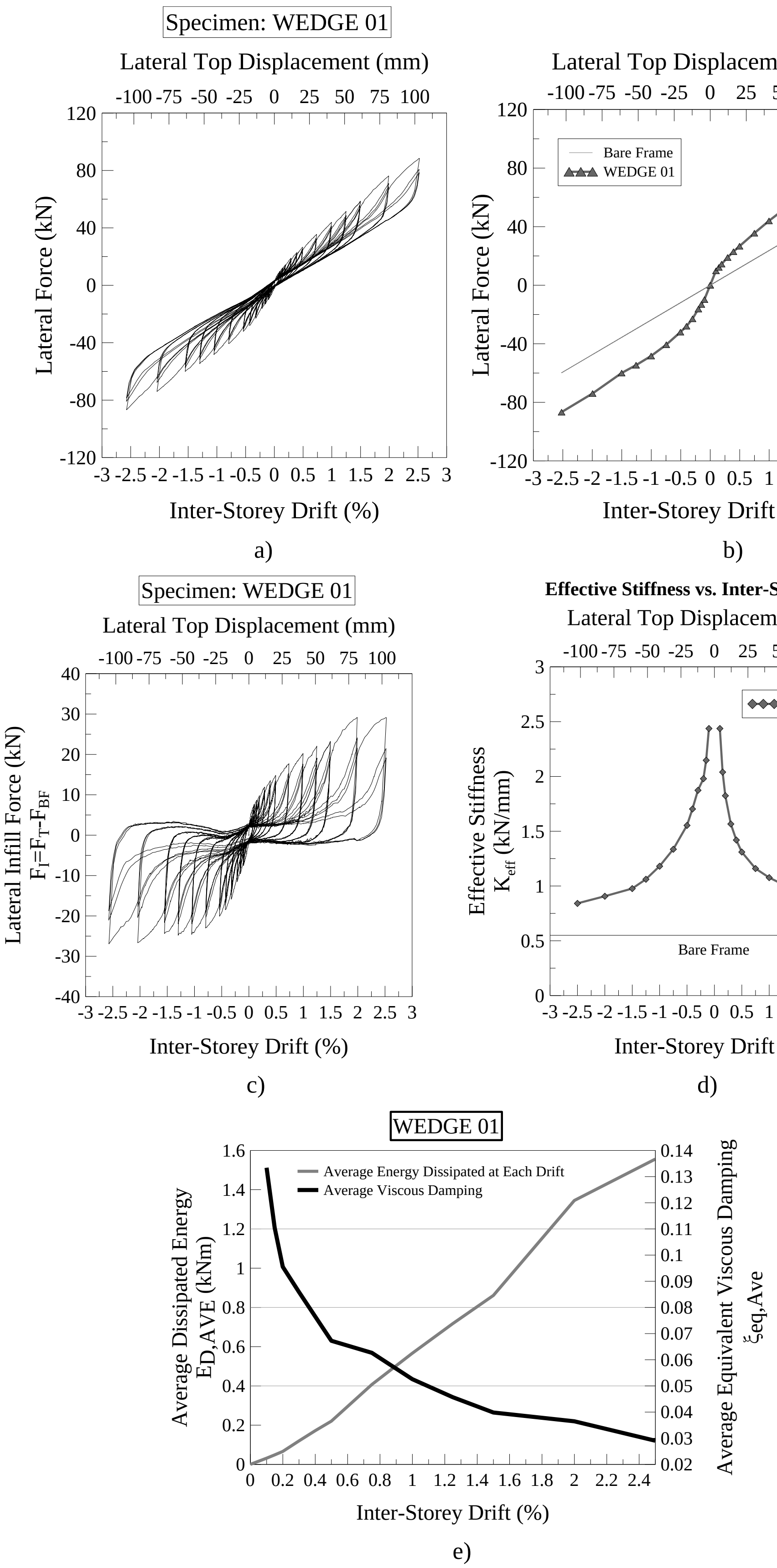


Figure 5.3. a) Total lateral force vs. inter-storey drift, b) Envelope curve for WEDGE 01 overall system compared to bare frame, c) Lateral force acting on the infill wall (WEDGE+Drywall composite), d) Total effective stiffness (Including bare frame stiffness of 0.55 kN/m), e) Dissipated energy and average equivalent viscous damping per drift level.

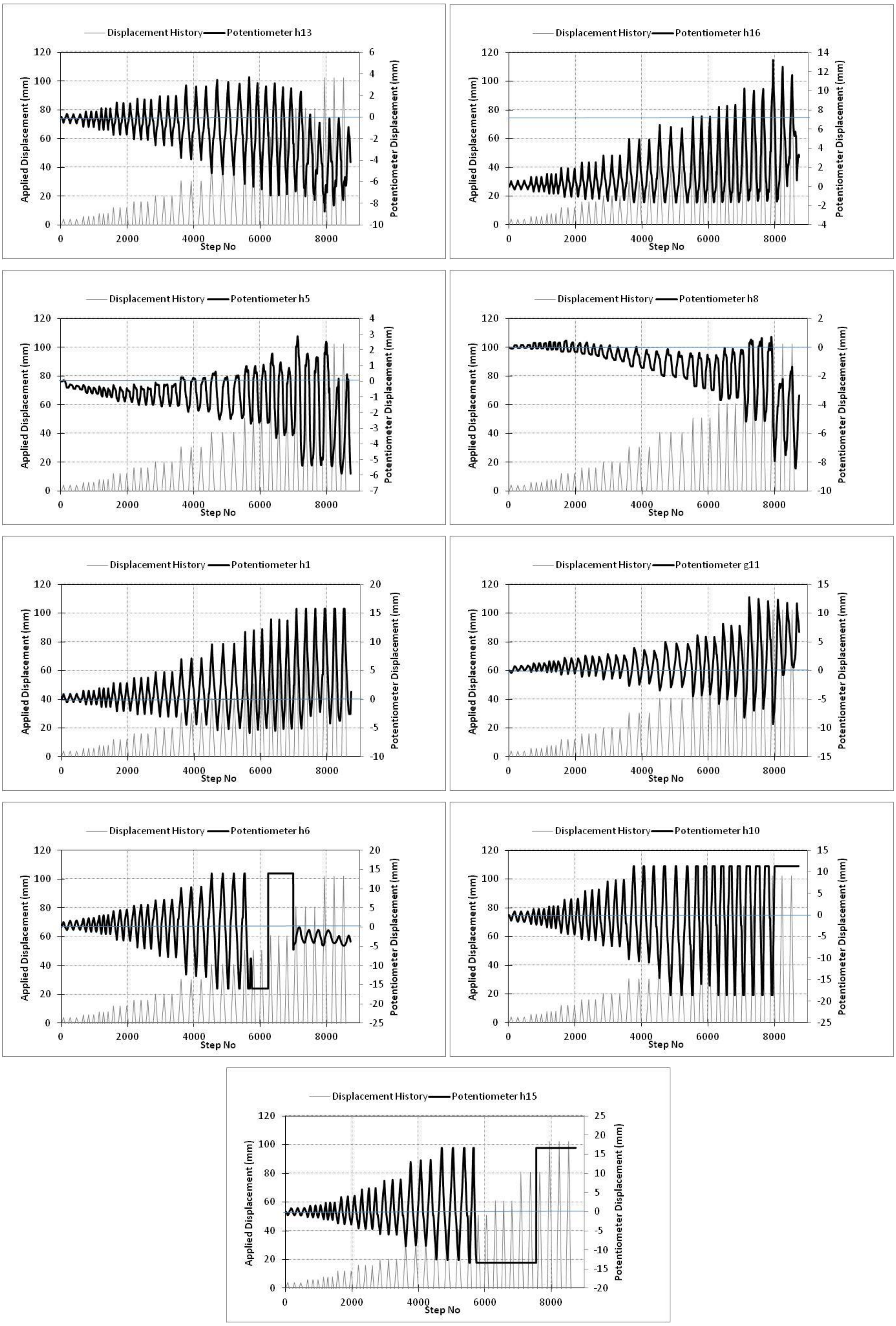


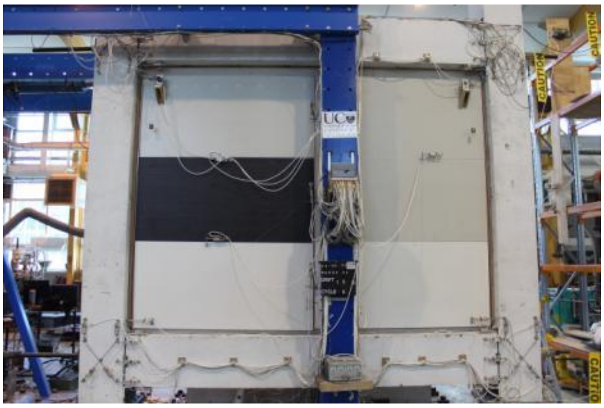
Figure 5.4. Potentiometer displacement readings at the borders of WEDGE 01 (For the location of the potentiometers, refer to Figure 5.1b) Note: Potentiometers can only read ±15 mm

5.2 Performance of WEDGE 02 (Seismic System)

The WEDGE02 seismic solution wall had similar if not superior seismic performance when compared to the WEDGE01 standard solution. As mentioned the only damage that occurred in WEDGE 01 was not in the panels but in the lowest horizontal aluminium element.

In the WEDGE02 seismic solution, the horizontal aluminium element was made of two separate pieces (e.g. instead of spanning the full length of the inner bay. Therefore, the damage to the aluminium element was prevented as suggested best practice by Wedge Interior Ltd. Apart from this, the behaviour was similar to WEDGE 01.

The sequential images of the testing are given in Figure 5.5 (Note: the deformation at the lowest part of the wall is also shown in Figure 5.5 for comparison with the WEDGE 01 Specimen) and the structural behaviour of the specimen is given in Figure 5.6.



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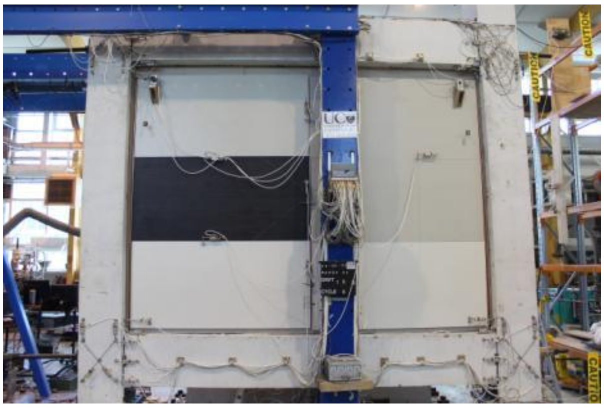

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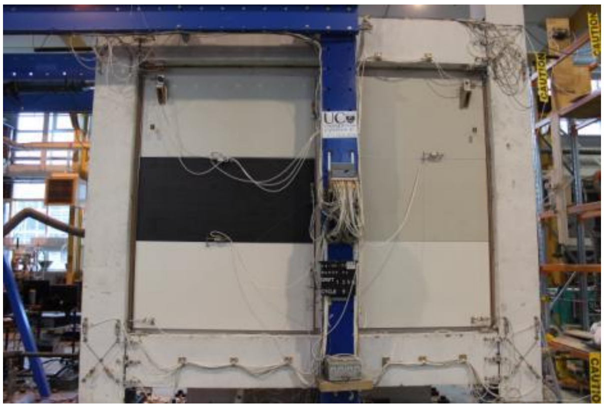

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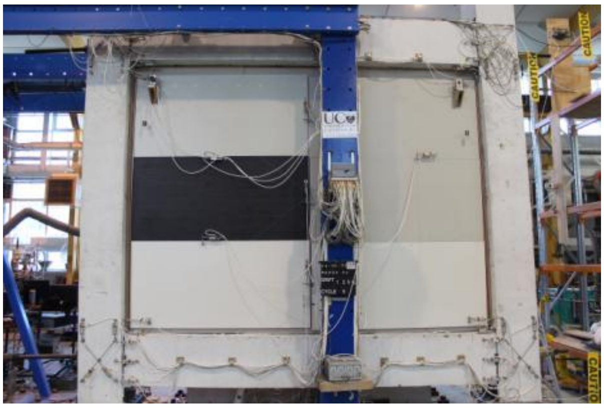
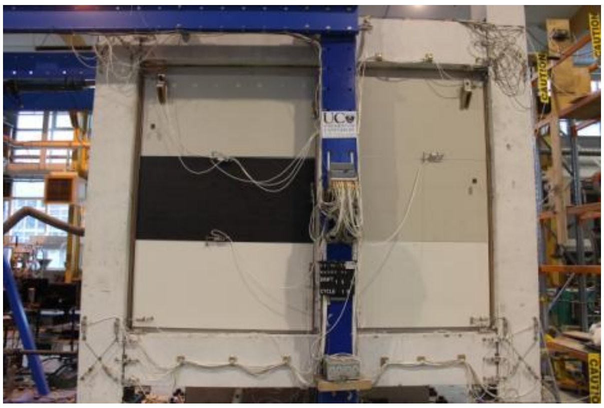


-1.25%



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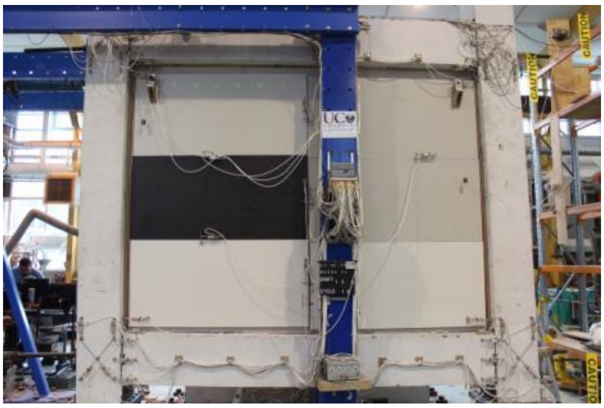

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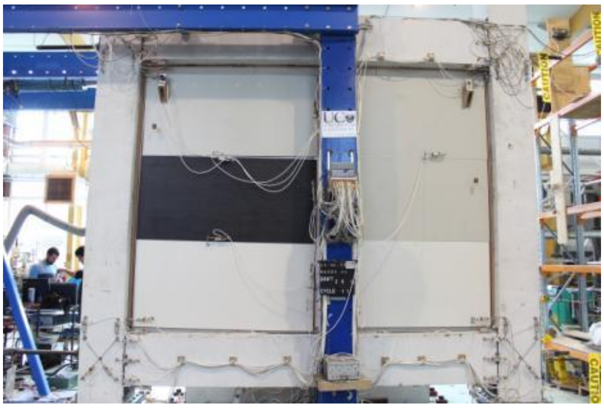
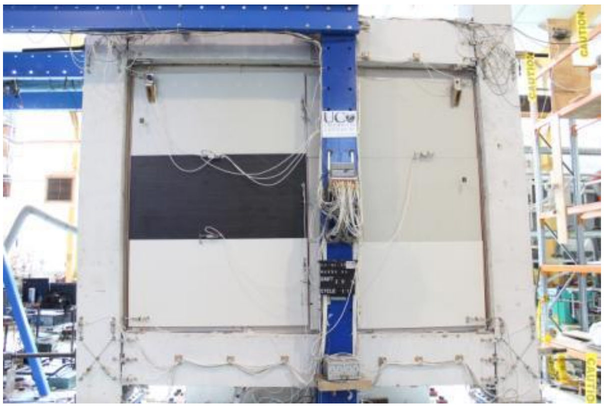
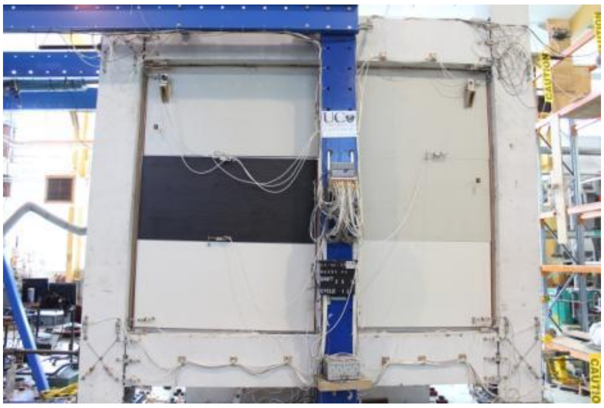
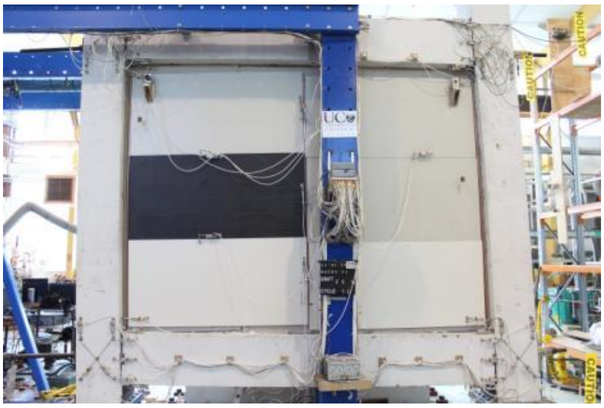




+2.0% -2.0%





+2.5% -2.5%

The deformations at the lowest part of the panels at -2.5% drift. The horizontal aluminium element is still intact.

Figure 5.5. The sequential images of WEDGE 02 during the test.

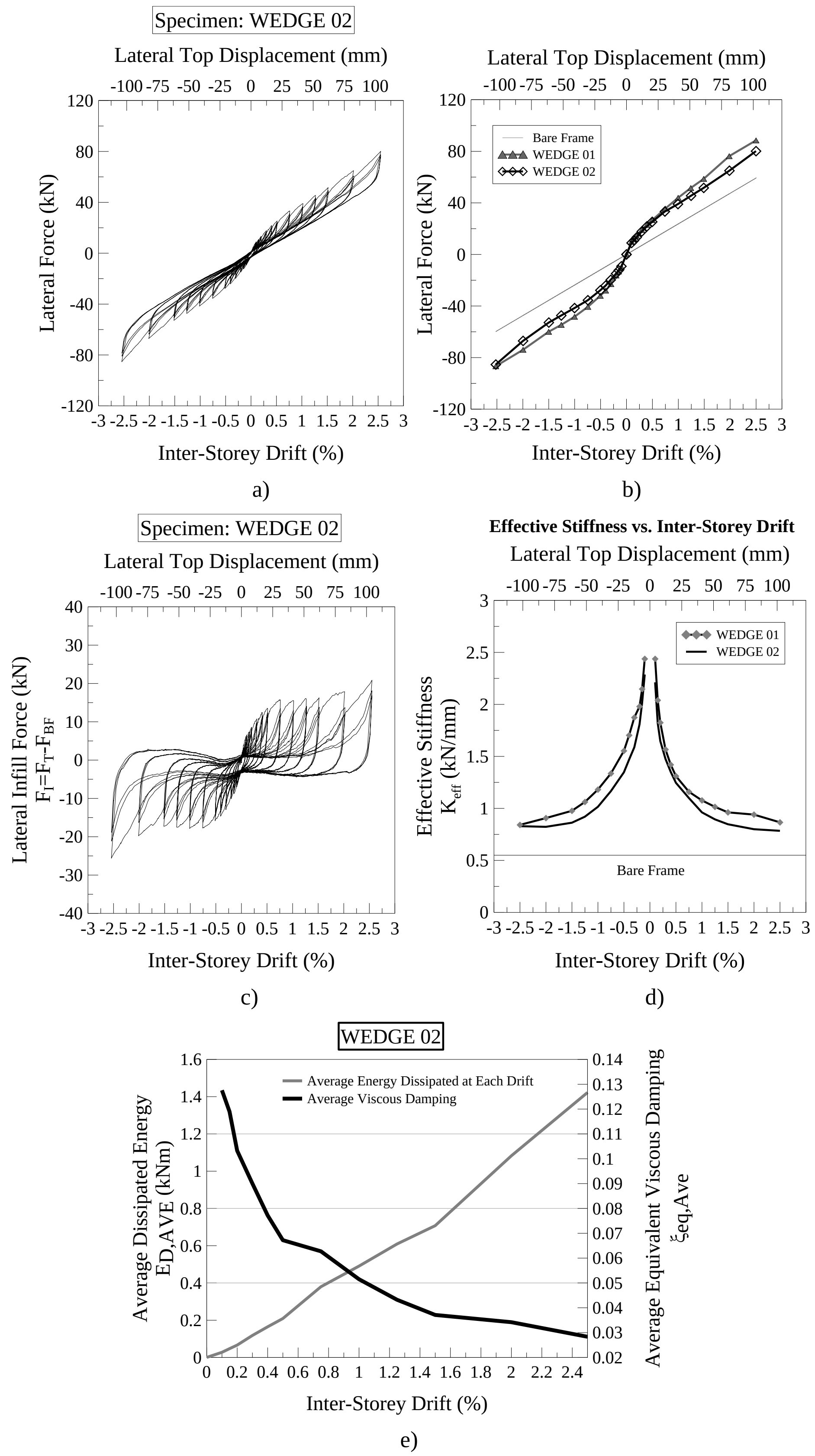


Figure 5.6. a) Total lateral force vs. inter-storey drift, b) Envelope curve for WEDGE 01 and WEDGE 02 compared to bare frame, c) Lateral force acting on the infill wall (WEDGE+Drywall composite), d) Total effective stiffness (Including bare frame stiffness of 0.55 kN/m), e) Dissipated energy and average equivalent viscous damping per drift level (WEDGE 01 and WEDGE 02 plotted together for comparison)

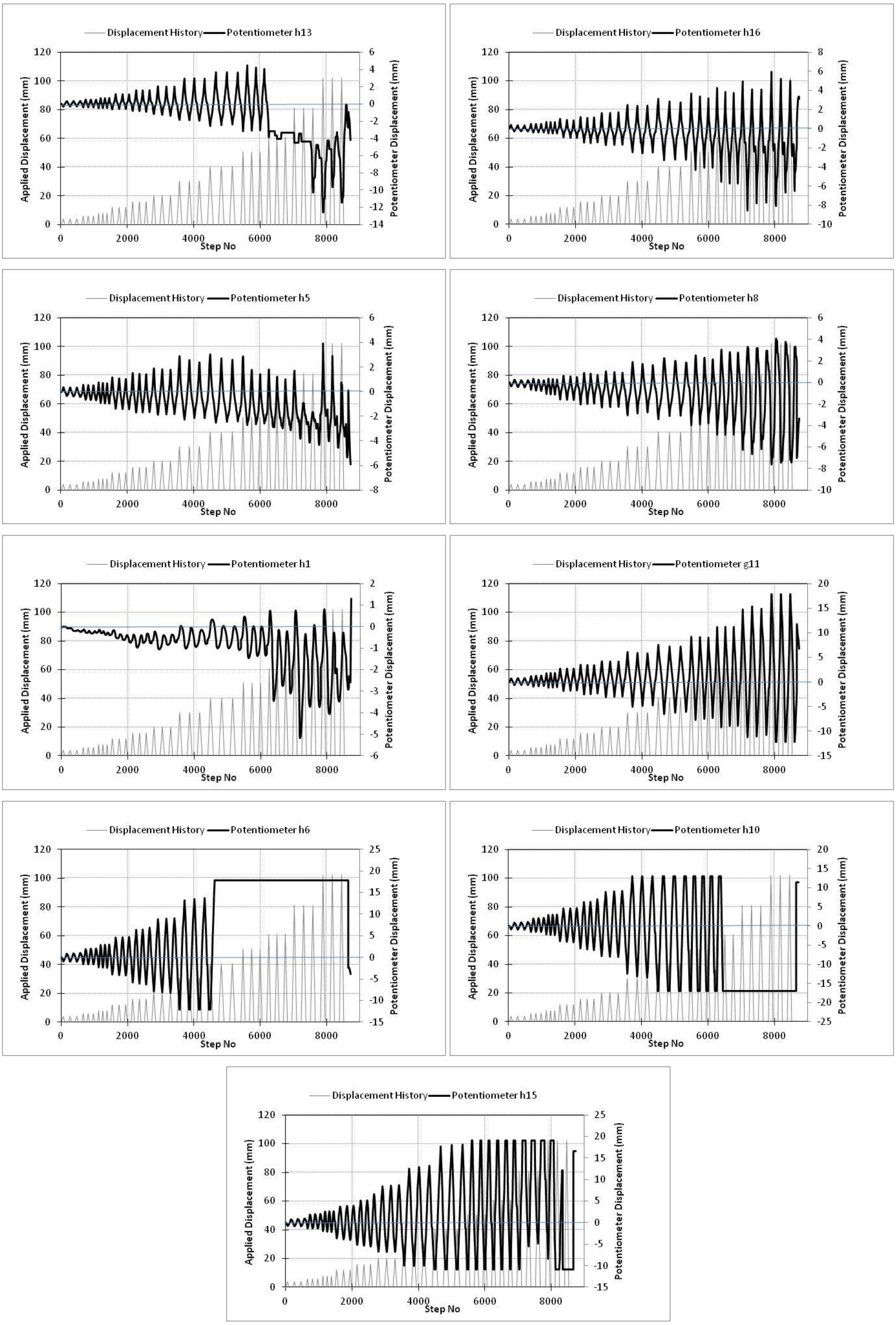


Figure 5.7. Potentiometer displacement readings at the borders of WEDGE 02 (For the location of the potentiometers, refer to Figure 5b) Note: Potentiometers can only read ±15 mm

6 COMMENTS AND CONCLUSIONS

Although the specimens showed no damage from the outside, both specimens had undergone severe deformations. Expectedly, during the tests some shearing of fasteners occurred in the WEDGE01 aluminium connection system, which was caused by the extreme rocking observed on the panels. However, this occurred due to the behaviour of the underlying steel framed drywall. In the WEDGE02 solution, where the aluminium element, was divided in two segments, no evident damage was observed until 2.5% drift.

It is worth reminding that 2-2.5% of drift is traditionally and internationally adopted as a code-design limit for the Ultimate Limit State (ULS) design (1/500 years event period for an IL2, Importance Level 2, or ordinary, structure).

Drywall systems typical of NZ (and international) practice, either based on steel framed or timber framed studs, would suffer damage at much earlier stages of interstorey drift as reported by the recent research carried out at University of Canterbury (Tasligedik et al., 2012) and shown schematically in Figure 6.1. As evident from Figure 6.1c and Figure 6.1d, the initiation of a vertical splitting crack would be expected to occur at a drift level as low as 0.2%-0.3% of drift. Due to the rapid development and widening of the cracking pattern, a severe level of damage, requiring substantial repairing if not full replacement of the boards, will be observed at about 0.5% drift if not less.

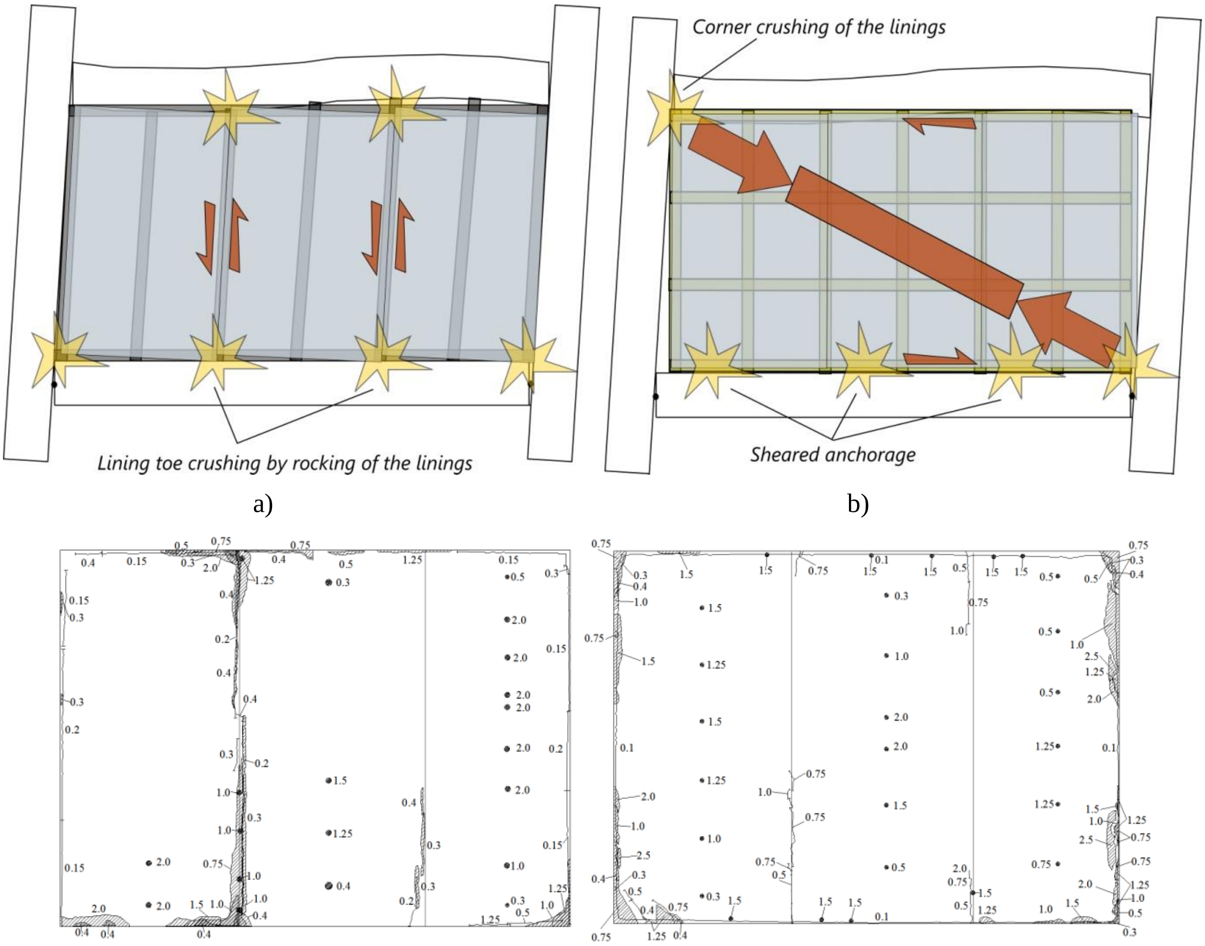


Figure 6.1. a) Behaviour of steel framed drywalls, b) Behaviour of timber framed drywalls, c) Damage map of steel framed drywall test (Tasligedik et al., 2012), d) Damage map of timber framed drywall test (Tasligedik et al., 2012), the values refer to the level of drift (%) at which the damage occurred at that point (the dots indicate damage to fasteners at that location)

Considering the rocking behaviour observed in the gypsum wall panels, it is advised to detail the horizontal aluminium members of the WEDGE systems to accommodate these deformations. Therefore, it can be recommended that these horizontal members should stay within each of the gypsum wallboard panel zone so that the rocking behaviour would not impose excessive demand on the WEDGE connection system and shearing of fasteners could be prevented (Referring to Figure 4.2a, it can be seen that the aluminium element crosses over the boundary between two adjacent gypsum wallboards, which creates demand on the fasteners used). Alternatively, if the WEDGE system is used on a timber framed drywall, it could be expected that this problem may be partly reduced. However, experimental evidences would be needed to confirm at what level of deformation the damage would start occurring. The shearing of fasteners is an important issue specific of steel framed drywalls. Also, some residual movement on the panels are also caused by the loosening of WEDGE connections. Should these be prevented, residual movements can also be reduced.

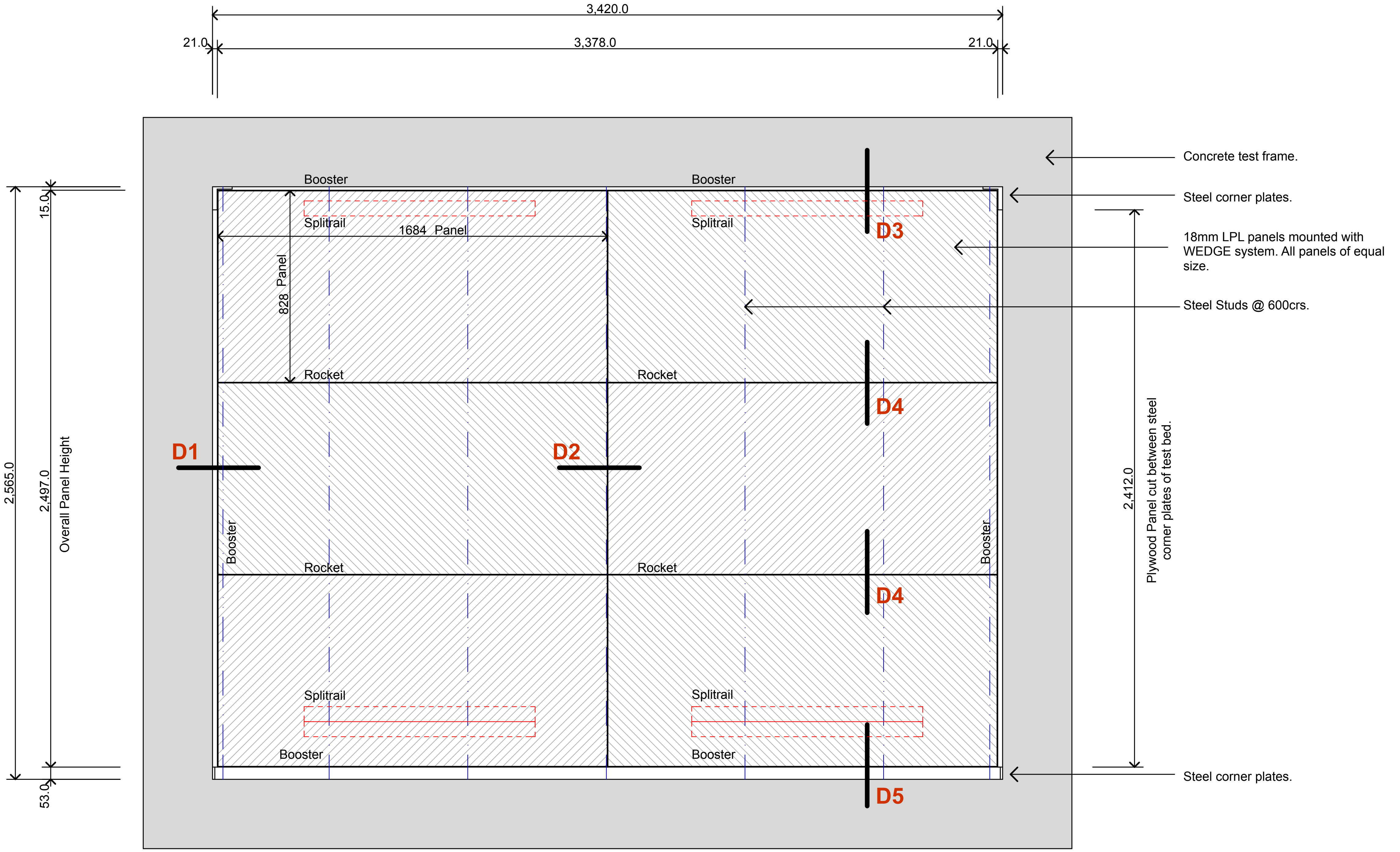
7 REFERENCES

ACI374.1-05. (2005). Acceptance Criteria for Moment Frames Based on Structural Testing and Commentary (Vol. 374.1-05): American Concrete Institute.

Pampanin, S., Palermo, A., & Marriott, D. (2010). *PRESSS Design Handbook*: NZ Concrete Society Inc.

Tasligedik, A. S., Pampanin, S., & Palermo, A. (2012). Damage States and Cyclic Behaviour of Drywalls Infilled Within RC Frames. *Bulletin of the New Zealand Society for Earthquake Engineering, 45*(2), 84-94.

8 APPENDIX A -– CONSTRUCTION DRAWINGS OF THE TEST SPECIMENS



STANDARD SYSTEM

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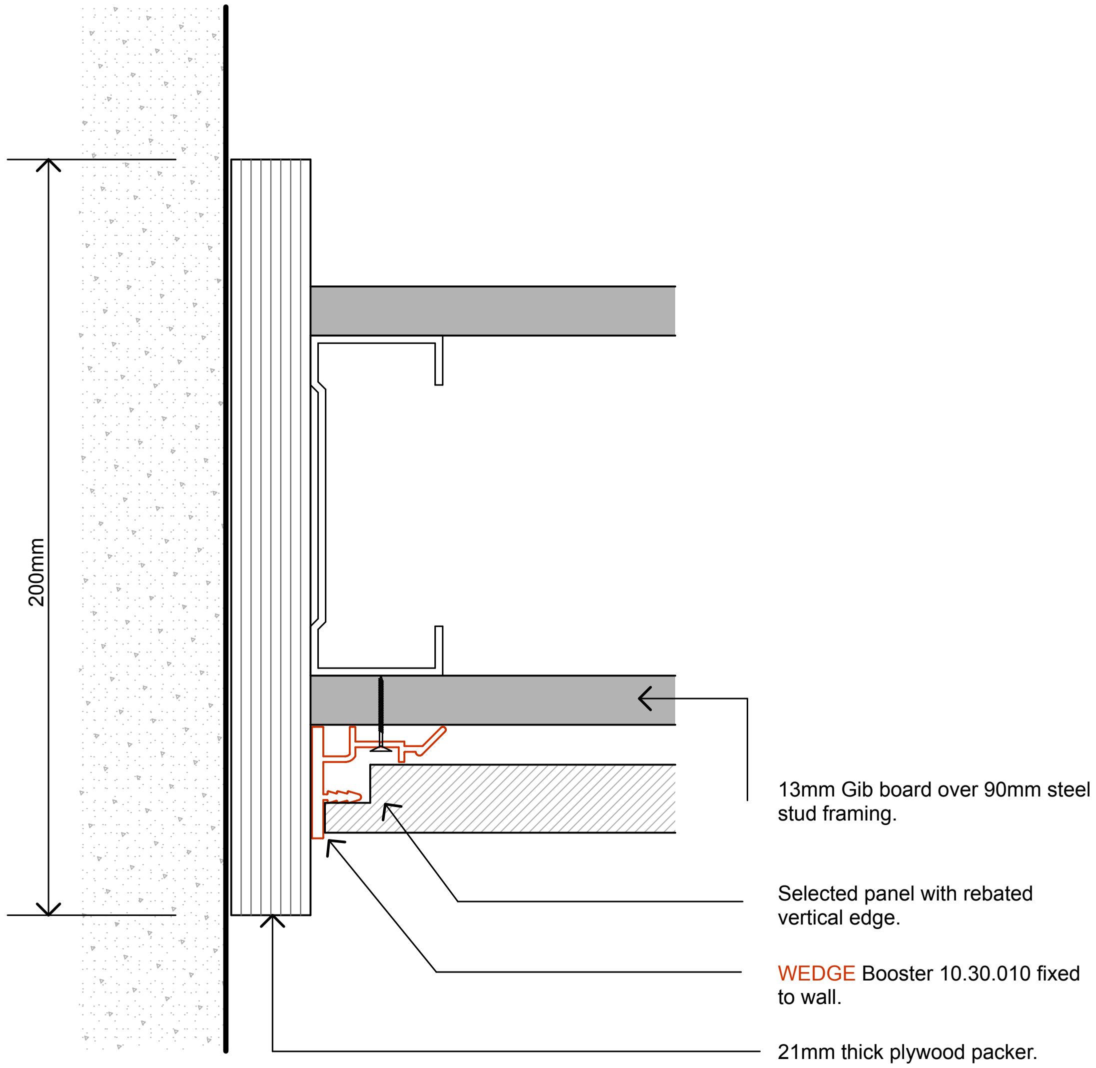
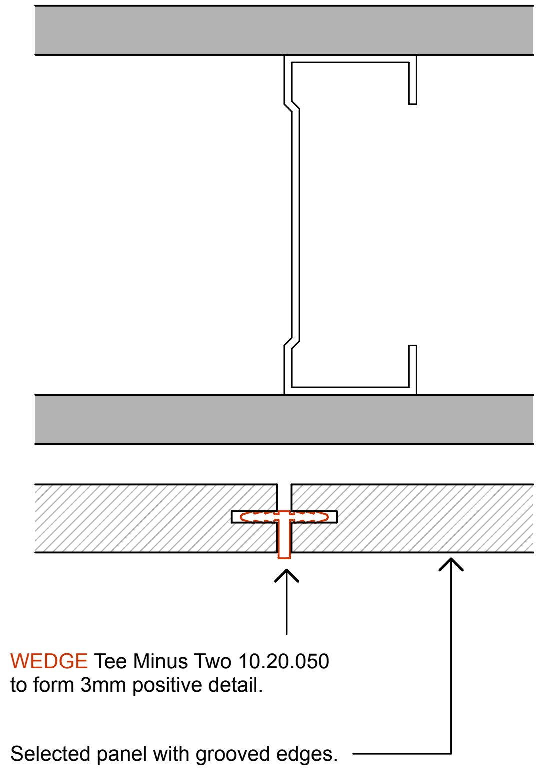
Refer also to the WEDGE Installation Manual for further information.

Standard Installation Elevation

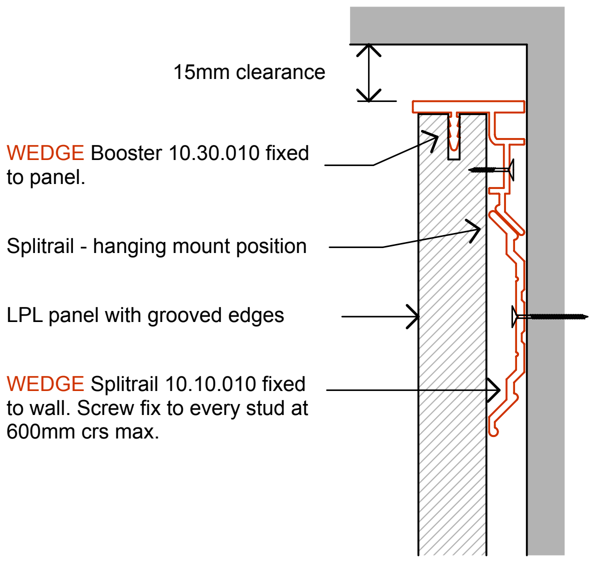
January 2013 01



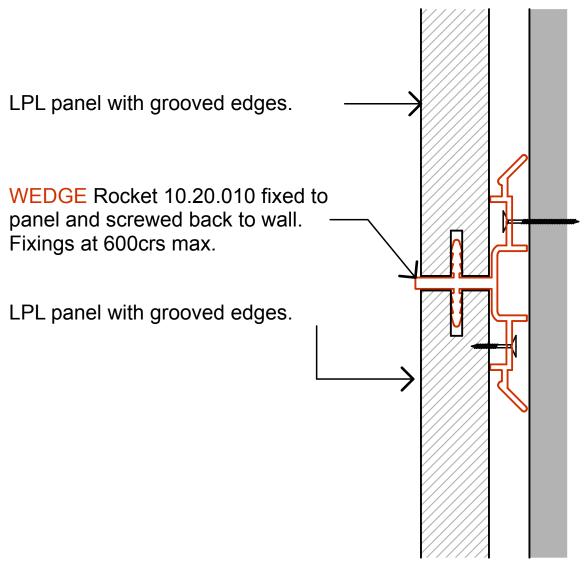
D1 VERTICAL EDGE DETAIL



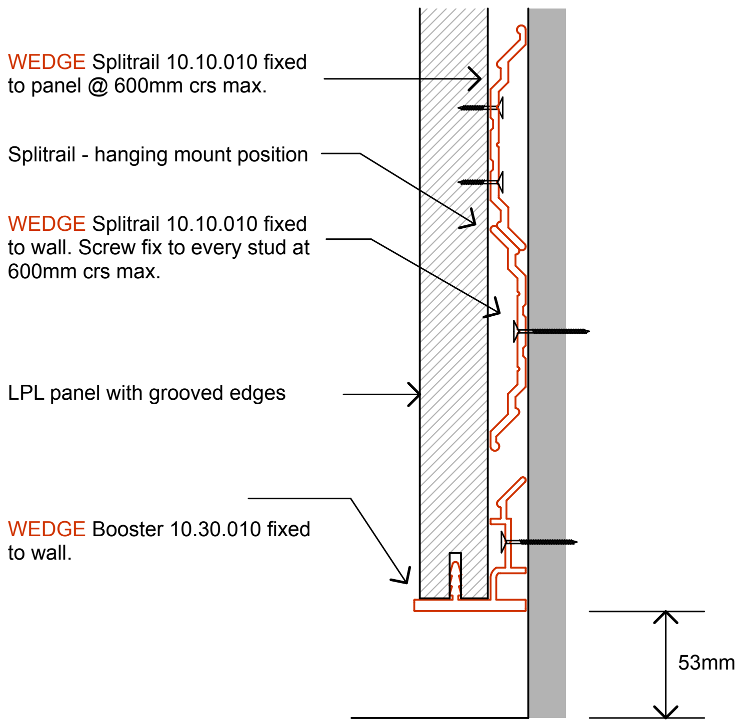
D2 TEE MINUS TWO - POSITIVE DETAIL



D3 BOOSTER - HANGING MOUNT



D4 ROCKET - STANDARD FIX



D5 BOOSTER - DIRECT FIX

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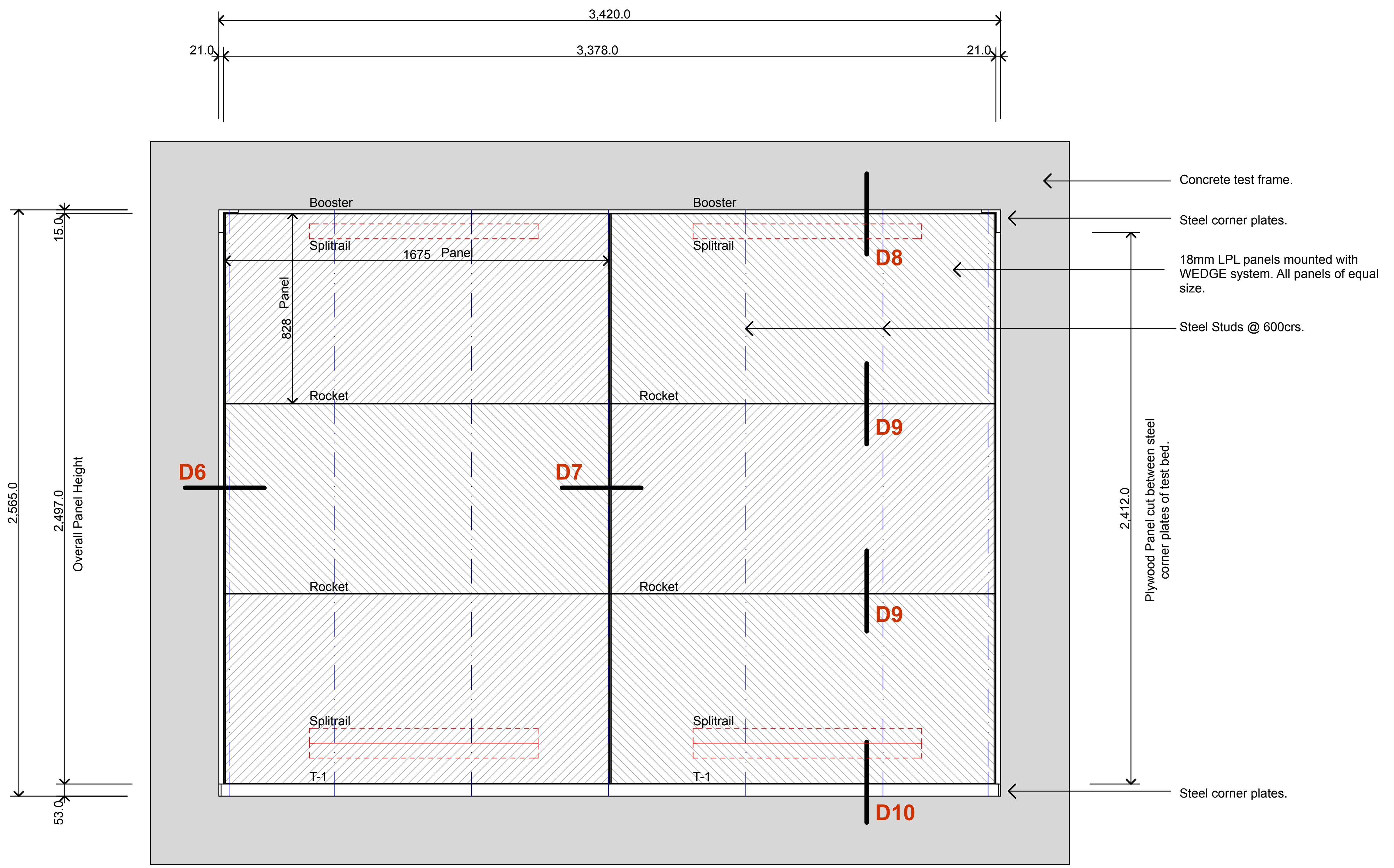
Standard Installation Details

January 2013 **02**



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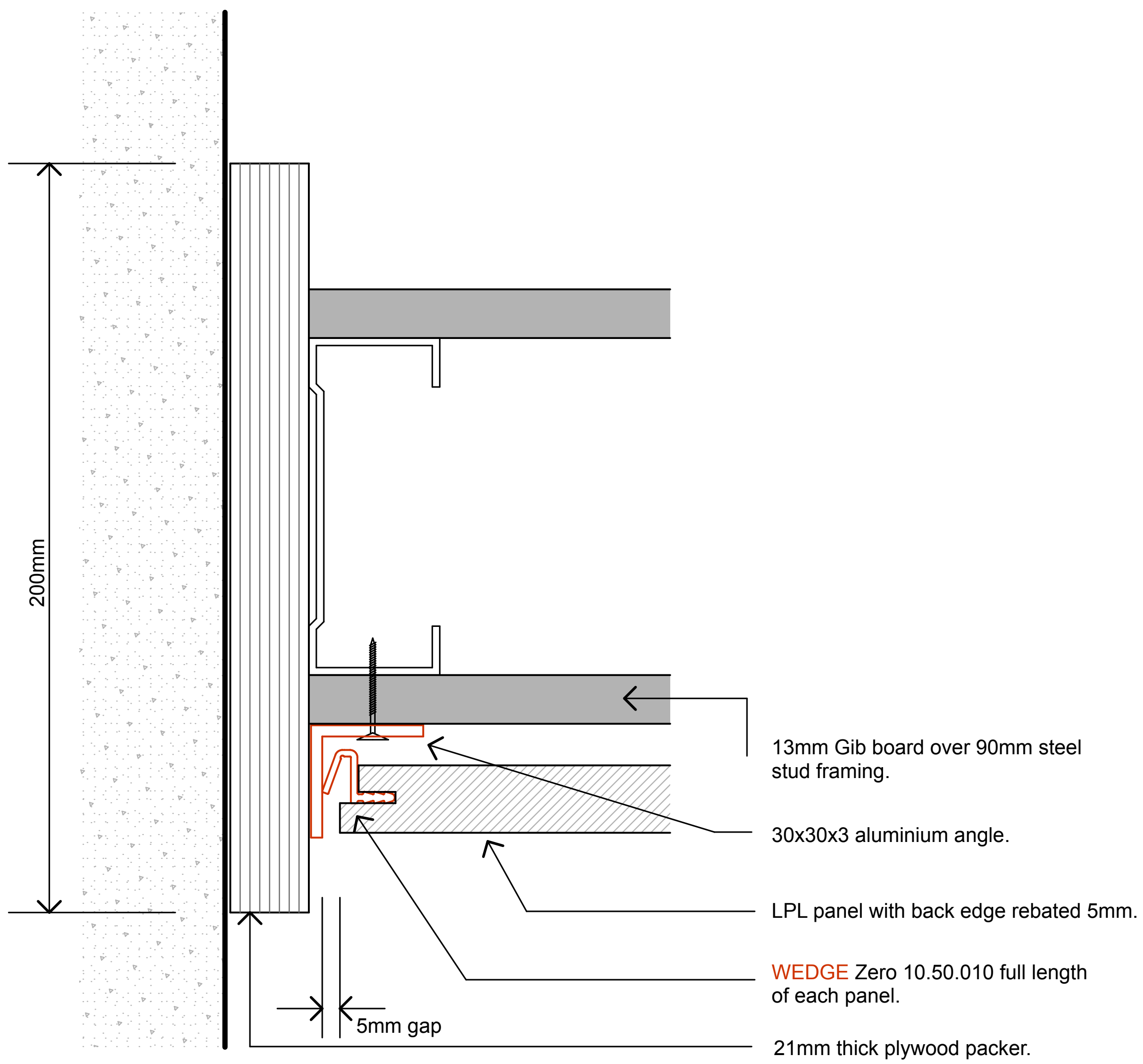
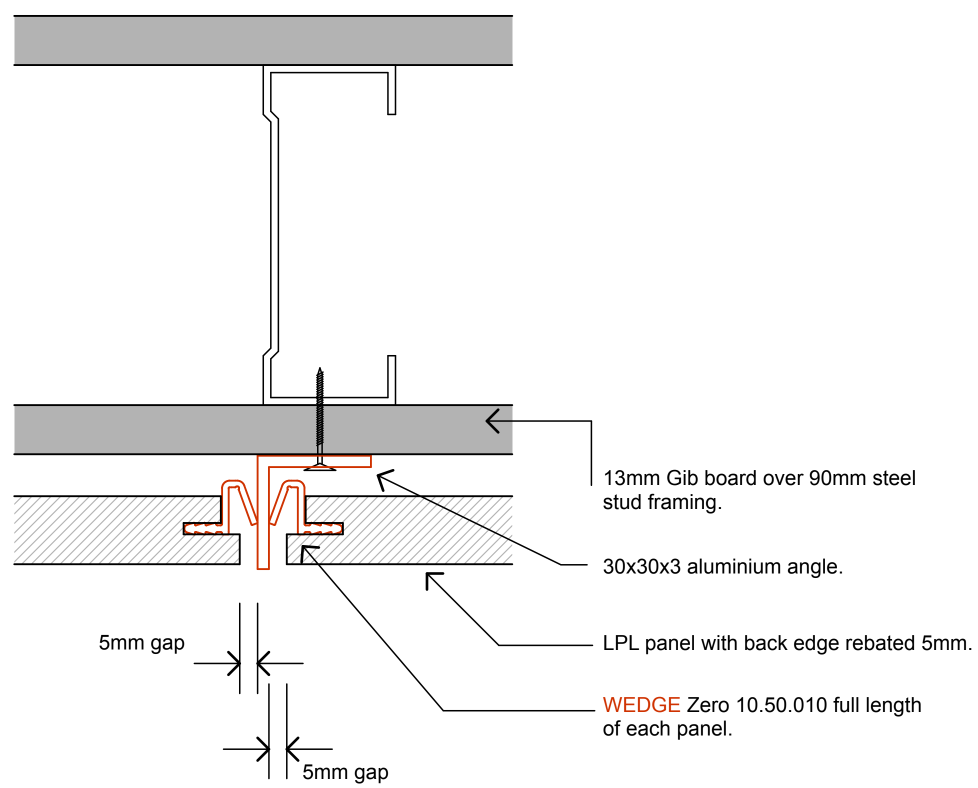
Seismic Installation Elevation

January 2013

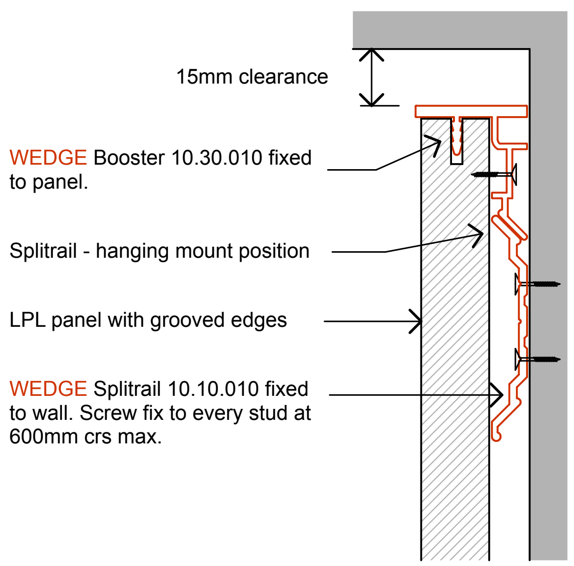
03



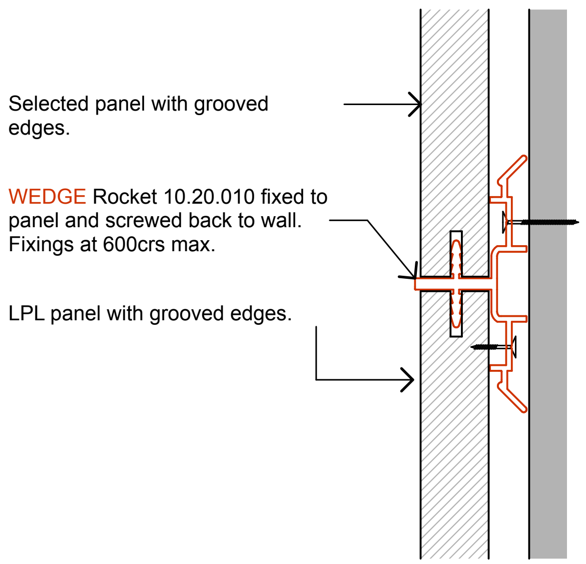
D6 VERTICAL EDGE DETAIL



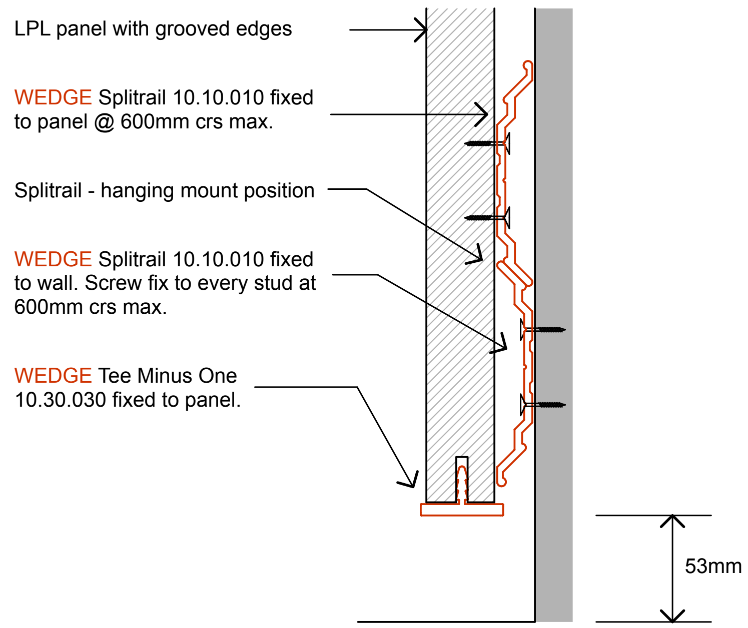
D7 VERTICAL JUNCTION DETAIL



D8 BOOSTER - HANGING MOUNT



D9 ROCKET - STANDARD FIX



D10 TEE MINUS ONE - HANGING MOUNT

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