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Furthering the Understanding of Seismic Resilience in the Ministry of Education Buildings

Wellington
18 November 2015

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aurecon


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Ministry of Education
Engineering Strategy Group

Structural and Geotechnical Guidelines for School Design

Version 1.1 for General Issue, June 2015

Endorsed by the Ministry of Business, Innovation & Employment

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Ministry of Education

DESIGNING SCHOOLS IN NEW ZEALAND
Requirements and Guidelines

Version 1.0, October 2015

Presentation Outline

- Nature and history of the school property portfolio
  - excludes integrated and independent schools
- Lessons from the Canterbury earthquakes
- Prioritising the structural assessment and upgrading of the school property portfolio
- The role and key activities of the Ministry's Engineering Strategy Group
- Evaluating the Resilience of Timber Framed Buildings
- Structural & Geotechnical Guidelines
- Design Review Panel
- More BRANZ Testing

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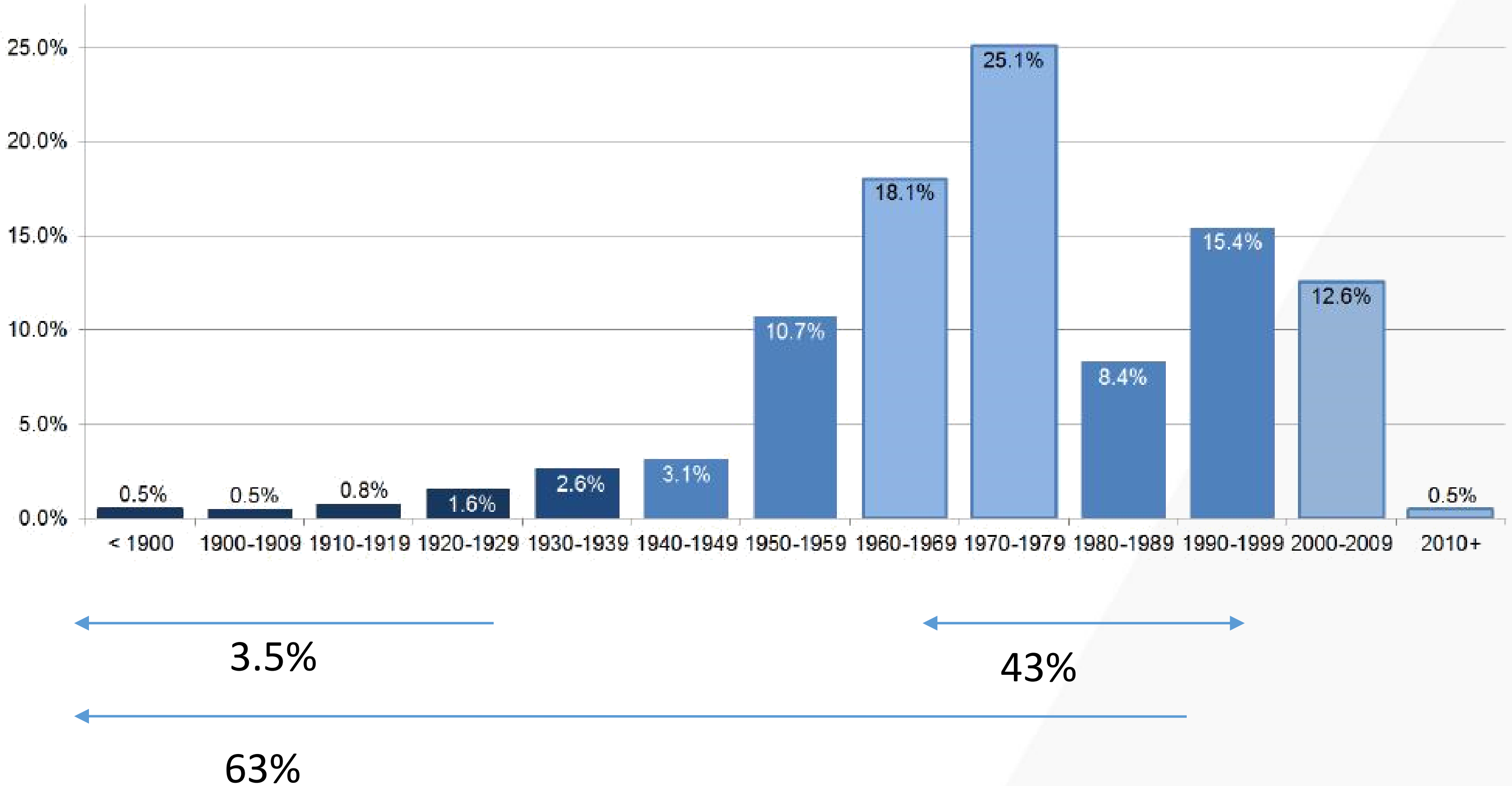
Nature and History of the School Property Portfolio

School Buildings

- 2400 Schools (Approx)
- 30,000 School Buildings (Approx)

- Priority 1A buildings – 29
- Priority 1B buildings – 244
- Priority 2 buildings – 1,526

Age of School Buildings



New Zealand has a long history of strengthening in schools

- As the standards for new buildings have increased, the Ministry of Education has progressively surveyed and strengthened schools
- The focus has been on unreinforced masonry and multi-storey buildings

Avalon Block

Front (fully glazed)

Back: High-level glazed (or “clerestory”) section

Dominion Block

Front (fully glazed)

Front

Formula Block

Front


Back

Nelson Two Storey Block

Full Nelson two storey ("H" block)

Half Nelson two storey ("T" block)

Canterbury Block

CEBUS Block

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Lessons from the Canterbury Earthquake

What have we learnt from the Canterbury Earthquakes?

Strengthened school buildings performed better than similar buildings of the same age

Lessons from the Canterbury Earthquakes - Types of Damage

Most school damage was due to land issues:

- Rockfall
- Cracks and fissures
- Subsidence and liquefaction
- Flooding

Light timber framed school buildings performed well

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Lessons from the Canterbury Earthquakes - Assessment Methods

- Assessment tools available for rapid type inspections were not adequate
- Responding to need for urgency across NZ schools
  - Post earthquake evaluation
  - Basic Screening Tool
  - Need for expert advice - **Engineering Strategy Group**
  - Review of design levels
- Usefulness of existing tools
  - Suitability of existing assessment tools for typical NZ school building
  - Need for targeted school property assessment tools

Key Message Overview

- Only a small proportion of the Ministry's building stock are earthquake prone
- The focus: *integrating the treatment of earthquake risk with asset management processes*
- Making yes / no and timing decisions on any strengthening required that tie in with decisions on the future utilisation of the building
- Acknowledging the many other factors at play in addition to seismic risk

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Priorities on assessments and upgrading the property portfolio

Assessing the Property Portfolio

- Assessment prioritisation framework
  - Focusing on risk
- Specific tools for assessment of school buildings
  - lightweight timber framed building assessment - is it needed?
- Destructive testing – gathering evidence
- Identified Earthquake Prone Buildings
  - to isolate or not to isolate
  - Boards of Trustees concerns around liability
  - emphasis on safety
  - role of the expert

Approaches to Structural Upgrades

- Goals for school buildings in NZ
  - short term 34% NBS
  - medium-term 67% NBS
- Is %NBS a useful measure?
- Establishment of an earthquake resilience team to address priority school buildings
- Developing standardised structural upgrade solutions
  - more difficult than anticipated due to modifications over time
- Most will be part of normal asset lifecycle upgrades
- Heritage building upgrade decisions remain problematic due to cost

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The Ministry's Engineering Strategy Group

The Ministry's Engineering Strategy Group (ESG)

Focus is on providing technical leadership for the Ministry's work relating to structural assessment and strengthening of school buildings

- Advising on issues relating to earthquake and building matters
- Seeking alignment between policies and technical processes
- Facilitating effective communications between the Ministry and other agencies and practitioners
- Production of design standards
- Trouble shooting

ESG's Activity Focus

- Aligning the Ministry's approach to Building Importance Levels with the Building Code
- Providing better guidance for engineers assessing light timber framed school buildings
- Supporting the panel of engineers undertaking Detailed Seismic Assessments throughout New Zealand
- Supporting the Design Review Panel (DRP)

ESG Assessment Prioritisation Recommendations

First Priority

1. Buildings constructed from URM
2. Buildings of two or more storeys of heavier construction

Second Priority

3. Single storey large area open floor area buildings (e.g.. libraries, assembly halls, gymnasia)

Third Priority

- One and two storey light timber framed classroom and admin blocks (***active assessment not required***)

Updating the 2006 NZSEE Guidelines


New Zealand Society
for Earthquake
Engineering

Assessment and Improvement
of the Structural Performance
of Buildings in Earthquakes

Prioritisation
Initial Evaluation
Detailed Assessment
Improvement Measures

Recommendations fo a NZSEE Study Group on
Earthquake Risk Buildings
June 2006
Including Corrigenda Nºs 1 & 2

<School Name>

Block X - <building name>

Initial Seismic Assessment

<Insert a good overview picture of the building/structure here if available>

<INSTRUCTIONS ON USING THIS TEMPLATE>

<All yellow highlighted text needs to be checked and overwritten as required.>

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<Complete the header on this page and the header & footer on page 2. Then ensure this has flowed through the rest of the document (including page numbers up to the start of "Section 8 Appendices". Note the appendices themselves do not have page numbers). You will need to update the footer on the Appendix A cover page also>

Revision 0

<Date>

Prepared By: <Consultant Name>

For the Ministry of Education

Earthquake Resilience Programme

ISA Templates

Executive Summary

This building report provides the results of an Initial Seismic Assessment completed for the following building by the Ministry of Education's Engineering Panel. The report provides an initial assessment of the building's %NBS seismic capacity, highlights the key seismic risks and presents recommendations. The table below presents a summary of the assessment findings.

School	<School name>
Block No (PMIS).	<PMIS block number or number off site plan>
Block Name/Description	<e.g. Main Hall or Admin block>
Known Standard Design	<e.g. CANTY, CEBUS, etc. or non-standard>
Storeys:	<1>
Year of Design (approx.)	<e.g. 1965 approx.>
Gross Floor Area (m^2)	<242>
Construction Type	<e.g. timber frame, gib lined with brick veneer cladding>
Assessment Type	Initial
Date Building Inspected	<date of actual inspection of building e.g. 20 November 2013>
Importance Level	<IL2>
Structural Assessment Summary	<e.g. An equivalent static analysis was undertaken of the building and demands on primary lateral load resisting elements were approximated to assist with determining estimated %NBS for components of the building. >
Current %NBS estimate	<45% NBS>
List specific CSWs and life safety hazards	<None or list specific CSWs/life safety hazards>
Occupancy Status	<Fit to Occupy>
Conclusions & Recommendations	< e.g. The building has an estimated seismic capacity of 45%NBS. It is recommended that the building is strengthened to at least 67%NBS in accordance with current NZSEE guidelines. Further detailed design will need to be undertaken to develop an optimum strengthening solution. It is recommended that the finalised strengthening design is implemented when other capital work is undertaken on this building.>
Rough Order of Cost for recommended strengthening	< $20,000> <add additional commentary here only if required.>

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Evaluating the Resilience of Timber Framed Buildings

Guidance for Evaluating Light Timber Frame Buildings

- Parameters for *qualitative* methods (e.g. IEP)
  - Including a more realistic overall ductility factor to reflect the added damping and redundancy that typically exists
- Highlighting the (few) vulnerabilities that could lead to sudden collapse
  - E.g. heavy roofs and floors coupled with significantly inadequate bracing walls
- Approaches for *quantitative* methods
  - Grouped by era (pre-NZS3604; 1978-1990; post-1990)
  - Linked back to NZS3604 bracing ratings
  - Provides additional information to the 2006 NZSEE Guidelines

Destructive Testing

Destructive Testing

Destructive Testing

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Avalon Block - Assessed Structural Capacity and Test Results

	Calculated Capacities		Estimated Actual Capacity	Actual Strength Achieved	Indicative Factor (Ratio of Actual/ Probable)
	Probable Strength Capacity	Overstrength Capacity			
Longitudinal Direction (two-classroom block)	27 kN	43 kN	65 – 130 kN	185 kN	6.8
Transverse Direction (individual internal wall)	9 kN	11 kN	17 kN - 34 kN	35 kN	3.9

Dominion Block - Assessed Structural Capacity and Test Results

	Calculated Capacities		Estimated Actual Capacity	Actual Strength Achieved	Indicative Factor (Ratio of Actual/ Probable)
	Probable Strength Capacity	Overstrength Capacity			
Longitudinal Direction (two-classroom block)	25 kN	38 kN	55 – 112 kN	200 kN	8.0
Transverse Direction (single classroom)	51 kN	102 kN	152 - 303 kN	125 kN	2.5

Nelson Block Framing Review

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Comparison between IEPs & Detailed Seismic Assessments (%NBS)

(1) Based on Z=0.4, IL=2, Soil Class C, located in Wellington

Block Type	MoE Guidelines, Qualitative (IEP) Sp=0.7 μ=2.5	NZSEE Nov 2013, Qualitative (IEP) Sp=0.5 μ=2.0	MoE Guidelines, Quantitative (DSA) Sp=0.7 μ=2.5	MoE Quantitative (DSA) Sp=0.5 (as per NZSEE) μ=2.5	MoE Quantitative (DSA) Sp=0.35 μ=2.5
Avalon	36%	51%	38%	53%	76%
Dominion	36%	51%	34%	48%	68%
Formula	49%	68%	74%	>100%	>100%
Nelson 2 Storey – T Block	36%	51%	33%/74%	46%/>100%	65%/>100%
Nelson 2 Storey – H Block (IL3)[1]	29%	41%	25%/57%	35%/80%	50%/>100%
Nelson Library	79%	>100%	76%	>100%	>100%
Nelson Single Storey	36%	51%	33%	46%	66%
Canterbury	36%	51%	29%	41%	58%
CEBUS[2]	>100%	>100%	49%	49%	49%
S68 Block (IL3)[3]	53%	53%	75%	75%	75%

1 – Nelson Two Storey (H Block) has an Importance Level of 3 due to its occupancy.
2 – CEBUS Blocks are not influenced by Carterton results due to their expected failure mode (foundation/pile failure).
3 – S68 Blocks are not influenced by Carterton results due to their construction type (reinforced concrete block).

Enhancing the Resilience of Timber-framed School Buildings

- Resilience enhancements should be included as part of modernisation projects
  - Whether or not building is at or above 67%NBS (i.e. assessment not required)
  - E.g. Re-lining with seismically-rated plasterboard, including the associated floor and ceiling connections
- Specific advice for standard blocks is currently being prepared

Reference designs for standard block ILE upgrade – Avalon, Formula, and Canterbury

Boiler Houses

- A number of boiler houses are being investigated, particularly those with chimneys
- Southland Chimney Replacement Project
- Earthquake reports for Christchurch boiler houses
- Up to 70 former Canterbury Education Board boiler houses possibly affected

Masonry Veneer

- An amount of veneer cladding detached from timber framed buildings during the Canterbury earthquake sequence
- Fortunately no one was injured at schools
- Some school blocks have been isolated due to concern about occupant or bystander safety
- Pilot study undertaken
- Investigation procedures standardised

Plan irregularity ✓

Potential life-safety hazard ☒

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Guidance for Evaluating Light Timber Frame Buildings

Parameters for qualitative methods (e.g. IEP)

- Including a more realistic overall ductility factor to reflect the added damping and redundancy that typically exists

Highlighting the (few) vulnerabilities that could lead to sudden collapse

- E.g. heavy roofs and floors coupled with significantly inadequate bracing walls

Approaches for quantitative methods

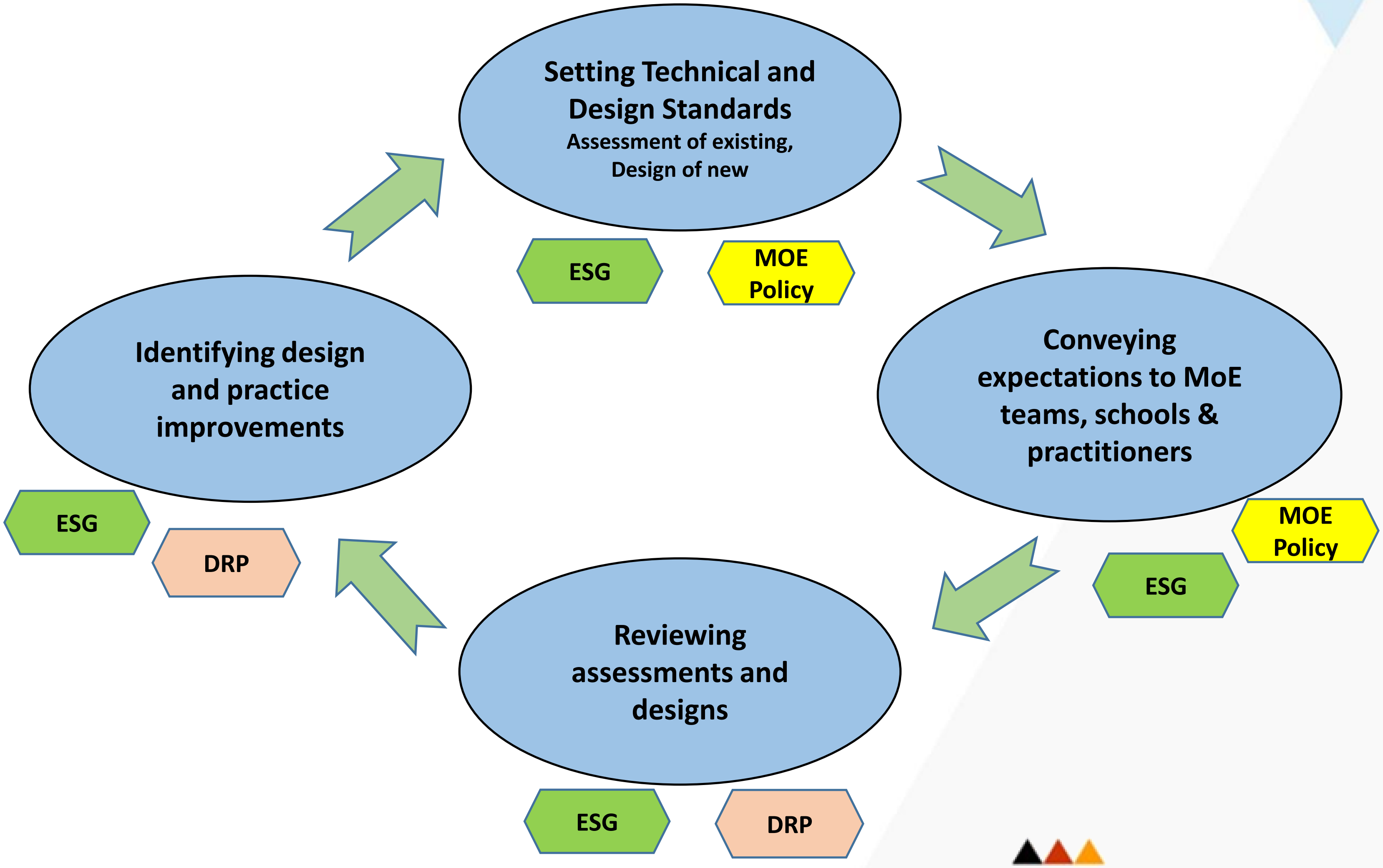
- Grouped by era (pre-NZS3604; 1978-1990; post-1990)
- Linked back to NZS3604 bracing ratings
- Provides additional information to the 2006 NZSEE Guidelines

The Opportunities: Taking a Portfolio Approach

- Viewing the issue of earthquake risk through the eyes of a large property portfolio owner is instructive
- Integrating the treatment of earthquake risk with asset management processes
  - Making yes/ no and timing decisions on strengthening that tie in with decisions on the future utilisation of the building
  - Acknowledging the many other factors at play in addition to seismic risk

Overview of the *Structural and Geotechnical Guidelines*

The Continuum of Technical Standards, Design and Practice



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Introducing the SGG and Design Guidance

Purpose

- Provide guidance for engineers and designers to deliver cost-effective school buildings that meet MoE's expectations for usability, capital cost, future maintenance obligations and anticipated repairs

- Helping design teams understand MoE's business and asset management drivers
- Making the requirements for design projects clear

Audience

- Engineers, architects and project managers (and MoE)

Why the SGG and Design Guidance?

What needs to change?

Improving the understanding of

- The Ministry's business and asset management drivers
- What good design in schools looks like

Increased consideration of

- Whole-of-life costing of building systems
- Design features that add unnecessary cost

Better packaged project documentation

- What is known (and not known) about sites
- The overall design philosophy and performance expectations

Key Features of the Structural and Geotechnical Guidelines

- Stating the Ministry's requirements that are above (or different to) the requirements of the Building Code
- Settlement tolerant foundation design approach
- Seismic design load levels to promote building usability following earthquake
- Emphasising project documentation requirements and communicating design/operational criteria and assumptions
- Endorsed and supported by MBIE

Format of the SGG

1. **Introduction**
   - Design principles
2. **Ministry Design Requirements**
   - The mandatory requirements of the Ministry that all projects must comply with (from 1 July 2015)
3. **Engineering Design Guidance**
   - The key engineering design principles that should be considered from the Master Planning stage

Design Guidance Document Suite

1. Designing Schools in New Zealand – Requirements and Guidelines
2. Project Brief Template
3. Design Compliance Checklist
4. Feed back lessons

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Project Documentation

- Project and Site Constraints Table
  - From the earliest state of project, e.g. Master Planning
- CIC (Construction Industry Council) guidelines, with some changes (refer ‘Designing Schools in NZ – Requirements and Guidelines’)
- Note Master Planning not in CIC – refer project-specific briefs and Ministry guidance
- Design Features Report required for all projects
  - Listing of general requirements provided
  - Emphasise presentation of structural concepts, not simply a list of Standards used *i.e. “tell the story”*

Design Compliance Checklist (DCC)

- Design stages: Master Plan, Preliminary Design, Detailed Design
- Specify whether “Mandatory” or “Guideline” for each item
- Current status: Final editing before being issued for trial. Version 1.0 to be issued in November.
- DCC will become part of formal MOE sign-off process
- Projects going to the Design Review Panel will need to get DCC sign-off first

Project Brief

- Project Brief template recently released for national use (draws heavily on the CSR Project Brief that was already operational). Should be used for most MOE projects
- There are two parts:
  - *Education Brief*: prepared by board of trustees. It sets out the school's vision for teaching/learning and how that translates into physical spaces to support the pedagogy.
  - *Property Brief*: prepared by MOE. It sets out key property related parameters/ constraints associated with the site
- Specific Project Brief should be prepared for individual project. *Property Brief* takes precedence over *Education Brief* should any contradiction occur between the two

Project and Site Constraints Table

- Version 1.0 was included in SGG.
- Version 2.0 was released on 1 October 2015 as a standalone document.
- Should be used from the earliest project stage and updated throughout projects to capture risks and constraints.

Project and Site Constraints Table

Project name: XX school   Design Stage: **[Master Planning]**   Version No. and Date: **[V.2, 1 October 2015]**

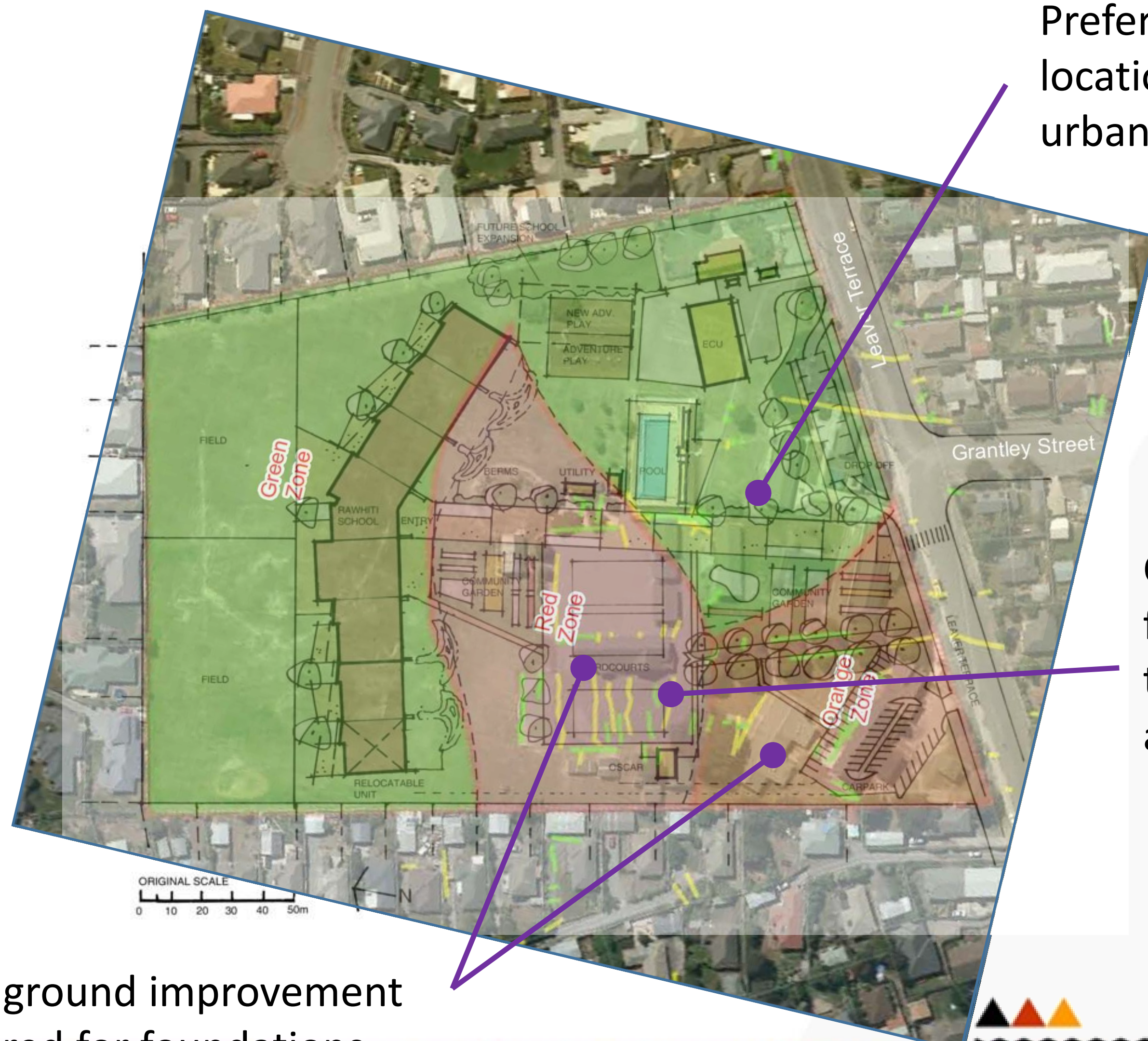
Purpose: for the Ministry's project lead and the design team to outline (and communicate) key physical and other (e.g. cultural, financial, amenity) project constraints/opportunities and confirm how these have been, or are to be, addressed. The completed table should "tell a story" by succinctly communicating what the key site issues/constraints/opportunities are and how these have influenced the design solution.

This information will form the basis for the Design Features Report (or similar) that will ultimately document the decisions made along the way to arriving at the final built form. Identifying the "magnitude" of the issues (i.e. the level of potential consequence and/or the risk level) will help to ensure people reviewing and signing-off at various design stages have confidence that the key site issues have been identified and addressed, or will be addressed in subsequent development stages.

It is not expected that all or detailed information is provided in each cell at the initial project stage – but the initial versions should reflect all known information.

Constraints	Commence this section (blue) at initial project stage and develop through onward design stages	
	Insert details of hazard or event (without treatment) List title, agency and date of relevant report(s)	**Proposed treatment(s) or strategies to address issues/constraints).** Briefly list other options considered that may have been discarded (will help demonstrate robustness of treatment strategy). Enter N/A if not applicable; outline any future investigations planned.
A. Geotechnical		
1. Geotechnical model/zoning evaluation?	Refer to geotechnical model demonstrating opportunities and constraints. Key points summarised here.	
2. Liquefiable ground?	e.g. if on liquefiable ground –SLS/ULS	

Site Master Planning Case Study: Rawhiti Primary



Preferred location wrt urban presence

Considerable future damage to services anticipated

Significant ground improvement likely required for foundations

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Importance Levels and SLS2

Seismic Design Load Levels: Building Importance Levels for School Buildings

- In Dec 2014, the policy for *new buildings* was revised to match current Building Code requirements, namely:
  - Buildings within primary school, secondary school, or daycare facilities with a capacity greater than 250 are to be IL3; others are IL2
- BUT - Added SLS2 requirement for specific types to:
  - reduce damage in moderate to severe earthquakes
  - increase likelihood of schools remaining operational (community resilience)
- This requirement applies to new buildings *of more than one storey and heavy structures* (concrete suspended floors and/or concrete and concrete masonry walls) irrespective of Importance Level

Return Periods for Seismic Design of School Buildings

Building Use	SLS1	SLS2	ULS
Small (< $30m^2$) ancillary buildings that are not usually occupied (IL1)	1 in 25	n/a	1 in 100
Offices and classrooms of lightweight construction, with less than 250 students in block (IL2)	1 in 25	n/a	1 in 500
Offices and classrooms of lightweight construction, with 250 or more occupants (IL3)	1 in 25	n/a	1 in 1000
All buildings of more than one suspended level and single storey classrooms of heavy construction, with less than 250 students in block (IL2)	1 in 25	**1 in 100**	1 in 500
All buildings of more than one suspended level and single storey classrooms of heavy construction, with 250 or more occupants (IL3)	1 in 25	**1 in 250**	1 in 1000

Seismic Design Load Levels: SLS2 in Practice

Tolerable damage for SLS2 includes

- settlement and structural damage within readily repairable limits
- reduced mechanical and electrical function, provided that all building warrant of fitness elements remain operational or a work-around is feasible
- minor loss of function of other non-structural elements that do not impact on safety.

Non-structural Systems

The most important determining factor for operability

Must be considered at design

- Cladding – keep it light, particularly in high seismic zones ($Z \geq 0.3$)
- Partitions – limit overall movement of the building (drift), or separate from the structure
- Ceilings – secure and brace, separate from services
- Services – independent restraint and/or tolerant of movement
- Glazing – allowances for building movement

Settlement Tolerant Foundations

Settlement-tolerant Foundations

- **Context**: concerns over ‘default’ deep foundation solutions for school buildings – not cost-effective
- **Reality**: MoE is a building owner that can tolerate <u>some</u> imperfect structural performance across their portfolio
  - e.g. repairable settlement
- **Solution**:
  - Now a <u>mandatory</u> requirement to assess shallow foundation options for <u>all</u> sites
  - Encouragement to consider differential settlements greater than ’25mm over 6m’

Settlement-tolerant Foundations (2)

Requires specific consideration of:

- potential settlement
- impact on superstructure
- re-levelling and repair methodology
- time frames involved

May involve collaboration with Ministry (as owner) on some projects to determine acceptable levels of performance

Settlement-tolerant Foundations (3)

Sample criteria

- *Any differential settlement does not prevent the continued use of the building*

- *Re-levelling of the foundation and floor and associated repairs can be carried out with non-specialist equipment, techniques or materials without unduly interrupting the normal operation of the building.*

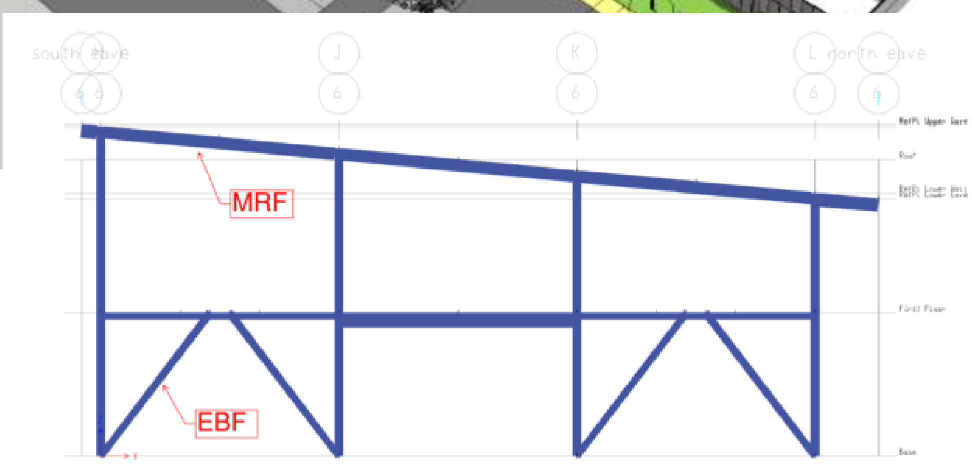
- *Any building repairs can be undertaken during school holiday periods or weekends. Disabled access must be maintained*

Design Review Panel

Design Review Panel

1. The DRP has been established to provide a level of quality assurance and consistency of approach to school design
2. It provides independent high level ‘snap shot’ reviews at key design stages that typically include:
   a) Master planning
   b) Preliminary design
   c) Developed design

Rototuna



Tarawera

The recommended depth of ground improvement is 1.5m.

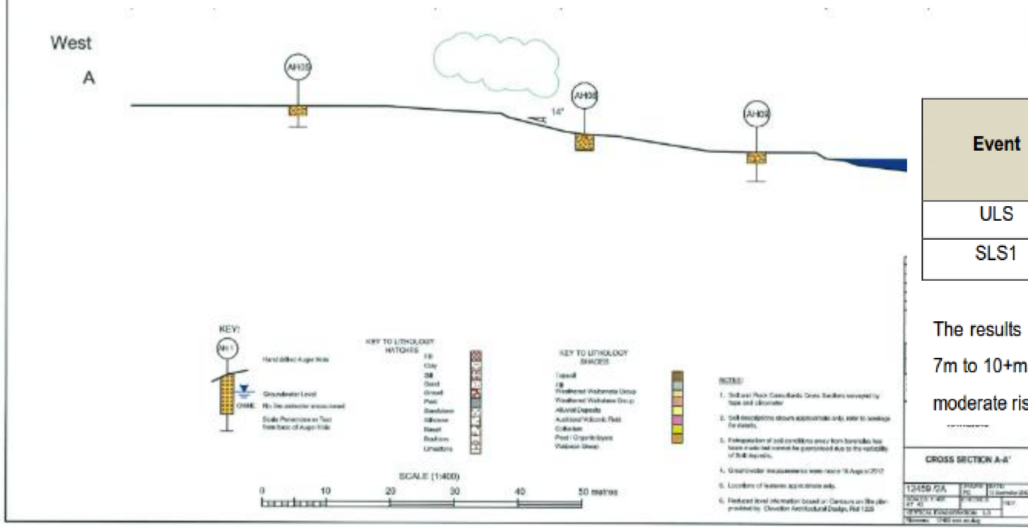
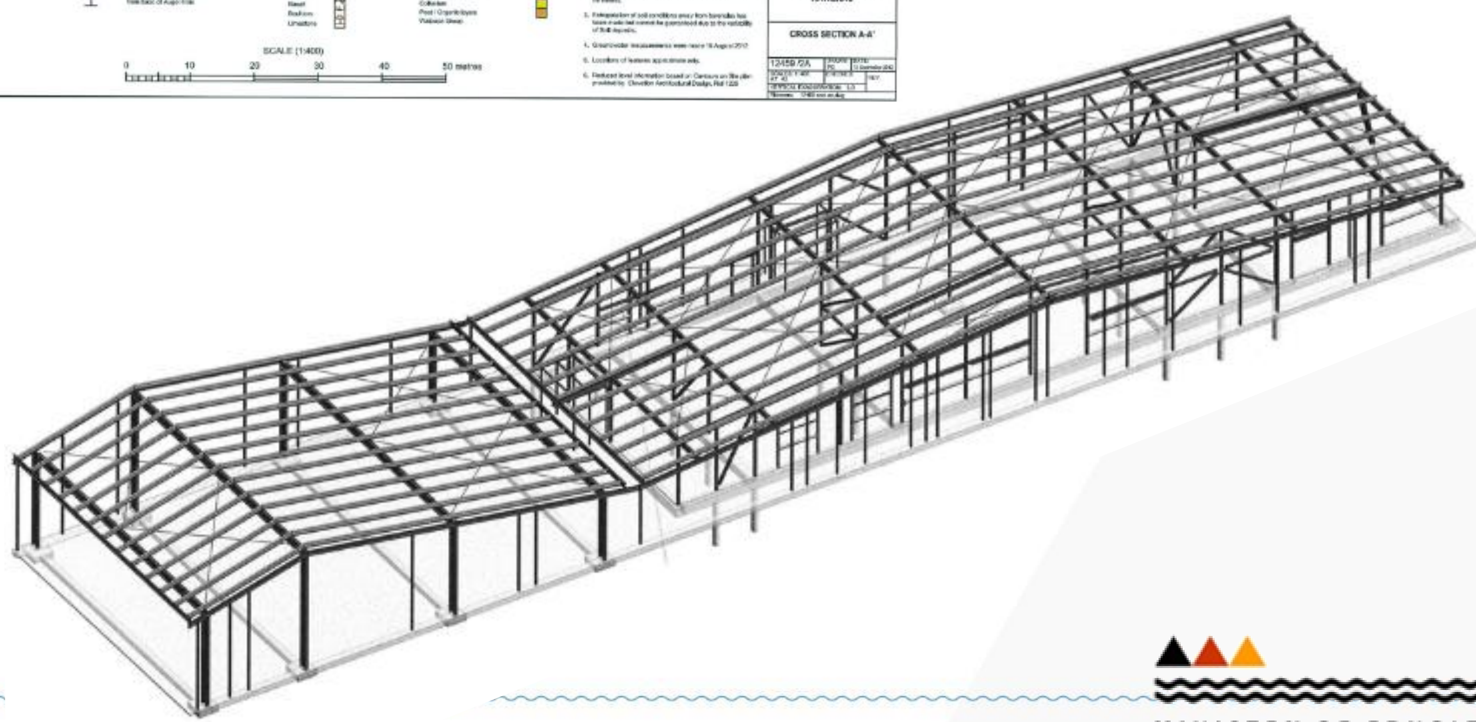


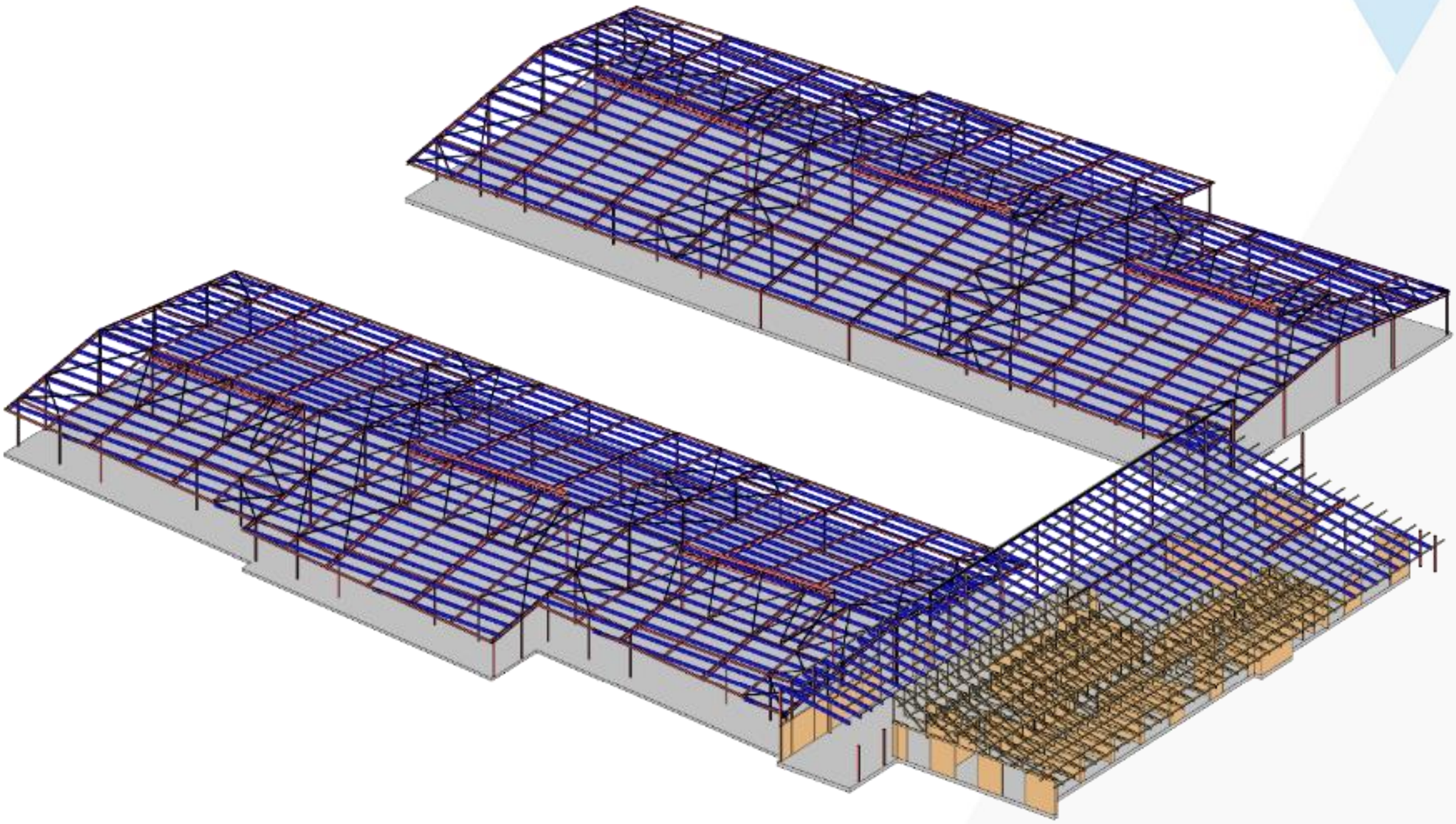
Table 3: Liquefaction Analysis Results

Event	Peak Ground Acceleration (g)	Earthquake Magnitude (M_L)	Liquefaction Induced Settlement (mm)
ULS	0.5	7.5	81 – 257
SLS1	0.1	7.5	0 – 69

The results obtained from our analysis indicated that the soil layers that are highly susceptible to liquefaction are from 7m to 10+m during an ULS event at the tested CPT locations. Based on our assessment we consider that the site is at moderate risk of liquefaction during an earthquake with a magnitude in the order of 7.5.



Waitakiri Primary



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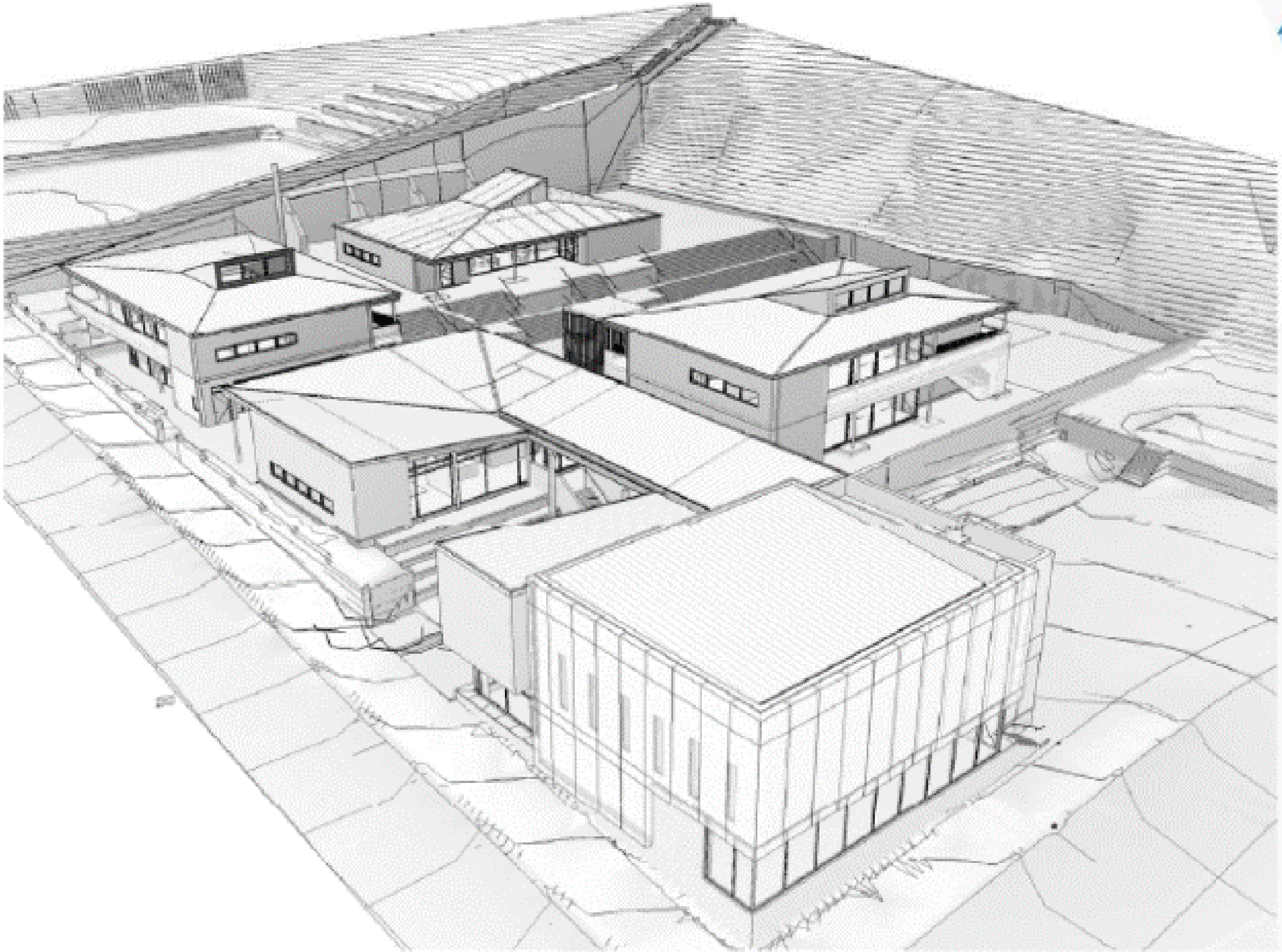
Shotover Primary

Lyttelton Primary



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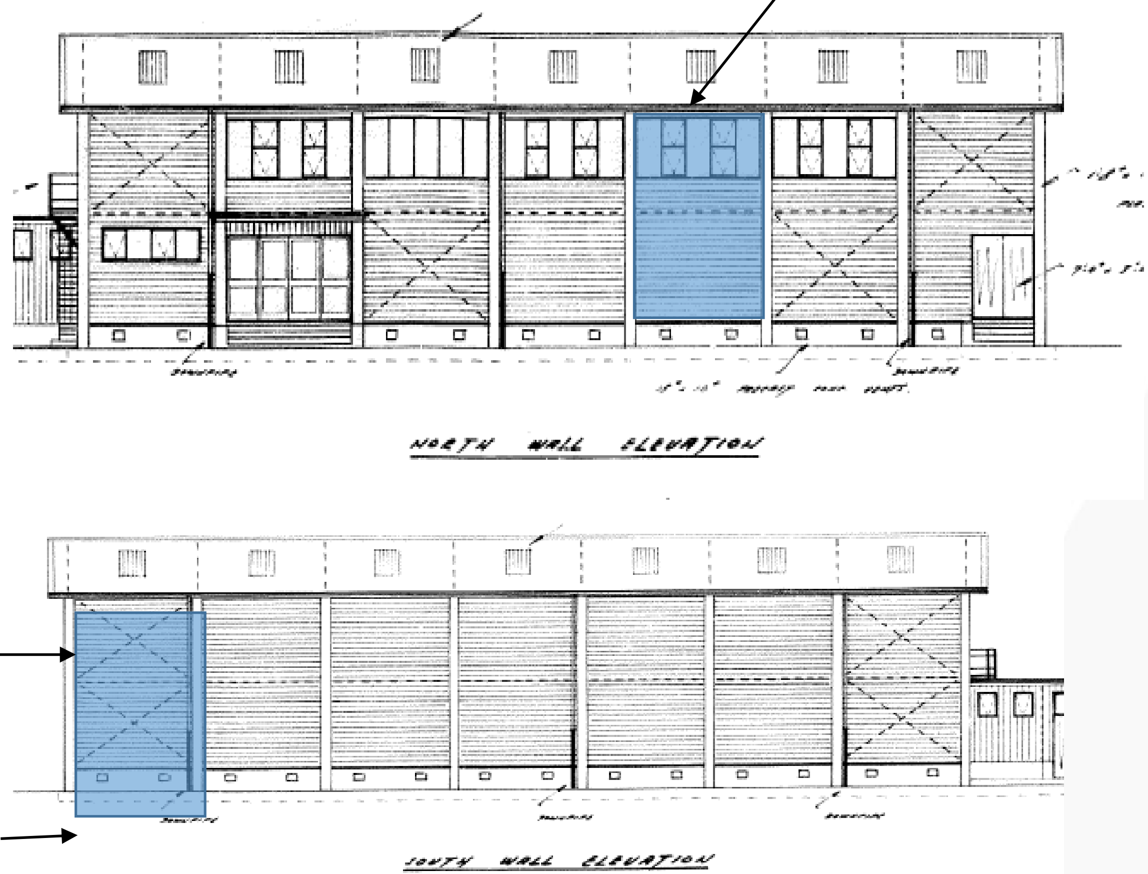
Results from recent BRANZ testing of low-rise structures

(Testing co-funded by MBIE & MoE)

Naenae College - Exterior Gymnasium Wall Elevations (Steel Bracing shown as dotted lines)

Replicated in tests



Replicated in tests

Concrete foundation wall

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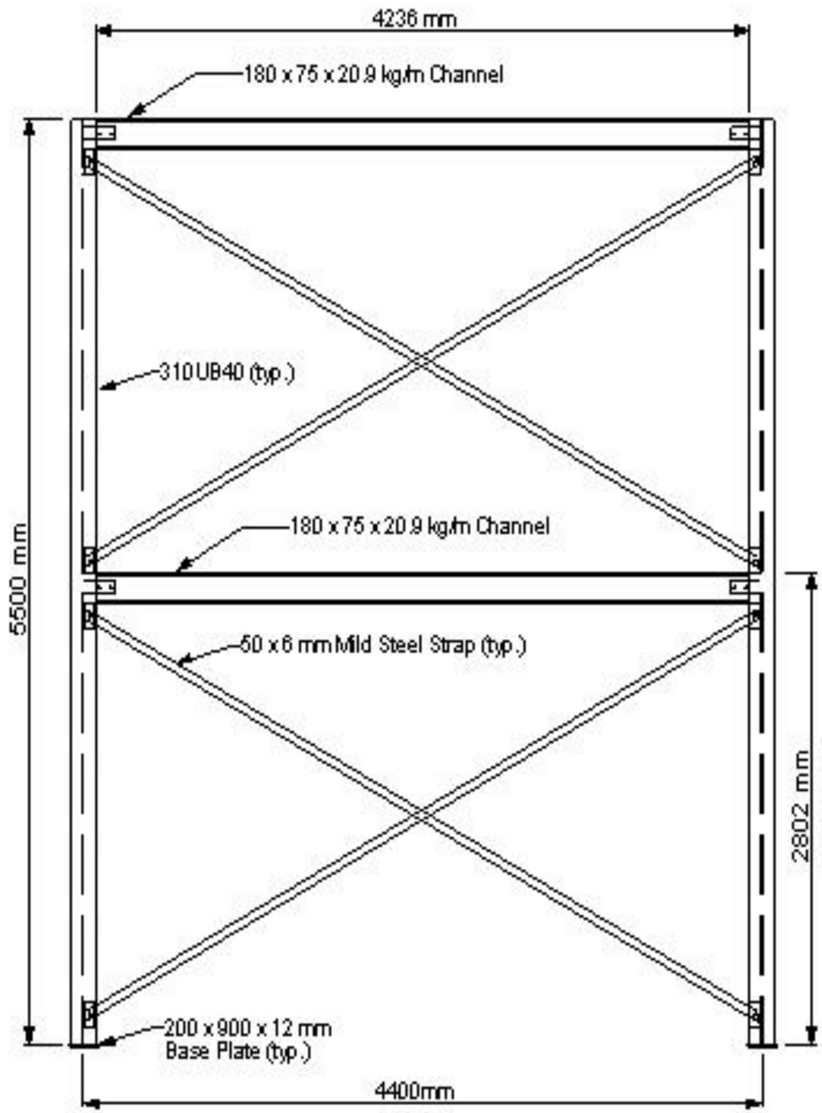
Wall Configuration Tests

Test	Description
A1	Steel frame with steel cross braces – ends bolted with a single grade 4.6 M12 bolt
A2	Steel frame with steel cross braces – ends bolted with a single grade 8.8 M12 bolt
A3	Steel frame with steel cross braces – ends welded to lugs with 6 mm fillet welds (150 mm length)
B	Interior linings (12mm particleboard and 4.75mm hardboard) with original nailing
C	Interior linings with new nailing
D	Weatherboard exterior cladding only (Rusticated – one nail per stud)
E	Interior linings (original nailing) and weatherboard with window near top
F	Interior linings (new nailing) and weatherboard with window near top
G	Steel columns and beams and timber frame only (no steel cross bracing, linings or weatherboard cladding)

Steel Components of Wall Test Specimen and Overall Dimensions



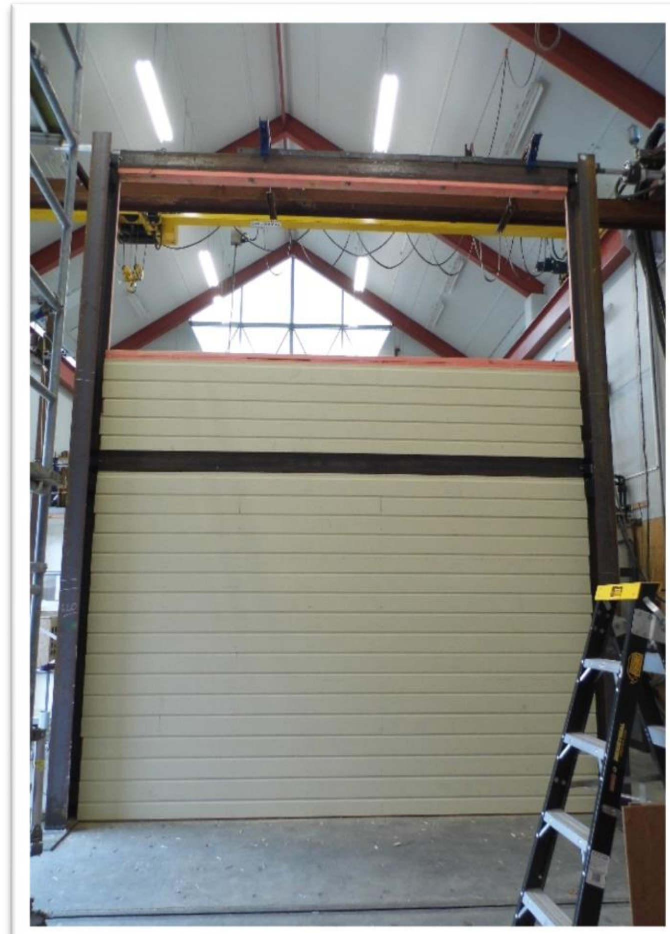
In reality:

- portal legs extended down into concrete foundation
- Portal legs concrete encased

Testing therefore conservative

Test Configuration E

Particle Board on the Interior (Left) and Rusticated Weatherboard on the Exterior (Right)



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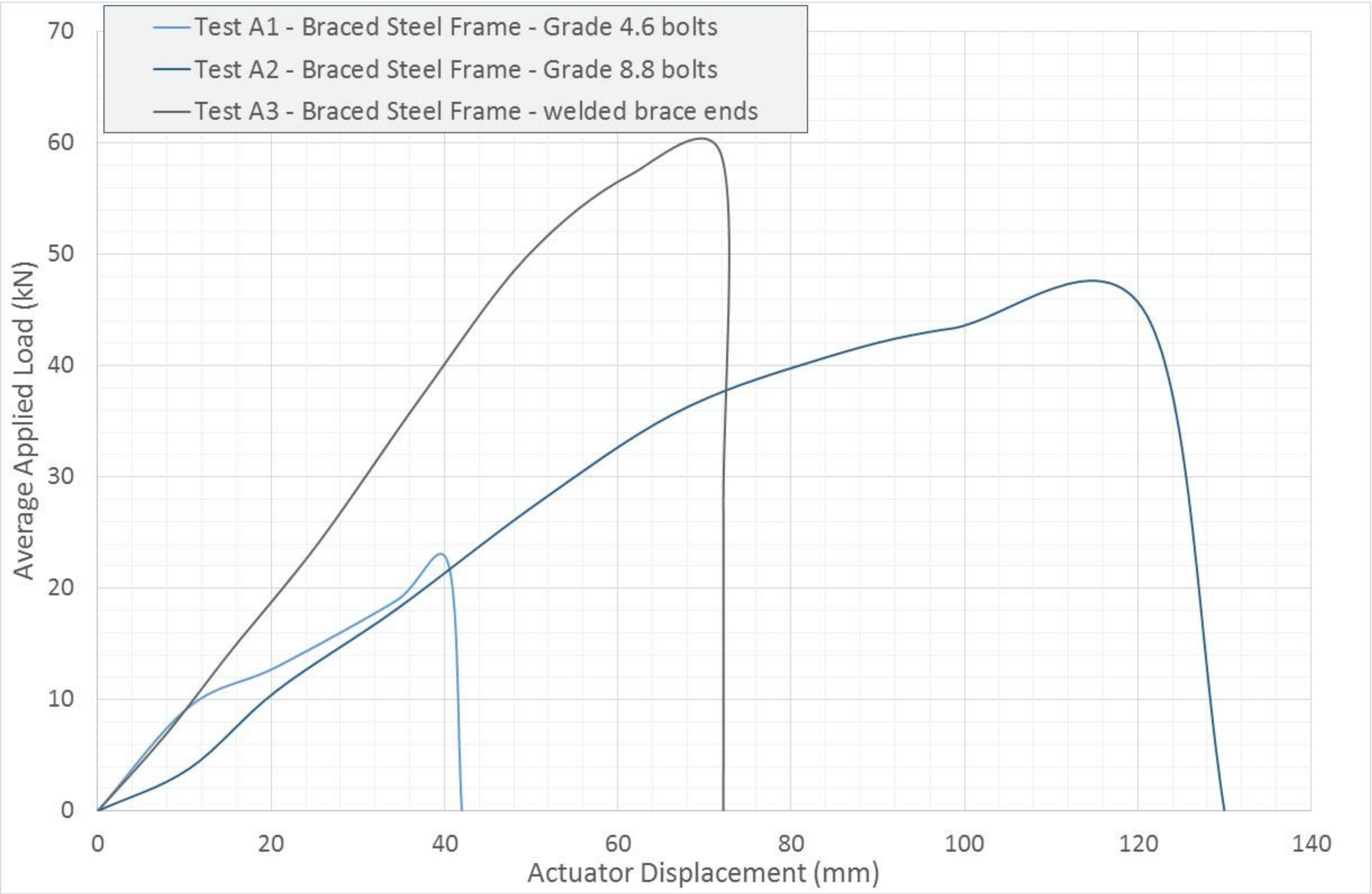
Average Backbone Curves for Tests, A1, A2 and A3



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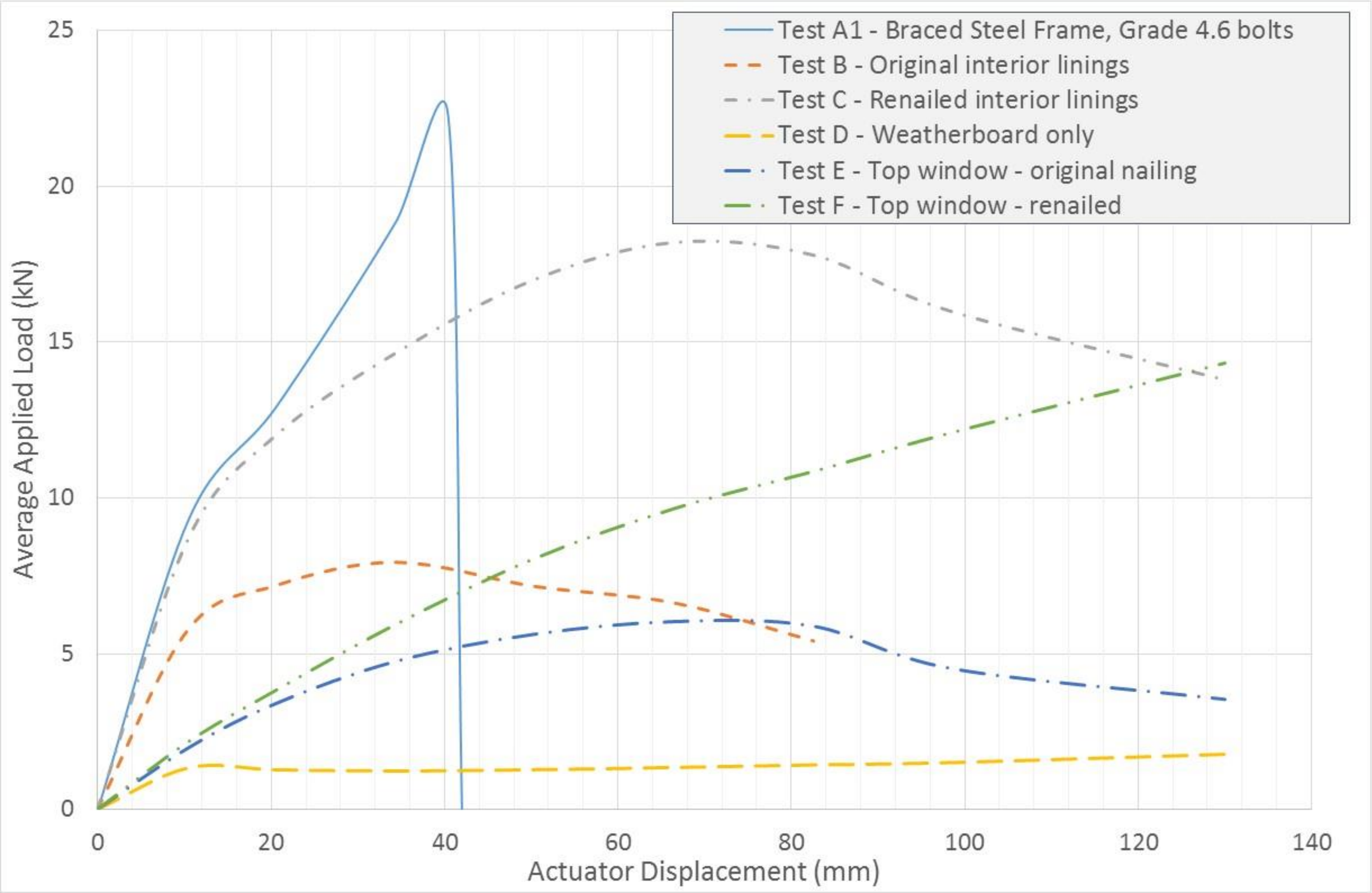
Adjusted Average Backbone Curves with Steel Frame and Timber Frame Contributions Subtracted (Tests A1, B to F)



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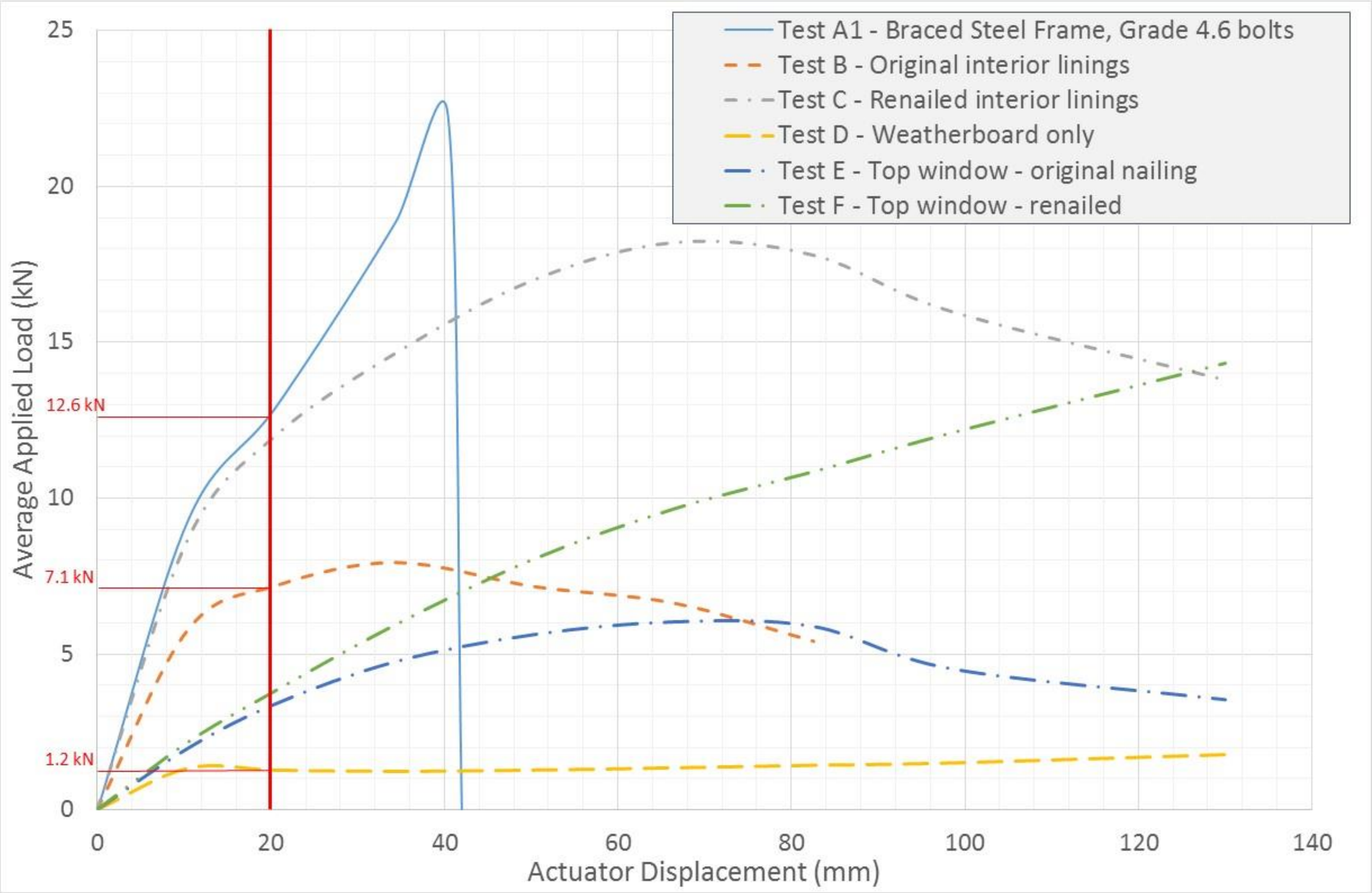
Suggested Use of Data

- This series of tests has provided load-deflection behaviour for a range of bracing systems that would be expected to be encountered on school gymnasium side walls
- It is suggested that engineers assessing the capacity of a school gymnasium side wall can aggregate these responses as required at any particular displacement
- As an example, consider the south wall of the gymnasium at Naenae College

Load Levels at 20 mm Displacement for Test A1, Test B and Test D



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South Wall Capacities (continued)

Element	Resistance per bay	Number of bays	Resistance provided
Steel bracing (Test A1)	12.6 kN/bay	2	25.2 kN
Interior lining (Test B)	7.1 kN/bay	7	49.7 kN
Weatherboards (Test D)	1.2 kN/bay	7	8.4 kN
Total			**83.3 kN**
Original capacity based on 12mm grade 4.6 bolt			**25.2 kN**
Significant increase in capacity			

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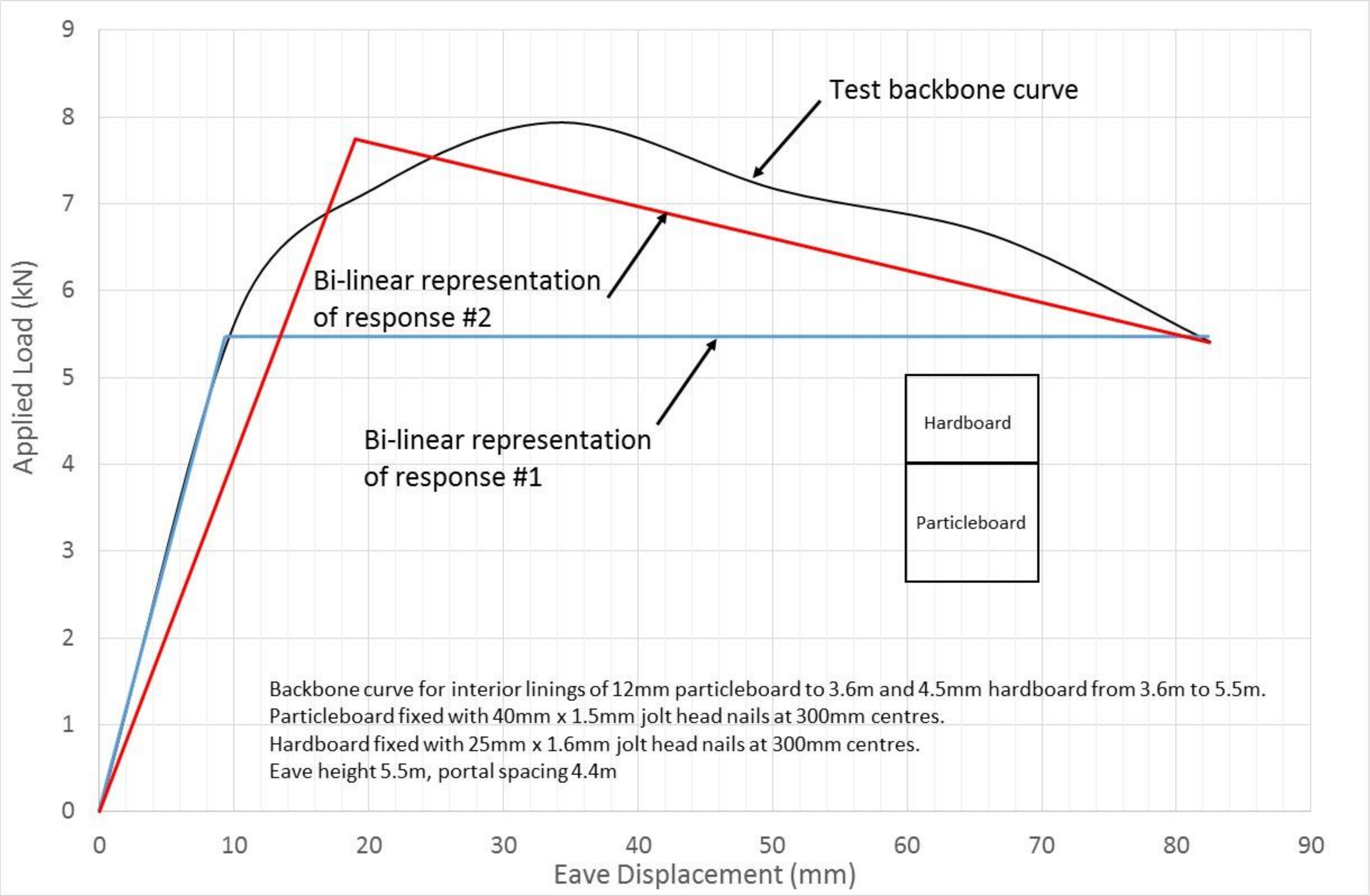
Curves for revised NZSEE Red Book



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