Flexible Learning Space Upgrade - Nelson Two Storey Block (Concrete Stairs)

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Design Features Report

Ministry of Education

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1. Introduction

Aurecon New Zealand Ltd has been commissioned by The Ministry of Education (MOE) to provide structural engineering services for the Flexible Learning Space (FLS) standard classroom upgrade for the Nelson Two Storey Block considered as an importance level 3 structure. The structural engineering design for this upgrade is to include seismic strengthening of the structure to 67% of New Building Code requirements as per NZS1170.5:2004. The design for FLS has been carried out on the Nelson Two Storey Block with concrete stairs. There are a number of different versions which also include a timber framed stair and stair core.

A number of the existing Nelson 2 Storey Blocks have already been seismically strengthened. This will alter how the FLS modifications shown on the Architectural Drawings can be carried out and the required seismic strengthening to meet the MOE target of 67% NBS. Prior to investigating the FLS modifications the school shall review their records and the records of the local territorial authority as well as have a chartered professional engineer carry out a site survey to establish whether any strengthening or alterations have already been carried out to the specific block.

Two FLS options are presented for the Nelson Two Storey Block, working within the limitations of the existing block layout. The main variances between the two options lie in the footprint the smaller breakout areas have relative to the general flexible learning areas. For these strengthening schemes, the lateral bracing elements are to have a minimum capacity of 67%NBS.

The purpose of this report is to provide a technical description of structural design parameters, coefficients and loadings utilised in the design. Secondly it describes our design assumptions and the structural systems that are to be considered for the project.

The report is intended to act as a reflective brief and outlines our proposed structure so that the client can ensure the design meets their expectations in terms of function, performance and load capabilities.

2. Existing Structure

Nelson Two Storey Blocks were first designed in 1962 prior to the introduction of the 1965 seismic code, and their use was widespread throughout the country. Construction of these blocks continued throughout the 1960's and the design evolved over a period of time.

Two-storey Nelson Block structures are of lightweight timber construction and consist of a central block of classrooms connected to a block of classrooms at either end, forming a symmetrical 'H' shaped plan layout. An annex structure is also attached to the Central Block. This attachment has a separate roof diaphragm and is therefore independent of the Main Structure.

Lateral bracing in both directions is provided by timber framed shear walls that are lined with a combination of diagonal timber sarking, plywood and plasterboard. Bracing layouts for a typical 2 storey Nelson Block structure are shown in Figure 1 and Figure 2 below:

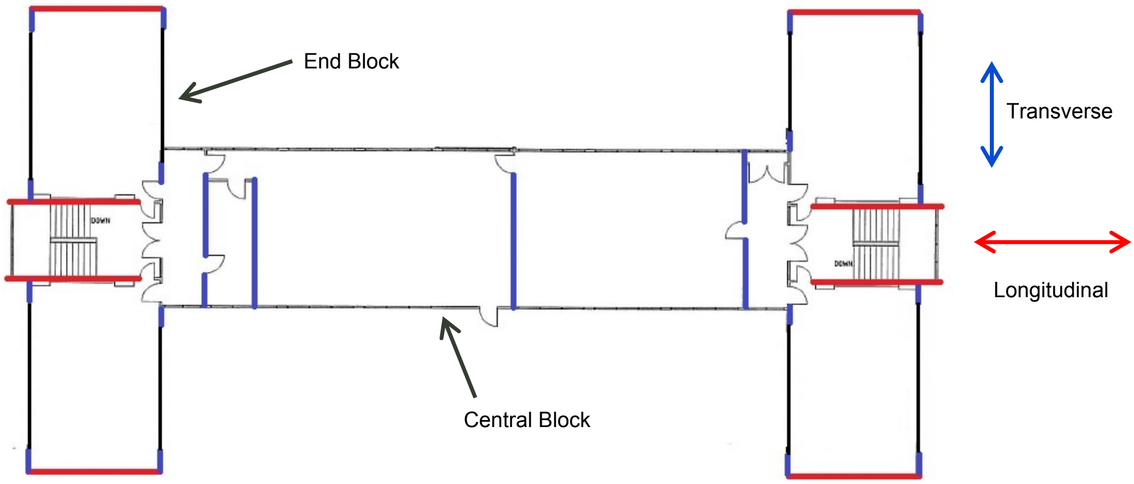

Figure 1 - Typical Nelson Block Bracing Layout - First Floor

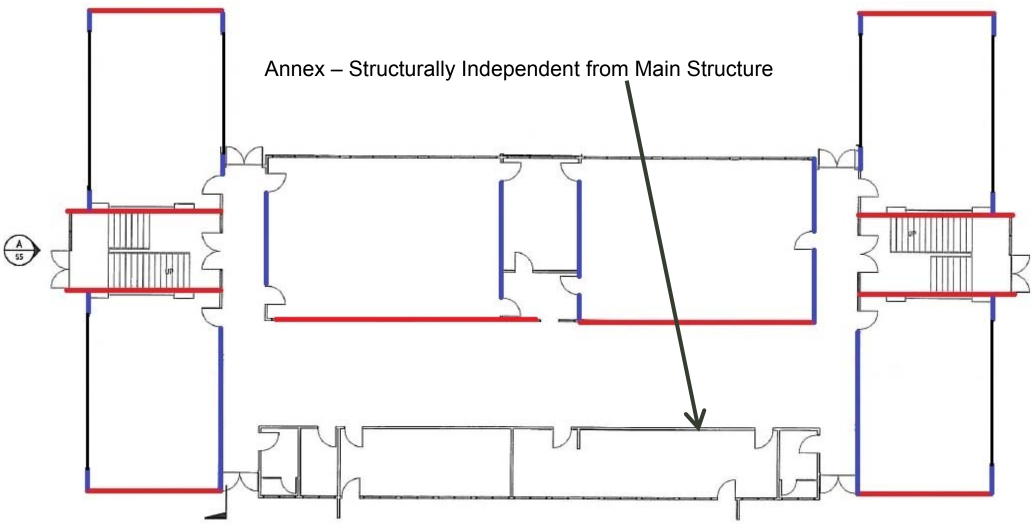

Figure 2 - Typical Nelson Block Bracing Layout - Ground Floor

Both the first floor and ground floor diaphragms are constructed of timber tongue and groove boards which provide good load transfer capability to the lateral load resisting elements. The roof diaphragm is constructed out of lightweight timber framing with timber cross bracing for seismic load transfer.

A typical Nelson Two Storey Block features a lightweight timber tongue and groove floor diaphragm resting on square concrete piles and foundation walls. The main lateral bracing elements rest directly onto the foundation walls, hence the foundation piles are required to resist the self-weight of the floor only. This system is expected to perform satisfactorily in an earthquake.

A number of detailed seismic assessments of Nelson Two Storey Blocks have been carried out by Aurecon on behalf of the MOE and depending on the specific site and building characteristics these buildings have achieved varying %NBS scores. The purpose of this report is to provide a generic strengthening methodology that will allow a typical Nelson Two Storey Block building to be strengthened to over 67% NBS.

Many of the Nelson Two Storey Blocks are still in use by the MOE and have undergone alterations ranging from minor to major and specific site and building characteristics have a significant effect on the performance of buildings during a seismic event. This means that any strengthening methodologies outlined in this report will need to be reviewed by a local engineer to ensure they are suitable for the building in which they are to be applied. Certain Nelson Two Storey Blocks have been found to have asbestos present in the roof cladding. Contractor to address any asbestos present in the building appropriately.

3. Proposed Modifications

3.1 Scope/Function

The scope of the structural design is to provide a lateral force resisting system that can achieve 67% of current code requirements for the two FLS options provided by Brewer Davidson. Where it has been possible to achieve a higher capacity without installing an excessive amount of additional structure a target of 100% of current code has been used. Strengthening designs for Wellington and Christchurch require re-lining a selection of walls with a more adequate bracing material and installing new steel portal frames to achieve a minimum of 67% NBS. For Auckland 100% NBS can be achieved with much smaller portal frame sizes and with a lower capacity bracing lining material for selected walls compared with Wellington and Christchurch.

3.2 Options

Two options have been put together by Brewer Davidson to achieve the goals set out by the Flexible Learning Space (FLS) Upgrade. Both options involve opening up classroom areas to create flexible learning spaces. The main variances between the two options lie in the footprint the smaller breakout areas have relative to the general flexible learning areas.

3.3 Gravity System

At roof level, the steel cladding and timber framing is supported by proprietary timber roof trusses spaced at regular intervals along each of the three main blocks. At the first floor level, the timber tongue and groove flooring is supported by a series of evenly spaced joists that are supported by primary laminated timber floor beams. The timber roof trusses and laminated timber floor beams in turn are supported by timber columns that are constructed by a series of 5” x 2” timber members spliced together to form a large member. These columns are continuous up the entire height of the structure. All timber columns, walls and partitions are supported by reinforced concrete foundation walls. In between the foundation walls lie a series of evenly spaced square concrete columns to support the timber tongue and groove ground floor.

During the upgrade works, the gravity system will be altered through the installation of timber and steel lintels to support the roof framing and first floor in the areas where load bearing walls are removed.

3.4 Roof and First Floor Diaphragms

The existing diaphragms’ capacities were then estimated according to the method outlined in the NZSEE publication “Assessment and Improvement of the Structural Performance of Buildings in Earthquakes”. Both the first floor and ground floor diaphragms are constructed of timber tongue and groove boards which provide good load transfer capability to the lateral load resisting elements. The roof diaphragm is constructed out of lightweight timber framing with timber cross bracing for seismic load transfer. Two destructive tests carried out at the Mairehau High School and Upper Hutt College have confirmed that the End Blocks and the Central Block are adequately tied together to allow for load transfer between the blocks. Diaphragms are adequate to transfer seismic loads to the lateral load resisting elements as it stands, therefore no further strengthening is required.

3.5 Longitudinal Lateral Bracing System

3.5.1 End Blocks

Lateral seismic loads in the longitudinal direction of the End Blocks are resisted on both levels by four existing timber framed shear walls that are lined with diagonal timber sarking. Diagonal timber sarking provides good bracing capacity to timber framed shear walls. These existing shear walls have adequate capacity to resist seismic demands equal to 67% of current code requirements (NZS 1170.5), therefore no further strengthening works are required.

3.5.2 Central Block

Lateral seismic loads in the longitudinal direction of the Central Block are resisted on both floors by the single interior wall and the columns on the exterior walls. Excess loads will be resisted by the End Block walls. The presence of the tongue and groove floor diaphragm provides an adequate load path to transfer seismic load from the Central block to the End Block bracing walls. This has been confirmed through on site de-construction of Nelson Blocks at Mairehau High School and Upper Hutt College.

3.6 Transverse Lateral Bracing System

3.6.1 End Blocks

Lateral seismic loads in the transverse direction of the End Blocks are resisted by a series of timber framed shear walls, timber columns and timber framed spandrel panels on both levels. In order to strengthen the transverse bracing capacity of the end blocks to a minimum of 67% of current code requirements on the ground floor an additional two three legged PFC portal frames will be installed in four of the window bays. A new concrete foundation pad will have to be poured alongside the existing column pads and the PFC beam will be fastened to the first floor with coach screws and nails.

3.6.2 Central Block

Lateral seismic loads in the transverse direction of the Central Block are resisted on both levels by existing timber framed shear walls distributed evenly across the structure. These walls are also capable of resisting some of the excess forces from the End Blocks.

On the first and ground floor the transverse timber framed shear walls are to be re-lined with Gib or new structural steel portal frames are to be installed to strengthen the buildings to 67% of current code requirements. The extent of Gib walls or portal frames depends on the building location and the FLS option adopted.

3.7 Roof and Floor Diaphragms

3.7.1 Roof Diaphragm

The roof diaphragm in both the End Blocks and the Central Block is constructed of a series of roof purlins and ceiling joists spanning across the timber trusses with timber cross braced members at select locations with diagonal sarking on both the Central Block as well as the End Blocks/

Seismic loads are transferred to the lateral seismic resisting elements through the timber cross bracing distributed throughout the roof diaphragm system. These cross bracing bays tie into the perimeter of the structure and the internal bracing walls. The roof of the Central Block is connected to the End Blocks and can therefore loads between the blocks.

The existing roof diaphragm can resist seismic loading equal to 67% of current code requirements. No additional strengthening works are therefore required for the roof diaphragm.

3.7.2 Floor Diaphragms

The existing floor diaphragms are constructed of timber tongue and groove sheathing. This sheathing has adequate capacity to resist seismic loading equal to 67% of current code requirements. No additional strengthening works are therefore required for these floor diaphragms.

3.8 Foundations

The lightweight timber sarking floor is supported by square concrete piles and a series of foundation walls around the perimeter and underneath internal walls. The main lateral bracing elements rest directly onto the foundation walls, hence the foundation piles are required to resist the self-weight of the floor only.

Suitable strengthening works are to be carried out to ensure the lateral bracing elements are adequately fixed to the foundation walls.

The new portal frames and gravity load carrying columns require new foundations.

3.9 Lift

A lift has been added to the building to provide better access to the building. The lift shaft shown on the structural drawings is a generic lift shaft and has been shown for information only.

The lift shaft will need to be sized to meet the minimum MOE requirements for lifts (1500 mm by 1800 mm) and will need to be sized, located and orientated to suit the specific requirements for each Nelson 2 Storey Block.

Once a lift supplier has been appointed for the FLS upgrade the lift shaft will need to be designed for the specific requirements of that supplier.

4. Design Criteria

4.1 Design Standards and Codes

The following design standards and codes will be used in the structural strengthening:

General Design

AS/NZS1170.0:	Structural Design Actions – General Principles
AS/NZS1170.1:	Permanent, imposed other actions
AS/NZS1170.5:	Seismic Design Actions (NZ)
NZS3603:1993:	Timber Structures Standard
NZS3604:2011:	Timber Structures Standard (Non-Specific Design)
NZSEE Handbook	"Assessment and Improvement of the Structural Performance of Buildings in Earthquakes" June 2006 by New Zealand Society for Earthquake Engineering (NZSEE)

In addition, code commentaries for the above codes will be referenced where applicable.

4.2 Design Gravity Loads

4.2.1 Existing Lightweight Roofs:

Dead (member self-weights):	0.35kPa
Live (Non Accessible Roof):	0 kPa (ψ_c=0.0 for roofs under seismic load)

4.2.2 Walls and Glazing:

Dead:	0.30 kPa (Timber Walls without Sarking)
	0.45 kPa (Spandrels and Timber Walls with Sarking)
	0.20 kPa (Glazing)

4.2.3 Floor Loadings:

Dead:	0.5 kPa (Timber Floor)
Live:	3.0 kPa (Classroom Areas)
	4.0 kPa (Stairs, Landings and Corridors)

4.3 Seismic Load Parameters and Coefficients

4.3.1 Wellington

Hazard Factors from AS/NZS1170.5

Importance Level	=	3
Soil Class	=	C
$C_h(T)$	=	2.36 (assumed T<= 0.4s)
Z	=	0.40 (Hazard factor – Wellington)
R	=	1.3 (Risk for Earthquake ULS = 1/500)
N(T,D)	=	1.0
C(T)	=	$C_h(T)$ Z R N(T,D)
	=	2.36 x 0.40 x 1.3 x 1.0 = 1.2272 (ULS)
μ	=	2.50 (ULS - existing timber framed bracing elements)
	=	3.00 (ULS - new timber framed lateral bracing elements)
S_p	=	0.5 (μ = 2.5)
	=	0.7 (μ = 3.0)
k_μ	=	1.857 (μ = 2.5)
	=	2.143 (μ = 3.00)

Seismic Coefficient:

$C_d(T)$	=	0.33 (μ = 2.50, Sp = 0.5)
$C_d(T)$	=	0.40 (μ = 3.00, Sp = 0.7)

4.3.2 Auckland

Hazard Factors from AS/NZS1170.5

Importance Level	=	3
Soil Class	=	D
$C_h(T)$	=	3.00 (assumed T<= 0.4s)
Z	=	0.13 (Hazard factor – Auckland)
R	=	1.3 (Risk for Earthquake ultimate = 1/500)
N(T,D)	=	1.0
C(T)	=	$C_h(T)$ Z R N(T,D)
	=	3.00 x 0.13 x 1.3 x 1.0 = 0.507 (ULS)
μ	=	2.50 (ULS - existing timber framed bracing elements)
	=	3.00 (ULS - new timber framed lateral bracing elements)
S_p	=	0.5 (μ = 2.5)
	=	0.7 (μ = 3.0)
k_μ	=	1.857 (μ = 2.5)
	=	2.143 (μ = 3.00)

Seismic Coefficient:

$C_d(T)$	=	0.14 (μ = 2.50, Sp = 0.5)
$C_d(T)$	=	0.17 (μ = 3.00, Sp = 0.7)

4.3.3 Christchurch

Hazard Factors from AS/NZS1170.5

Importance Level	=	3
Soil Class	=	D
$C_h(T)$	=	3.00 (assumed T<= 0.4s)
Z	=	0.30 (Hazard factor – Christchurch)
R	=	1.3 (Risk for Earthquake ultimate = 1/500)
N(T,D)	=	1.0
C(T)	=	$C_h(T)$ Z R N(T,D)
	=	3.00 x 0.30 x 1.3 x 1.0 = 1.17 (ULS)
μ	=	2.50 (ULS - existing timber framed bracing elements)
	=	3.00 (ULS - new timber framed lateral bracing elements)
S_p	=	0.5 (μ = 2.5)
	=	0.7 (μ = 3.0)
k_μ	=	1.857 (μ = 2.5)
	=	2.143 (μ = 3.00)

Seismic Coefficient:

$C_d(T)$ = 0.32 (μ = 2.50, Sp = 0.5)

$C_d(T)$ = 0.38 (μ = 3.00, Sp = 0.7)

4.4 Load Combinations

As the design works carried out have been for seismic strengthening, the following Ultimate Limit State load combination factor shall be taken as specified in AS/NZS1170.0, Section 0:

$$G + \Psi_c Q + E_u$$

Where:

G = Dead Load

Q = Live Load

E = Seismic Load

Ψ_c = Load Combination Factor

4.5 Site Geology

The site geology can have significant impact on the level of loading imparted on a building during an earthquake. Deep, soft soil conditions tend to amplify the ground motions, increasing the forces on a building structure.

Three sites have been selected for this design through consultation with the MOE. One in Wellington with site subsoil class C, one in Auckland with site subsoil class D and one in Christchurch with site subsoil class D. This is intended to provide a strengthening approach that has the flexibility to be applied widely, without being overly conservative. This site subsoil class is used to determine the elastic site hazard spectrum for the horizontal loading, ‘C(T)’ (Section 3 NZS 1170.5:2004).

When these FLS options are implemented at a specific school the site subsoil class will need to be defined by the Geotechnical Engineer for the specific classroom location. This will allow a structural engineer to revise this generic document package and produce a document package for the specific classroom.

4.6 Importance Level

The strengthening design has been carried out as for a classroom with an importance level of 3 and a design working life of 50 years. The importance level is dictated by the expected occupancy being greater than 250 people in the building as per NZS 1170. A return period factor ‘R’ of 1.3 has therefore been used.

5. Methodology: Structural Analysis and Design

5.1 Design Method

In terms of the Building Code, the structural design will follow the established principles of the verification method; part B1 - Structure (Part only).

5.2 Analysis

The building seismic loads will form the basis of structural calculations for member sizing.

The calculations will rely on the use of numerous software packages for analysis, calculation and documentation of the structural systems. These will utilise theories of structural mechanics and input material strengths to refine the design. This approach will be aided by computer software such as ETABS for the determination of the seismic actions in the End Block wall and spandrel bracing system. Excel Spreadsheets were also used to calculate the various seismic coefficients for the structure.

5.3 Section Properties

5.3.1 Serviceability Limit State

All serviceability responses shall be analysed using members modelled with gross section properties.

5.3.2 Ultimate Limit State

For ultimate limit state analysis of steel members, the section modulus may be taken as being plasticised rather than elastic depending on ductility and rotation limitations of the appropriate material codes.

5.4 Documentation

The following computer aided drafting (CAD) programs will be used for documentation of the structural drawings for the works:

- Revit: Three dimensional drawing package to produce structural drawings.

6. Explanatory Notes

- This report contains the professional opinion of Aurecon as to the matters set out herein, in the light of the information available to it during preparation, using its professional judgment and acting in accordance with the standard of care and skill normally exercised by professional engineers providing similar services in similar circumstances. No other express or implied warranty is made as to the professional advice contained in this report.
- We have prepared this report in accordance with the brief as provided and our terms of engagement. The information contained in this report has been prepared by Aurecon at the request of its client, the Ministry of Education, and is exclusively for its client’s use and reliance. It is not possible to make a proper assessment of this assessment without a clear understanding of the terms of engagement under which it has been prepared, including the scope of the instructions and directions given to and the assumptions made by Aurecon. The assessment will not address issues which would need to be considered for another party if that party’s particular circumstances, requirements and experience were known and, further, may make assumptions about matters of which a third party is not aware. No responsibility or liability to any third party is accepted for any loss or damage whatsoever arising out of the use of or reliance on this assessment by any third party.
- The assessment is also based on information that has been provided to Aurecon from other sources or by other parties. The assessment has been prepared strictly on the basis that the information that has been provided is accurate, complete and adequate. To the extent that any information is inaccurate, incomplete or inadequate, Aurecon takes no responsibility and disclaims all liability whatsoever for any loss or damage that results from any conclusions based on information that has been provided to Aurecon.
- The enclosed strengthening scheme assumes that the existing building is as per the enclosed original Nelson Block 2 Storey drawings. The Appropriateness of this assumption is to be verified on site by a suitably qualified structural engineer prior to the FLS and seismic strengthening being applied to any building. Aurecon accepts no liability for the strengthening of any building which has in any way been altered from the original drawings.
- Engineers utilising calculations and drawings produced by Aurecon for Nelson Block strengthening need to make their own conclusions as to the applicability for their own specific situation. It is noted that Nelson Blocks have been constructed in a broad range of variants e.g. T Blocks, additional central classrooms and different construction methodologies. Ground conditions and site flexibility will also vary and need to be appropriately considered.

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