aurecon

Project: Kelburn Normal School

Seismic Assessment of School Hall

Prepared for: Ministry of Education

Project: 226732

19 February 2013

Leading. Vibrant. Global.
www.aurecongroup.com

Document Control Record

Document prepared by:

Aurecon New Zealand Limited
Old Bank Chambers
102 Customhouse Quay
Wellington 6011 New Zealand

T +64 4 472 9589
F +64 4 472 9922
E wellington@aurecongroup.com
W aurecongroup.com

Document control						aurecon
Report Title		Seismic Assessment of School Hall				
Document ID			**Project Number**		226732	
File Path		P:\226732\Structural\Project Delivery\Assessment of Hall\Seismic Assessment of Kelburn Normal School - Hall.docx				
Client		Ministry of Education	**Client Contact**		Stephen Cross	
Rev	**Date**	**Revision Details/Status**	**Prepared by**	**Author**	**Verifier**	**Approver**
0	19 February 2013		ALZ	ALZ	GL	DMcG
Current Revision		**0**				

Approval			
Author Signature		Approver Signature	
Name	Alex Zha	Name	David McGuigan
Title	Structural Engineer	Title	Technical Director

Contents

1. Executive Summary

This report presents the findings of the detailed seismic assessment of the school Hall at Kelburn Normal School, situated at 12 Kowhai Road, Kelburn.

The purpose of the assessment was to further investigate the likely seismic performance of the above building following an initial assessment conducted by Spencer Holmes Ltd, which found the building to be 'Potentially Earthquake Prone'.

The Hall has been assessed based on site measurement of the main dimensions as structural drawings were unavailable.

The structure is a single storey timber framed building which houses the school hall and stage area. Rooms have been added to two sides of the building. These include storage areas as well as toilet facilities. The structure was modelled using the 'Equivalent Static Method' (ESM). This method of analysis was used as the building is low-rise and has a regular wall layout.

The structural capacity of the building was compared to the applied loading from the current New Zealand seismic loading standard - NZS 1170.5:2004. The structure has been assessed as a school hall giving it an importance level of 3 as stipulated by the Ministry of Education.

Bracing against lateral seismic loading is provided through lined shear walls in the longitudinal direction. Moment resisting timber trusses contribute to the lateral capacity in the transverse direction.

The assessment has concluded that the building has sufficient capacity to resist seismic loading equal to **21%** (NBS) when assessed as an importance level 3 structure. This rating is governed by the capacity of the longitudinal lateral bracing elements. This is below 33% NBS meaning that under the Building Act 2004 the Hall is categorised as 'earthquake prone' and requires strengthening.

This report does not address other requirements that may be required under the Building Act 2004, such as Fire Safety and Access and Facilities for the Disabled.

%NBS rating = the design coefficient for a similar building designed to meet current code requirements – referred to as the New Building Standard (NBS)

NZSEE rating = extracted from New Zealand Society for Earthquake Engineering (NZSEE) - Assessment and Improvement of the Structural Performance of Buildings in Earthquakes, Section 2.8, namely

A+	>100% NBS	**A**	80-100% NBS
B	67-80% NBS	**C**	33-67% NBS
D	20-33% NBS	**E**	<20% NBS

2. Introduction

Aurecon have been engaged by the Ministry of Education (MOE) to provide a detailed assessment of the seismic strength of the Hall building situated at Kelburn Normal School on Kowhai Road, Kelburn. The building is located to the west of the Kelburn Normal School campus. The building is timber framed constructed in 1955.

The seismic capacity of the building has previously been assessed by Spencer Holmes Ltd using the Initial Evaluation Procedure (IEP). This assessment estimated that the Hall had the capacity to resist 38% of current building code requirements, which means the building achieved an NZSEE rating of C.

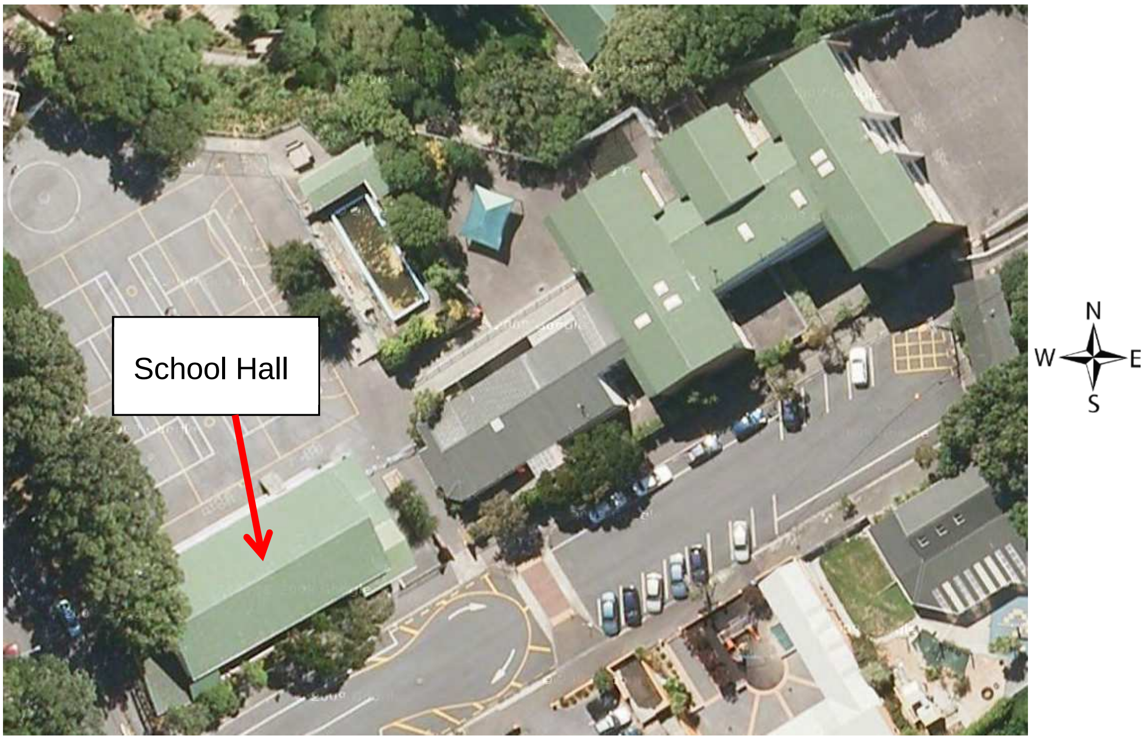

Figure 1 – Plan View of Kelburn Normal School

A detailed analysis of the structure has been carried out and capacities of the various lateral resisting components have been compared to applied loadings equal to 100% of the current building code requirements.

3. Building Description

The main School Hall is a single story timber building approximately 27m by 12m. There are two annexes: two toilets and a storage room attached to the east and west sides of the building respectively. As the main building and the annexes have different roof heights they will act independently in an earthquake and have been assessed as separate structures.

In the longitudinal direction seismic loads are resisted by a combination of wall studs in bending, braced partially by particleboard, and softboard lined shear walls. In the transverse direction seismic loads are resisted by the moment resisting timber trusses spaced evenly throughout the Hall as shown in Figure 2.

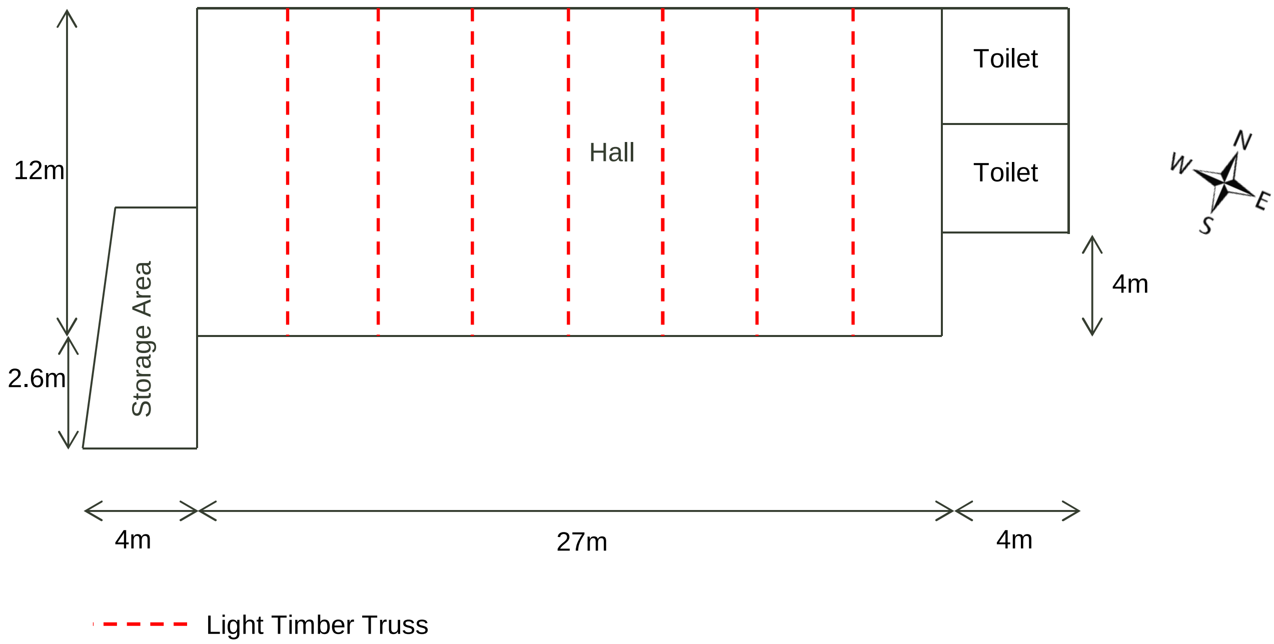

Figure 2 – School Hall Floor Plan

The load resisting system for the annexes are derived from the hardboard lined walls for both the toilets and storage areas. Seismic loads for the entire structure are transferred to the foundatiions via the concrete perimeter walls.

The roof is corrugated iron cladding on timber sarking and light timber trusses. A reinforced concrete wall runs around the perimeter of the Hall with a maximum height at the eastern boundary of 800mm tapering to ground level at the western boundary.

The lack of bracing in the perimeter walls was identified to have a significant effect on the building's performance. No strengthening works are visible so all strength values are based on standard building practice at the time of construction.

4. Seismic Analysis

The capacity of the building has been assessed in accordance with the current New Zealand seismic loading standard (NZS1170.5:2004), the Timber Structures Standard (NZS3603:1993), the Concrete Structures Standard (NZS3101:2006) and the New Zealand Timber Framed Buildings Standard (NZS3604:2011).

Reference has also been made to the New Zealand Society of Earthquake Engineering's (NZSEE) publication "Assessment and Improvement of the Structural Performance of Buildings in Earthquakes" and the Ministry of Educations online publication "Technical Guidelines for Structural Mitigation Work".

4.1 Building Ductility

Ductility is a measure of the ability of a building to resist the earthquake forces/energy by inelastic deformation. Under current design standards the level of ductility is generally determined by:

a) Identifying an appropriate mechanism that can sustain inelastic deformations without leading to collapse of a building.

b) The ability to achieve an appropriate level of structural detailing to ensure that the chosen ductile mechanism is achievable.

c) Code limitations on the inter-storey deflections for the structure.

The choice of ductility factor affects the load level selected for the design and the complexity of detailing required. Generally the higher the ductility demand, the lower the loading, but the more stringent the detailing requirements. Ductility demands typically vary between $\mu = 1.0$ for elastic, $\mu = 3.0$ for limited ductile and $\mu = 6.0$ for fully ductile.

The building assessed is of light timber framing. For our calculations we have used a ductility of 3.0. We note that a ductility of 2.0 was used during the IEP. For timber structures however, a ductility of 3.0 is a commonly accepted value due to the effect of nail and bolt slip.

4.2 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.

Given the known regional geology and expected site soil conditions, a site soil class A/B (Rock) classification, as per the IEP and following consultation with our geotechnical engineering team was adopted to determine the elastic site hazard spectrum for the horizontal loading, 'C(T)' (Section 3 NZS 1170.5:2004).

4.3 Importance Level

The School Hall has been assessed as an educational facility, giving it an importance level of 3 and a design working life of 50 years. A return period factor 'R' of 1.3 has therefore been used. This is in line with the Ministry of Educations latest requirements.

4.4 Analysis Method and Assumptions

The Kelburn Normal School Hall is a single storey, timber frame structure and was analysed based on the equivalent static method (ESM) as per NZS 1170.5.

The inputs to the analyses were:

- Site measure of the entire building to determine dimensions and materials.
- The initial evaluation procedure (IEP) for the School Hall provided by the Ministry of Education (MOE).

The following assumptions have been made with regards to material properties, analytical modelling, and design review:

- In seismic loading, values specified in accordance with NZS1170.5 have been used. The building has been assessed as importance Level 3 and a design working life of 50 years has been used. Therefore, a return period factor of 1.3 has been used.
- The Hazard factor, Z for Wellington CBD (north of Basin Reserve) is 0.4
- The Near Fault Factor, N is 1.0 as the period of the structure, in both directions, is lower than 1.5 seconds (0.4 seconds was used).
- The structural ductility throughout the structure is 3 which results in a structural performance factor, Sp, of 0.7.
- The subsoil class for the site is A/B – Rock as per the IEP.
- In calculating the self-weight of the structure, 0.40kPa was used for the roof and flooring and 0.30kPa was used for walls, doors and glazing.
- The bracing capacity of lined timber walls has been estimated with reference to the New Zealand Society of Earthquake Engineering's (NZSEE) publication "Assessment and Improvement of the Structural Performance of Buildings in Earthquakes" and Ministry of Education online publication "Technical Guidelines for Structural Mitigation Work".
- Load combinations used in the analysis were as required by NZS1170.0.
- Particleboards were assumed to provide partial bracing to wall studs, hence the capacity was reduced by 50% of a full fixity assumption.
- P-Delta effects caused by large displacements as well as accidental eccentricities have been ignored due to the low weight and high ductility of the single storey timber frame.
- Wall/foundation connections were assumed to be concrete nails as no hold down bolting system was observed on site.
- The School Hall and annexes were analysed separately as they do not share the same roof height.

5. Results

5.1 Lateral Seismic Resisting Elements

The loads in the critical structural elements were assessed and compared to their likely capacities. Bracing elements consist of lined timber shear walls, cantilever wall studs and moment resisting timber trusses. The capacities of these elements were assessed with reference to The Timber Structures Standard - NZS3603:1993, the Timber Framed Buildings Standard - NZS3604:2011 and the NZSEE publication "Assessment and Improvement of the Structural Performance of Buildings in Earthquakes".

It was found that the lateral bracing elements in the School Hall are able to resist **21%** and **41%** of the current building code requirements in the longitudinal and transverse directions respectively. This is governed by the softboard lined upper half of the walls and strength of supporting timber columns.

The lateral bracing elements in the annexes were found to be able to resist 100% of the current building code requirements in both the longitudinal and transverse directions.

5.2 Roof/Floor Diaphragms

The loads in the critical diaphragms were assessed based on the tributary areas of lateral resisting elements. The diaphragms capacities were then estimated according to the method outlined in to the NZSEE publication "Assessment and Improvement of the Structural Performance of Buildings in Earthquakes".

Roof and floor diaphragms in all areas were found to be able to resist **100%** of the current code requirements as set out in NZS1170.5 in both the longitudinal and transverse directions.

5.3 Foundations

Foundations are required to transmit earthquake forces from the timber superstructure into the ground. The foundation loads have been assessed based on the equivalent static method, as set out in NZS1170.5.

The foundation walls and piles are founded on flat ground and are stronger than the connections between the lateral bracing elements and the foundation walls. The wall/foundation connections was found to be able to transfer **100%** of the current building code requirements to the foundations in both the longitudinal and transverse directions. These connections will need to be verified before strengthening works are carried out.

The concrete perimeter wall foundations have been assumed to be adequate based on a minimum assumed reinforcement detailing requirement to NZS3604:2011, Figure 6.13. This will need to be verified before strengthening works are carried out.

5.4 Strength Summary

Load Resisting Element	Longitudinal Direction (% New Building Standard)	Transverse Direction (% New Building Standard)
Lateral Bracing	**21%**	**41%**
Ceiling Diaphragm	100%	100%
Floor Diaphragm	100%	100%
Foundations	100%	100%
Building Capacity	**21%**	**41%**

5.5 Comparison to the IEP

The IEP provided by the MOE estimated that the School Hall had a capacity of **38%** of the current building code requirements. We believe that the School Hall has the capacity to resist **21%** of current code requirements when considered as an Importance Level 3 building, governed by the lateral bracing capacity in the longitudinal direction.

This means that the School Hall receives an NZSEE rating of E and is designated as “Earthquake Prone” and requires strengthening.

5.6 Critical Structural Weaknesses

A critical structural weakness is a building characteristic, usually related to horizontal or vertical building configuration, which greatly increases the risk of collapse during a seismic event.

No critical structural weaknesses were observed during the seismic assessment of the Kelburn Normal School Hall.

5.7 Suggested Strengthening and Improvements

The capacity of the School Hall could be increased to above 100% of current code requirements by increasing the bracing capacity of the perimeter walls, strengthening of the columns in the moment resisiting timber truss and verification of hold down capacity between the timber bottom plate and the concrete perimeter walls.

5.7.1 Bracing Capacity of the Walls

To increase the bracing capacity of the walls it will be necessary to either install a higher capacity wall lining or replace some existing windows with effective wall. By replacing the current linings with Gib Braceline and upgrading the wall hold-downs it may be possible to increase the lateral capacity of the School Hall to above 100% of current building code requirements without losing any window space.

5.7.2 Wall-to-Foundation Hold-Down Capacity

If the inspected hold down capacity is inadequate, threaded rods could be drilled and epoxied through the wall bottom plate, into the concrete perimeter walls during the replacement of the wall linings.

5.7.3 Moment Resisting Timber Truss Capacity

The capacity of the moment resisting timber truss is limited by the moment capcity of the supporting columns. The capacity of the columns could be improved by adding additional full height timber members alongside the existing.

6. Conclusions and Recommendations

The seismic assessment of the School Hall at Kelburn Normal School has found that the structure is able to withstand **21%** of current building code requirements, governed by the bracing capacity of the longitudinal walls. This is less than 33% NBS meaning that under the Building Act 2004 the structure is classified as 'Earthquake Prone' and requires strengthening.

Strengthening can be achieved by replacing some of the existing longitudinal wall linings with Gib Braceline and strengthening the timber columns which support the timber trusses.

7. Explanatory Notes

- This assessment 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.

Aurecon New Zealand Limited
Old Bank Chambers
102 Customhouse Quay
Wellington 6011 New Zealand

T +64 4 472 9589
F +64 4 472 9922
E wellington@aurecongroup.com
W aurecongroup.com

Aurecon offices are located in:
Angola, Australia, Bahrain, Botswana, China, Ethiopia, Hong Kong, Indonesia, Lesotho, Libya, Malawi, Mozambique, Namibia, New Zealand, Nigeria, Philippines, Singapore, South Africa, Swaziland, Tanzania, Thailand, Uganda, United Arab Emirates, Vietnam.