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Two-Storey Nelson Blocks – Physical Inspections of Existing Buildings and Effects on Previous Seismic Assessments

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Document prepared by:
Aurecon New Zealand Limited
Level 1, 102 Customhouse Quay
Wellington 6011
PO Box 1591
Wellington 6140
New Zealand

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

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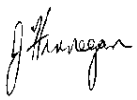
Author signature		Approver signature	
Name	Phil Don	Name	John Finnegan
Title	Structural Engineer	Title	Project Director

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1. Executive Summary

Aurecon New Zealand Ltd has been engaged by the Ministry of Education to undertake inspections of two, standard 'H' shaped two-storey Nelson Block classroom buildings prior to undertaking scheduled demolition. This follows on from a previous engagement where Aurecon undertook detailed seismic assessments to determine the seismic performance of two-storey Nelson blocks and provide typical structural improvements for identified vulnerabilities.

Two-storey Nelson Block structures at Upper Hutt College in Upper Hutt and Mairehau High School in Christchurch were inspected prior to demolition. The building inspected at Upper Hutt College was a lightweight stair type Nelson Block and the building inspected at Mairehau was a concrete stair variant. This provided an opportunity to inspect key structural elements in the building to find construction variations between the as-built structure and the original standard drawings and review the validity of assumptions made in previous detailed seismic assessments.

A few key variations were found in each building that encouraged a revision of the previously calculated strength capacity determined from the theoretical Aurecon detailed seismic assessments. In both Nelson Block structures inspected, a greater connection between the end and central portions of the structure was found, resulting in a greater seismic load transfer between these two segments in the structure, increasing the overall bracing capacity.

In the Nelson Block at Upper Hutt College, the exterior walls in the end portions of the structure were also found to contain 'hit and miss' sarking as opposed to full diagonal sarking, reducing the longitudinal bracing capacity of the structure from what was calculated in the seismic assessment.

Revised %NBS capacities have been determined to take account of the observed variations and have generally increased the governing %NBS value for the two types of two-storey Nelson Block building. The lowest bound %NBS values for the two types of Nelson Block structures, taking account of the physical inspection findings are as follows:

- Two-storey Nelson Block – Lightweight stair version **36%NBS** (previously 19%NBS)
- Two-storey Nelson Block – Concrete stair version **34%NBS** (previously 15%NBS)

The calculated %NBS values stated above for the different Two-storey Nelson Blocks were based on seismic loading parameters for the Wellington Region and a site subsoil classification of C (shallow soil). Comparisons of the %NBS values for the different Nelson Blocks have also been made for the major regions throughout the country and are summarised in Section 6 in the report.

2. Introduction

The Ministry of Education has requested Aurecon New Zealand Ltd to undertake inspections of two standard two-storey Nelson Block classroom buildings prior to undertaking scheduled demolition. This follows on from a previous engagement where Aurecon undertook detailed seismic assessments to determine the seismic performance of two-storey Nelson blocks and provide typical structural improvements for identified vulnerabilities.

The two schools where the inspected Nelson blocks were located are as follows:

- Mairehau High School – inspected on 14 October 2013
- Upper Hutt College – inspected on 9 January 2014

These inspections provided an opportunity to inspect key structural elements in order to gain a better understanding of how Nelson Block structures were constructed and to compare the as-built observations to the details contained on original design documentation.

This report compares the findings from the inspections to the assumptions made during the detailed seismic assessments based on the original design documentation and how the differences observed affected the results obtained from the previous detailed seismic assessments.

Revision 4 itemises the %NBS values for the five main centres, as show in Section 6.

Figure 1: Two-storey Nelson Block with Sarking Exposed Prior to Demolition

3. Background

Two storey Nelson Blocks were originally designed and built in the early 1960s prior to the introduction of the 1965 seismic code. The construction of Nelson Blocks was widespread throughout New Zealand. Construction of these blocks continued throughout the 1960's and the design evolved over a period of time. Figure 2 below shows a typical plan of a two-storey Nelson 'H' shaped Block with the corresponding building segments and loading directions that will be described further in this report:

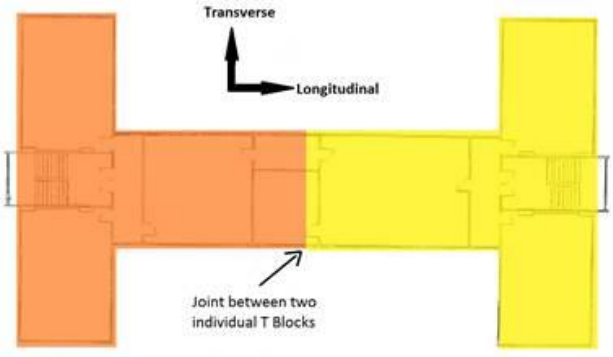

Figure 2: Layout of Nelson 'H' Block Building

Nelson Two-storey Blocks were originally designed and often built as 'T' blocks and then extended (as necessitated by school growth) to form a symmetrical 'H' shaped plan layout. These structures come in two standard types, a concrete stair type and a lightweight stair type. The Nelson Block structure inspected at Mairehau High School was found to have a Concrete Stair and the Nelson Block structure inspected at Upper Hutt College was found to be a Lightweight Stair version. The intrusive investigations helped to clarify if the 'H' blocks should be assessed as single integral buildings as opposed to distinct end and central blocks as had been previously considered applicable.

A number of other differences exist beyond the material of stair construction for the two types of two-storey Nelson Blocks. The key differences include the following:

- Concrete stair Nelson Blocks contain concrete shear walls adjacent to the stairs up to the underside of the first floor level, whereas these walls are constructed of lightweight timber framing in the lightweight stair version.
- Lightweight stair Nelson Blocks contain timber shear walls with diagonal cross bracing in the four corners of the end portions of the 'H' block. These do not exist in the Concrete Stair version.
- A number of timber bracing walls in the Lightweight Stair variant possess full diagonal timber sarking, which is less common in the Concrete Stair version.

Aurecon New Zealand Ltd had previously been commissioned by the Ministry of Education to provide structural engineering services for the assessment and development of generic seismic strengthening solutions for the two-storey Nelson Block Concrete Stair and Lightweight Stair standard classroom buildings. Subject to the findings of the seismic assessment the requirement was to strengthen the building to achieve an overall minimum of 67% of New Building Code requirements as per NZS1170.5:2004 and the relevant material standards. The Seismic assessment was based on the buildings being in the Wellington Region with a site soil class of C and an Importance Level of 3. (These parameters provide a close correlation with a building located in Christchurch with a site soil class of D). A complete set of %NBS values for the five main centres are shown in Section 6.

4. Review of Inspection

The two-storey Nelson Block structures at both Mairehau High School and Upper Hutt College were in the process of being demolished. Prior to demolition, a range of key bracing elements were exposed in order to gauge a more accurate understanding of the structure and see if there were any variances between the as-built structure and details contained on the standard drawings.

The key elements exposed and inspected on site included the following:

- Framing of lateral bracing elements (behind linings)
- Framing of columns (behind linings)
- Roof bracing layout
- First and second floor diaphragms
- Spandrels
- Subfloor foundation layout/system
- Connection detailing between floor and roof diaphragms and lateral bracing elements

5. Comparison with Original Design and Previous Seismic Assessments

5.1 Mairehau High School (Concrete Stair)

The two-storey Nelson Block inspected at Mairehau High School generally matched the existing standard drawings. It was observed that some alterations had been carried out on the building and as a result some of the internal walls had been relined with plasterboard. This however has no effect on the previously assumed bracing capacities of the walls, as the bracing capacity of a standard plaster board wall was assumed in the seismic assessment.

The key variations that have an effect on the potential seismic performance determined from the previous seismic assessment were found in the roof space. At the ceiling level in the end portion of the 'H' section, it was found that all truss bays contained diagonal timber cross bracing (one set of cross braces per bay). This is more cross bracing than was specified in the original drawings. Since the original design assumptions already arrived at a capacity of above 100%NBS for this element, this variation has no effect on the results from the previous assessment. The roof framing in the end portion is shown in Figure 3 below:

Figure 3: Inspected Roof Framing in End Portion of the 'H' Section

Another key variation was at the roof connection at transition between the end and central portions of the 'H' block. Timber cross bracing in the ceiling space in the end portion was found to connect to the timber trusses. Ceiling bracing in the central portion terminates in the corners of this segment directly adjacent to the end portion. This detail is shown in Figure 4 below:

Figure 4: Roof Connection Transition between End Portion and Central Portion

This bracing is not shown in the original drawings and allows for a load transfer between the end portion and central portion to occur, which was not assumed in the original calculations. On the first floor, the timber framed walls in the end portion can provide additional capacity to resist some of the seismic loads from the central portion. This increases the longitudinal capacity of the central portion. On the ground floor, the concrete walls in the end portion are able to provide additional capacity to the seismic loads generated by the central portion. This finding effectively allows the building to be considered as a 'single' building effectively tied at the junction between the notional 'end' and 'central' blocks.

Table 1 shows a comparison of the theoretical %NBS capacities determined from the previous detailed seismic assessment undertaken prior to the inspection and compared with revised theoretical %NBS capacities determined after the inspection.

Table 1: Comparison of %NBS Pre and Post Inspection – Mairehau High School

Longitudinal Bracing Capacity*			
Level	***Portion***	***Original %NBS***	***Post-Inspection %NBS***
First Floor	Central Portion	74%	100%
	End Portion	100%	
Ground Floor	Central Portion	67%	100%
	End Portion	100%	

Transverse Bracing Capacity*			
Level	***Portion***	***Original %NBS***	***Post-Inspection %NBS***
First Floor	Central Portion	100%	58%
	End Portion	19%	
Ground Floor	Central Portion	69%	34%
	End Portion	15%	

*** The above %NBS values are based on the following parameters:**

- **Z = 0.40**
- **Soil Classification = C**
- **Importance level = 3**
- **Ductility = 2.5**
- **S_p = 0.5 (for timber elements)**

5.2 Upper Hutt College (Lightweight Stair)

As with the Mairehau High School Nelson Block, the Nelson Block building inspected at Upper Hutt College generally matched the original drawings with a few key variations that will revise some of the seismic assessment results determined during the generic seismic assessment/strengthening project. These variances are discussed below.

In one of the end portions of the 'H' section, the exterior longitudinal walls contained 'hit and miss' diagonal sarking on both levels as opposed to the full diagonal sarking that is shown in the original drawings. This reduced the assumed bracing capacities of these wall elements. The likely bracing capacity of 'hit and miss' sarking is considered to be 50BU/m, which is the recommended bracing capacity for a standard timber bracing wall as recommended by MOE guidelines. This effectively reduced the overall %NBS seismic capacity in the longitudinal direction from what was determined in the Aurecon seismic assessment. This detail is shown in Figure 5 below:

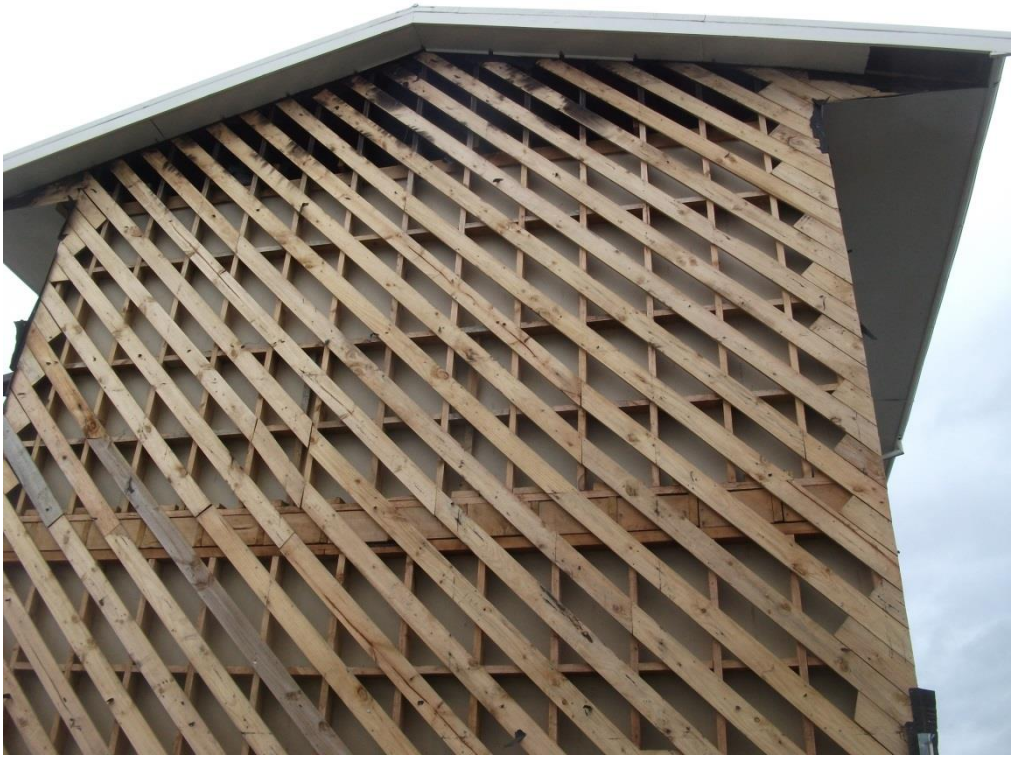

Figure 5 – End Block Elevation Showing Hit and Miss Sarking

A physical inspection of the roof and floor diaphragms found the end and central portions of the 'H' section were effectively connected. In the roof space, the ceiling cross bracing in the end portions were connected on the same wall line as the adjacent ceiling cross bracing in the central portion. At the first floor level, the diagonal timber tongue and groove boards in the central portion were found to be well connected into the end portions. This finding effectively allows the building to be considered as a 'single' building effectively tied at the junction between the notional 'end' and 'central' blocks, which was not assumed in the original assessment calculations in the transverse direction. The transverse timber framed walls in the central portion can therefore provide additional capacity to resist seismic loads generated by the end portions, providing an increase in the %NBS seismic bracing capacity in the transverse direction.

Figure 6 - First Floor Diaphragm at the Interface between the End and Central Portions

Under longitudinal loading, load transfer between the central and end portions has already been assumed due to a more direct load path to the bracing elements between blocks in this direction.

Based on taking the above aspects into consideration, the revised %NBS capacities and %NBS capacities determined from the previous detailed seismic assessment are summarised in Table 2 below:

Table 2: Comparison of %NBS Pre and Post-Inspection – Upper Hutt College

Longitudinal Bracing Capacity*			
Level	***Portion***	***Original %NBS***	***Post-Inspection %NBS***
First Floor	Central Portion	100%	97%
	End Portion		
Ground Floor	Central Portion	72%	55%
	End Portion		

Transverse Bracing Capacity*			
Level	***Portion***	***Original %NBS***	***Post-Inspection %NBS***
First Floor	Central Portion	85%	44%
	End Portion	19%	
Ground Floor	Central Portion	53%	36%
	End Portion	25%	

*** The above %NBS values are based on the following parameters:**

- **Z = 0.40**
- **Soil Classification = C**
- **Importance level = 3**
- **Ductility = 2.5**
- **S_p = 0.5 (for timber elements)**

6. Summary of %NBS Values for Different Regions

As mentioned above, the %NBS values evaluated for the different Two-storey Nelson Blocks were based on seismic loading parameters for the Wellington Region only.

In accordance with the seismic loading standard NZS 1170.5:2004, seismic loading demands throughout the country vary based on a Hazard 'Z' factor. A comparison of the %NBS values for the Concrete Stair Nelson Block and the Lightweight Stair Nelson Block for the major regions throughout the country are summarised in Table 3 and Table 4 below respectively:

Table 3 - Comparison of %NBS for Different Regions - Concrete Stair

Region	Z Factor	Level	%NBS* Longitudinal Direction	%NBS* Transverse Direction
Auckland	0.13	First Floor	100%	100%
		Ground Floor	100%	100%
Hamilton	0.16	First Floor	100%	100%
		Ground Floor	100%	85%
Wellington	0.40	First Floor	100%	58%
		Ground Floor	100%	34%
Christchurch	0.30	First Floor	100%	77%
		Ground Floor	100%	45%
Dunedin	0.13	First Floor	100%	100%
		Ground Floor	100%	100%

*** The above %NBS values are based on the following parameters:**

- **Soil Classification = C**
- **Importance level = 3**
- **Ductility = 2.5**
- **S_p = 0.5 (for timber elements)**

Table 4 - Comparison of %NBS for Different Regions - Lightweight Stair

Region	Z Factor	Level	%NBS* Longitudinal Direction	%NBS* Transverse Direction
Auckland	0.13	First Floor	100%	100%
		Ground Floor	100%	100%
Hamilton	0.16	First Floor	100%	100%
		Ground Floor	100%	90%
Wellington	0.40	First Floor	97%	44%
		Ground Floor	55%	36%
Christchurch	0.30	First Floor	100%	59%
		Ground Floor	73%	48%
Dunedin	0.13	First Floor	100%	100%
		Ground Floor	100%	100%

*** The above %NBS values are based on the following parameters:**

- **Soil Classification = C**
- **Importance level = 3**
- **Ductility = 2.5**
- **S_p = 0.5 (for timber elements)**

7. Conclusions and Recommendations

Two-storey Nelson Block structures at Upper Hutt College in Upper Hutt and Mairehau High School in Christchurch were scheduled for demolition. This provided an opportunity to inspect key structural elements in the building to find construction variations between the as-built structure and the original standard drawings and review the validity of assumptions made in previous detailed seismic assessments.

The inspected Nelson Blocks were 'H' shaped, two-storey Nelson Block structures. The building inspected at Upper Hutt College was a lightweight stair type Nelson Block and the building inspected at Mairehau was a concrete stair variant.

It was found that generally the inspected buildings were built in accordance with what was shown on the standard block drawings. There were however, a few key variations found in each building that encouraged a revision of the previously calculated strength capacity determined from the theoretical Aurecon detailed seismic assessments. A key finding for both buildings was that they were effectively connected at the junctions between what were considered individual blocks allowing the building to be considered as one integral building with a redistribution of seismic forces able to occur.

The key variations found in the Nelson Block at Mairehau High School were in the roof space. It was found that the roof bracing connection between the end and central portions of the structure was greater than previously assumed, based on what was shown on the original drawings. This will allow some transfer of seismic load between these two segments, increasing the overall seismic bracing capacity of the building.

In the Nelson Block at Upper Hutt College, the exterior walls in the end portions of the structure were found to contain 'hit and miss' sarking as opposed to full diagonal sarking. This will reduce the longitudinal bracing capacity of the structure from what was calculated in the seismic assessment.

It was also found that the end and central portions of the structure were effectively connected at the roof and first floor level. This will increase the %NBS seismic capacity from that calculated in the original assessments.

Revised %NBS capacities have been determined to take account of the observed variations and have generally increased the governing %NBS value for the two types of two-storey Nelson Block building. The lowest bound %NBS evaluation for the two types taking account of the physical inspection findings for the two Nelson Block buildings inspected are as follows:

- Two-storey Nelson Block – Lightweight stair version **36%NBS**
- Two-storey Nelson Block – Concrete stair version **34%NBS**

The calculated %NBS values stated above for the different Two-storey Nelson Blocks were based on seismic loading parameters for the Wellington Region. Comparisons of the %NBS values for the different Nelson Blocks have since been made for the major regions throughout the country. These %NBS comparisons are summarised in Section 6 in the report.

The above results can still be considered lower bound conservative evaluations. They do not take into account the resilience that has been demonstrated by the physical destructive tests of selected similar style buildings undertaken to date that have revealed significantly greater lateral strength capacity than that indicated by theoretical lateral strength assessments.

Utilising the Engineering Strategy Group's preliminary recommendations of using an enhanced Structural Performance Factor (Sp=0.35), the lateral bracing capacity for both style of Nelson Block structures will increase to 50%NBS.

Aurecon New Zealand Limited
Level 1, 102 Customhouse Quay
Wellington 6011
PO Box 1591
Wellington 6140
New Zealand

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