Flexible Learning Space Upgrade – Avalon Block

Design Features Report

Ministry of Education

10 September 2015

Revision: 3

Reference: 246313

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Document control record

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Document control						
Report title		Design Features Report				
Document ID			**Project number**		246313	
File path		P:\246313\03 Project Delivery\Reports\Avalon Block Design Features Report.docx				
Client		Ministry of Education	**Client contact**		Bo-Yao Lee	
Rev	**Date**	**Revision details/status**	**Prepared by**	**Author**	**Verifier**	**Approver**
0	20 July 2015	Draft Issue for Comment	O Kingsnorth	O Kingsnorth	M McGechie	J Finnegan
1	24 July 2015	Draft Issue for Comment	O Kingsnorth	O Kingsnorth	M McGechie	J Finnegan
2	10 September 2015	Draft Issue for Comment	P Don	P Don	M McGechie	J Finnegan
3	20 October 2015	Issue to Client	P Don	P Don	M McGechie	J Finnegan
Current revision		**3**				

Approval			
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1 Introduction

A target strength of 67% of current New Zealand Building Code requirements as per NZS1170.5:2004 has been used for design.

Two options are presented for the Avalon Block, working within the limitations of the existing block layout. The first option provides the minimum work required to achieve the principles of the Flexible Learning Space; and the second provides an optimum solution.

The purpose of this report is to provide a technical description of the 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

The typical Avalon Block is composed of 1 to 4 classrooms laid end to end. Clerestory windows are present near the rear of the classrooms as shown in Figure 1 below. A cloakroom and toilet area is attached to the back of the classrooms.

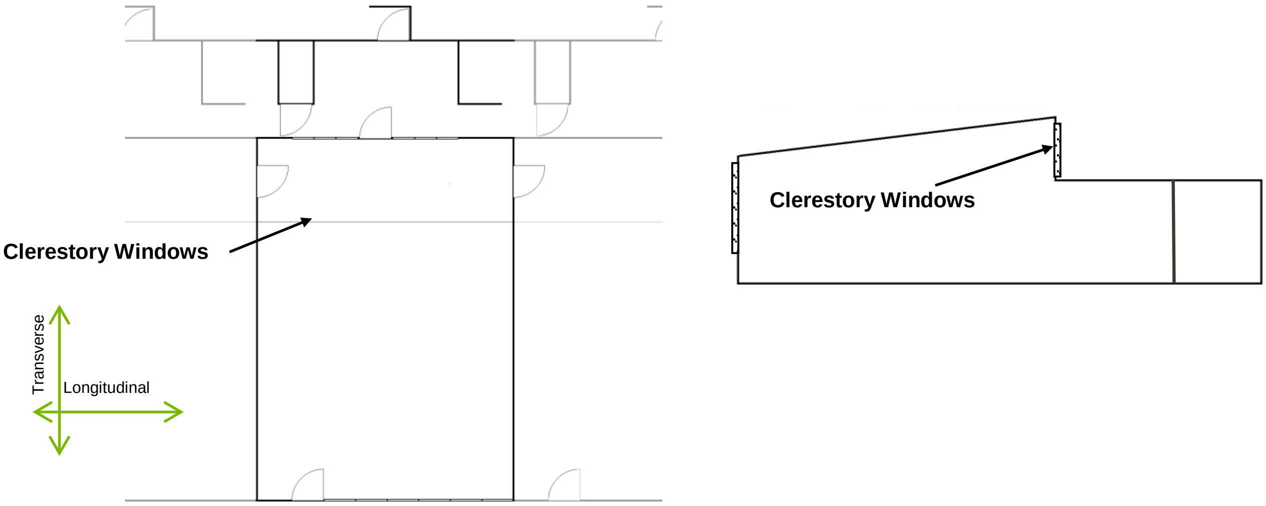

Figure 1 – Typical Avalon Block Plan View (left) and Side Elevation (right)

Lateral bracing in the longitudinal direction governs the building's seismic response. This is due to the large proportion of full height windows on the longitudinal external walls. On these lines there is very little wall that would be recognised as effective bracing wall under NZS 3604.

In the transverse direction, lateral bracing is provided by lined timber shear walls with diagonal timber cross bracing members.

The roof consists of timber purlins spanning longitudinally onto the transverse shear walls. The roof covering consists of corrugated iron fastened directly to timber sarking, which assists with seismic load transfer to the lateral load resisting elements.

The typical Avalon Block features concrete foundation walls. These walls are continuous beneath the walls of the building. The foundations for the cloakroom/toilet area feature a concrete slab on grade.

A number of detailed seismic assessments of Avalon Blocks have been carried out by Aurecon on behalf of the Ministry and these buildings have achieved between approximately 45% and 100% NBS.

Many of the Avalon Blocks still in use by the Ministry have undergone alterations ranging from minor to major. 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.

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 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. The work needed to meet these requirements involves re-lining a selection of walls with a more adequate bracing material, as well as ensuring hold-down fixings are adequate.

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. Each option represents a different cost level. Option 1 sets out the minimum work required to achieve the desired goals. Option 2 is the optimum solution, given the limitations of the existing structure.

3.3 Gravity System

The steel roof cladding is supported by purlins supported by timber framed walls. Loads are transferred through these elements into the concrete foundation walls below. During the upgrade works, the gravity system will be altered through the installation of timber and steel lintels to support the roof framing in the areas where load bearing walls were removed.

3.4 Ceiling Diaphragm

The required bracing capacities of the ceiling diaphragms were assessed based on the tributary areas of lateral resisting elements. 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".

Original drawings show that roofing iron is fastened to diagonal timber sarking. The diagonal timber sarking provides the diaphragm for the roof level. This sarking is adequate to transfer seismic loads to the lateral load resisting elements as it stands, therefore no further strengthening is required.

3.5 Wall Hold Downs

Steel bolts are required to transfer shear between the timber wall bottom plate and the concrete foundation walls. These wall hold downs are also required to resist uplift forces on the ends of the shear walls.

Gib Braceline and Ecoply walls have minimum hold down requirements of a Gib HandiBrac at each end, secured with a 15kN tension capacity hold down bolt. These hold down bolts are to be 12mm diameter threaded steel rods, which can be readily installed by drilling through the bottom plate, into the foundations and inserting along with an epoxy based adhesive. NZS 3604 requires that hold downs of this type are present at a maximum of 900mm centres.

3.6 Lateral Load Resisting Elements

Earthquake demands were assessed as per the equivalent static method, outlined in NZS1170.5:2004 and structural elements were designed to resist these demands. Lateral load resisting elements were oriented within existing walls where possible to minimise the loss of window space. Care was taken to distribute these elements evenly and locate them as near as practical to the external faces of the building in order to provide good torsional response.

The new lateral load resisting elements have been designed with reference to the Gib Ezy Brace Systems 2011 manual, the EcoPly Specification and Installation Guide 2011, the New Zealand Timber Structures Standard – NZS3603:1993 and the New Zealand Timber Framed Buildings Standard – NZS3604:2011.

Option 1 has more internal walls and consequently the target strength can be achieved through the use of GIB Braceline and EcoPly Plywood. Connections between these new bracing elements and the roof and floor will also need to be upgraded to ensure a complete and resilient load path is able to transmit seismic loads safely into the ground.

Option 2 has fewer usable bracing walls and therefore required additional use of GIB Braceline and EcoPly Plywood as well as Standard GIB on selected timber framed walls.

3.7 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.

No foundation works will be necessary except for connections between the bracing walls and the foundations.

4 Design Criteria

4.1 Design Standards and Codes

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

4.1.1 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)

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	0.40 kPa (member self-weights)
Live:	0.25 kPa (Non Accessible Roof)

4.2.2 Walls and Glazing:

Dead:	0.30 kPa (Timber Walls with Plasterboard)

4.2.3 Floor Loadings:

Dead:	0.4 kPa (Timber Floor)
Live:	3.0 kPa (Classroom)

4.3 Seismic Load Parameters and Coefficients

4.3.1 Wellington

Hazard Factors from AS/NZS1170.5

Importance Level	=	2
Soil Class	=	C
$C_h(T)$	=	2.36 (assumed T<= 0.4s)
Z	=	0.40 (Hazard factor – Wellington)
R	=	1.0 (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 1.0 x 1.0 = 0.9440 (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 = 2.50)
	=	2.143 (μ = 3.00)

Seismic Coefficient:

$C_d(T)$	=	0.2542 (μ = 2.50, Sp = 0.5)
$C_d(T)$	=	0.3084 (μ = 3.00, Sp = 0.7)

4.3.2 Auckland

Hazard Factors from AS/NZS1170.5

Importance Level	=	2
Soil Class	=	D
$C_h(T)$	=	3.00 (assumed T<= 0.4s)
Z	=	0.13 (Hazard factor – Auckland)
R	=	1.0 (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 1.0 x 1.0 = 0.3900 (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:

$C_d(T)$	=	0.1050 (μ = 2.50, Sp = 0.5)
$C_d(T)$	=	0.1274 (μ = 3.00, Sp = 0.7)

4.3.3 Christchurch

Hazard Factors from AS/NZS1170.5

Importance Level	=	2
Soil Class	=	D
$C_h(T)$	=	3.00 (assumed T<= 0.4s)
Z	=	0.30 (Hazard factor – Christchurch)
R	=	1.0 (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 1.0 x 1.0 = 0.9000 (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:

$C_d(T)$	=	0.2423 (μ = 2.50, Sp = 0.5)
$C_d(T)$	=	0.2940 (μ = 3.00, Sp = 0.7)

4.4 Load Combinations

The following ultimate limit state load combination factor have been used as specified in AS/NZS1170.0, Section 0:

$$G + \Psi_c Q + E_u$$

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 normal classroom with an importance level of 2 as per the MOE guidelines and a design working life of 50 years. A return period factor ‘R’ of 1.0 has therefore been used.

5 Methodology: Structural Analysis and Design

5.1 Design Method

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

5.2 Analysis

The building seismic loads have formed 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. Excel Spreadsheets were also used to calculate the capacity of the Gib and plywood wall bracing systems and the various seismic coefficients for the structure.

The individual structural components (bracing walls) were modelled two dimensionally and individually.

5.3 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 strengthening scheme 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 strengthening 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 FLS and seismic strengthening scheme is also based on information that has been provided to Aurecon from other sources or by other parties. The strengthening 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 FLS and seismic strengthening scheme assumes that the existing building is as per the enclosed original Avalon Block 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.

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