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# MOE – FLS Reference Designs for Standard Classroom Upgrade – Formula Block

Design Features Report

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# Contents

# 1 Introduction

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

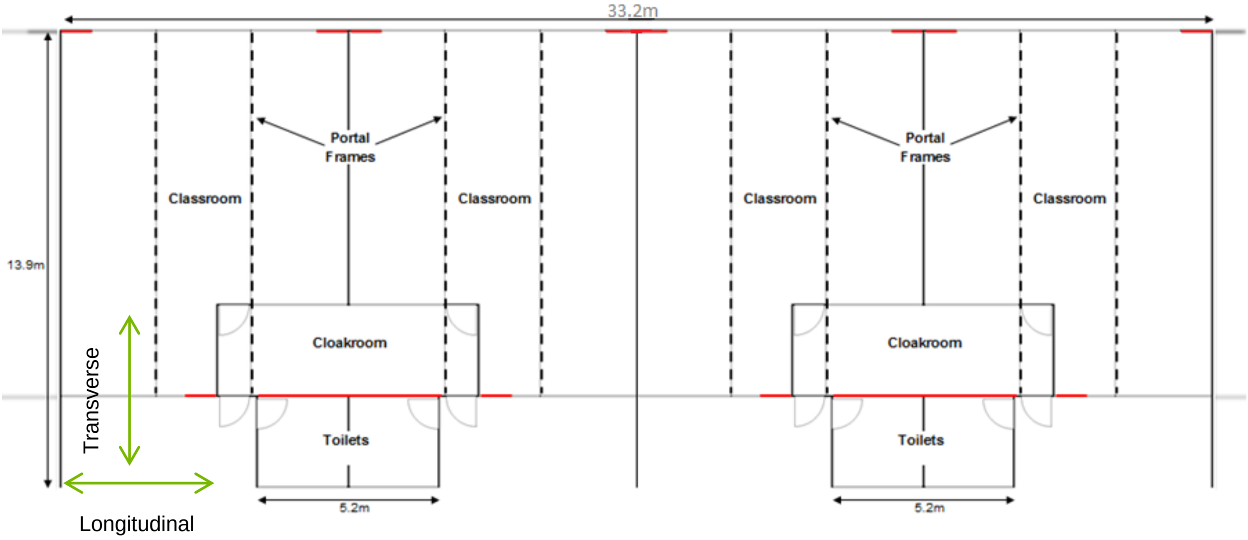
Three options have been explored ranging from the minimum work to achieve the principles of the FLS, through to an optimum solution, given the limitations of the existing block layout.

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

A typical Formula Block is composed of either 2 or 4 classrooms laid end to end. They are of lightweight timber construction and are characterised by consecutive pairs of classrooms with common cloakroom and brick clad toilet facilities. The figure below shows a plan of a typical 4 classroom Formula Block.




**Typical 4 Classroom Formula Block Plan View**

Lateral bracing in the longitudinal direction governs the buildings seismic response. This is due to the large proportion of full height windows on the longitudinal external walls. The red lines in the figure above show the original locations of longitudinal effective wall.

In the transverse direction lateral bracing is provided by a combination of lined timber shear walls and either glulam or steel portal frames. These portal frames were intended primarily to resist gravity forces, but have been found to provide some lateral resistance.

Ceiling diaphragms were originally made of timber sarking which provided good bracing performance, however; skylights running longitudinally down the centre of the roof cause a weak point in these systems.

The typical formula block features a concrete slab on grade which is expected to perform satisfactorily in an earthquake.

Many of the Formula Blocks still in use by the MOE 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.

# 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 three 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

Three options have been put together by Brewer Davidson to achieve the goals set out by the Innovative Learning Space Upgrade. Each option represents a different cost level. Option 1 sets out the minimum work required to achieve the desired goals. Option 3 is the optimum solution, given the limitations of the existing structure. Option 2 is an intermediate solution that provides some additional benefits over Option 1, while, taking in to consideration some cost savings.

## 3.3 Gravity System

The steel roof cladding is supported by a combination of timber framed walls and structural steel or glulam timber portal frames. Loads are transferred through these elements directly into the concrete slab foundations. The gravity system is not to be altered during the seismic strengthening of the building.

## 3.4 Roof/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 the roof diaphragm consists of timber rafters with a sarking roof covering. There is also a large skylight running down the apex of the roofline. This dissects the original diagonal sarking and is a weak point in the ceiling diaphragm. Subsequent building alterations have resulted in the removal of these skylights in many of the observed schools. Assessment of the roof diaphragm in this design package has found that the roof diaphragm is adequate to support a minimum of 67%NBS seismic demands and therefore not seen as requiring additional strengthening.

## 3.5 Wall Hold Downs

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

Braced 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 steel bars, which can be readily installed by drilling through the bottom plate, into the foundations and inserting along with an epoxy based adhesive. NZS3604 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 NZS1170.5:2002 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.

Lateral load resisting elements 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.

It was found that 100% of the lateral demands in a typical Formula Block can be resisted by upgrading the capacity of existing walls. High capacity bracing elements will need to be installed. These will consist of Ecoply plywood shear walls to the rear of the building.

## 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.

The foundations will not undergo any strengthening works.

# 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 kPa (Non Accessible Roof) |

### 4.2.2 Walls and Glazing:

| | |
|---|---|
| Dead: | 0.30 kPa (Timber Walls with Plasterboard and Glazing) |
| Dead: | 19kN/m$^3$ (Brick Veneer) |

### 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) |
| $\mu$ | = | 1.25 (ULS - existing portal frames) |
| | = | 2.50 (ULS - existing timber framed bracing elements) |
| | = | 3.00 (ULS - new timber framed lateral bracing elements) |
| $S_p$ | = | 0.925 ($\mu$ = 1.25) |
| | = | 0.5 ($\mu$ = 2.5) |
| | = | 0.7 ($\mu$ = 3.0) |
| $k_\mu$ | = | 1.143 ($\mu$ = 1.25) |
| | = | 1.857 ($\mu$ = 2.50) |
| | = | 2.143 ($\mu$ = 3.00) |

**Seismic Coefficient:**

| | | |
|---|---|---|
| $C_d(T)$ | = | 0.7641 ($\mu$ = 1.25, Sp = 0.925) |
| $C_d(T)$ | = | 0.2542 ($\mu$ = 2.50, Sp = 0.5) |
| $C_d(T)$ | = | 0.3084 ($\mu$ = 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) |
| $\mu$ | = | 1.25 (ULS - existing portal frames) |
| | = | 2.50 (ULS - existing timber framed bracing elements) |
| | = | 3.00 (ULS - new timber framed lateral bracing elements) |
| $S_p$ | = | 0.925 ($\mu$ = 1.25) |
| | = | 0.5 ($\mu$ = 2.5) |
| | = | 0.7 ($\mu$ = 3.0) |
| $k_\mu$ | = | 1.143 ($\mu$ = 1.25) |
| | = | 1.857 ($\mu$ = 2.50) |
| | = | 2.143 ($\mu$ = 3.00) |

**Seismic Coefficient:**

| | | |
|---|---|---|
| $C_d(T)$ | = | 0.3157 ($\mu$ = 1.25, Sp = 0.925) |
| $C_d(T)$ | = | 0.1050 ($\mu$ = 2.50, Sp = 0.5) |
| $C_d(T)$ | = | 0.1274 ($\mu$ = 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) |
| $\mu$ | = | 1.25 (ULS - existing portal frames) |
| | = | 2.50 (ULS - existing timber framed bracing elements) |
| | = | 3.00 (ULS - new timber framed lateral bracing elements) |
| $S_p$ | = | 0.925 ($\mu$ = 1.25) |
| | = | 0.5 ($\mu$ = 2.5) |
| | = | 0.7 ($\mu$ = 3.0) |
| $k_\mu$ | = | 1.143 ($\mu$ = 1.25) |
| | = | 1.857 ($\mu$ = 2.50) |
| | = | 2.143 ($\mu$ = 3.00) |

**Seismic Coefficient:**

| | | |
|---|---|---|
| $C_d(T)$ | = | 0.7284 ($\mu$ = 1.25, Sp = 0.925) |
| $C_d(T)$ | = | 0.2423 ($\mu$ = 2.50, Sp = 0.5) |
| $C_d(T)$ | = | 0.2940 ($\mu$ = 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:

$$G + \Psi c\, Q + Eu$$

| | | |
|---|---|---|
| G | = | Dead Load |
| Q | = | Live Load |
| E | = | Seismic Load |
| Ψc | = | 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 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 Formula 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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