*Bay Venues Ltd*

# Memorial Pool Complex – Main Building

## Detailed Seismic Assessment Report

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Date: 30 May 2018
Reference: 2-9B341.00
Status: Issue 2

# Executive Summary

A Detailed Seismic Assessment was carried out for the Memorial Pool Complex – Main Building for Bay Venues Limited. The purpose of the assessment is to establish whether the seismic performance of the building satisfies the Building Act minimum standards for existing buildings, and to identify improvements required to meet those standards if necessary.

The seismic performance was assessed in terms of new building design standard (%NBS), where %NBS is the estimated lateral resistance of the existing building relative to the current Building Code requirements for a new building at the same site with the same functional requirements. The Building Act minimum standard is 33%NBS. Both the New Zealand Society for Earthquake Engineering and the Tauranga City Council recommend strengthening to at least 67%NBS, and as close to 100%NBS as practicable.

The results of the assessment are summarised in the following table:

Table 1: Analysis Results

| Importance Level | %NBS(IL2) |
|---|---|
| IL2 | 25% |

The seismic performance of the building is limited by the capacity of the perimeter longitudinal URM walls under the windows, under out-of-plane actions. The capacity of the short URM internal partition walls in the transverse direction under in-plane actions of a similar magnitude (33%NBS).

Whilst the short walls are susceptible to rocking (33% NBS) for the in-plane loading, this is not regarded as a capacity issue, but rather something that will lead to increased localised damage. The out-of-plane actions of the URM walls (25% to 69% NBS) can lead to significant damage as this is an instability failure with potential for collapse. The critical external longitudinal walls have potential to collapse inward or outward of the building.

The Building (Earthquake-prone Buildings) Amendment Act 2016 places the responsibility for determining the Earthquake-prone status of a building on the Territorial Authority, in this case Tauranga City Council, based on the outcomes of this report.

Strengthening to a minimum of 67%NBS is recommended. Strengthening works would be required to the URM walls (both internal and infill).

# Contents

# 1 Introduction

## 1.1 Purpose

This report presents the results of a Detailed Seismic Assessment (DSA) on the performance of the main building at Memorial Pool. The building is a single storey building that has been designed in 1954 and is currently being used as an Aquatic and Recreational building. The purpose of the assessment is to establish whether the building performance satisfies the Building Act minimum standards for existing buildings, and to identify improvements required to meet those standards if necessary.

The building on the site for this DSA is indicated in the figure below.

**Figure 1: Site Aerial View of Memorial Pool (Source: LINZ)**

## 1.2 Scope of work

The scope of work for this Seismic Assessment includes the following:

- Sourcing of structural drawings and a site visit to the building have been undertaken previously;
- Quantitative structural assessment to determine the percentage of New Building Standards (%NBS) of the building based on Importance Level 2
- Schematic options for improving the building performance above 67%NBS if required

The seismic bracing of the building contents has not been assessed.

## 1.3 Performance Standards

The performance is assessed in terms of new building standard (%NBS), where %NBS is the estimated earthquake resistance of the existing building relative to the current Building Code requirements for a new building design at the site with the same functional requirements. The Building Act minimum standard for existing buildings is 33%NBS. The commonly adopted preferred standard is a minimum of 67%NBS as recommended by the New Zealand Society for Earthquake Engineering[1].

Current design standards require buildings to be designed for two levels of performance or "limit states":

1. Serviceability Limit State (SLS): The degree of damage to the structure is minor, readily repairable and will not prevent immediate occupancy of the building.
2. Ultimate Limit State (ULS): Damage may be extensive but will permit safe exiting of the building. Occupancy may be restricted until repairs are made, or the building might be demolished if it is not feasible to repair.

The design standards depend upon the building's Importance Level (IL) as shown in Table 2. These importance levels are defined in NZS 1170.0[2].

Table 2: Importance Levels and Design Loads

| **Importance Level** | **Annual Probability of Exceedance of Load** | |
|---|---|---|
| | **SLS** | **ULS** |
| IL2: normal occupancy, e.g. commercial offices | 1/25 | 1/500 |
| IL3: public utilities not having special post-disaster function | 1/25 | 1/1000 |
| IL4: facilities with special post-disaster function. | 1/500 | 1/2500 |

The Memorial Pool Main Building has been classified as IL2 for assessing its seismic performance.

## 1.4 Tauranga City Council Earthquake Prone Building Policy

Tauranga City Council updated their Dangerous, Earthquake Prone and Insanitary Building Policy in March 2011 and is now due for review. The Policy requires any building with a capacity of less than 34% of New Building Standard (including consideration of critical structural weaknesses) to be strengthened to a minimum of 34%NBS. The policy includes the following:

- Where it becomes apparent that a building may be earthquake-prone, Council's role is to undertake an assessment of the building to establish whether it is earthquake-prone within the terms of the Building Act, and the imminence of any danger.

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[1] Assessment and Improvement of the Structural Performance of Buildings in Earthquakes, guidelines prepared by the New Zealand Society for Earthquake Engineering, 2006.

[2] NZS 1170.0, 2002, Structural Design Actions: General principles.

- Where a building has been deemed to be earthquake-prone, Council will work with the owner of the building to make it safe.
- The building owner's responsibility is to undertake works to remove or reduce the danger, and assume full financial responsibility.
- If a building which is deemed to be dangerous, earthquake-prone or insanitary is also classified as a heritage building the approach is the same as for dangerous, earthquake-prone or insanitary buildings which are not heritage buildings. However, Council and the building owner/s will work in conjunction with the Historic Places Trust to remedy the building.

The policy does not provide time frames for undertaking strengthening work for a building that has been deemed earthquake-prone.

## 1.5 Assessment Methodology

The New Zealand standard methodology for assessing the earthquake performance of existing buildings is specified in guidelines that were prepared by the New Zealand Society for Earthquake Engineering[3].

The general process is to:
(1) Assess the seismic loads or **demand** in accordance with the new building seismic loadings standard NZS1170.5:2004[4], and
(2) Assess the **capacity** of the structure to withstand seismic loads using processes and criteria in the NZSEE guidelines. The building's rating in terms of %NBS is then:

$$\%\text{NBS} = \frac{\text{Capacity}}{\text{Demand}} \times 100$$

## 1.6 Sources of Building Data

The following information was obtained from the Tauranga City Council Property File:

- Structural drawings of the building by Normal J Jenkins dated June 1954

- Initial Seismic Assessment (ISA) undertaken by Opus in October 2014.

No original structural calculations or specifications were located. A non-intrusive walk through site investigation was undertaken during the ISA to determine the geometry and confirm the fabric of the building.

The site investigation was also used to confirm the structural systems, investigate potential critical structural weaknesses (CSW) and identify details which required particular attention.

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[3] Assessment and Improvement of the Structural Performance of Buildings in Earthquakes, guidelines prepared by the New Zealand Society for Earthquake Engineering, 2006.

[4] NZS 1170.5, 2004, Structural design actions: Earthquake actions – New Zealand

## 1.7 Geotechnical

No specific geotechnical investigations have been undertaken at the site as a part of this assessment.

Reference has been made to the Western Bay of Plenty Lifelines Study Microzoning for Earthquake Hazards by Opus dated 2002. Based on the results of this study, the site subsoil class is classified as Class E- Very soft soil and the liquefaction potential for the founding materials is considered to be minor.

# 2 Building Description

The Main Building is a rectangular, single storey concrete framed structure in both directions with concrete masonry infill walls around the perimeter and concrete masonry internal partition walls.

The original building is a 27.7m long x 7.62m wide with a maximum ceiling height of approximately 2.8m. The structural drawings show that the ground floor of the building is supported on strip foundations around the perimeter of the building. Figure 2 below illustrates the original plan layout of the building, excluding the northern extension.

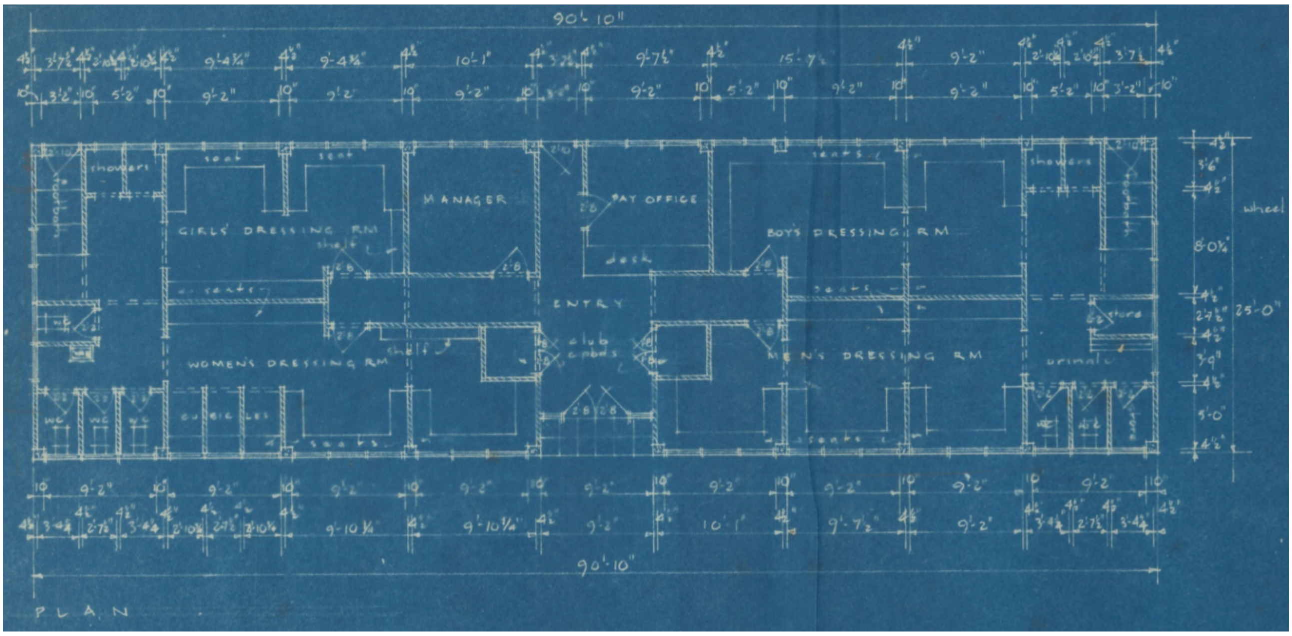

Figure 2: Overall plan of the Memorial Pool building

The following photos (Figures 3 – 6) illustrate the building further.

Figure 4: Southern and Western elevation of the building

Figure 3: Internal view of building interior with internal masonry walls

Figure 6: Eastern Elevation

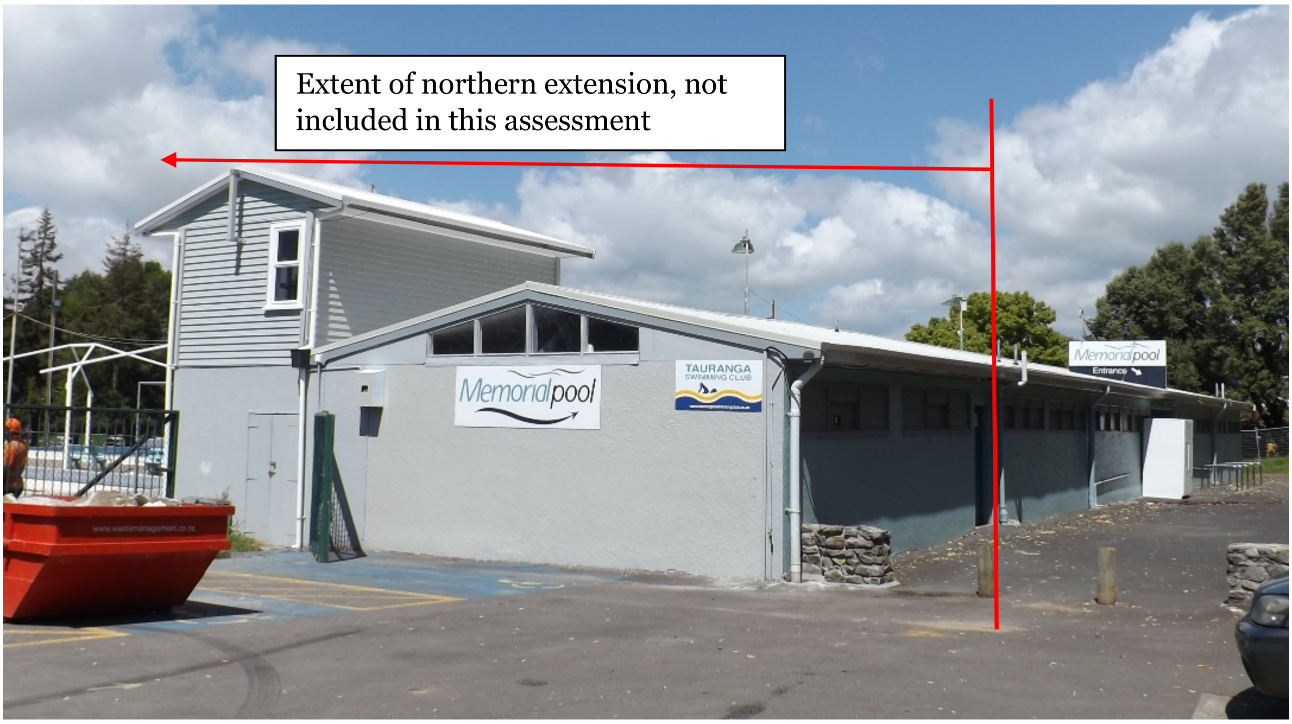

Figure 5: Transverse end wall (Northern Elevation). The extension to the left is not included in this assessment

## 2.1 Structural System

Gravity forces of the building are resisted by the timber framed roof spanning across the building. The forces from the roof are in turn supported by the concrete frame around the perimeter of the building, masonry infill walls and internal concrete masonry walls. These forces are in turn supported on concrete strip and pad footings respectively.

Lateral loads induced by earthquake and wind loadings across the building are resisted by the reinforced concrete frames, masonry infill walls around the perimeter walls and the internal masonry walls in both the longitudinal and transverse direction.

## 2.2 Building Condition

Non-intrusive inspections of the building were completed during the Initial Seismic Assessment stage by Opus Engineers. The building at the time was generally found to be in good condition,

# 3 Seismic Loading

The criteria in the table below, taken from the earthquake loadings standard NZS 1170.5:2004[5], were used to determine the site loading spectrum. NZS 1170.5 loads are derived from a 2002 version of the New Zealand Seismic Hazard Model. This model has been updated subsequently, but there have been no significant changes that would affect the design loadings.

**Table 3: Parameters for Seismic Loads**

| **Parameter** | **Value** | **Comments** |
|---|---|---|
| Site Subsoil Class | E | Typical soil type in the surrounding area |
| Z | 0.20 | Seismic hazard factor for Tauranga |
| Structural Ductility, μ | 1.0 | Concrete frame and unreinforced concrete masonry walls (URM) |
| Structural Performance Factor, Sp | 0.9 | As per NZS 1170.5 |
| N (T,D) | 1.0 | >20 km from nearest major fault |
| $R_u$ (ULS) | 1.0 | Importance level 2 |

Seismic loads are derived from multiplying the seismic weight of the building by the horizontal seismic coefficient. The induced seismic forces for individual building elements such as internal walls and concrete frames are derived from their respective tributary areas from each direction of loading.

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[5] NZS 1170.5, 2004, Structural design actions: Earthquake actions – New Zealand

# 4 Material Properties

The following material properties were used to determine the probable strength capacity of the timber framed building:

Table 4: Probable strength values for existing materials

| Material | Nominal Strength |
|---|---|
| Concrete Masonry | f'm = 13.3 MPa |
| Concrete Masonry Mortar Compressive Strength | f'j = 2MPa |
| Concrete compressive strength | f'c = 25 MPa |
| Steel reinforcement | f'y = 255 MPa |

# 5 Analysis

Equivalent static analysis of the building was completed due to the simple geometry and regular layout of the structure with light weight roof above. A structural ductility of 1.0 was used throughout the analysis for both the URM walls (both internal and perimeter infill walls) and the concrete frame due to reinforcement detailing deficiencies typical of the time of construction. A period of vibration of 0.4s was assumed in both directions.

The detailed seismic assessment has considered the concrete frame and masonry walls in each direction based on seismic loading from the tributary width. Capacity assessment for the concrete frame and internal unreinforced concrete masonry (URM) walls has been based on the NZSEE and EQ-Assess guidelines taking into account the probable capacities of the individual elements. Both in-plane shear and out-of-plane actions were considered for the masonry walls and their capacities were compared with the seismic demands.

Drawings do not show any reinforcement to the concrete masonry walls other than bed joint reinforcement, which does not provide any resistance to out-of-plane loading. The bed joint reinforcement does extend into the concrete frame columns, however due to the size and unknown anchorage of the reinforcement, it is considered that the masonry walls are independent of the frame for analysis purposes other than in direct bearing. The perimeter infill walls are therefore considered to cantilever from the foundation. The internal masonry partition walls are also tied to each other at roof level with a reinforced concrete bond beam.

In-plane capacity assessment of the URM infill walls was also based on the NZSEE guidelines using diagonal struts to simulate the effect of the infill wall. Like the internal URM walls, both in-plane and out-of-plane actions were considered and their capacities were compared with the demands.

The building overall was relatively well divided into gridlines based on the column spacing at approximately 3.05m.

Hand and spreadsheet calculations were used to calculate the strength of the building elements.

# 6 Analysis Results

The analysis results for the buildings seismic performance is summarised in the table below:

Table 5: Analysis Results (IL2)

| Parameter | | %NBS |
|---|---|---|
| Longitudinal | Concrete Frame | >100% |
| | External URM longitudinal infill walls (in-plane) | >100% |
| | Internal URM transverse walls (out-of-plane) | 61% |
| | Internal URM longitudinal walls (in-plane rocking) | 55% |
| Transverse | Concrete Frame (internal bays) | >100% |
| | Internal URM transverse walls (in-plane rocking) | 33% |
| | Internal URM longitudinal walls (out-of-plane) | 69% |
| | Concrete Frame (End bays) | 66% |
| | End Bay URM infill wall (In-plane) | >100% |
| | External URM longitudinal infill walls (cantilever out-of-plane) | 25% |

For the purposes of these results, the building the transverse direction is taken as east-west.

The seismic performance of the unreinforced concrete masonry walls in the transverse direction has been assessed as 33%NBS(IL2) for rocking of the short length walls under in-plane actions. The out-of-plane capacity of the walls varies between 25% and 69%, depending on whether they are cantilever walls or support roof loads. Due to the masonry walls being essentially independent of the reinforced concrete frame, the frame capacity has been assessed as >100%NBS(IL2).

## 6.1 Concrete Masonry Walls – In-plane

The internal concrete masonry walls have been assessed based on being unfilled, with a reinforced concrete bond beam at the top of the wall only, tying the adjacent walls together. This tie beam acts as a restraint top the walls, providing support both in-plane (in the direction of the wall run) and out-of-plane (in the direction perpendicular to the plane of the wall).

There are several short partition walls approximately 1.5m long throughout the building, typically in the changing rooms between bays or as dividing walls between toilets. The short length of these walls means that they are prone to rocking (or overturning) under seismic load at 33%NBS(IL2). Some restraint is provided by the tie beam at the top of the wall and the rocking response has some resilience, however these walls will sustain damage and their capacity degrade. The remaining longer walls have a better performance.

The perimeter full length masonry infill panels, part height to the longitudinal walls and full height to the end walls, have a seismic performance of 100%NBS(IL2) in the in-plane direction.

## 6.2 Concrete Masonry Walls – Out-of-plane

The masonry walls to the perimeter of the building have been assessed as unreinforced and acting as cantilevers from the foundation as they have no reliable tie to the reinforced concrete frames and have windows above for the full length of the building. Their seismic performance has been assessed as 25%NBS(IL2).

The internal walls are taller and have restraint at the top from the reinforced concrete tie beam. Their performance varies between 61% and 69%NBS(IL2), depending on whether the walls have additional load for supporting the roof trusses (e.g. the central longitudinal wall).

# 7 Evaluation of Results

Table 6: Analysis Results

| Importance Level | %NBS(IL2) |
|---|---|
| IL2 | 25% |

The seismic performance of the building is limited by the capacity of the perimeter longitudinal URM walls under out-of-plane actions, with the capacity of the short URM internal partition walls in the transverse direction under in-plane actions of a similar magnitude.

The out-of-plane actions of the URM walls (25% to 69% NBS) can lead to significant damage as this is an instability failure with potential for collapse. The critical external longitudinal walls have potential to collapse inward or outward of the building. The potential instability occurs at earthquake shaking levels below the earthquake prone limit.

Whilst the short transverse walls are susceptible to rocking (33% NBS) for in-plane loading, this is not regarded as a capacity issue, but rather something that will lead to increased localised damage. The rocking failure of the wall is not considered likely to cause collapse.

# 8 Increasing Seismic Performance

NZSEE Guidelines recommend strengthening to as nearly as is reasonably practicable to 100%NBS, but with a minimum of 67%NBS. To increase the seismic performance of the building to at least 67% NBS, the strengthening works are required to the unreinforced concrete masonry walls. However, due to the thickness of the masonry (only 114mm), adding reinforcement and grouting of the hollow masonry cells is likely to be difficult and have minimal effect. Options therefore include:

- Add steel posts and beams behind the walls, tied to the reinforced concrete frames and/or roof structure. However, this will add load to the frames, reducing their seismic performance slightly. The connection of the posts to unreinforced masonry cells is also not very reliable; or

- Demolish and replace the walls with new thicker (150mm) reinforced concrete masonry walls; or

- Demolish and replace the walls with new lightweight walls however there are potential durability issues considering the wet environment; or

- Fibre reinforced plaster coatings can be used to strengthen the walls, though this would be most effective for the full height internal walls.

# 9 Conclusions

The building has been found to have a seismic performance of 25%NBS (IL2). The building does not exceed the Building Act minimum seismic performance requirement of 33%NBS.

The Building (Earthquake-prone Buildings) Amendment Act 2016 places the responsibility for determining the Earthquake-prone status of a building on the Territorial Authority, in this case Tauranga City Council, based on this report.

Strengthening to a minimum of 67%NBS is recommended. Strengthening works would be required to the URM walls (both internal and infill).

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