Petone Settlers Museum

136 The Esplanade Petone
Detailed Seismic Assessment

November 2019

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Executive Summary

Background

WSP has completed a Detailed Seismic Assessment (DSA) of the Petone Settlers Museum – 136 The Esplanade, Petone for the Hutt City Council (HCC). The assessment was completed in accordance to the MBIE guidelines 'The Seismic Assessment of Existing Buildings: Technical Guidelines for Engineering Assessments, July 2017, Version 1'.

The purpose of the assessment was to determine the overall seismic performance of the building in terms of a New Building Standard (%NBS). The table below presents a summary of our assessment findings:

Building	Description
Building Address	136 The Esplanade, Petone
Building Name	Petone Settlers Museum
Storeys	One storey with an 11 metre high tower
Year of Design	1939
Gross Floor Area	400 m^2
Construction Type	Reinforced concrete shear walls
Assessment Type	Detailed Seismic Assessment
Inspection Date	24 August 2019
Importance Level	2
Structural Assessment Summary	The assessment was based upon visual observations during a site investigation and undertaking a detailed structural analysis of the building's seismic load resisting systems.
Estimated % NBS	70%
Specific CSW's and Life Safety Hazards	In-plane strength of concrete walls around the Memorial Hall.
Conclusions and Recommendations	We consider the Early Settlers Museum to be rated at **70% NBS** for an IL2 building. We do not recommend any further work for this building.

Contents

Document History and Status

Revision	Date	Author	Reviewed by	Approved by	Status
A	15/11/19	[redacted]	[redacted]	[redacted]	Draft
B	15/11/19	[redacted]	[redacted]	[redacted]	Final

Revision Details

Revision	Details
A	Draft for client comment
B	Final

1 Introduction

1.1 Objective

A Detailed Seismic Assessment (DSA) of the Petone Settlers Museum, located at 136 The Esplanade, Petone, was carried out by WSP in accordance with the following seismic assessment guidelines (The Guidelines).

- The Seismic Assessment of Existing Buildings: Technical Guidelines for Engineering Assessments, July 2017, Version 1.
- Technical Proposal to Revise the Engineering Assessment Guidelines Part C5 Concrete Buildings, November 2018

The Guidelines have been produced by New Zealand engineering technical societies in conjunction with the Ministry of Business, Innovation and Employment (MBIE) and the Earthquake Commission. The Guidelines came into force on 1 July 2017 and supersede the previous guidance published in 2006 by the New Zealand Society of Earthquake Engineering (NZSEE).

1.2 Sources of Building Data

The DSA was carried out using the following information. The complete drawing set and specifications of the Petone Settlers Museum were reviewed and are listed below:

- Sheets 1 to 6 for the Wellington Provincial Centennial Memorial dated 1939 by Horace L Massey, registered Architect.
- Specification for the Wellington Provincial Centennial Memorial dated March 1939 by Horace L Massey, registered Architect. Pages 1 to 26.

1.3 Design Standards, Guidelines and References

The following standards, guidelines and references were used in the assessment of the structure in this document:

- AS/NZS1170.0:2002 General Principles
- AS/NZS1170.1:2002 Permanent, Imposed and other Actions
- NZS1170.5:2004 Earthquake Actions - New Zealand
- NZS3101:2006 Concrete Structures Standard, Amendment 1-3
- NZS3603:1993 Timber Structures Standard
- The Seismic Assessment of Existing Buildings: Technical Guidelines for Engineering Assessments, July 2017, Version 1

1.4 Buildings Regulations

The Building (Earthquake-prone Buildings) Amendment Act 2016 is the current amendment to the Building Act 2004 that sets the performance objectives for buildings and provides a system for managing earthquake-prone buildings that include the MBIE guidelines. The intent of the act is to protect people and property and, therefore, performance limits are set in terms %NBS as an Ultimate Limit State (ULS).

2 Building and Site Description

2.1 General Overview

Building Information	
Building	Description
No. of Storeys	One storey with an 11 metre Tower
Gross Floor Area (approx.)	400 m^2
Year of Design (approx.)	1939
Current Use	Public Museum
Importance Level	2
NZ Standards designed to	1935 Model Bylaws
Gravity Load Resisting System	Timber purlins supported by steel RSJ beams which span onto reinforced concrete walls.
Lateral Load Resisting System	Lateral loads are resisted by reinforced concrete shear walls.
Wall/Roof Cladding	Lightweight metal roofing on timber sarking and cement plastered concrete walls.
Floor System	In-situ concrete slab on grade.
Foundations	Reinforced concrete ground beams on concrete pad foundations.
Key features of ground profile and identified geo-hazards	Located on the Petone foreshore – the site subsoil is assumed as class 'D' in the absence of any Geotechnical studies on site (refer Section 2.3).
Previous strengthening and/ or significant alteration	Removal of some internal concrete walls in Gallery Wings in 2005.

2.2 Building Description

The Petone Settlers Museum is a single storey concrete walled building, consisting of a central tower (Memorial Hall) and two gallery wings (Dressing Sheds) that include toilets and ancillary rooms. The building was designed in 1939 as the Wellington Provincial Centennial Memorial. Original drawings and specifications were reviewed as part of this assessment.

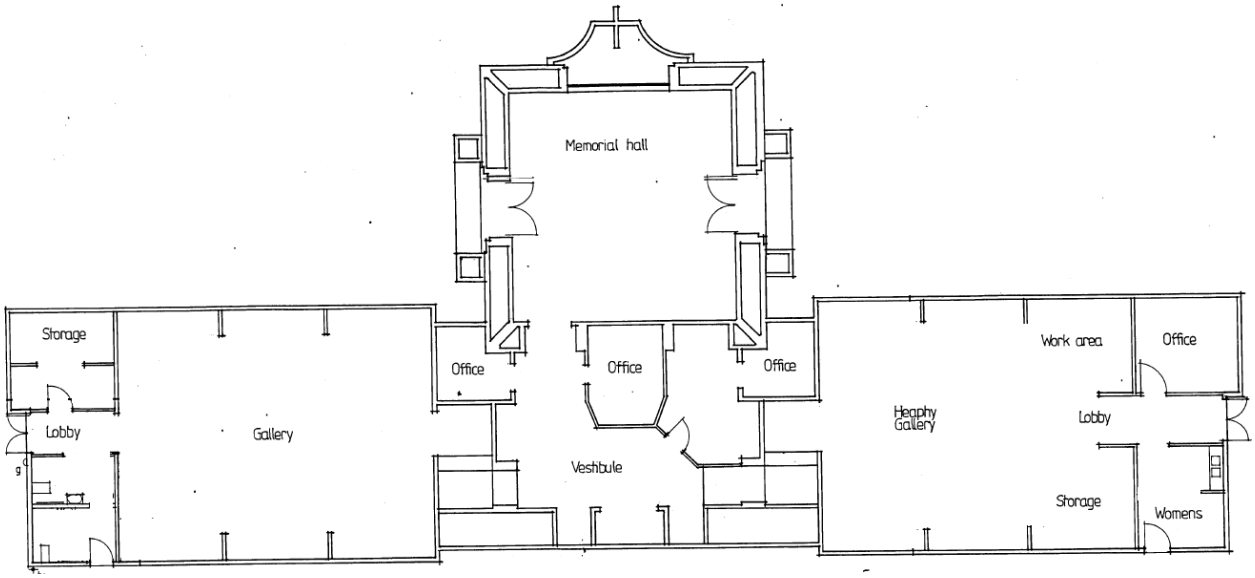

Figure 1: Existing Floor Plan from 2005 Drawings

The building is founded on perimeter reinforced concrete ground beams which span onto shallow concrete pads. There are reinforced concrete ground beams spanning across the building which support the internal concrete walls and tie the foundations together. The floor is a 150mm thick concrete slab with reinforcing to allow it to span between the transverse ground beams.

The perimeter walls of the Memorial Hall are made up of two 125mm thick reinforced concrete walls spaced 650mm apart which are connected by concrete columns and beams positioned around door and window openings. A timber roof is formed over the hall which is supported by steel beams that are bolted into the concrete walls. The outside walls reach a maximum height of 11m above ground level.

On two sides of the Memorial Hall are lampstands that are 6.5m high. The lampstands are hollow precast concrete tubes which have been fitted inside a square walled reinforced concrete base. This is tied into the foundations of the Memorial Hall.

Figure 2: West elevation of Memorial Hall with lampstands in front.

The vestibule and gallery wings consist of perimeter 150mm thick reinforced concrete walls that are 3.5m to 4.5m high. Internal walls are 100mm thick reinforced concrete. The roof over these areas consists of timber rafters supporting timber sarking and metal roofing, like the Memorial Hall. Drawings from proposed alterations in 2005 suggest that there are existing steel beams that support the roof over the gallery wings, however such beams have not been mentioned in the original 1939 drawings.

Figure 3: South elevation of Vestibule and Gallery Wing.

2.3 Site Geotechnical Conditions

There is no site specific geotechnical information available for the location. In the absence of specific soil type information, an assumption based on the geology of the general area was made for the assessment. The sub soil class has been considered as 'Class D' (soft soil site), as per NZS1170.5.

2.4 Site Investigation

A site visit was conducted by WSP on 24th August 2019. The aim of the inspection was to verify the information available on drawings. The main findings of the site visit are listed below:

- The structural form of the building appeared to be in general accordance with the available structural drawings.
- The roof is clad with a lightweight metal sheeting.
- Minor alterations have been made to the internal wall layout at the outer ends of the gallery wings.

3 Seismic Capacity of the Building

3.1 Assessment Methodology

Section C2 of the updated Guidelines (MBIE, 2017) recommend that a force-based assessment approach is considered sufficient for most simple low-rise buildings, and has been adopted for the assessment of the Petone Settlers Museum. Seismic demand on the building was calculated to NSZ1170.5 following the Equivalent Static Method using a ductility of 1.25 under ULS seismic loading and a period of less than 0.4s.

The perimeter and internal concrete walls are the main lateral load resisting system for the building which are reasonably stiff. Round bars were used to reinforce the concrete members which is common for buildings of its age. The drawings show that the vertical reinforcing in the walls are hooked into the ground beams which means the bars can develop their full strength and have limited ductility. The timber roof over the building is a flexible structure so seismic load is proportioned to the concrete walls according to their tributary width.

The concrete walls are tied into a grid of concrete ground beams which distribute the seismic load into the ground through bearing and friction. Overturning is prevented by the weight of the foundations and return walls.

The capacities of the concrete walls, columns and foundations were determined using section C5 of The Guidelines (MBIE, 2017) and NZS3101:2006. The capacities were compared directly to the demands associated with each element, to determine the %NBS value for the building.

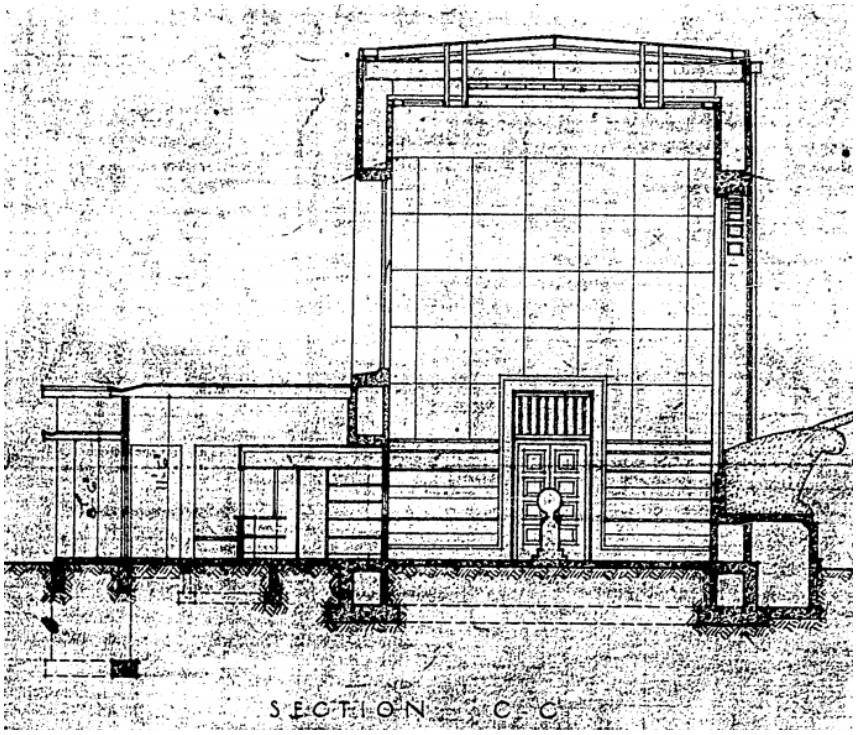

Figure 4: North-South cross-section of Memorial Hall and Vestibule

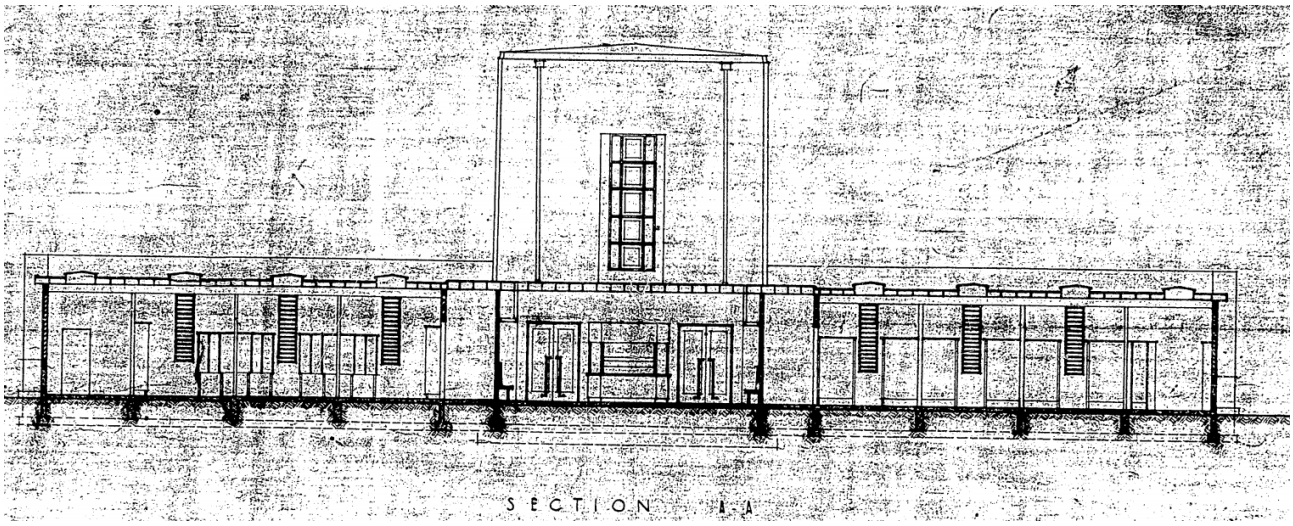

Figure 5: East-West cross-section of Settlers Museum

3.1.1 Parts and Components

When seismic acceleration acts across the weak axis of the concrete walls they span horizontally between return walls or columns. The concrete walls also transfer the seismic weight from the timber roof to the support walls/columns. The seismic demand in this case has been determined using the parts and components method from NZS1170.5 and is compared to the strength of the walls in their weak axis.

The lampstand acts separately from the main building when seismic acceleration is applied. Seismic load on the lampstand is calculated using the parts and components method assuming a ductility of 1.0. The precast concrete tube bends about the base concrete walls which provide resistance through its connection into the foundations of the Memorial Hall.

3.2 Assessment Criteria and Building Properties Assumptions

The parameters used to derive the seismic demands at 100% Ultimate Limit State (ULS) shaking were based on the information provided in NZS 1170.5 and are listed in Table 1. We have assumed that the timber roof does not act as a diaphragm to support the top of the concrete walls. The original drawings and specification give little information about the connection between the roof and the walls, therefore we have assessed the worst case scenario for the building.

Table 1: Parameters for determining seismic demands for 100%ULS Shaking

Parameter	Value	Comments
Importance Level, IL	2	As per AS/NZS 1170.0 Table 3.2.
Hazard Factor, Z	0.40	As per NZS 1170.5 Table 3.3. Hutt City.
Near fault factor, N(T,D)	1.0	As per NZS 1170.5 Table 3.6.
Site sub-soil class	Class D	Assumed in the absence of site specific geotechnical data.
Annual probability of exceedance	1 in 500 years	As per NZS 1170.0 Table 3.3 (IL2, 50 year design life)
Return period factor, R	1.0	As per NZS 1170.5 Table 3.5.

3.3 Material Properties and Parameters

The following material properties and parameters were used for the purpose of the seismic assessment of the structure. In the absence of site-specific data, necessary assumptions were made, based on recommendations provided in section C5 of The Guidelines (MBIE, 2017). Material properties are listed in Table 2.

Table 2: Material properties used for assessment

Material	Property
Reinforcing probable yield strength, $1.08f_y$	243 MPa (Table C5.4)
Concrete probable compressive strength, $1.5f_c'$	30 MPa (Table C5.3)

The assumed soil properties which have been used to assess the capacity of the building's foundations are shown in Table 3. This includes the ultimate bearing capacity and soil stiffness, which is used when modelling the distribution of forces through the concrete ground beams.

Table 3: Foundation bearing capacity and soil stiffness

Location	Ultimate Bearing Capacity	Equivalent Soil Stiffness
BGL (below ground level) = 0.8m Under reinforced concrete ground beams	100kPa	5,000kN/m
BGL = 1.0m Under north square concrete footings	200kPa	10,000kN/m
BGL = 2.2m Under south square concrete footings	200kPa	10,000kN/m

3.4 Detailed Seismic Assessment Results

Table 4 below summarizes the findings of the DSA on the building in terms of Percentage New Building Standards (%NBS). The structure is assessed against the performance criteria for an IL2 facility under ULS limit states.

Table 4: %NBS for assessed structural elements

Structural Element	%NBS (IL2)	Remarks
Gallery Wing		
Internal transverse concrete walls	80%	Shear strength of small columns governs.
Perimeter concrete walls	75%	We have assumed that the roof is not well tied into the building - the in-plane flexural strength of the end wall governs.
Foundations	100%	Soil bearing capacity under concrete ground beams is reliant on no liquefaction occurring. Minimum ultimate bearing capacity of 200kPa is assumed.

Memorial Hall		
Concrete walls	70%	In-plane flexural strength governs.
Concrete beams	90%	Seismic load is redistributed into columns when the beam flexural strength is exceeded.
Concrete columns	100%	
Vestibule		
Concrete walls	100%	In-plane and out-of-plane flexural and shear strength is adequate.
Lampstand		
Precast column tube	100%	

3.5 Assessment Results Summary

3.5.1 Gallery Wings and Vestibule

Concrete walls around the Vestibule and Gallery Wings resist lateral seismic loads through in-plane shear strength. The concrete walls have been assessed assuming they span horizontally between return walls by bending out-of-plane. No roof diaphragm contribution has been considered.

We consider that the roof connection to the concrete walls is satisfactory to prevent the roof from moving relative to the concrete walls under wind and seismic loads. However, due to the lack of information on the connection we have not relied on the roof to support the concrete walls. The original building specification indicates that the rafters bear on a timber top plate which is bolted into the concrete walls. The rafters are nailed to the top plate but the number of nails is not quantified.

The internal nib walls meet 80%NBS and are assumed to support a tributary width of 3.4m. They are 0.9m long up to a height of 2 2m and above this height they reduce to 0.25m long. The reduced length results in a reduction in strength which is the likely point of failure. Concrete ground beams underneath the nib walls have been modelled using springs to represent the equivalent soil stiffness. The beams prevent the walls from overturning by distributing seismic loads into the ground. These foundations meet 100%NBS provided that no liquefaction occurs and a minimum soil bearing capacity of 200kPa is achieved.

The perimeter concrete walls at the end of the Gallery Wings comply with 75%NBS for in-plane seismic loads applied in the east-west direction. This rating is based on the walls acting independently from the roof structure. All other walls in the Vestibule and Gallery Wings meet 100%NBS.

3.5.2 Memorial Hall

The concrete perimeter walls for the Memorial Hall meet 100%NBS when the walls bend out-of-plane. The concrete beams and columns transfer the seismic loading from these walls into the adjacent walls which provide in-plane resistance. The in-plane flexural capacity of these concrete walls is rated at 70%NBS.

3.5.3 Lampstand

Both the precast concrete tube that makes up the lampstand and its concrete base are rated as 100%NBS. The lampstand relies on its connection to the foundations of the Memorial Hall to prevent overturning.

3.5.4 Foundations

The soil at the site is expected to be a mixture of sand and gravels which has sufficient bearing capacity to support the walls when they try to overturn, provided liquefaction does not occur at the site. Technical studies by GNS Science and others have shown that the composition of soils along the Petone waterfront are susceptible to liquefaction in large seismic events. Liquefaction can cause differential settlement across the building and lateral spreading of the soil towards the shore. In this case, cracking could occur in the concrete floor slab and minor rotation of the walls out-of-plumb. The concrete ground beams are well reinforced and regularly spaced, therefore we expect the foundations can accommodate a moderate amount of differential soil settlement across the building.

3.6 Critical Structural Weaknesses

The building's critical structural weakness is the in-plane strength of the concrete walls to the Memorial Hall. The concrete walls are specified with a reasonably high level of reinforcing for a building of its age, however the yield strength of the bars is not enough to accommodate the amount of seismic load applied at an Ultimate Limit State event. The reinforcing is also round bars, instead of deformed bars, which means that the wall has only limited ductility. When the strength of the walls is exceeded a large amount of cracking is expected. The building is not expected to be a life safety risk however it is unlikely to be able withstand another seismic event of similar magnitude.

4 Seismic Improvements

The building is considered to be a Low to Medium risk when compared with a building which meets the current New Zealand Building Code. Strengthening works could be implemented so that the building meets 100%NBS, however, consideration should be given to the cost and the likely benefits of such strengthening works. The building has a Category 1 heritage status by the Historic Places Trust which means that proposed strengthening works must not infringe upon the heritage fabric of the building.

A geotechnical site investigation should be conducted before planning strengthening works to assess the impacts of potential liquefaction on the structure. Potential liquefaction and lateral spread at the site could be mitigated by improving the building's foundations. This could involve construction of new piles such as gravel columns. These would need to be designed by a specialist geotechnical engineer.

Further investigation could be made to determine the connection between the roof over the Gallery Wings and the concrete walls. The existing connection may be strong enough to allow the roof to act as a diaphragm and transfer seismic loads to the end walls. This would reduce the seismic demand on the concrete nib walls and so improve the %NBS rating. If the existing connection is not adequate two options to strengthen the Gallery Wings could be considered: (1) construct additional reinforced concrete columns with a new footing along the north and south walls, or (2) improve the connection between the timber roof and concrete walls by adding metal fixings.

To strengthen the Memorial Hall would require improving the flexural strength of the walls. This could be achieved by applying a thin layer of Fibrewrap to the ends of the walls.

5 Discussion Points

5.1 Liquefaction or lateral soil spread

The %NBS rating for the building is based on the assumption that seismic acceleration at 70%NBS does not cause the soil to liquefy or lateral spreading. Foundation support for the concrete wall structure relies on the ground beams bearing on the soil and resistance to sliding through friction with the soil. If liquefaction occurs at the site then there will be a loss of bearing support and resistance to sliding. Global building movement is expected in this case and differential settlement across the building.

Lateral spreading of the soil can cause additional stresses on the foundations as the ground under the building tries to move apart. Differential settlement could cause the foundations to rotate and the walls to move out of plumb. This would be observed by cracks occurring in the concrete floor slab. The lower walls around the Gallery Wings and Vestibule can accommodate much more settlement than the Memorial Hall since they are lower in height. Cracking in the floor slab is not a life safety risk, however it will disrupt the continued functionality of the building. The actual performance of the foundations could be confirmed after receiving further information about the site soils from a geotechnical engineer.

5.2 Timber Roof Connection

The timber roof is connected to the concrete walls, however there is sparse information in the original building drawings and specification to indicate the amount of nailing. The connection between the rafters and top plate is noted in the specification as, "*framing shall be nailed and spiked together in best possible manner with nails of size and gauge to Architect's satisfaction.*" A couple of nails between the roof rafters and timber top plate is sufficient to prevent the roof from losing its gravity support. If the roof connection was better than anticipated, then the roof could act as a diaphragm to support the concrete walls. In this case the concrete walls in the Gallery Wings may have a higher %NBS rating than shown.

6 Conclusions and Recommendations

Based on the outcome of our DSA, we consider the Petone Settlers Museum to be rated at **70% NBS** for an IL2 building.

A building with an earthquake rating less than 34% NBS fulfils one of the requirements for the Territorial Authority to consider it to be an Earthquake-Prone Building (EPB) in terms of the Building Act 2004, and a building rating less than 67% NBS is considered as an Earthquake Risk Building (ERB) by the New Zealand Society for Earthquake Engineering.

Given the high %NBS rating of the building we do not consider that strengthening works require urgent attention. The building is quite robust given that it a concrete walled structure and is well reinforced. If a lower risk building is desired, then possible strengthening could involve improving the roof connection in the Gallery Wings and adhering thin sheets of carbon fibre to the walls of the Memorial Hall.

External factors that may affect the building's performance in a seismic event are soil liquefaction, lateral spreading and a tsunami. These factors are quite difficult to design for and are relatively costly to implement. The benefit gained from strengthening the foundations for soil liquefaction and lateral spreading may not be worth the cost, considering the building's current use as a museum. These improvements will also not mitigate the effects from a tsunami unless the building was made water tight. Specialist studies should be conducted to determine the likelihood of liquefaction, lateral spreading and a tsunami before strengthening works are considered.

7 Limitations of this Report

Below are the limitations and assumptions made during the assessment the building.

- Our assessment is based on the structure being in 'as new' condition, without taking in to account any damage or deterioration to the elements.
- The opinions in this document are based on the conditions and information available at the time the document was published and assume that the building was constructed as per the materials, reinforcement sizes, etc. shown on the drawings available to us.
- The assessment does not cover any non-structural components within the building such as light fittings, roof tiles and services.

Appendix A

Technical Summary Tables

Appendix A

The tables below are provided by MBIE. It is recommended they are included in all Detailed Seismic Assessment reports.

1. Building Information	
Building Name/ Description	Petone Settlers Museum
Street Address	136 The Esplanade, Petone
Territorial Authority	Hutt City Council
No. of Storeys	One Storey with an 11m central tower
Area of Typical Floor (approx.)	400m^2
Year of Design (approx.)	1939
NZ Standards designed to	1935 Model Bylaws
Structural System including Foundations	**Roof** – Lightweight metal roofing on timber sarking and rafters. **Ground Floor** – In-situ concrete slab on grade. **Foundations** – Reinforced concrete ground beams on concrete pad foundations. **Lateral System** – Concrete shear walls are the primary lateral load resisting system in both directions.
Does the building comprise a shared structural form or shares structural elements with any other adjacent titles?	No
Key features of ground profile and identified geo-hazards	Potential liquefaction, High Tsunami Risk
Previous strengthening and/ or significant alteration	Removal of some internal concrete walls in Gallery Wings in 2005.
Heritage Issues/ Status	NZHPT – Historic Place Category 1 – List No 206
Other Relevant Information	N/A

2. Assessment Information	
Consulting Practice	WSP
CPEng Responsible, including: • Name • CPEng number • A statement of suitable skills and experience in the seismic assessment of existing buildings[1]	[redacted]
Documentation reviewed, including: • date/ version of drawings/ calculations[2] • previous seismic assessments	The complete original drawing set and specifications for the Wellington Provincial Centennial Memorial was available and are listed below: • Sheet 1 – Floor plan • Sheet 2 – Elevation and sections • Sheet 3 – Details of reinforced concrete in Hall and Vestibule • Sheet 4 – General construction & set-out of Hall • Sheet 5 – Reinforced concrete details single storey portions • Sheet 6 – Side elevations & Miscellaneous details • Specifications for Wellington Provincial Centennial Memorial, pages 1 to 26 Assumptions included: • Timber rafters nailed to timber top plate with a minimum of 2 – 3.15mmϕ nails. • No liquefaction at 70%NBS seismic acceleration • Minimum soil bearing capacity of 200kPa
Geotechnical Report(s)	None available
Date(s) Building Inspected and extent of inspection	A site visit was conducted by WSP on 24th August 2019. The site visit consisted of a walk through the building to verify if the main structural elements were in accordance with the available structural drawings. No destructive or invasive testing was carried out.
Description of any structural testing undertaken and results summary	N/A
Previous Assessment Reports	N/A

[1] This should include reference to the engineer's Practice Field being in Structural Engineering, and commentary on experience in seismic assessment and recent relevant training
[2] Or justification of assumptions if no drawings were able to be obtained

Other Relevant Information	N/A

3. Summary of Engineering Assessment Methodology and Key Parameters Used	
Occupancy Type(s) and Importance Level	Importance Level 2
Site Subsoil Class	Subsoil Class D – NZS1170.5
Summary of how Part C was applied, including: • the analysis methodology(s) used from C2 • other sections of Part C applied	Section C2 of the updated Guidelines (MBIE, 2017) recommend that a force-based assessment approach is considered sufficient for most simple low-rise buildings. A force-based approach was therefore adopted for the assessment of the Petone Settlers Museum. The structure was assumed to have a limited ductility and was assessed with a ductility of 1.25. The seismic demands were therefore calculated to NSZ1170.5 using this ductility. Without confirmation of the reinforcing a higher ductility cannot be used. Out-of-plane seismic loading on the concrete walls and the precast concrete lampstand was calculated using the parts and components method of NZS1170.5. The capacities of the concrete walls, columns and foundation were determined using section C5 of The Guidelines (MBIE, 2017) and NZS3101:2006. The capacities were compared directly to the demands associated with each element, to determine the %NBS value for the building.
Other Relevant Information	The foundation ground beams are assumed to bear on the soil and friction with the soil provides resistance to sliding. If liquefaction occurs at the site, then there will be a loss of bearing support and resistance to sliding. Global building movement is expected in this case and differential settlement across the building.

4. Assessment Outcomes		
Assessment Status (Draft or Final)	Final	
Assessed %*NBS* Rating	70% NBS (IL2)	
Seismic Grade and Relative Risk (from Table A3.1)	B (Low to Medium risk)	
Comment on the nature of Secondary Structural and Non-structural elements/ parts identified and assessed	Seismic restraint of non-structural elements and equipment within the building has not been reviewed as part of this assessment.	
Describe the Governing Critical Structural Weakness	The in-plane flexural strength of the concrete walls to the Memorial Hall is the Critical Structural Weakness due to the use of round bars with low yield stress.	
If the results of this DSA are being used for earthquake prone decision purposes, and elements rating <34%NBS have been identified (including Parts)[3]:	Engineering Statement of Structural Weaknesses and Location N/A	*Mode of Failure and Physical Consequence* Statement(s) N/A
Recommendations	None required.	

[3] If a building comprises a shared structural form or shares structural elements with other adjacent titles, information about the extent to which the low scoring elements affect, or do not affect the structure.

Appendix B

Detailed Seismic Assessment Calculations

Contents

Appendix C

Existing Structural Drawings

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