

# Central Library

Hollowcore Seismic Assessment

**Wellington City Council**

Reference: 253267

Revision: 1

2019-03-18

**aurecon**

*Bringing ideas  
to life*

# Document control record

Document prepared by:

**Aurecon New Zealand Limited**



Spark Central  
 Level 8, 42-52 Willis Street  
 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

A person using Aurecon documents or data accepts the risk of:

- a) Using the documents or data in electronic form without requesting and checking them for accuracy against the original hard copy version.
- b) Using the documents or data for any purpose not agreed to in writing by Aurecon.

Document control							aurecon
<b>Report title</b>		Hollowcore Seismic Assessment					
<b>Document code</b>		<b>Project number</b>		253267			
<b>File path</b>		P:\253267 WCC Workplace\03 Project Delivery\02 Structural\Reports\Hollowcore assessment summary\253267-REP-ST-0001[1] - WCC Central Library Hollowcore Assessment.docx					
<b>Client</b>		Wellington City Council					
<b>Client contact</b>		<b>Client reference</b>					
<b>Rev</b>	<b>Date</b>	<b>Revision details/status</b>	<b>Author</b>	<b>Reviewer</b>	<b>Verifier (if required)</b>	<b>Approver</b>	
0	2019-03-16	For Review	T. Holden	C. Stevenson		D. Fleming	
1	2019-03-18	For Issue	T. Holden	C. Stevenson		D. Fleming	
<b>Current revision</b>		<b>1</b>					

Approval			
<b>Author signature</b>		<b>Approver signature</b>	
<b>Name</b>	T. Holden	<b>Name</b>	D. Fleming
<b>Title</b>	Associate	<b>Title</b>	Technical Director

# Contents

<b>1</b>	<b>Introduction</b> .....	<b>1</b>
1.1	Overview.....	1
1.2	Explanatory Statement .....	1
<b>2</b>	<b>Hollowcore Assessment</b> .....	<b>2</b>
2.1	Analysis .....	2
2.2	Hollowcore Assessment Results .....	2
<b>3</b>	<b>Summary</b> .....	<b>4</b>

# 1 Introduction

## 1.1 Overview

Aurecon have been engaged by Wellington City Council (WCC) to investigate the seismic risk associated with the Central Library building, in particular that associated with the existing hollowcore floors.

In July 2017 the latest revision of the “The Seismic Assessment of Existing Buildings – Technical Guidelines for Engineering Assessments” was issued. This is a document managed jointly by the Ministry of Business, Innovation and Employment, the Earthquake Commission, the New Zealand Society for Earthquake Engineering, the Structural Engineering Society and the New Zealand Geotechnical Society.

On 30<sup>th</sup> November 2018 an update to Section C5 was issued, namely Appendix C5E, which provides a systematic assessment methodology for assessing precast concrete floor systems.

This investigation was initiated to respond and investigate the implications on the building’s reported capacity and potential vulnerability as a result of the updated guidance.

It is understood that the latest revisions to Section C5 should not be used for an assessment that a Territorial Authority will use to decide if a building is earthquake prone. Aurecon consider the revisions, which are based on the latest academic research, learnings and observed failures following recent major seismic events, and through extensive consultation and technical input from many of the foremost engineering consultancies in New Zealand, represents best practice and provides WCC the most accurate assessment of the hazard which the hollowcore units as installed within the Central Library present.

## 1.2 Explanatory Statement

- This report has been prepared by Aurecon at the request of our client WCC and is exclusively for WCC’s use for the purpose for which it is intended in accordance with the agreed scope of work. It is not possible to make a proper assessment of this review 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.
- 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.
- The report 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. Aurecon accepts no responsibility or liability to any third party for any loss or damage whatsoever arising out of the use of or reliance on this report by that party or any party other than our client.
- The report is also based on information that has been provided to Aurecon from other sources or by other parties. The report 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 resulting from any conclusions based on information that has been provided to Aurecon.
- While this report may assist the client in assessing whether the building should be modified/ strengthened, or restrictions placed on occupation/access or otherwise, those decisions are the sole responsibility of the client.

## 2 Hollowcore Assessment

### 2.1 Analysis

Aurecon have followed the recommendations of “The Seismic Assessment of Existing Buildings” (July 2017) in conjunction with the latest Section C5 revisions in completing our review.

An important parameter when assessing the performance of the hollowcore floor units is to establish an accurate estimate of the imposed displacements that the structure will undergo following a design level earthquake event. Aurecon have computed the expected deformations based on a 3D analysis model of the Central Library that was created as part of separate assessment studies.

Numerical analyses completed to date indicate that the building is flexible with respect to earthquake excitation. The distortions that could be induced at the Ultimate Limit State (ULS) event are such that P-Delta effects are also significant. These in turn increase the probable distortions that would be expected to be imposed on the structure.

The calculated drifts were found to exceed the code limit of 2.5%. The potential for significant inelastic ductile behaviour in the main structural frames and highly flexible performance in regards to lateral displacements are significant issues when considered against the relatively brittle performance and deformation incompatibility of the hollowcore floor units installed and detailed throughout the Central Library.

The most recent method as outlined in Section C5 of the guidance documents for considering the impact imposed distortions have on the performance of hollowcore floors has been made considerably more onerous than those that are formally attached to the Earthquake Prone legislation. (The EPB methodology is set by the Chief Executive of the Ministry of Business, Innovation and Employment under section 133AV of the Building Act 2004). These guidelines require that the distortions imposed on the floor units be twice those determined by the normal structural analysis. This increase is in part associated with the uncertainty in accurately establishing the probable drift, as well as the higher risk and consequence of failure that these elements present. The failure of a unit can result in individual sections or full units falling, presenting a potentially catastrophic risk to occupants.

Various examples of significant damage and failures of precast hollowcore units were observed following the recent 2016 Kaikoura earthquake, reinforcing and highlighting issues that have previously been observed following past significant events, as well as that noted through research and testing.

### 2.2 Hollowcore Assessment Results

The assessment of the precast hollowcore involved a close review of the complex interaction between the various main structural elements and the floor units themselves. Significant research is ongoing in this area and there still remains a degree of uncertainty as to the cause and effect that earthquake demands have on hollowcore performance.

The analysis has been conducted based on an Importance Level 2 (IL2) classification. This is in line with previous detailed seismic assessments completed for the Library. This classification is primarily based on there not being a normal occupancy of more than 300 people congregated in one area. If this level of occupancy was exceeded, the building would likely be re-classified as an Importance Level 3 (IL3) building which would further reduce the %NBS scores reported.

In general damage to hollowcore can be attributed to 5 main failure mechanisms. These include:

- 1) Loss of Seating of the hollowcore unit - The support on which the units rest is lost due to a combination of factors which include geometric deformations, beam elongation due to inelastic hinging, and spalling of the concrete support itself.
- 2) Positive Moment Failure near support
- 3) Negative Moment Failure near support

- 4) Web-cracking - Due to deformation incompatibility between precast units adjacent and running parallel to beams deformed under seismic loading.
- 5) Torsion - Due to varying displacements imposed on the support beams at either end of the precast units.

Each of these mechanisms have been assessed by Aurecon. The capacity of each mechanism has been compared to the current ULS (IL2) design requirements and presented in the table below.

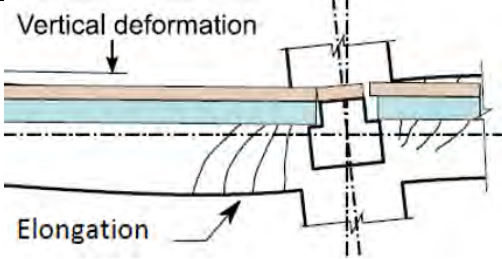
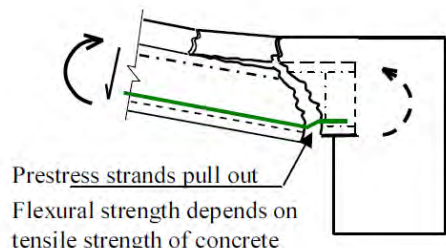
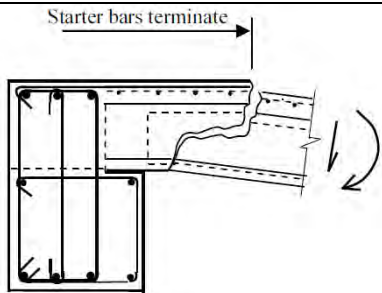
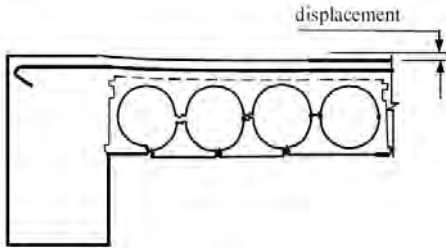
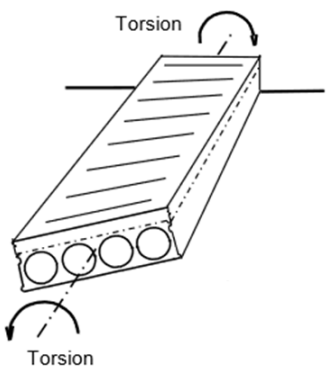
Potential Mechanism	%NBS (IL2)	Failure Mechanism <sup>1)</sup>
1. Loss of Seating	20	 <p>Vertical deformation</p> <p>Elongation</p>
2. Positive Moment Failure	55	 <p>Prestress strands pull out</p> <p>Flexural strength depends on tensile strength of concrete</p>
3. Negative Moment Failure	100	 <p>Starter bars terminate</p>
4. Web-Cracking	25	 <p>displacement</p>
5. Torsion	100	 <p>Torsion</p> <p>Torsion</p>

Table 1: Assessed capacity of potential hollowcore failure mechanisms

<sup>1)</sup> Diagrams adapted from Appendix C5E “The Seismic Assessment of Existing Buildings”

The capacities presented are the critical values which vary depending on the location and story/level within the building. They are however reflective of a significant area of the building and are representative of the general hazard.

It is noted that the high score for the mechanism of Negative Moment Failure is based on the presence of exceptionally long starter and saddle bars as detailed in the existing structural drawings. It is recommended that on-site investigations be performed to verify the as-built detailing of these bars.

The most critical mechanism of failure has been assessed to be the potential loss of seating/support to the hollowcore units. The existing structural drawings indicate that the seating as specified typically ranges between 50 and 60mm. It is on this basis when allowance has been made for construction tolerances, and creep and shrinkage effects, that the hollowcore precast floor system at IL2 achieves a score of **20%NBS** as assessed by the MBIE guidelines for assessing existing buildings. There are a large number of parameters included in the calculations to determine the score. A sensitivity study of those factors indicates that this range could potentially extend from **15% - 25%NBS (IL2)**.

The available hollowcore seating at this stage has solely been determined based on our review of the existing structural drawings. It is recommended that a comprehensive on-site measurement of the as-built seating dimensions is completed in line with the methodology described in the MBIE assessment guidelines.

### 3 Summary

Our assessment has been limited to review of the hollowcore floor units only. It does not cover other aspects of the Central Library design which may present further risks to occupants and the general public.

The low score based on the potential loss of seating of the hollowcore units presents a significant hazard and potential risk to building occupants following a significant earthquake event.

Based on the low score, as well as the brittle and catastrophic nature of a potential failure it is Aurecon's recommendation that the structural weaknesses identified with the hollowcore units are addressed to improve their seismic performance.

It is recommended that on-site investigations be completed to verify the as-built condition of the existing seating dimensions, and starter and saddle bar reinforcing. It is possible some variation exists which could increase or decrease the desktop results presented in this report.

Based on the assessed capacity of the hollowcore units for each potential failure mechanism there are remedial solutions that could be employed that would significantly improve their seismic performance. Further developed design would be required to establish how these potential works could be introduced in the most effective and efficient manner.

**Document prepared by**

**Aurecon New Zealand Limited**

Spark Central  
Level 8, 42-52 Willis Street  
Wellington 6011

PO Box 1591  
Wellington 6140  
New Zealand

**T** +64 4 472 9589

**F** +64 4 472 9922

**E** [wellington@aurecongroup.com](mailto:wellington@aurecongroup.com)

**W** [aurecongroup.com](http://aurecongroup.com)

**aurecon**

*Bringing ideas  
to life*

**Aurecon offices are located in:**

Angola, Australia, Botswana, China,  
Ghana, Hong Kong, Indonesia, Kenya,  
Lesotho, Macau, Mozambique,  
Namibia, New Zealand, Nigeria,  
Philippines, Qatar, Singapore, South Africa,  
Swaziland, Tanzania, Thailand, Uganda,  
United Arab Emirates, Vietnam.

