NZ Horizons Hospitality Group

Dunedin Moray Place Hotel

Resource Consent Structural Engineering Report

January 2017

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1. Introduction

1.1 Objective

This Resource Consent Structural Engineering Report outlines the proposed building structure's expected major structural engineering systems based on the proposed design to date. It outlines proposed design loading, structural modelling assumptions, material properties, foundation systems and design standards.

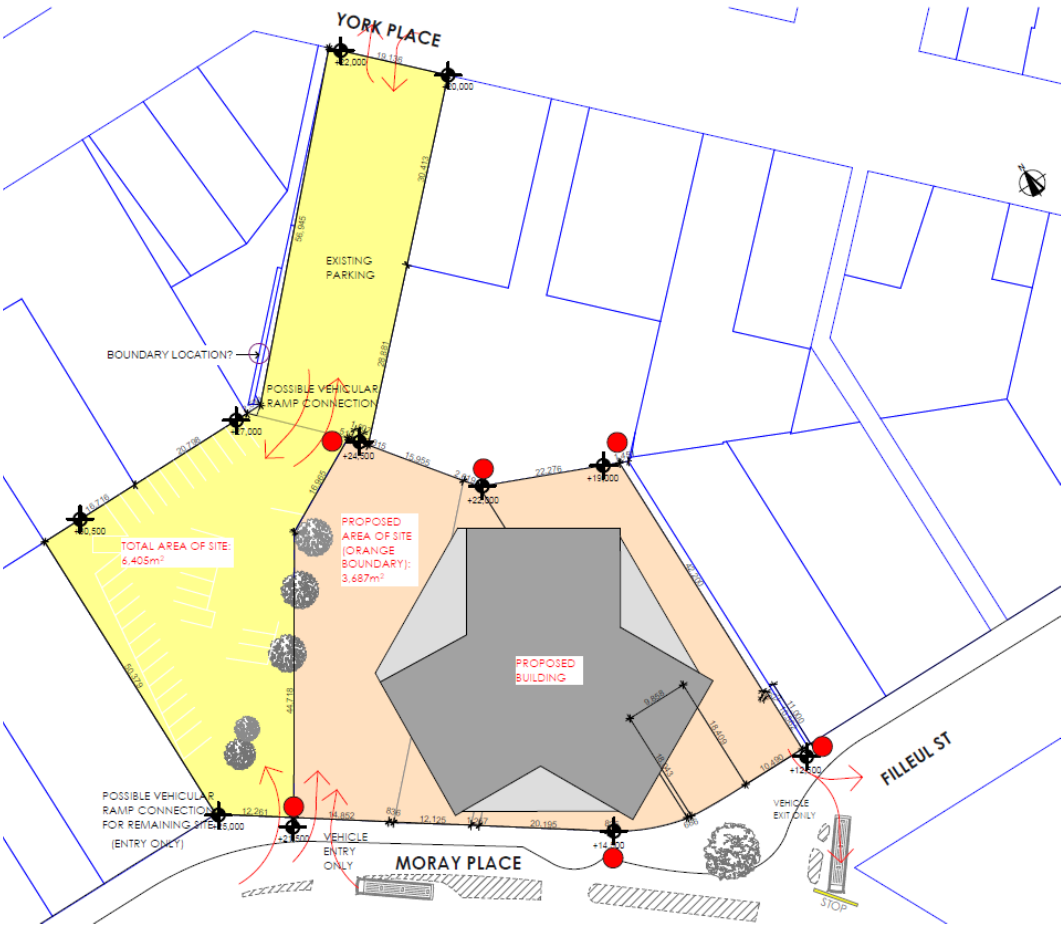
1.2 Scope

In general terms, the scope of work is as follows:

- Review and assessment of architectural documentation prepared to date
- Review and assessment of other engineering related documentation prepared to date including geotechnical investigation and reporting.
- Assess likely structural engineering building systems that will suit the architecture, building layout and performance requirements.
- Provide feedback to the architect regarding building layout and arrangements to align with suitable structural engineering systems
- Undertake initial structural modelling and analysis to determine approximate primary member sizes to inform architecture.

The figure below shows the proposed building site and positioning on site:

Figure 1 Site Plan



1.3 Means of Compliance

The analysis has been undertaken with the intent of achieving compliance with the New Zealand Building Code (NZBC) section B1.

The following compliance documents have been considered:

Table 1 Design standards referenced in the design of the structure

Subject	Code Reference
General	• NZ Building Code for Structure (B1)
Loading	• AS/NZS 1170.0 Structural Design Actions, Part 0: General Principles • AS/NZS 1170.1 Structural Design Actions, Part 1: Permanent, imposed and other actions • AS/NZS 1170.2 Structural Design Actions, Part 2: Wind actions • AS/NZS 1170.3 Structural Design Actions, Part 3: Snow and ice actions • NZS 1170.5 Structural Design Actions, Part 5: Earthquake actions – New Zealand
Steelwork	• NZS 3404 Steel Structures Standard • NZS 3404 Part 1 Steel Structures, Materials, Fabrication and Construction
Reinforced Concrete	• NZS 3101 Concrete Structures Standard • NZS 4671 Steel Reinforcing Materials • NZS 3109 Concrete Construction • New Zealand Reinforced Concrete Design Handbook

1.4 Alternative Solutions

No alternative solutions have been currently considered for the design of the structure. However, as the design progresses alternative solutions may be required for some potential structural systems such as those requiring displacement based design principals.

1.5 References

The following drawings and reports have been referred to while writing this report:

- Thom Craig Architects Resource Consent drawing package dated 13/01/2017.
- Geosolve Geotechnical Report dated November 2016

1.6 Limitations

This report: has been prepared by GHD for NZ Horizons Hospitality Group and may only be used and relied on by NZ Horizons Hospitality Group for the purpose agreed between GHD and the NZ Horizons Hospitality Group as set out in this report.

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2. Site Soil Conditions

A site specific geotechnical report has been prepared by Geosolve and dated November 2016. The investigation included 7 machine boreholes with standard penetration testing to supplement a desktop review of prior investigations and knowledge of the site.

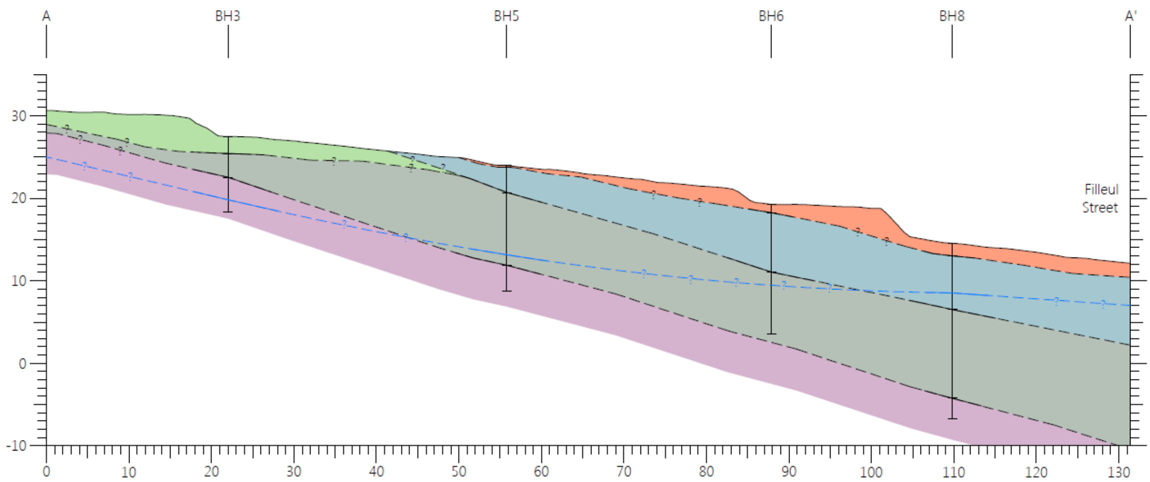
The report stops short of providing advice in relation to potential foundation systems for a building and therefore would require further discussion and coordination with the geotechnical engineer as the design progresses.

2.1 Summary of Geotechnical Characteristics

The following summary of geotechnical characteristics has been interpreted from the geotechnical report:

- The groundwater table was observed at 4.0-4.15m below ground level at the rear of the site. This will have implications in terms of excavation for the basement carparking.
- The underlying subsoil layers generally follow a slope similar to that observed in the surface topography.
- Subsoil layers include uncontrolled fill, overlying slopewash deposits with underlying weathered volcanic rock met at between 3m and 9m below ground level.
- Extent of weathering and density of volcanic rock layer varied in depth however most SPT's met refusal within the depth of the bore and subsequently could be considered competent material for founding foundations such as piles in.

Figure 2 Inferred Stratigraphy



2.2 Foundation Options

Currently no suggested foundation system options have been provided in the geotech report to date. Refer to Section 3.3 for commentary on potential foundation system options for the proposed building.

3. Potential Building Structural Systems

3.1 General

GHD has undertaken an assessment of the proposed architectural design with the intent of developing a potential structural system for the building. Given the geometry of the floor plan and the arrangement of spaces throughout the building there are numerous construction systems that will be feasible for this building.

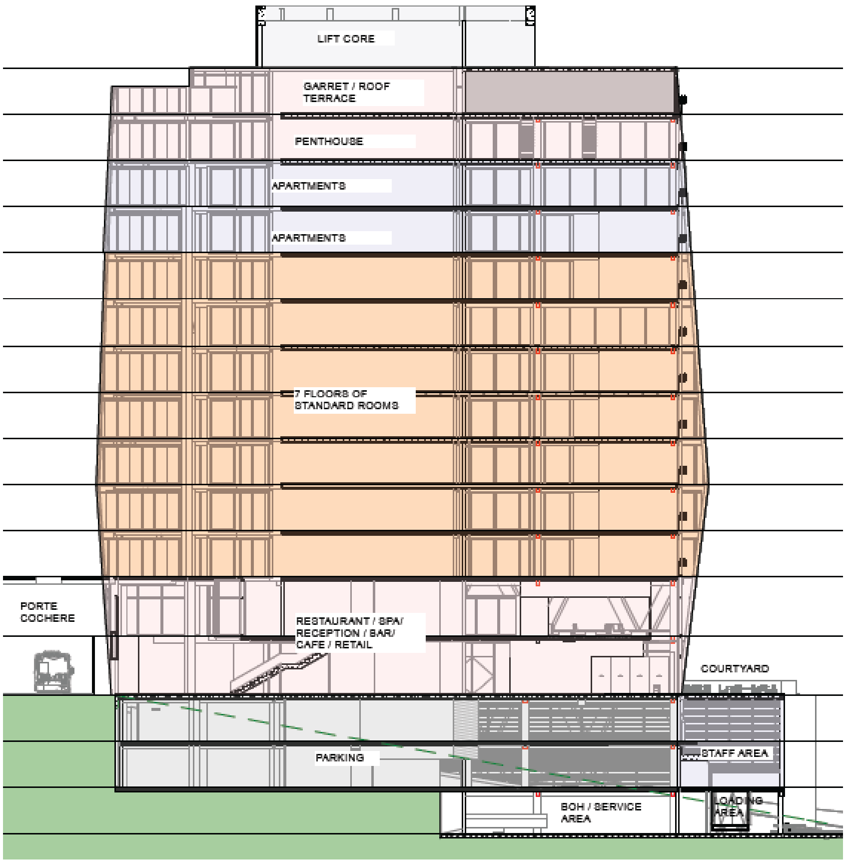
The collaboration between architect and structural engineer on this project to date has resulted in achieving a coordinated arrangement that allows continuous gravity systems over the height of the building. The possibilities for lateral load resisting systems will remain flexible into the next stage of design development which will ensure potential systems can be assessed in terms of cost and performance to determine the optimal solution.

The following sections outline the primary structural engineering systems that are currently proposed for the development.

3.2 Building Layout Overview

The proposed building has a mixed-function layout which is generally separated across different floors. The floor plan and structural system can remain relatively consistent from the highest level down to the lowest level of hotel rooms. Below the hotel room level the gravity load system has been coordinated to minimise changes to this, however the lateral load system will need to change to accommodate larger spaces and floor voids for double height spaces.

Figure 3 Building Cross Section



3.3 Foundations

There are a number of considerations that need to be taken into account for the foundation design of this building which include, but may not be limited to, the following:

- Overturning resistance of building lateral loads including tension hold-down
- Transmission of seismically induced building base-shear into the ground
- Waterproofing of the below-ground parts of the building
- Resistance to vertical settlements of the structure

The variability of the subsoil profile and stratigraphy will have an impact on the foundation type and construction methodologies possible and therefore close assessment of the ground model in relation to the building structural systems will be important.

The following points outline the expected foundation systems that will be required for this building:

- Due to the geometries and height of the building, tension holddown is expected to be required which can be generated by physical connection into competent rock layers below the site which are indicated to be 12-16m below ground surface on this site.
- The softer layers between ground surface and competent rock are unlikely to be able to reliably support the structural loads. It is likely that rock may be contacted during excavation of the basement areas in some places but not across the entire footprint.
- Bored reinforced concrete piles are likely to be the most efficient method of transmitting building loads down to the rock layer. Other piling systems exist however aren't likely able to provide all required elements of load resistance (tension, compression and lateral load resistance).
- Earth retaining and tanking of ground water will also be required in excavations which can be achieved by a variety of means such as sheetpiling or diaphragm walls in conjunction with dewatering.

3.4 Gravity Structure

The following sections outline the main gravity load systems expected for this project.

3.4.1 Roof

It is likely that the roof will have a combination of structural systems to allow for conventional weathertight roofing areas together with accessible areas for rooftop plant and/or terrace access for guests.

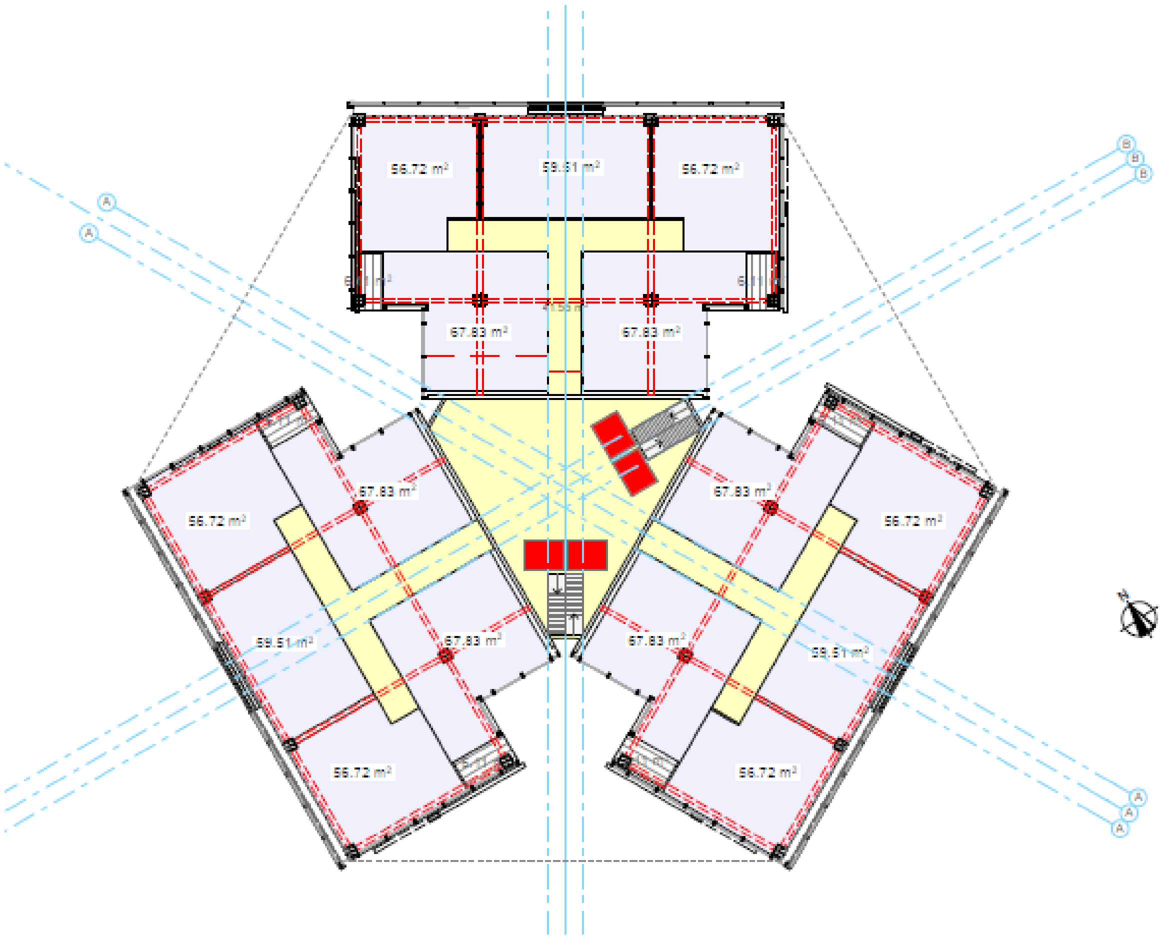
Rooftop plant will also include requirements for equipment to safely clean and maintain the façade of the building.

3.4.2 Walls

The central core system will have a number of walls which will provide lateral load resistance, gravity load resistance and fire rating to egress paths. We anticipate that reinforced concrete will be the optimal structural system for these elements.

Most other walls in the building can be lightweight systems with requirements such as acoustics and prevention of spread of fire taking precedence over structural requirements.

Figure 4 Upper Stories Structural Layout



3.4.3 Primary Gravity Structure

The primary gravity structure will largely be governed by the requirements of the lateral load resisting system.

At this stage both reinforced concrete (combination of precast and insitu) and structural steel beam and column systems will be suitable and therefore considerations regarding cost and construction programme can be reviewed prior to selecting a final system.

Other considerations will need to be taken into account as follows:

- Floor vibration and acoustics
- Building services routes
- Locations of interfloor services risers
- Fire rating requirements

3.4.4 Suspended Floors

To allow rapid construction a maximise flexibility for things like floor setdowns and penetrations a shortspan proprietary floor system is proposed. The final solution would depend on what primary gravity system is utilised however one of the following two systems are most likely:

- Rib and Infill with insitu concrete topping (allow 100mm topping with 175mm rib)
- Metal tray with insitu concrete topping (allow 150mm thick total)

Depending on the final layout of the central core area, a combination of structural systems may be used in this area for the suspended floor.

3.5 Lateral Load Resisting System

3.5.1 General Approach

In general, the building layout and geometry allows for a lateral load resisting system that will be robust and offer an appropriate level of redundancy and a high level of safety to the building occupants. Modern structural technologies including low damage systems can be incorporated to ensure the resilience of the building during seismic activity can be maintained.

Overall the building will have some sensitivity to torsional matters which will need to be controlled with increased stiffness at the outer edges of each wing of the building. Current analysis shows that the building is close to the allowable interstory drift limits which can be overcome by stiffening the building at the lower levels as described in Section 3.5.4.

The following sections outline the possible lateral load resisting systems that could be considered and appropriate for this building.

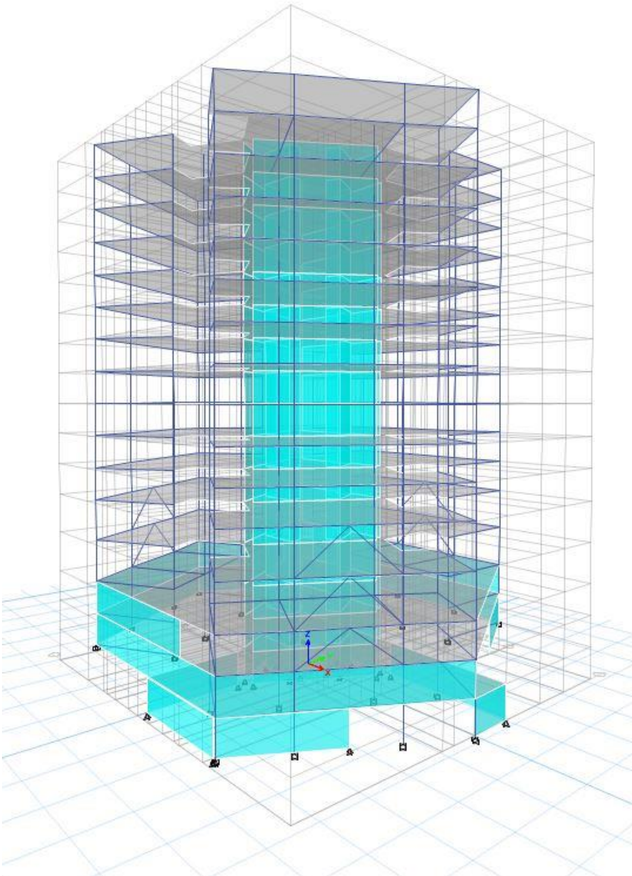
At this stage we have not considered any increase in ductility above limited ductile (mu=1.25) given the seismic zone factor and the expected wind loadsbeing roughly in the same order.

3.5.2 Central Core

The central core will, ideally, be a very stiff element which will resist the majority of building lateral loads. It is likely that there will be some need for fire rating of this area to allow safe egress from the building therefore utilisation of the walls surrounding the core as a lateral load resisting element is preferred. Precast or insitu reinforced concrete will be the optimal system for this element.

The walls will be very stiff and able to be designed for a low level of displacement ductility. We estimate the wall thickness at the lowest level of this wall to be approximately 250mm thick. A small reduction in thickness could be achieved at higher levels.

Figure 5 ETABS Model



3.5.3 Accommodation Wings at Upper Levels

A number of options exist for the lateral load resisting system to the accommodation wings at upper levels. Again, this will be assessed in conjunction with the options for gravity load resistance however, the follow systems should be feasible:

- Reinforced concrete moment resisting frame using either conventional or PRESSS yielding elements
- Structural steel moment resisting frame potentially including sliding hinge joints
- Buckling restrained braces
- Structural steel or reinforced concrete shear walls.

The primary matter for consideration of the lateral load resisting system for the accommodation wings at upper levels will be the ability to resist tension and compression coupling forces at the ends of elements and transmit them into the lower levels without the need for significant transfer elements.

Given the complexities with coordinating continuous lines of support through the height of the building, we consider that the most appropriate structural system will be a moment resisting frame system constructed from either structural steel or reinforced concrete.

The following allowances should be made for structural elements in the accommodation wings:

Beams:- allow 850mm overall depth at all levels

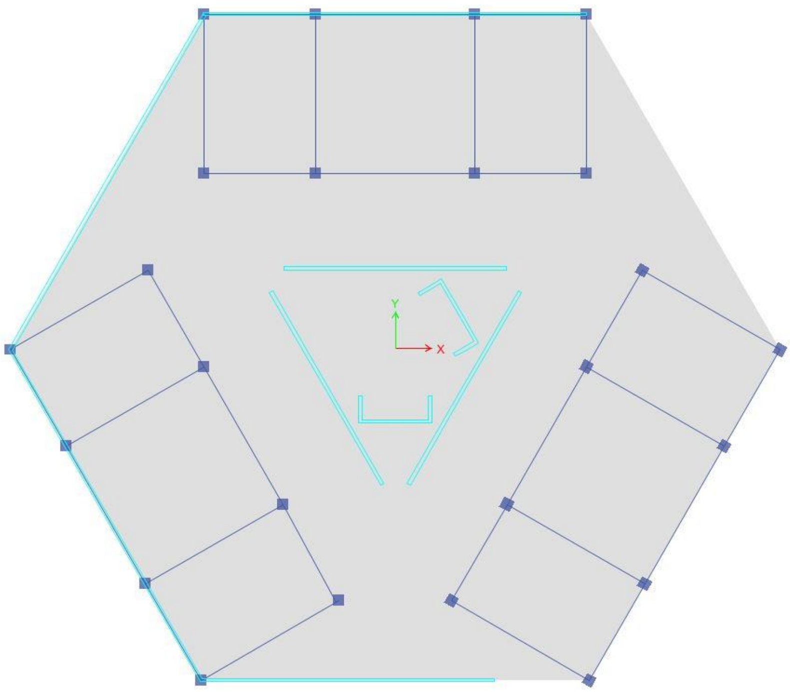
Columns:- allow 800mm square columns to bottom half of building reducing to 600mm square at top half

3.5.4 Lower Floors and Basement

Whilst the gravity system has been coordinated to be continuous down through the building, the lateral load resisting system requires change in the entrance areas of the building. A proposed reduction in the length of the walls surrounding the central core results in a reduction in building stiffness at these levels.

Ultimately this can be overcome by the inclusion of new bracing lines to the perimeter of the building which would likely be in the form of BRB's or eccentrically braced frames. These loads can them be transmitted through a floor diaphragm at ground floor level into the perimeter basement walls which will in turn transmit loads into the ground.

Figure 6 Lower Stories Structural Layout



3.6 Non-structural systems

The following non-structural systems will likely require specific engineering design to achieve compliance with NZBC and prevent life-safety hazards:

- Mechanical plant and associated ductwork
- Partition walls and ceilings
- Facades
- Hot pools
- Stairs

3.7 Construction Considerations

The feasibility of a project like this will largely be driven by construction considerations which will impact on the cost and delivery programme. Some of the considerations that will need to be taken into account as the design progresses include, but may not be limited to:

- Availability of specialist foundation construction equipment such as drilling rigs
- Relative costs between material options such as structural steel and reinforced concrete
- Availability of suitable cranes – it would be expected a tower crane would be necessary for this site.
- Preferences regarding speed of construction vs cost

4. Structural Design Actions

The following outlines the structural design actions

4.1 General

For the purposes of consideration of loading, this structure is classified as Importance Level 2 with a design life of 50 years in accordance with AS/NZS 1170.0:2011.

The annual probability of exceedance adopted for the purposes of determining loadings have been summarised in Table 2.

A peer review of the structural engineering design and associated PS2 would typically be required for a building of this type and scale. Ideally the peer reviewer would be engaged from the outset of the design to ensure optimal benefit from their input.

Table 2 Return periods

Action	SLS1	SLS2	ULS
Wind	1 in 25	N/A	1 in 500
Snow	1 in 25	N/A	1 in 150
Seismic	1 in 25	N/A	1 in 500

4.2 Imposed Loads

Vertical imposed actions on the structure are summarised in Table 3.

Table 3 Imposed gravity loads

Activity	Specific Uses	Design actions
Shopping areas	Shop floors for the sale and display or merchandise	4.0 kPa or 3.6 kN
Hotel	General hotel areas including bedroom and bathroom Corridors, hallways, stairs, landing, lobbies Laundries, service work room	2.0 KPa & 1.8KN 4.0KPa & 4.5KN 3.0KPa &2.7KN
Apartment	General apartment areas, kitchen and laundries Stair and landing in self-contained dwelling	1.5KPa & 1.8KN 2.0KPa & 2.7KN
Shopping areas	Shop floors for the sale and display or merchandise	4.0 kPa & 3.6 kN
Areas where people may congregate	Cafes and restaurants Balcony, roof used for floor type activity	5.0 kPa & 2.7 kN 4.0KPa & 1.8KN
Offices and work areas not covered elsewhere	Offices for general use, Commercial kitchens	3.0 kPa & 2.7 kN, 5.0 kPa & 4.5 kN
Roofs	Not accessible except for normal maintenance	0.25 kPa & 1.4 kN
Light vehicle traffic areas	Parking, driveways and ramps restricted to cars, light vans	2.5 kPa & 13 kN

4.3 Wind Loads

Parameters used in the determination of wind loads in accordance with AS/NZS 1170.2:2011 are summarised in Table 4.

Table 4 Wind load parameters to AS/NZS 1170.2:2011

Parameter	Value
Region	A7
V_{R} (ULS)	45 m/s
V_{R} (SLS)	37 m/s
M_{d}, wind direction multiplier	1.0 (any direction)
Terrain category	2
Height, z	varies
$M_{z,cat}$, terrain multiplier	To be determined based on the structural height along the floor
M_{s}, shielding multiplier	1.0
M_{t}, topographic multiplier	1.0
$V_{sit,\beta}$ (ULS)	To be determined based on floor height
$V_{sit,\beta}$ (SLS)	To be determined based on floor height

4.4 Snow and Ice Loads

The structure is in Region N5. Snow loads used for the purpose of structural design are summarised in Table 5.

Table 5 Snow load parameters to AS/NZS 1170.3:2003

Parameter	Value
Region	N5
S_{g} (ULS)	0.90 kPa (minimum NZBC requirement)
S_{g} (SLS)	0.34 kPa
ULS Snow Load, S_{ULS}	0.63 kPa (for balanced roofs only, no parapet)
SLS Snow Load, S_{SLS}	0.24 kPa (for balanced roofs only, no parapet)

4.5 Seismic Loads

4.5.1 Site Parameters

Site subsoil class: C

Fault proximity: > 20 km

4.5.2 Analysis Methodology

The seismic analysis has been completed in accordance with AS/NZS 1170.5:2004, using both equivalent static method and modal response spectrum method.

Design Spectra are in accordance with NZS 1170.5:2004 for site subsoil class C.

4.5.3 Seismic Load Coefficient-Equivalent static method

Parameters used in the determination of seismic load coefficient to NZS 1170.5:2004

Table 6 Seismic load coefficient parameters to NZS 1170.5:2004

Parameter	Value

Zone factor, Z	0.13 (Dunedin)
Period, T	≤ 1.8 s (assumed for initial calculations)
$C_h(T)$	1.1
S_p	0.9 (steel and concrete)
R_u	1.0
R_s	0.25
Ductility	$\mu = 1.25$
$C_d(T_1)_{ULS}$	0.28 (steel and concrete)
$C_d(T_1)_{SLS}$	0.07

4.5.4 Parts and Components

The actions will be Calculated in accordance with NZS 1170.5:2004 section 8.

5. Serviceability Criteria

5.1 Displacements

Particular elements are designed to the more stringent of the recommended serviceability deflection limits of AS/NZS 1170.0:2011, Table C1 at SLS_1 or manufacturers required tolerances for affected systems

5.2 Design Life

Foundations: 50 years minimum

Superstructure: 50 years minimum

Where structural elements are accessible, normal maintenance has been assumed to achieve the required design life.

Note: non-structural elements and cladding specification are by the Architect and are not covered by this design features report.

5.3 Durability of Structural Elements

Note that overall building durability and weather tightness is addressed through the architectural design.

Durability of structural elements is to be achieved by meeting the requirements of the following standards:

Reinforced concrete NZS 3101:2006 Part 1 Section 5

Steel surface treatments AS/NZS 2312:2002

Table 7 Summary of Steel Surface Treatments

Element	Design Life	Exposure Category	Surface Treatment	Time to First Major Maintenance
Internal Structural Steelwork	50 years	Low	75µm zinc primer	25 years
Exterior Structural Steelwork	50 years	Low	Hot dip galvanised to HDG600 (AS/NZS 4680) or metal zinc sprayed to TSZ100 (AS/NZS 2312:2002)	25 years
Cold-formed Steel Purlins (internal only)	50 years	Low	275 g/m2 factory applied zinc coating	25 years

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5.4 Reinforced Concrete

5.4.1 Concrete Strengths

Foundations	30 MPa
Slab on grade	30 MPa
Precast Concrete	40 MPa
Concrete column and wall	40 MPa
Insitu topping concrete and slab	35 MPa

5.4.2 Reinforcing Steel

Foundations	Grade 500E (stirrups Grade 300E)
Slab on grade	Seismic mesh and Grade 500E bars
Precast concrete	Grade 500E

5.5 Structural Steel

All structural steel shall be manufactured in New Zealand or Australia unless it can be demonstrated by certification from a local NATA accredited laboratory that the materials comply with New Zealand, Australian, British or Japanese Standards for steel as required by NZS 3404.1, section 2, including, type, category, and suppression of brittle fracture.

Trace-ability of steel materials shall be maintained throughout all stages of construction included the completed project.

All bolts to be tensioned in accordance with the drawings and specification.

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