# Lend Lease (Millers Point) Pty Limited

## Barangaroo South - C5 Commercial Building

## Structural Engineering Report - Project Application

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# Contents

# 1 Introduction

This report supports a Project Application submitted to the Minister for Planning pursuant to Part 3A of the Environmental Planning and Assessment Act 1979 (EP&A Act). The Application seeks approval for construction of a commercial building (known as Building C5) and associated works at Barangaroo South as described in the Project Description section of this report.

## 1.1 Background

The 22 hectare Barangaroo site has been divided into three distinct redevelopment areas (from north to south) – the Headland Park, Barangaroo Stage 2 and Barangaroo Stage 1 (herein after referred to as Barangaroo South).

Lend Lease was successfully appointed as the preferred proponent to develop Barangaroo Stage 1 (otherwise known as Barangaroo South) on 20 December 2009.

## 1.2 Planning History and Framework

On 9 February 2007 the Minister approved a Concept Plan for the site and on 12 October 2007 the land was rezoned to facilitate its redevelopment. The Approved Concept Plan allowed for a mixed use development involving a maximum of 388,300m$^2$ of gross floor area (GFA) contained within 8 blocks on a total site area of 22 hectares.

Modification No. 1 was approved in September 2007 which corrected a number of minor typographical errors.

On 25 February 2009 the Minister approved Modification No. 2 to the Concept Plan. The Approved Concept Plan as modified allowed for a mixed use development involving a maximum of 508,300m$^2$ of gross floor area (GFA) contained within 8 blocks on a total site area of 22 hectares.

On 11 November 2009 the Minister approved Modification No. 3 to the Concept Plan to allow for a modified design for the Headland Park and Northern Cove. The Approved Concept Plan as modified allows for a mixed use development involving a maximum of 489,500m$^2$ of gross floor area (GFA) across Barangaroo as a whole.

On 16 December 2010 the Minister approved Modification No. 4 to the Barangaroo Concept Plan. The Approved Concept Plan as modified allows for approximately 563,965m$^2$ Gross Floor Area of mixed use development across the entire Barangaroo site.

This Project Application forms one of a series of individual Applications that Lend Lease will be submitting to deliver Barangaroo South. This Project Application is consistent with the established planning framework for the site, including the approved Concept Plan (as modified).

A Project Application (MP10_0023) has been approved for the bulk excavation and construction of a basement car park to accommodate up to 880 car parking spaces and associated services and infrastructure to support the initial phases of

the future development of Barangaroo South. A Section 75W Modification Application was subsequently submitted seeking to modify MP10_0023 to extend the area of the approved basement to the south. This modification was approved by the Minister for Planning on 3 March 2011.

A further Section 75W application has been submitted to the Department of Planning and Infrastructure (the Department) and is currently being assessed, which seeks the Minister's approval to modify the depth of the excavation and change the reduced levels of the basement structure, using the same construction methodology as detailed and approved as part of the original project application. This includes:

- reduced excavation and bulk earthworks;
- reduced structural works – foundations, basement levels, perimeter retention system etc; and
- installation of associated services and infrastructure to support the initial phases of the future development of Barangaroo South.

A project application for the first commercial building, known as C4, was submitted to the Department of Planning on 29 October 2010. This application sought consent for construction and use of a new commercial Building C4 with a maximum 98,514m$^2$ GFA accommodating commercial and retail uses, a child care centre, bicycle parking and associated use and operation of car parking and loading facilities in the basement. Consent was issued by the Minister on 3 March 2011.

A Section 75W application for C4 has been submitted to the Department and is currently being assessed which seeks the Minister's approval to modify certain elements of the approved C4 building, including:

- mix of the uses within the building;
- total GFA;
- shape of floor plates of the podium and the tower elements of the building;
- facade details;
- roof treatment; and
- basement layout.

A project application for the second commercial building, known as C3, was submitted to the Department of Planning in October 2011. This application sought consent for the construction of a 49 storey building, comprising ground floor retail, a commercial lobby, childcare, podium and office tower, provision for associated cars and bicycle parking and the construction of the surrounding ancillary temporary public domain and landscaping.

## 1.3 Site Location

Barangaroo is located on the north western edge of the Sydney Central Business District, bounded by Sydney Harbour to the west and north, the historic precinct of Millers Point (for the northern half), The Rocks and the Sydney Harbour Bridge approach to the east; and bounded to the south by a range of new development dominated by large CBD commercial tenants.

The Barangaroo site has been divided into three distinct redevelopment areas (from north to south) – the Headland Park, Barangaroo Stage 2 (also known as Barangaroo Central) and Barangaroo South.

The area of land within which development is proposed under this Project Application extends over land generally known and identified in the approved Concept Plan as Block 2 which comprises Lot 5 in DP 876514.

## 1.4 Project Description

This Project Application seeks approval for the construction of ground floor retail, a commercial lobby, retail and commercial podium area and office tower, provision for associated cars and bicycle parking and the construction of the surrounding ancillary temporary public domain which includes access streets and landscaping.

## 1.5 Purpose of this Report

This report has been prepared to accompany the Project Application for the C5 Commercial Building and associated works at Barangaroo South. It addresses the relevant Director-General Requirements for the project.

These Director-General Requirements are discussed in the Environmental Assessment Report (EAR) that has been prepared to support the application.

## 1.6 Proximity to Metro Rail Corridor

The C5 footprint partially overlies the proposed Sydney Metro rail corridor, with a number of superstructure columns and walls lying directly over the proposed Metro tunnels. The foundations for C5 will need to be located clear of the Metro tunnels – either side of the corridor and/or between the tunnels. Transfer structures will be required within the C5 superstructure and/or basement to redirect the forces from the columns and walls away from the Metro tunnels to the foundations. These transfer structures may include one of the following; reinforced concrete raft under the basement slab, transfer walls within the basement levels or within the podium levels of the superstructure, or inclined columns within the podium.

Design of the foundations and substructure will require consideration of issues such as structure-borne vibration of from the rail tunnels, and avoidance of transferring loads from the building onto the rail tunnels.

## 1.7 Geotechnical Site Investigation

Reference is made to the Geotechnical Report for the Project Application (MP10_0227). The report is a desktop study based on existing information about the site and surroundings, which provides a description of the site history, geology, and ground conditions. The report contains sufficient information to provide confidence that an adequate foundation solution can be developed.

An additional geotechnical investigation comprising deep cored boreholes has been undertaken to provide specific foundation data for the foundation design and

construction of Building C5. The results of this investigation will be presented in an interpretive geotechnical report and used in the development of the design.

### 1.7.1 General Ground Conditions

The Sydney Geological Map scale 1:100,000[1] and the Sydney Geological Map scale 1:250,000[2] indicate that the site is underlain by the Hawkesbury Sandstone of the Wianamatta Group, which is overlain by Quaternary sediments and manmade fill.

A general description constitutes reclaimed land from the original shoreline approximating the Hickson Road alignment to the existing sea wall, comprising general fill overlying alluvial sediments overlying sandstone increasing in strength with depth. The depth to alluvium from existing surface level trending away from Hickson Road varies from approximately 3m to 13m, and top of sandstone approximately 3m to 18m. Over the footprint of C5, top of rock has been interpreted as approximately RL -2 AHD at the eastern extent to RL -15m AHD at the west. The alluvial material is acid sulphate soil.

### 1.7.2 Groundwater

Groundwater across the site is heavily influenced by tidal fluctuations of the adjacent Darling Harbour, with daily tidal ranges of typically 0.5m to 1.5m AHD indicating that much of the site is subject to seawater flushing. Sydney Ports gives values for maximum high tide (Spring Tide) of 1.6m AHD, and minimum high tide (Neap Tide) of 1.3m AHD.

*1 Geological Map of Sydney, Geological Series Sheet 9130, N.S.W Department of Mineral Resources, First Edition 1983*

*2 Geological Map of Sydney, Geological Series Sheets S1 56-5, Geological Survey of ..W, Third Edition 1966*

# 2 The Structural Scheme

## 2.1 General Description

The building structure proposed is a reinforced concrete frame stabilised by an arrangement of reinforced concrete shear walls, which may be supplemented by steel bracing elements.

The typical floors are proposed to be of in situ post-tensioned banded slab construction.

General building data:

| | |
|---|---|
| Building height above ground: | ~178.8m |
| Number of stories (incl Ground): | 40 |
| Typical floor to floor height: | 3,800mm |
| Number of basement levels: | 2 generally |
| Number of plant levels: | 2 tower levels plus ancillary roof, podium, and basement central plant |
| Primary Grid: | 10.5m x 10.5m |

## 2.2 Substructure

### 2.2.1 Foundations

Due to the depth of the rock founding strata in relation to the lowest basement level, bored piles are currently proposed for the foundations of C5. It is intended that the bored piles are founded within the Class II sandstone providing minimum end bearing of 6MPa, with shaft adhesion generated through the rock above toe level also utilised. The piles may be constructed top down from the existing ground level, or from the lowest basement level following excavation.

Alternatives to bored piles include barrettes and caissons, or over-excavation for construction of pad or strip footings founded on Class II/III sandstone. Pre-stressed ground anchors may be required to resist tension forces resulting from wind and seismic loading or construction staging.

The foundations will be located to coordinate with the Sydney Metro rail corridor.

The foundation design will be developed following incorporation of the results of the additional site geotechnical investigations mentioned in Section 1.7.

### 2.2.2 Retaining Walls

Building C5 sits entirely within a site wide basement envelope which is the subject of a separate Project Application. The retaining walls forming this basement may require propping from the stability system and horizontal structure associated with Building C5.

### 2.2.3 Vertical Structure

The vertical structure through the basement will consist primarily of reinforced concrete columns and shear walls utilising medium and high strength concrete. Composite columns (concrete filled steel tubes or encased structural sections) may be used where appropriate to minimise column sizes, simplify connection to steel bracing, or facilitate jump start construction.

Where superstructure columns and/or walls are located over the Metro rail corridor, reinforced concrete walls within the basement may be used as transfer structures to direct the loads from the columns and walls away from the Metro corridor to foundations located clear of the corridor.

### 2.2.4 Basement Levels

There will be a single basement level across the majority of the C5 footprint, intended for uses such as parking and a loading dock.

The slab at this level may be integral to the pile cap and/or link slab between pile caps. The requirement for this slab to be watertight and designed for significant hydrostatic pressure will be dependent on final geotechnical designs and the structural design and detailing of the basement.

An intermediate reinforced concrete floor is intended for between the main basement level and the ground level across a portion of the C5 footprint, for support of ancillary plant rooms, storage areas, and retail back of house areas. This slab will be linked to the C5 tower structure for overall stability.

### 2.2.5 Ground Level

Ground level is intended to be of reinforced concrete band beam and slab construction.

The ground level slab may consist of multiple levels and set-downs to accommodate trunk services, road pavements, planters and landscaped areas, ramps, escalators, etc; and will need to accommodate multiple penetrations for plant access, intake and exhaust risers, substation access, etc.

Ground level will be designed for an increased temporary load allowance for construction access, logistics, and materials storage.

## 2.3 Superstructure

### 2.3.1 Vertical Structure

The vertical structure through the tower will consist primarily of reinforced concrete columns and shear walls utilising medium and high strength concrete. Composite columns may be used where appropriate to minimise column sizes, simplify connection to steel bracing, or facilitate jump start construction.

### 2.3.2 Podium Levels

Multiple podium levels for commercial and retail use will be located between ground level and the first office floor. The structure for these levels will be designed to suit the extent and function of the space, and may be of post-tensioned or reinforced concrete, or composite construction.

### 2.3.3 Typical Floors

Typical floors will be of post-tensioned banded slab concrete construction.

### 2.3.4 Plant Levels

Plant levels will be of post-tensioned banded or beam and slab construction.

### 2.3.5 Fire Stairs

Fire stairs will be of reinforced concrete or structural steel construction with appropriate fire separation from the occupied spaces.

## 2.4 Stability

Robustness, wind, and seismic loading will be applied in accordance with the relevant sections of AS/NZS1170 and AS1170 Parts 0, 2 and 4, with additional wind load data based on the results of wind tunnel testing.

Structural stability will be provided by an arrangement of reinforced concrete shear walls. The stability system may be supplemented by outriggers, belt trusses or steel bracing at plant or other selected locations.

## 2.5 Green Star Initiatives

It is intended that Green Star initiatives relating to structure for Building C5 will include the following where appropriate:

- Use of cement replacement and/or recycled aggregate for concrete; and
- Use of steel with recycled content.

# 3 Design Standards and Sources of Reference

## 3.1 General

The design and documentation of the building and associated works shall comply with all relevant Australian Standards and the Building Code of Australia (BCA).

Standard Specifications or Codes of the British Standards Institute (BS) or the American Society for Testing and Materials (ASTM) are referenced only when a relevant Standards Australia publication does not exist.

Current editions of all codes and standards shall apply.

## 3.2 BCA Structural Provisions

Building C5 is classified as follows in accordance with Part B1 of the BCA.

Table 1: BCA Classification

| BCA Table | Classification |
|---|---|
| **Table B1.2a** – Importance Level of Building | 3 - Structures designed to contain a large number of people |
| **Table B1.2b** – Design Events for Safety | Annual Probability of Exceedance |
| Wind | 1:1000 |
| Earthquake | 1:500 |

## 3.3 Codes and Standards

The following codes and standards will form the basis for the structural design:

| | |
|---|---|
| AS/NZS 1170.0 | Structural design actions – General Principles |
| AS/NZS 1170.1 | Structural design actions – Permanent, imposed, and other actions |
| AS/NZS 1170.2 | Structural design actions - Wind actions |
| AS 1170.4 | Structural design actions – Earthquake actions in Australia |
| AS 1720.1 | Timber Structures Code - Design Methods |
| AS 2121 | Cold Formed Steel Structures Code |
| AS 2159 | Piling code |
| AS/NZS 2312 | Guide to the protection of structural steel against atmospheric corrosion |
| AS 2327.1 | Composite structures - Simply supported beams |
| AS 3600 | Concrete Structures Code |
| AS 3700 | Masonry Code |

| | |
|---|---|
| AS 3735 | Concrete Structures for Retaining Liquids |
| AS 4100 | Steel Structures Code |
| AS 5100.6 | Bridge design – Steel and composite construction |
| BS 5950-8 | Structural use of steelwork in building – Code of practice for fire resistant design |
| BS 8102:1990 | Code of practice for protection of structures against water from the ground |
| Eurocode 4 | Design of composite steel and concrete structures |
| BCA | Building Code of Australia |

# 4 Loads

## 4.1 Self Weight

Structural self weights are to be calculated on the basis of the following densities:

Reinforced concrete: 24.5 kN/m$^3$

Steel: 78.5 kN/m$^3$

## 4.2 Superimposed Dead Loads and Live Loads

Table 2: Design Loads

| Area | Superimposed Dead Load | Live Load |
|---|---|---|
| Offices (General) | 1.0 kPa moveable partitions<br>0.4 kPa raised floor<br>0.5 kPa ceiling & services | 3.0 kPa |
| Office High Loading Zones | 0.4 kPa raised floor<br>0.5 kPa ceiling & services | 7.5 kPa storage areas over 5% office floor area |
| Lift Lobbies / Vertical Villages | 1.5 kPa finishes<br>0.5 kPa ceiling & services | 4.0 kPa |
| Toilets | 1.0 kPa finishes<br>2.0 kPa partitions<br>0.5 kPa ceilings & services | 2.0 kPa |
| Foyer | 2.0 kPa finishes<br>0.25 kPa ceiling & services | 5.0 kPa<br>15 kPa temp. for construction staging |
| Retail | 2.5 kPa finishes & partitions<br>0.5 kPa ceilings | 5.0 kPa |
| Terraces (including trafficable roofs) | 2.5 kPa finishes<br>0.25 kPa ceiling & services | 4.0 kPa |
| Stairs and landings | 1.5 kPa finishes<br>0.5 kPa balustrades | 4.0 kPa |
| Car parking | 0.25 kPa | 2.5 kPa |
| Loading Dock | 2 .0 kPa | 15 kPa |
| Plant Areas | 3.5 kPa partitions & plinths<br>0.5 kPa ceiling and services | As calculated for relevant use.<br>5.0 kPa minimum |
| Tank rooms | 4.0 kPa plinths | Tank volume as calculated. |
| Substation and main switch room | As calculated for trenches, plinths, fire rated walls in accordance with approved substation design | 7.5 kPa |
| Non-trafficable concrete roofs | 2.5 kPa finishes<br>0.25 kPa ceiling & services | 2.0 kPa<br>BMU loads as provided by supplier |
| Lightweight roofs | As calculated | Generally 0.25 kPa<br>Street awnings 1.0 kPa |

Superimposed dead loads include floor finishes, ceiling, services, and partitions.

## 4.3 Wind Loads

For the structural design of components, wind loading applied to the structural elements will be assessed in accordance with AS1170 Part 2: Wind Actions. Terrain categories will be calculated based on the roughness length calculation.

For global stability detailed design and assessment of accelerations, a high frequency force-balance (HFFB) wind tunnel test will be conducted to a brief prepared by Arup.

Environmental wind and façade pressure tests will also be conducted on the building. The results of the façade pressure test is also of use for the structural design of individual components and may be numerically integrated and calibrated as a check on the results of the HFFB.

The following design parameters have been assessed in accordance with AS1170 Part 2:

Region: A2

Basic wind speeds:

| | | | | |
|---|---|---|---|---|
| Ultimate - | $V_{100}$ | = | 46 | m/s |
| Serviceability - | $V_{20}$ | = | 37 | m/s |

## 4.4 Seismic Loading

Earthquake loading applied to the structural elements and detailing of the seismic stability system will be in accordance with AS 1170.4: 2007: Earthquake actions in Australia.

Specific seismic data is summarised as:

| | | |
|---|---|---|
| Importance level | = | 3 |
| Annual probability of exceedance (P) | = | 1:500 |

## 4.5 Earth Pressure Loading

Building C5 sits within a site-wide basement envelope. Shear walls provided within the basement will resist earth pressures transferred through the permanent diaphragm slabs. This may include use of shear walls and or bracing associated with the stability structure of C5.

Earth retaining structures shall be designed in accordance with the recommendations in the interpretive geotechnical report which is being completed as part of design development.

## 4.6 Water Pressure Loading

The existing groundwater level is above the level of the lowest basement slab. Depending on the design of the basement (tanked or drained), the design of the foundations to C5 may require consideration of uplift due to buoyancy (hydrostatic pressure on pile caps). The local buoyancy impact on the pile design will be considered regardless.

## 4.7 Balustrade Loadings

Balustrades are to be designed in accordance with AS/NZS1170.1.

## 4.8 Blast Forces

The building will not be designed for blast forces of any kind.

# 5 Serviceability

## 5.1 Design Life

The structure is intended to be designed for a nominal 50 year design life. The BCA and Standards Australia material standards will be used as the basis for the durability specification for the structure.

Reference should be made to the relevant material standard regarding maintenance assumptions that form the basis of the design code.

## 5.2 Deflection Limits

The deflection criteria specified in AS 3600 and AS 4100 and as specified below are appropriate for this building.

Table 3: Deflection Limits

| Type of member | Deflection to be considered | Deflection limitation ($\triangle L_{ef}$) for spans | Deflection limitation ($\triangle L_{ef}$) for cantilevers |
|---|---|---|---|
| Beams and slabs | The total vertical deflection | 1/250 | 1/125 |
| Members supporting masonry partitions | The deflection which occurs after the addition or attachment of the partitions | 1/500 where provision is made to minimise the effect of movement, otherwise 1/1000 | 1/250 where provision is made to minimise the effect of movement, otherwise 1/500 |
| Mullions and wind columns | Deflection under wind load | 1/240 | - |
| Storey drift under wind | H/500 | - | - |
| Overall sway under wind/earthquake | H/500 | - | - |
| Differential settlement between foundations | L/1000 | - | - |

## 5.3 Concrete

### 5.3.1 Durability

The requirements of AS 3600 will be applied to all reinforced and post-tensioned concrete. For the foundations, the concrete mix and cover to reinforcement selected will be appropriate for the ground conditions.

Structural requirements for certain elements may increase concrete strengths above the minimum required for durability.

### 5.3.2 Crack Control

The degree of crack control to be provided in concrete elements will be in accordance with AS 3600.

## 5.4 Steelwork Corrosion Protection

The corrosion protection system for structural steelwork will be dependent on the location of the steel elements within the building. Systems will be selected in accordance with AS/NZS 2312 as a minimum specification.

## 5.5 Fire Resistance Levels for Structural Elements

Fire resistance levels for structural elements shall be determined in accordance with the BCA and fire engineered outcomes.

FRLs of 180/180/180 may be required for selected areas such as substations, and 240/240/240 for areas such as loading docks.

Concrete covers are to be in accordance with AS 3600 Section 5.

# 6 Conclusion

This report has been prepared to inform and accompany the C5 Commercial Building Project Application. It describes the structural scheme and summarises the structural design criteria at the time of the Project Application.

Our conclusion is that the project presented in the proposed C5 Commercial Building Project Application can be designed and constructed utilising proven design and construction techniques