

Lend Lease (Millers Point) Pty  
Limited

**Barangaroo South - C3  
Commercial Building**

**Structural Engineering Report -  
Project Application**

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Arup  
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# 1 Introduction

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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 C3) and associated works at Barangaroo South as described in the Project Summary 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 & 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<sup>2</sup> 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<sup>2</sup> 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<sup>2</sup> 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<sup>2</sup> 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<sup>2</sup> 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 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.

### 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 3 which comprises Lot 5 in DP 876514.

## **1.4 Project Summary Description**

This Project Application seeks approval 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 which includes access streets and landscaping.

## **1.5 Purpose of this Report**

This report has been prepared to accompany the Project Application for the C3 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 proximity of Building C3 to the future Sydney Metro rail corridor is shown in Figure 1.

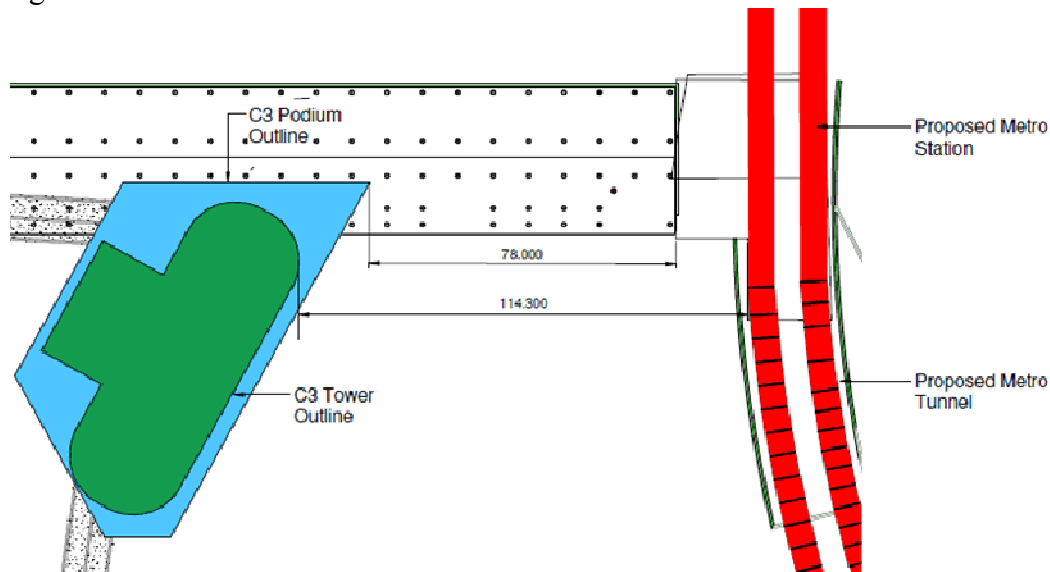


Figure 1: Proximity to Metro Rail Corridor

The building's footprint lies outside the Metro protection corridor defined by the first and second reserve documented in the Development Guidelines within the vicinity of Sydney Metro Network Line 1, prepared by the Sydney Metro Authority, CBD Metro, document reference CBD-2100-PBACH-R-GN-0159 dated 30 March 2010, Revision A-1, Status Final. The proposed foundations of C3 are approximately 114m from the face of the Metro tunnel at the nearest point, with all load transferred to foundations below the top of rock. The top of sandstone bedrock is located at between RL -24m AHD to -10m AHD at the location of C3. On the basis of the above information it is considered that the building will not impede the Metro rail corridor or affect the future operations of the Metro project.

## 1.7 Geotechnical Site Investigation

Reference is made to the Geotechnical Report for the Project Application (MP10\_0023 - Bulk excavation and basement car parking). 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 C3. 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<sup>[1]</sup> and the Sydney Geological Map scale 1:250,000<sup>[2]</sup> 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 2m to 15m, and top of sandstone approximately 5m to 25m. Over the footprint of C3, top of rock has been interpreted as approximately RL -10mAHD to RL -24mAHD. 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.

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<sup>1</sup> Geological Map of Sydney, Geological Series Sheet 9130, N.S.W Department of Mineral Resources, First Edition 1983

<sup>2</sup> Geological Map of Sydney, Geological Series Sheets S1 56-5, Geological Survey of ..W, Third Edition 1966

## 2 The Structural Scheme

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### 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:	200m
Number of stories above ground:	49
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:	15.0m x 10.5m
Façade module:	1,500mm

### 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 C3. 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 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 C3 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 C3.

### 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.

It is intended that all Building C3 tower columns and primary walls continue uninterrupted through the basement levels to avoid the inefficiency and cost of transfer structures.

### 2.2.4 Basement Levels

There will be a single basement level across the majority of the C3 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 C3 footprint, for support of ancillary plant rooms, storage areas, and retail back of house areas. This slab will be linked to the C3 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 C3 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 C3 is classified as follows in accordance with Part B1 of the BCA.

Table 1: BCA Classification

BCA Table	Classification
<b>Table B1.2a –</b> Importance Level of Building	3 - Structures designed to contain a large number of people
<b>Table B1.2b –</b> 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<sup>3</sup>

Steel: 78.5 kN/m<sup>3</sup>

### 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 0.4 kPa raised floor 0.5 kPa ceiling & services	3.0 kPa
Office High Loading Zones	0.4 kPa raised floor 0.5 kPa ceiling & services	7.5 kPa storage areas over 5% office floor area
Lift Lobbies / Vertical Villages	1.5 kPa finishes 0.5 kPa ceiling & services	4.0 kPa
Toilets	1.0 kPa finishes 2.0 kPa partitions 0.5 kPa ceilings & services	2.0 kPa
Foyer	2.0 kPa finishes 0.25 kPa ceiling & services	5.0 kPa 15 kPa temp. for construction staging
Retail	2.5 kPa finishes & partitions 0.5 kPa ceilings	5.0 kPa
Childcare centre	1.0 kPa partitions 0.5 kPa ceiling & services	3.0 kPa
Terraces (including trafficable roofs)	2.5 kPa finishes 0.25 kPa ceiling & services	4.0 kPa
Stairs and landings	1.5 kPa finishes 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 0.5 kPa ceiling and services	As calculated for relevant use. 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 0.25 kPa ceiling & services	2.0 kPa BMU loads as provided by supplier
Lightweight roofs	As calculated	Generally 0.25 kPa 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 1170 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 C3 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 C3.

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 C3 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 ( $\Delta L_{ef}$ ) for spans	Deflection limitation ( $\Delta L_{ef}$ ) 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.

FRL's 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.

A fire engineered approach will be undertaken in relation to the requirements for passive protection to structural steel wherever possible. Where required, fire protection to structural steel will be provided using fire rated cladding, vermiculite (or similar) spray, or intumescent paint.

## 6 Conclusion

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This report has been prepared to inform and accompany the C3 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 C3 Commercial Building Project Application can be designed and constructed utilising proven design and construction techniques.