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Master's Thesis

Sustainable Urban Regeneration of Barangaroo, Sydney

Relatore: Prof. Massimo Tadi

Tesi Di Laurea di:

Serkan CAKIR matr: 736742

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ABSTRACT

For my Master's thesis, it is chosen ongoing competition project that incorporates all, Urban, Architectural and Structural Design. Barangaroo (formerly known as East Darling Harbour) is a 22-hectare area adjoining the CBD of Sydney, Australia's global capital city. At present the Barangaroo area is a vacant land and it's used for gathering and recreational activities. A unique opportunity exists for us of capacity, capability and creative excellence to play a critical role in this renewal project that will reshape and define the most significant site on Sydney's harbour foreshore this century.

In the subsequent chapters I have explained the design process as well as the final out- comes of the project. Each chapter is then subdivided into sections or subsections to further clarify the design process. It is our goal to make this report as explanatory as possible. Overall we have managed our design to meet with the standards and codes while providing comfort and still being an environmentally sustainable project.

Chapter 1

Introduction

1.1 Geography and Facts

Australia is a country, an island and a continent. The geographic co-ordinates are 27 degree South 144 degree east. It is the sixth largest country in the world with a total land area of 7.7 million square kilometers. Australian landmass is on indo-Australian plate. Surrounded by the Indian, Southern and pacific oceans, Australia is separated from Asia by the Arafura and Timor seas.

Figure 1.1 Australia in Globe

Australia has a total 25,760 kilometers of coastline and claims an extensive Exclusive Economic Zone of 8,148,250 square kilometers. This Exclusive Economic Zone does not include the Australian Antarctic Territory. The land area of Australia is almost as great as that of the United States of America (excluding Alaska), about 50% greater than Europe (excluding the former USSR) and 32 times greater than the United Kingdom.

Australia is the lowest, flattest and, apart from Antarctica, the driest of the continents. Unlike Europe and North America, where some landscapes date back to around 20,000 years ago, when great ice sheets retreated, the age of landforms in Australia is generally measured in many millions of years. This gives Australia a very distinctive physical geography.

Australia has a wide variety of landscapes. These include deserts, mountains, from alpine heaths to tropical rainforests and long beaches. The country also hosts a great variety of marsupial animals such as the koala and the kangaroo. Mount Augustus, located in Western Australia, is the world's biggest monolith. But Uluru, also called Ayers Rock, is the most popular monolith and is an icon for Australia. The Great Barrier Reef is the world's largest coral reef. It extends for over 2,000 kilometers on the north-eastern coasts of the country.

Figure 1.2 Australia superimposed on the mainland United States.

Much of the center of Australia is flat, but there are numerous ranges (e.g. Macdonnells, Musgrave) and some individual mountains of which Uluru (Ayers Rock) is probably the best known. Faulting and folding in this area took place long ago. The area was worn to a plain, and the plain was uplifted and then eroded to form the modern ranges on today's plain. In looking at

Uluru, one remarkable thing is not so much how it got there, but that so much has been eroded from all around to leave it there.

Figure 1.3 Ayers Rock, Australia

The Australian landforms of today are thus seen to result from long continued processes in a unique setting, giving rise to typical Australian landscapes, which in turn provide the physical basis for the distribution and nature of biological and human activity in Australia.

1.2 Climate.

Australia is a continent that experiences a variety of climates due to its size. The weather can range from below zero temperatures in the Snowy Mountains to intolerable heat in the north-west. It is considered to be one of the driest continents on earth.

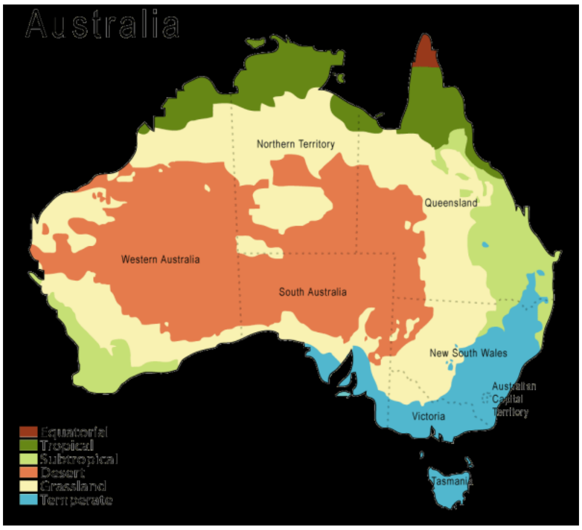

Figure 1.4 Australian Climate Map.

The temperate south has cool, wet winters and warm, dry summers. In the north, a tropical climate prevails with a warm, dry season and a hot, wet season. The extreme north-west experiences the ends of the monsoon systems, while the mountains of the south-east attract seasonal snow to form the Alpine snowfields. The temperatures vary from an average 30 degrees C in midsummer in the Red Centre, to an average of 6 degrees C in the highlands in winter.

The inland deserts can remain totally dry for years whilst rains can produce floods.

1.3 Cultural Characteristics.

1.3.1 Aboriginal Australian Culture

As one of the world's most primitive races, the Aboriginal Australian Culture is composite and diverse in nature. This culture has a long historical background that goes to some 150,000 years back when more than 500 different tribe groups or 'nations' existed in the continent.

The Latin word 'Aborigine' means 'original inhabitants'. Aborigines consist of the native Australians, who migrated from places in Asia at least 30,000 years back. The different tribes which comprise Aboriginal Australian Culture shared diverse heritage and beliefs, customs, dialects, languages, rituals, art forms, painting styles, food and hunting habits. All these together contribute towards the gradual growth and development of a diverse aboriginal culture down the ages.

Prior to the arrival of the Europeans in Australia, Aboriginal Australian Culture was highly distinct and exclusive, having several common features. Most of the tribes were partly nomadic hunters and gatherers, earning their living from the particular areas where they resided. People belonging to the Aboriginal Australian Culture established a peculiar affinity with the surrounding nature which was a part of their spiritual life. This is the secret behind their survival for millions of years.

The Aboriginal Australian Culture was basically a primitive one. The tools used by these tribes varied according to location and groups. Mainly, axe-heads, spears, knives and scrapers were some of the life-saving weapons used during this time. The language spoken by the tribal people were diverse in nature. There were about 200 to 250 Aboriginal languages that were randomly used by these tribes.

Figure 1.5 Aboriginal Dance

The oral storytelling tradition of the aboriginals' speaks about the vibrant cultural life they led. The tribal songs demonstrate the Dreamtime and other tales of the land. The diagrams drawn in the sand along with their dances go together with the oral tales.

Aboriginal music had a distinct identity for its most famous instrument - Didgeridoo. It is a five-foot long wind instrument made of bamboo, producing low, vibrating hum. Didgeridoos were extensively used in formal ceremonies such as circumcisions, sunsets and funerals.

The relationship existing between the different tribes influenced important social issues like marriage decisions and individual behaviors. The tribes believed that each person has a role to play and something to contribute in all major social decisions taken. Kinship took care of the mutual obligations and was a part of the aboriginal regulations.

Figure 1.6 Various Types of Didgeridoo

Aboriginal Australian Culture is one of the best pre-historic and ancient cultures of the world, which was assorted and exceptional. It a tribal culture of art and storytelling, like other indigenous populations of the world. The culture established a close relationship between man and environment. May be that this culture declined with the European arrival in the continent.

1.3.2 Australian Culture

Australian culture is founded on stories of battlers, bushrangers and brave soldiers. It’s all about a fair go, the great outdoors and a healthy helping of irony. Today Australia also defines itself by its Aboriginal heritage, vibrant mix of cultures, innovative ideas and a thriving arts scene.

The Dreamtime is the sacred ‘time before time’ of the world’s creation. According to Aboriginal belief, symbolic spirit ancestors emerged from the earth and descended from the sky to awaken a dark and silent world. They created the sun, moon and stars, forged mountains, rivers, trees and waterholes and changed into human and animal forms. Spirit ancestors connect this ancient past with the present and future through every aspect of Aboriginal culture.

Australians believe in mate ship and a 'fair go' and have a strong affection for the underdog or 'battler'. These values stem from convicts and early colonialists who struggled against a harsh and unfamiliar land and often unjust authority. Australia's most famous bushranger Ned Kelly protested against the poverty and injustice of a British class system shipped here along with the convicts. This flawed hero's fight for 'justice and liberty' and 'innocent people' has been embraced as part of the national culture and inspired countless books and movies. On the goldfields of the mid-1850s, diggers were portrayed in stories and songs as romantic heroes, larrikins and villains who embraced democracy. The bloody 1854 Eureka Stockade, where Victorian miners rose up against an authoritarian licensing system, came to symbolize a triumph of social equality. Later, during World War I, the courageous ANZAC soldiers who served in Gallipoli gave new meaning to the term 'tough Aussie'.


Figure 1.7 National Rugby League

It's no secret that Australians are sports mad. With more than 120 national and thousands of local, regional and state sporting organizations, it's estimated that six-and-a-half million people in Australia are registered sport participants. The Australians love sports and watch lot of sport - Australian Rules Football (AFL), National Rugby League (NRL), Cricket, Tennis Australian Open, Hobart Yacht Race and Formula One Grand Prix. Australia is a nation of swimmers and Olympic medals attest to their performance in the pool. The list of sports Australian love goes on.

With more than 80 per cent of Australians living within 50 km of the coast, the beach has become an integral part of Australians famous relaxed lifestyle. Australians love life on their sandy shores. Australians crowd for a spot on packed city beaches, relax at popular holiday spots and drive to secret, secluded beaches in coastal national parks. Australians go to the beach to enjoy the sun and surf or to sail, parasail, fish, snorkel, scuba dive and beach comb. It's where they socialize and play sport, relax and enjoy romance. It's also the site for celebration.

Since 1945 more than six million people from across the world have come to Australia to live. Today, more than 20 per cent of Australians are foreign born and more than 40 per cent are of mixed cultural origin. In Australian there are 226 languages - after English, the most popular are Italian, Greek, Cantonese and Arabic.

Australian rich cultural diversity is reflected in their food, which embraces most of the world's cuisines and artfully fuses quite a few of them. You'll find European flavors, the tantalizing spices of Asia, Africa and the Middle East and bush tucker from Australian backyard on offer everywhere from street stalls to five star restaurants. You can also embrace Australian melting pot of cultures in the many colorful festivals. See samba and capoeira at Bondi's Brazilian South American festival, dance behind the dragon parade during Chinese New Year or stroll through streets transformed into a lively piazza during the annual Italian celebrations. As a nation, Australia embrace a rainbow of religious belief and you'll find Catholic and Anglican churches, Hindu, Sikh and Buddhist temples, mosques and synagogues lining their streets.
Australia's unique geography and relative isolation has made it a fertile ground for new ideas. In 1879, Australians developed a way for ice to

be manufactured artificially, allowing them to export meat to Great Britain on refrigerated ships. In 1906, the surf lifesaving reel was designed so lifesavers could reach distressed swimmers with a rope attached to their vests. In 1929, Alfred Traeger built a pedal-powered radio as the communications for the Royal Flying Doctor Service.

Figure 1.8 Cultural Diversity

Australians were also responsible for more everyday inventions such as notepads (1902), aspirin (1915), the pacemaker (1926), penicillin (1940) the Hills Hoist clothesline (1946), the plastic disposable syringe (1949), the wine cask (1965), the bionic ear (1978), dual-flush toilet flush (1980)anti-counterfeiting technology for banknotes (1992) and long-wearing contact lenses (1999).

Long before European colonization, the Aboriginal people were already leading the world. They invented the aerodynamic boomerang and a type of spear thrower called the woomera. They were also the first society to use ground edges on stone cutting tools and the first to use stone tools to grind seeds, everyday tools which were developed only much later by other societies.

1.3.3 Australian Food Culture

Australian Food, the cocktail of different culture is famous for its miscellany rich cuisines. Traditionally Australian cuisines were based on British cooking from its conception. Current report on Australian food customs states: "Australians have thrown off the British yoke of pub grub and have embraced the great bounty from their own seas along with home-grown fruit and vegetables and the spices of Asia." The nostril-tweaking scents of Asian spices, the hot delight of chilies, the surprising pleasure of finger foods and dipping sauces are to be found not just in restaurants but on Australian tables everywhere.

Figure 1.9 Grilled steak

The palate-tantalizing flavors of Indonesia, Malaysia, India, and Vietnam, brought to Australia by travelers and immigrants, have found a new home and are creating a new tradition of fusion cuisine that is startlingly original, memorable and delicious.
The inhabitants of Australia are fond of both veg and non-veg foods consisting pies, roasted cuts of meat, grilled steak and chops, and other forms of meat generally accompanied by vegetables. For centuries the native Australians are using the fruits and plants growing in their local lands to make mouth-watering delicacies like, Calamari seasoned with lemon myrtle, Lemon myrtle linguine tossed with local scallops and

prawns, Native spinach fettuccine with Springs Smoked Salmon with creamy bush tomato and macadamia sauce etc.
Australian wines have long been making their presence appreciated in world markets, but more recently, visitors to the land down under are bringing back delicious accounts of bush tucker. The basic wilderness foods of the Aboriginals are gaining in popularity and sophisticated preparation. These include herbs like mountain pepper, watercress oil, and wattle seed (with a "coffee-hazelnut flavor") as well as rabbit, kangaroo, wallaby, crocodile, emu, and bunya nuts. Many fruits and vegetables unknown to most of the world await discovery. Examples of these include: greens called warrigal, lemon aspin that looks like a little pumpkin and tastes like citrus fruit, munthari berries with their apple-like taste, and tiny kakadu plums, their size belying their prodigious vitamin C content.

Figure 1.10 Authentic Bush-Tucker

1.4 Economy.

Australia has recorded 17 consecutive years of economic growth since 1992 – averaging 3.3 per cent a year. It has been one of the most stable and productive periods of Australia's modern history, and places Australia in the top class of developed countries in terms of sustained rates of growth. Australia is forecast to grow again at 2.75 per cent in 2009-10 which is above the average growth rate members of the Organization of Economic Cooperation and Development (OECD) of 2.2 per cent. Furthermore, Australia ranks first in the Asia-Pacific region for labour, agricultural and industrial productivity per person employed, according to the IMD World Competitiveness Yearbook. The 2006 OECD Economic Survey noted that living standards in Australia surpass those of all Group of Eight countries except the United States.

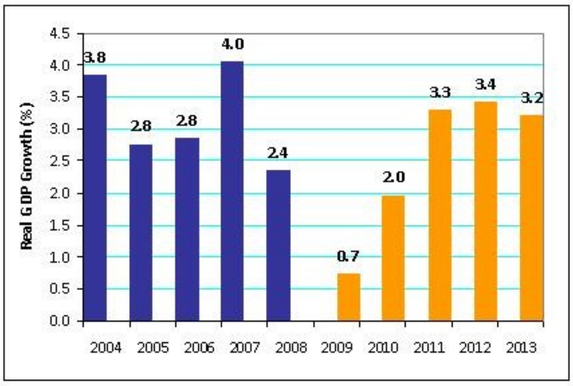

Figure 1.11 Australia's GDP Growth%

Australia's positive outlook is also sustained by its strong economic position. A sustained period of Government budget surpluses has enabled the Australian Government and many state level Governments to retire large amounts of Government debt. Net Government debt was eliminated in 2005-06 making Australia a net creditor nation. In May 2008, the Australian Government committed to a budget surplus equivalent to 1.8 per cent of GDP – some $21.7 billion. Australia's independent central bank, the Reserve Bank of Australia (RBA), is responsible for financial policy, in particular to keep consumer price inflation between two and three percent, on average, over business cycles.

In the last century, it could be strongly argued that Australia's economic success was based on its abundant agricultural and later mineral and fuels resources. While these sectors are still important, Australia has increasingly become a knowledge-based economy. Numerous factors have contributed to this development: the pace of technological and social change; advances in transport making travel, and the exchange of ideas, easier; and broader access to higher standards of education. Information and communications technology (ICT) is a key driver of economic growth, and continuing expansion of ICT infrastructure is essential to keep pace with world standards. Australia's ICT market is worth an estimated $89 billion with 25000 companies employing 236000 IT specialists.

1.5 History of Australia.

Australia's Aboriginal people were thought to have arrived here by boat from South East Asia during the last Ice Age, at least 50,000 years ago. At the time of European discovery and settlement, up to one million Aboriginal people lived across the continent as hunters and gatherers. They were scattered in 300 clans and spoke 250 languages and 700 dialects. Each clan had a spiritual connection with a specific piece of land. However, they also travelled widely to trade, find water and seasonal produce and for ritual and totemic gatherings.

Despite the diversity of their homelands - from outback deserts and tropical rainforests to snow-capped mountains – all Aboriginal people share a belief in the timeless, magical realm of the Dreamtime. According to Aboriginal myth, totemic spirit ancestors forged all aspects of life during the Dreamtime of the world's creation. These spirit ancestors continue to connect natural phenomena, as well as past, present and future through every aspect of Aboriginal culture.

A number of European explorers sailed the coast of Australia, then known as New Holland, in the 17th century. However it wasn't until 1770 that Captain James Cook chartered the east coast and claimed it for Britain. The new outpost was put to use as a penal colony and on 26 January 1788, the First Fleet of 11 ships carrying 1,500 people – half of them convicts – arrived in Sydney Harbour. Until penal transportation ended in 1868, 160,000 men and women came to Australia as convicts.

While free settlers began to flow in from the early 1790s, life for prisoners was harsh. Women were outnumbered five to one and lived under constant threat of sexual exploitation. Male re-offenders were brutally flogged and could be hung for crimes as petty as stealing. The Aboriginal people displaced by the new settlement suffered even more. The dispossession of land and illness and death from introduced diseases disrupted traditional lifestyles and practices.
By the 1820s, many soldiers, officers and emancipated convicts had turned land they

Figure 1.12 Captain James Cook

received from the government into flourishing farms. News of Australia's cheap land and bountiful work was bringing more and more boatloads of adventurous migrants from Britain. Settlers or 'squatters' began to move deeper into Aboriginal territories – often with a gun - in search of pasture and water for their stock.

In 1825, a party of soldiers and convicts settled in the territory of the Yuggera people, close to modern-day Brisbane. Perth was settled by English gentlemen in 1829, and 1835 a squatter sailed to Port Phillip Bay and chose the location for Melbourne. At the same time a private British company, proud to have no convict links, settled Adelaide in South Australia.

Gold was discovered in New South Wales and central Victoria in 1851, luring thousands of young men and some adventurous young women from the colonies. They were joined by boat loads of prospectors from China and a chaotic carnival of entertainers, publicans, illicit liquor-sellers, prostitutes and quacks from across the world. In Victoria, the British governor's attempts to impose order - a monthly license and heavy-handed troopers - led to the bloody anti-authoritarian struggle of the Eureka stockade in 1854. Despite the violence on the goldfields, the wealth from gold and wool brought immense investment to Melbourne and Sydney and by the 1880s they were stylish modern cities.

Australia's six states became a nation under a single constitution on 1 January 1901. Today Australia is home to people from more than 200 countries

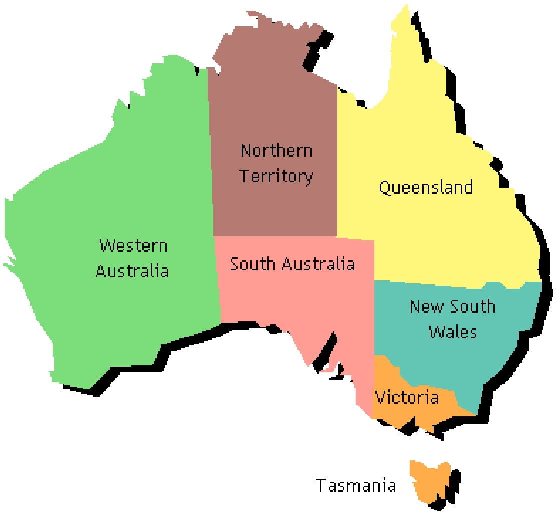

Figure 1.13 Six States of the Commonwealth of Australia

The First World War had a devastating effect on Australia. There were less than 3 million men in 1914, yet almost 400,000 of them volunteered to fight in the war. An estimated 60,000 died and tens of thousands were wounded. In reaction to the grief, the 1920s was a whirlwind of new cars and cinemas, American jazz and movies and fervour for the British Empire. When the Great Depression hit in 1929, social and economic divisions widened and many Australian financial institutions failed. Sport was the national distraction and sporting heroes such as the racehorse Phar Lap and cricketer Donald Bradman gained near-mythical status.

Figure 1.14 Great Depression hit in 1929

During the Second World War, Australian forces made a significant contribution to the Allied victory in Europe, Asia and the Pacific. The generation that fought in the war and survived came out of it with a sense of pride in Australia's capabilities.

After the war ended in 1945, hundreds of thousands of migrants from across Europe and the Middle East arrived in Australia, many finding jobs in the booming manufacturing sector. Many of the women who took factory jobs, while the men were at war continued to work during peacetime.

Australia's economy grew throughout the 1950s with major nation-building projects such as the Snowy Mountains Hydroelectric Scheme in the mountains near Canberra. International demand grew for Australia's major exports of metals, wools, meat and wheat and suburban Australia also prospered. The rate of home ownership rose dramatically from barely 40 per cent in 1947 to more than 70 per cent by the 1960s.

Like many other countries, Australia was swept up in the revolutionary atmosphere of the 1960s. Australia's new ethnic diversity, increasing independence from Britain and popular resistance to the Vietnam War all contributed to an atmosphere of political, economic and social change. In 1967, Australians voted overwhelmingly 'yes' in a national referendum to let the federal government make laws on behalf of Aboriginal Australians and include them in future censuses. The result was the culmination of a strong reform campaign by both Aboriginal and white Australians.

In 1972, the Australian Labor Party under the idealistic leadership of lawyer Gough Whitlam was elected to power, ending the post-war domination of the Liberal and Country Party coalition. Over the next three years, his new government ended conscription, abolished university fees and introduced free universal health care. It abandoned the White Australia policy, embraced multiculturalism and introduced no-fault divorce and equal pay for women. However by 1975, inflation and scandal led to the Governor-General dismissing the government. In the subsequent general election, the Labor Party suffered a major defeat and the Liberal–National Coalition ruled until 1983.Between 1983 and 1996, the Hawke–Keating Labor governments introduced a number of economic reforms, such as deregulating the banking system and floating the Australian dollar. In 1996 a Coalition Government led by John Howard won the general election and was re-elected in 1998, 2001 and 2004. The Liberal–National Coalition Government enacted several reforms, including changes in the taxation and industrial relations systems. In 2007 the Labor Party led by Kevin Rudd was elected with an agenda to reform Australia's industrial relations system, climate change policies, and health and education sectors.

Figure 1.15 Formation of Australian Labor Party

Chapter 2

Urban Design.

2.1 Study and Analysis.

2.1.1 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. It has a 1.4 km harbour foreshore frontage, with an eastern street frontage to Hickson Road.

The site has been used by commercial shipping for much of the 19th and 20th centuries but stevedoring operations have now ceased and much of the site has been cleared of buildings in preparation for its redevelopment.

The site's legal description and ownership are shown in Table 1 and Figure.

Figure 2.1 Sydney, Australia in Globe

Figure 2.2 Barangaroo, Sydney

Figure 2.3 Barangaroo Site Locations

Table 1.1 Legal Descriptions and Ownership

Legal Description	Land Ownership
Lot 1 DP 876514	Marine Ministerial Holding Corporation
Lot 2 DP 876514	Sydney Ports Corporation
Lot 3 DP 876514	Sydney Harbour Foreshore Authority
Lot 4 DP 876514	Sydney Ports Corporation
Lot 5 DP 876514	Sydney Harbour Foreshore Authority
Lot 6 DP 876514	Marine Ministerial Holding Corporation
Lot 7 DP 43776	Crown (Gov. Gaz. 30.7.1982 Fol 3503)
Lot 100 DP 838323	The Maritime Services Board of NSW
Lot 7 DP 869022	The State of New South Wales
Lot 6 DP 869022	Marine Ministerial Holding Corporation

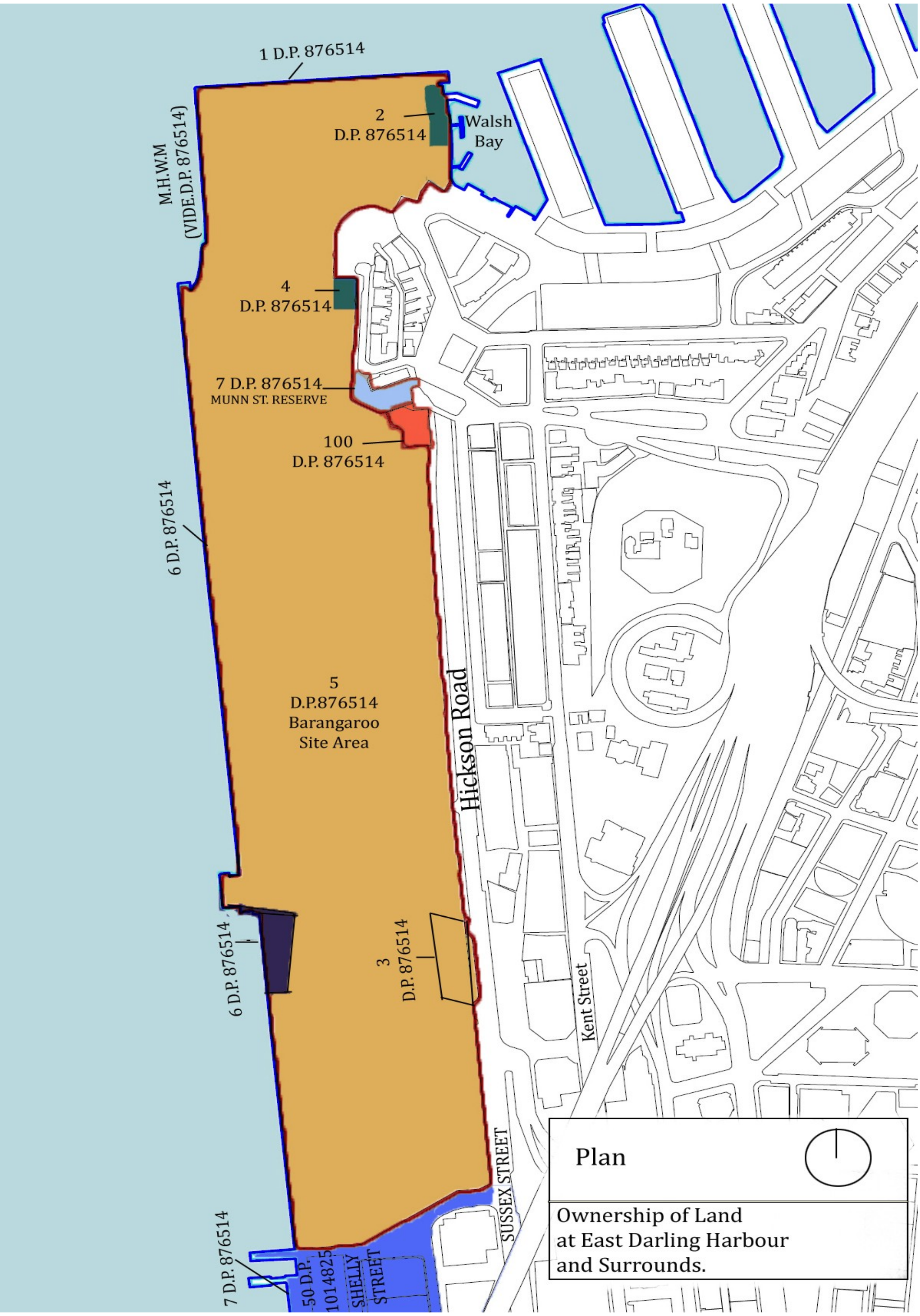

Figure 2.4 Ownership of Land at East Darling Harbour and Surrounds

2.1.2 History of the site.

Before we proceed to speak of the history of Barangaroo, it would be remiss of us not to give a visual profile on how Sydney has been shaped throughout history. The site of the first British colony in Australia, Sydney was established in 1788 at Sydney Cove by Arthur Phillip, commodore of the First Fleet as a penal colony. The city is built on hills surrounding Port Jackson which is commonly known as Sydney Harbour, By the middle of the 19th century, 'Sydney' extended to the municipalities of Glebe, Randwick, Waverley, Woollahra, and Marrickville, Newtown, Paddington and Balmain and had a population of 100,000, which was still only approximately a quarter of the State population. These suburbs were linked to the city centre by the emerging tram network.

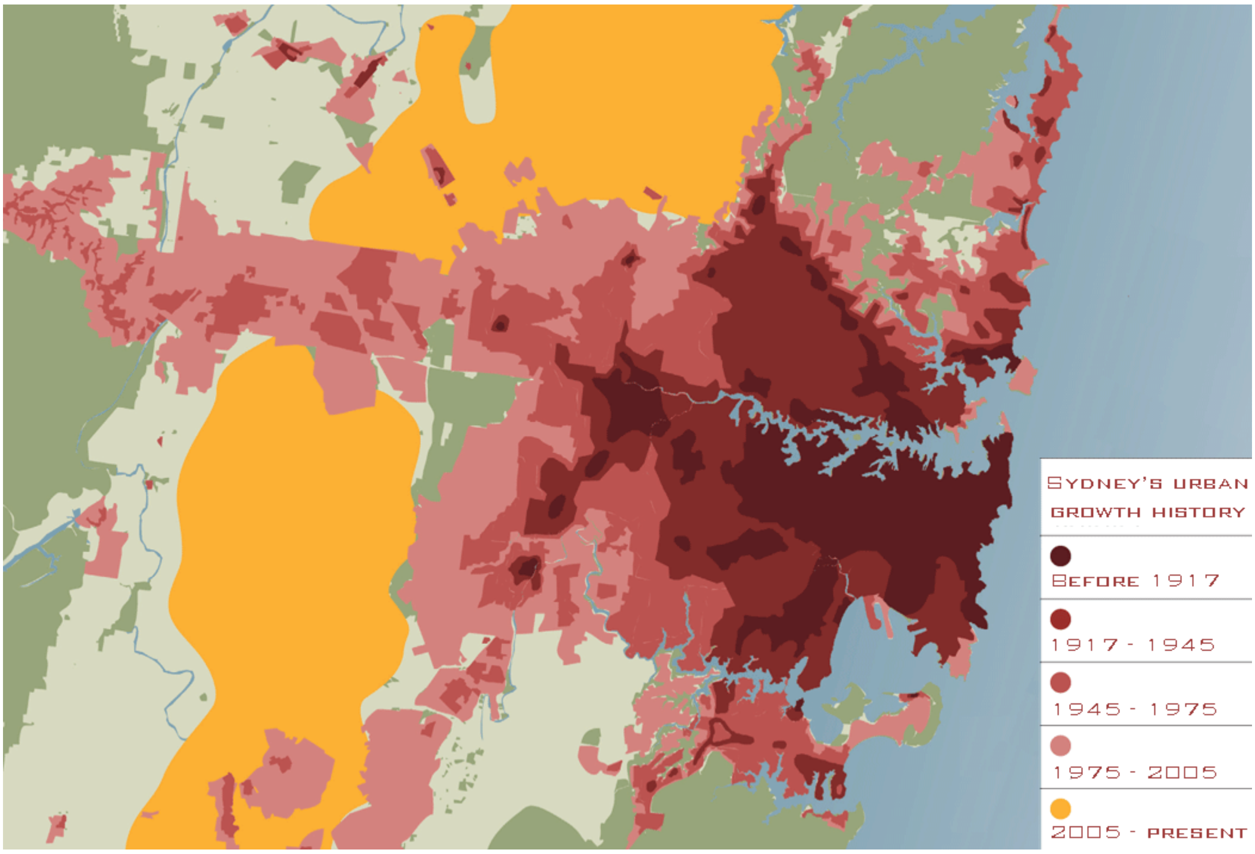

Figure 2.5 Sydney's Urban Growth History

Until, the 1950s, the pattern of the city continued to be dominated by access to the rail and tram network. Old industrial sites have been converted to residential development. The city has continued expanding westwards, with areas between the corridors filling in. With the addition of the North West and South West growth centers, new sub-regions in Western Sydney are emerging.

Over the last 15 to 20 years, Sydney is described as local concentration of linked jobs and gateway infrastructure from Macquarie Park through Chatswood, St Leonards, North Sydney and the CBD to Sydney Airport and Port Botany- has emerged as a critical feature of Sydney and Australia's economy, where the iconic Sydney Opera House and the Harbour Bridge are featured prominently.


Figure 2.6 Sydney Opera House

The Sydney CBD is bounded on the east side by a chain of parkland, and the west by Darling Harbour, a tourist and nightlife precinct. The most significant outer business districts are Parramatta in the central-west, Penrith in the west, Bondi Junction in the east, Liverpool in the southwest, Chatswood to the north, and Hurstville to the south. The extensive area covered by urban Sydney is formally divided into 649 suburbs and administered as 40 local government areas. Sydney has various heritage listed buildings, including Sydney Town Hall, The Queen Victoria Building, Parliament House, and the Australian Museum. There is no architecture style that entirely characterizes the whole of Sydney. Prominent styles include Gothic Revival, Georgian, Classical, Romanesque, Italianate, Federation, Edwardian, Second Empire, Queen Anne, as well as more contemporary styles.

The summers are hot/humid and the winters are mild. Sydney has over 340 days of sunshine each year. This creates a perfect atmosphere for outdoor living. If we talk on the open space history; many parks in central downtown have strong ties with local residents.

Three of the biggest parks in this area were all used by the original settlers in the early 1800's. Several parks in Sydney are known for their plant collections. The Royal Botanic Gardens in particular is a prime example. Today there are 248 parks, reserves and open spaces located within the City of Sydney covering 934 acres, roughly 14 % of Sydney's land coverage.


Figure 2.7 Queen Victoria Building

Barangaroo (formerly, East Darling Harbour) has seen dramatic change and growth throughout its history. Historically, the site was an economic trade base for the early colony, and with changes in technology and the formation of important business synergies, it evolved into an important nodal point for the city of Sydney. The area was not only connected to the local community through its relationship to worker housing, merchant housing and places of gathering, but was also connected to Sydney at large, to other cities, and to the international stage through the interchange of goods and the maritime industry.

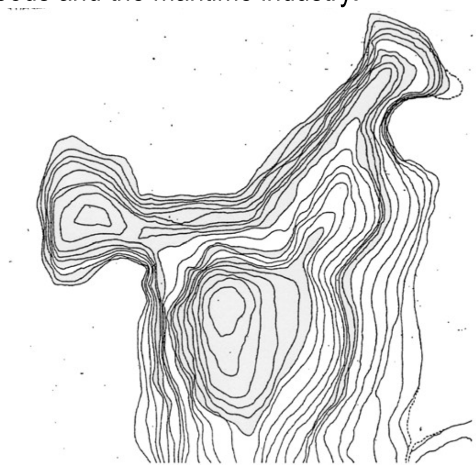
Figure 2.8 Natural Topography before European settlement - 1788.

Millers Point did not develop as quickly as Sydney Cove and The Rocks. The steep terrain and lack of easy land access kept the area fairly quiet and undisturbed for the first few decades of European occupation. Indigenous people used the land around Barangaroo both before and after European occupation.

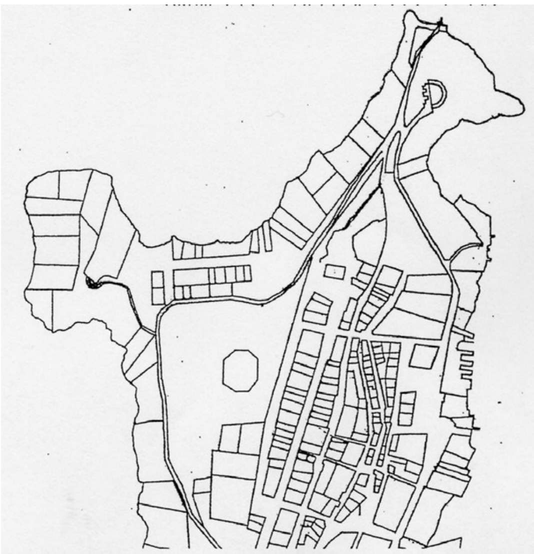

Figure 2.9 Based on 'parish of St. Philip' surveyor general's office Sydney, March 27th 1835.

By the 1820s Millers Point had started to develop. Windmills would have been present, buildings scattered, tracks established, cattle and sheep grazing, convicts working and sailing vessels in the Harbour. Images from the period show undulating topography and sandstone ridges before the modification; quarrying began in the area in the early 1820s, eventually changing the landscape dramatically.

Industry in the early 19th century including whaling and sealing, combined with the rise of the wool industry, created a demand for wharves and docks.

In the early decades Millers Point was mainly used as moorage for the unloading of cargoes in Sydney Cove and the newly named Darling Harbour.Industry, including the establishment of Dickson's Steam Engine in 1813, followed by Barkers Steam Mill in 1827 stimulated the building of waterfront activities. Urban form was slowly establishing, with the formation of some early streets, e.g. Windmill Street. There was still no direct route to Millers Point from Sydney Cove.

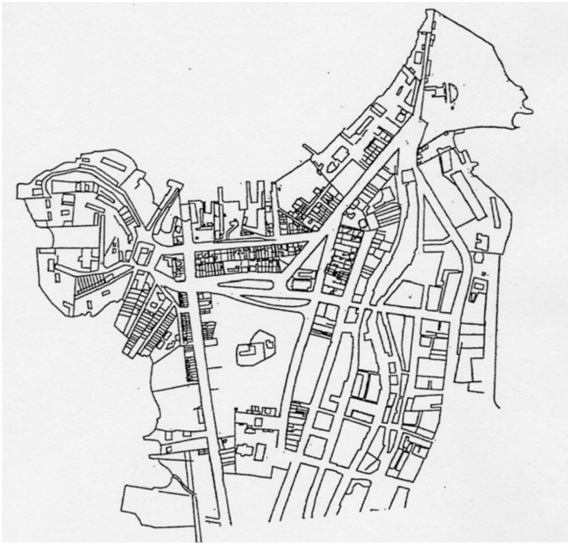

Figure 2.10 Based on Woolcott and Clarkes Map of the City Of Sydney 1854

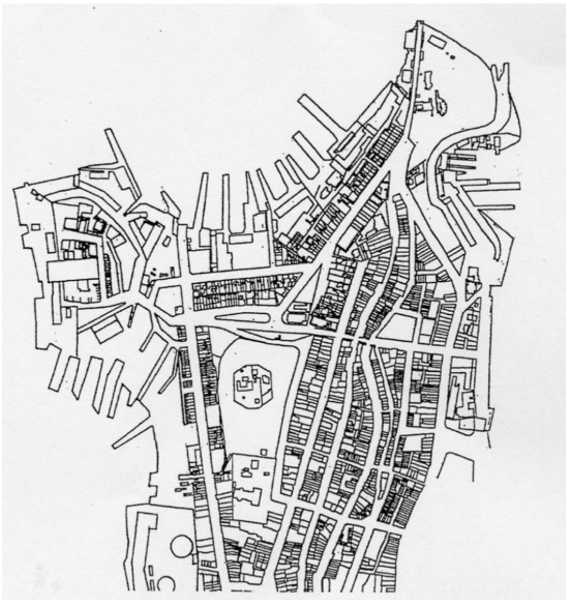

Figure 2.11 Based on Harvey Shore, City of Sydney, Harbour Maps, 1906

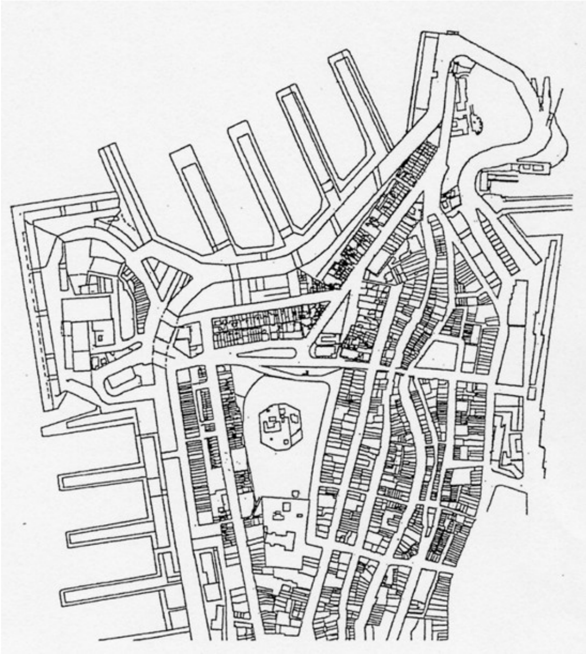

Figure 2.12 Based on Harvey shore, from the quay map, 1926.

Gas works constructed by 1843 further stimulated wharf construction as coal was supplied to produce gas. The unloading of goods and the building of wharves created the need for a local workforce and hence the provision for worker housing. Grand homes were also built in the more salubrious positions around The Rocks and Millers Point quite often on the higher ridges taking advantage of the views. Recreation facilities were also built just south of the site in the 1830s. Millers Point further developed as a village with the establishment of the areas two most famous pubs, the Lord Nelson Hotel and the Hero of Waterloo. The pubs were important as a local gathering place and a source of accommodation for immigrants to the country.

It was during this period that the landform started to change more dramatically with the reclamation of land and the cutting of land. Sandstone was used in construction, which came from the local quarries, and the Argyle Cut which was commenced in 1843. The cutting down of Millers Point for building lots, maritime facilities and roads continued well into the 20th Century.

The waterfront at what is now known as Barangaroo has changed over the years to reflect the changes in technology. Windmills were built for power provision in the area. The early whaling ships whose products provided power for lighting gave way to gas lighting, and the gas works were built in the 1840s, remaining on site until the 1920s. Sail gave way to steam, and ships became much larger, requiring larger wharves to service them. Manpower and horsepower began to be supplemented with hydraulic power from the 1870s, increasing the weight and height of loads to be lifted. Eventually gas lighting and hydraulic power was replaced by electric power and machinery such as forklifts, and diesel-powered ships replaced steamships.

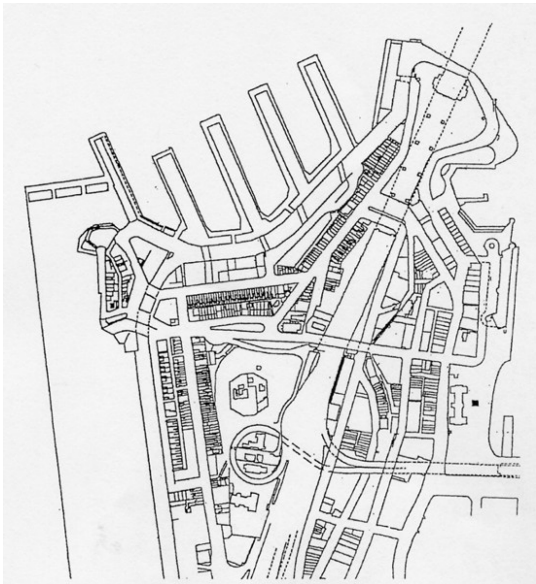

Figure 2.13 Based On City Planning and Building Department, City of Sydney 2000

Containerization was the last step in this process and required the modification of the wharves yet again. In response to this, long finger wharves became redundant and large concrete aprons built for roll on, roll off, method of unloading large ships. With the relocation of Patrick Corporations' stevedoring facilities to Port Kemble completed and the proposal to redevelop Barangaroo announced, the next stage for the city's biggest urban renewal project in a generation is well underway.

In July 2006, Cabinet transferred land ownership and appointed the Sydney Harbour Foreshore Authority as manager for the redevelopment of Barangaroo. The Barangaroo Name Between July to November 2006, a NSW Government State-wide naming competition received over 1,600 entries. The winning name “Barangaroo” was announced to honor a determined and independent Wangal woman who played an important role in the early days of colonial Sydney. Barangaroo was also the wife of Bennelong, after whom Bennelong Point – the site of the Sydney Opera House – is named. The name therefore completes an historical bookending between the eastern and western points of Sydney’s CBD. The name Barangaroo was published in 2007.

2.1.3 Buildings and points of importance.

Barangaroo is a 22-hectare site located on the foreshore of Sydney Harbour, adjacent to the city’s central business district.

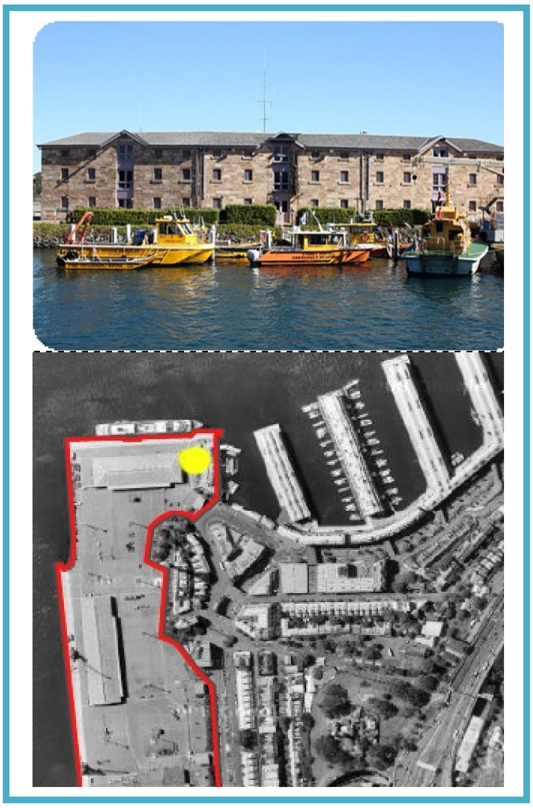

Figure 2.14 Moore’s Wharf on Walsh Bay

Moore’s Wharf on Walsh Bay at Millers Point was established in the 1830 by Henry Moore, the first Australian P&O agent. The sandstone warehouse built by William Long using convict labour and stone quarried on site. Moore bought the wharf and accompanying building from Long in 1837. The warehouse was originally located further west but in 1978 was moved, stone by stone, to its present location when it became the Operational Headquarters of the Sydney Ports Corporation. The vessels moored at Moore's Wharf are used by Sydney Ports Corporation on Sydney Harbour.

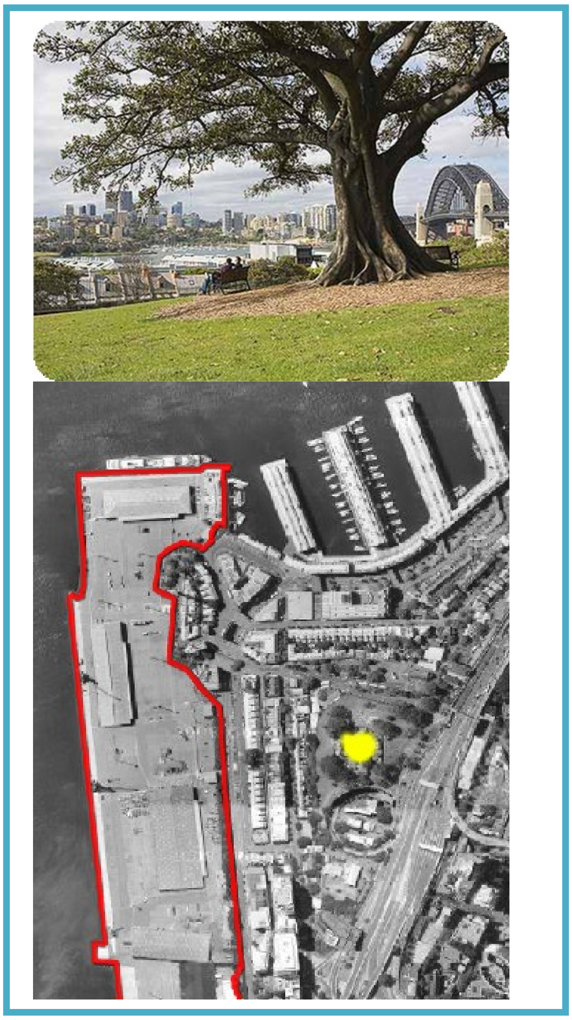

Figure 2.15 Observatory Hill Park

Built in 1858, Sydney Observatory is Australia's oldest observatory and one of the most signify cant sites in the nation's scientific history Observatory Hill Park is a popular attraction for locals, workers and tourists boasting one of the City's best terrestrial vantage points for unobstructed panoramic views of Sydney Harbour and the Harbour Bridge.

Figure 2.16 Millers Point

The Agar Steps provide pedestrian access from Kent Street and a cutting through the Harbour Bridge pylons provides pedestrian and cycle access from Cumberland Street. However no parking is available within Observatory Hill Park. The park contains numerous works of public art and a wooden rotunda flanked by magnificent mature Port Jackson Figs.

Millers Point is an urban locality within Sydney's city centre, in the state of New South Wales, Australia. Millers Point is located on the north-western edge of the Sydney central business district, adjacent to The Rocks and is part of the local government area of the City of Sydney. A small mill that was owned by Jack Leighton was located here. The area became known as Jack, the Miller's Point. Millers Point is the oldest existing place of Catholic worship in Australia. Two separate pubs in the area claim to be Sydney's oldest surviving pubs, the Lord Nelson here at Millers Point and the Fortune of War nearby at The Rocks. Where it is called as 'Windmill st.' in the 1820s windmills were built out on what was to become known as Millers Point and European settlers started constructing houses and building a small village. In 1859 a direct route from the Rocks to Millers Point was created, The Argyle Cut.

This made the journey back and forth from the main colony much safer and quicker. The route was a major catalyst for development in east Darling Harbor and Millers Point.

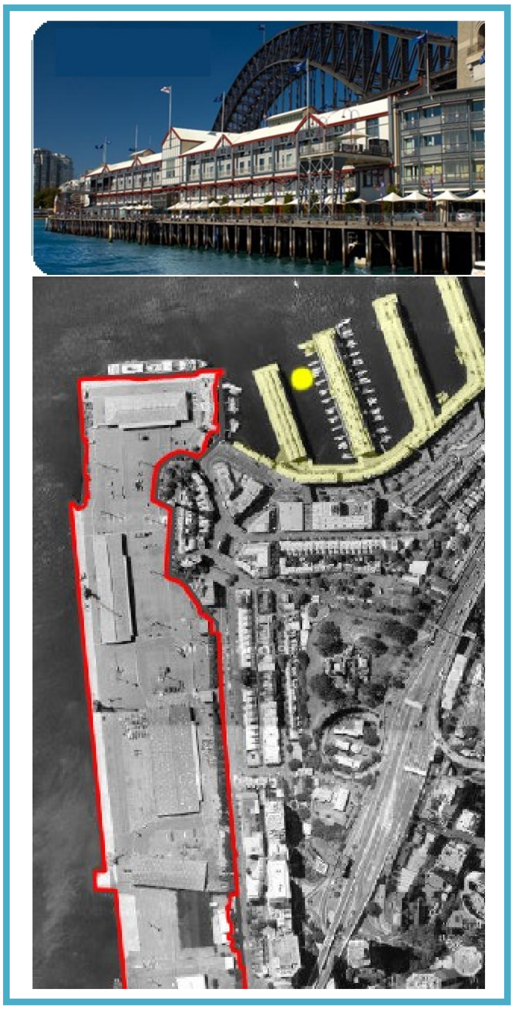

Figure 2.17 Walsh Bay

At the end of the 19th century, without a seawall, the Walsh Bay foreshore was awash with rubbish and infested with rats. A major disaster changed everything in 1900 when Arthur Payne, a van driver, became the first person to contract the Bubonic Plague, which arrived in Sydney in January. The rats were brought under control and by August the outbreak was over. In October that year The Sydney Harbour Trust was established to rebuild the port of Sydney. Wharves were renewed and whole streets disappeared as the cliffs were cut down to form Hickson Road. New double-decked finger wharves were built with a series of bridges, which connected the upper levels to the high roads of Millers Point. In 1919, the wharves between Dawes point and Millers point were named Walsh Bay after the Trust's Engineer in Chief, H.D.Walsh. By the early seventies the wharves fell into a period of disuse. It languished for a time until in 1982 Pier One was turned into a shopping and amusement complex. But the real transformation started when the Sydney Theatre Company and the restaurant took over wharves 4 and 5. Today, Walsh Bay is Sydney's cultural hub.

Figure 2.18 Clyne Reserve

Clyne Reserve is between Merriman Street and Dalgety Terrace, Millers Point. In the 1830s the prime residences in Millers Point were clustered around this area. At the end of Merriman Street, Crown Road (later Dibbs Street) ran west to 'Spencer Lodge', the most famous of the area's houses. 'Spencer Lodge' was a twelve-room colonial townhouse with a garden complete with 'lawns, rosaries and plantations of flowering shrubs'. Soon after the purchase of

Long's Wharf in 1837, Henry Moore built 'Moorecliff'.The separate eye hospital was created at 'Moorecliff'. A children's playground was established on 13 June 1950 at the corner of Dibbs Street and Merriman Street on a site leased from the Maritime Services Board. In 1952 the playground was named Clyne Reserve in honour of Hon Daniel Clyne MLA. In 1978 the Maritime Services Board acquired the Clyne Reserve land for excavation and building works to redevelop Darling Harbour as a container port, which was completed in April 1981. The Board then landscaped the remaining area and handed it back to the Council in September 1981. Four teams of stonemasons worked for six months to construct 420 meters of stone walls around Clyne Reserve. The adjacent Port Operations and Communications Centre tower opened on 12 August 1974.The Port Operations and Communications Centre tower has joined the harbor bridge as a distinct landmark on the harbour foreshore.

King Street Wharf covering approximately five hectares is a former maritime industrial area on the eastern shore of Darling Harbour, an inlet of Sydney Harbour, Australia that has been redeveloped into mixed use tourism, commercial, residential and maritime development as part of the extensive redevelopment in the general area. It is adjacent to the Darling Harbour tourist precinct, and on the western edge of Sydney's central business district.

The residential towers occupy the area bounded by King Street to the South, Shelley Street to the East, Erskine Street to the North and Lime Street to the West. The commercial waterfront is between Lime Street and Darling Harbour, and extends slightly north of the end of Erskine Street. This retail area contains 11 restaurants, the largest of which seats 450 including its outdoor areas. In the south to King Street Wharf, by the mid-1970s Darling Harbour was a series of empty warehouses and rarely used train tracks. Darling Harbour stretches from Paddy's Markets and Sydney Entertainment Centre. Home to the Australian National Maritime Museum, Sydney

Figure 2.19 King Wharf

Aquarium, IMAX Theatre, Sydney Wildlife World and Powerhouse Museum, it offers some of the finest museums and attractions in Australia.

Wynyard is a major underground City Rail station in the central business district of Sydney, Australia, 2.05 km from Central. The station opened on 28 February 1932. The length from the northwest part of Barangaroo site to

Wynyard train station is approximately 1.7km, from the south part is 500m. The passenger concourse is on an intermediate level between the upper and lower platforms.

Figure 2.20 Wynyard Station Point

Wynyard is connected via underground passageways to several surrounding buildings and shopping arcades and is located immediately below Wynyard Park. Direct access via tunnels is possible to George Street, Hunter Street, Pitt Street, Clarence Street and Kent Street. Escalators connect the station concourse with York Street (emerging underneath Transport House) and Carrington Street (under Wynyard Park).

2.1.4 Land use.

Land-use change detection is one of the basic pillars of global change towards sustainability. Landscape sustainability requires an understanding of the evolution and usage of land and the nature and extent of land resources. Analysis of historical and current land-use helps to determine potential future challenges for policy, planning and governance in pursuing more sustainable land uses.

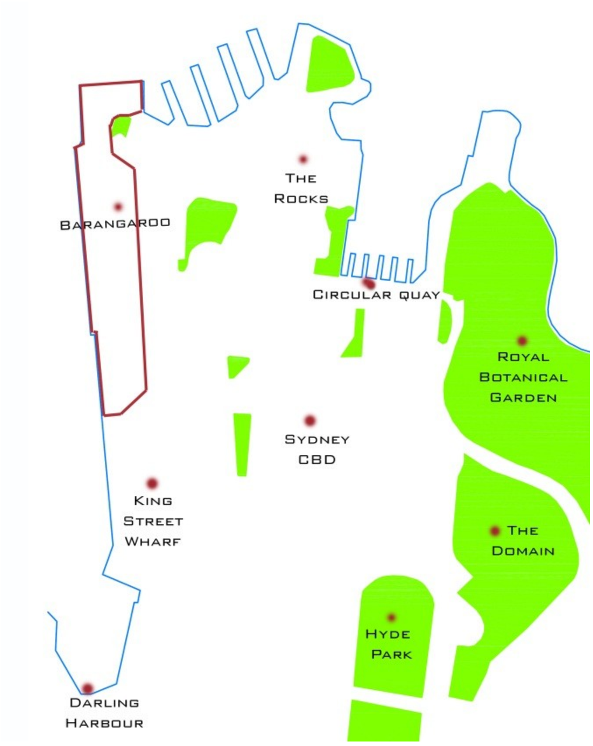

Figure 2.21 Land Use in City of Sydney

The Sydney central business district (CBD) is the main commercial center of Sydney, New South Wales, Australia. It extends southwards for about 3 kilometers from Sydney Cove, the point of first European settlement. Its north–south axis runs from Circular Quay in the north to Central railway station in the south. Its east–west axis runs from a chain of parkland that includes Hyde Park, The Domain, Royal Botanic Gardens and Farm Cove on Sydney Harbour in the east; to Darling Harbour and the Western Distributor in the west. It is the largest and busiest central business district in Australia.

Darling Harbour is a large recreational and pedestrian precinct that is situated on western outskirts of the Sydney central business district. The locality extends northwards from Chinatown, along both sides of Cockle Bay (Barangaroo) to King Street Wharf on the east, and to the suburb of Pyrmont on the west.

King Street Wharf covering approximately five hectares is a former maritime industrial area on the eastern shore of Darling Harbour, which has been redeveloped into mixed use tourism, commercial, residential and maritime development as part of the extensive redevelopment in the general area.

Circular Quay is made up of walkways, pedestrian malls, parks and restaurants. It hosts a number of ferry quays and a train station.

Figure 2.22 Land Use Map, Barangaroo

The figure illustrates the various land use characteristics of the existing buildings and is done so using a self-explanatory color coded legend on the figure itself. Immediately following figure are figure and for the green space network and mobility around Barangaroo area.

2.1.5 Green space network.

Green spaces are one of the major features of Sydney's centers and suburbs. Everyone enjoys the benefits of Sydney's green spaces; they are the key to many people's sense of enjoyment of urban life. They exist as a result of acquiring and conserving land for recreation and the environment over many years as part of Sydney's long term planning.

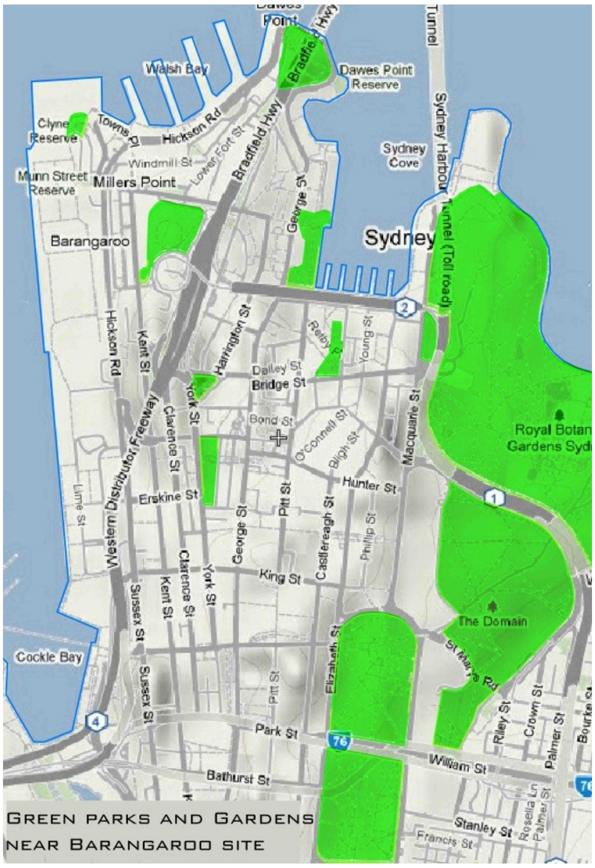

Figure 2.23 Green Space around Barangaroo

The main elements of Sydney's open space are the regional parks, bush land, sports grounds and trails. These spaces have an important role in community life, for social interaction and to provide a sense of place. The variety of Green spaces contributes to the distinct character of regions. These spaces help make Sydney's centers and cities great places to live.

The domain, the botanical gardens, the cook and Philip Park and Hyde Park in close proximity to the Barangaroo site.
These vast parklands offer a diversity of recreational possibilities for the people of Sydney and hold the opposites to a dense and busy city Centre - Quietness, space for big events or for space demanding activities, few sensual impacts and the low noise and pollution level. As such the qualities of this natural resource are needed ingredients in a busy city.

Trees are an important urban asset that can transform the City's streets and provide environmental, aesthetic, cultural and economic benefits.

Trees create a sense of place. Tree lined streets provide orientation and contribute to the City's character. They provide a human scale that contrasts with the towers that dominate some city streets. Trees diminish traffic noise, screen unwanted views, reduce glare and provide summer shade for the comfort of pedestrians and residents.

The City of Sydney's street trees are one of the most important assets of people living in Sydney. These trees are crucial to maintaining the high quality of people's public realm and provide numerous environmental, social, health and financial benefits to the City and community.

The City's street tree population consists of approximately 28,500 trees, of over 120 differing species, that are both native and exotic species, evergreen and deciduous and range in age, size and condition.

Some 49 per cent of the Sydney region is made up of national parks, state forests, regional parks, nature reserves and recreational areas - protected from any future development. There is 31,000 hectares in the Sydney urban green space network. In Sydney, 91 per cent of people live within 800 meters or around a 5 to 10 minute walk of some kind of open space,

either local or regional parks, sporting fields or bush land. About 90 per cent of Sydney's population lives within at least a 25 minute drive to regional open space.

Figure 2.24 Tree Lined Streets near Barangaroo

2.1.6 Transportation and mobility

Sydney's transport system supports the economic growth of the city by getting people to jobs and services and other daily activities in a fast, safe and reliable way, and through efficient freight movements. If we talk on the moving people, Sydneysiders make 15.5 million trips on an average weekday, at a rate of 3.8

trips per person. On weekends, there are 13.4 million trips, at a rate of 3.3 trips per person. There are regional differences in the way people travel. The further people live from the CBD, the longer their trips tend to be, the greater the reliance on car travel and the less likely they are to walk or ride a bicycle. In eastern Sydney, almost 30 per cent of all weekday trips are made by walking or cycling, while in north western and south western Sydney, only 11 per cent of trips are made by walking or cycling.

Sydney has the highest use of public transport of all Australian capital cities. Sydney's transport system includes the public transport networks of rail (heavy and light rail), transit ways and bus services, ferries and taxis; the road network; and walking and cycling networks.

Figure 2.25 Light Rail Systems

Metro Light Rail run from historic Central Station through vibrant Chinatown and Darling Harbour to the Star City Casino, the Sydney Fish Markets and Wentworth Park 24 hours a day, seven days a week. From central to Lily field it takes approximately 25 minutes. Metro Light Rail role is highly accessible mode for Inner City corridors with segregation from traffic necessary. The system includes high level of safety and security.

Sydney Monorail travels through the City and goes along above Chinatown, the Spanish Quarter, over Sydney's main street, George Street. The monorail leaves every 3-5 minutes and takes approximately 15 minutes to do the circuit. Single trips or day passes can be purchased at every station. The following figure shows the existing transport system networks on Sydney.

Figure 2.26 Mono Rail Systems

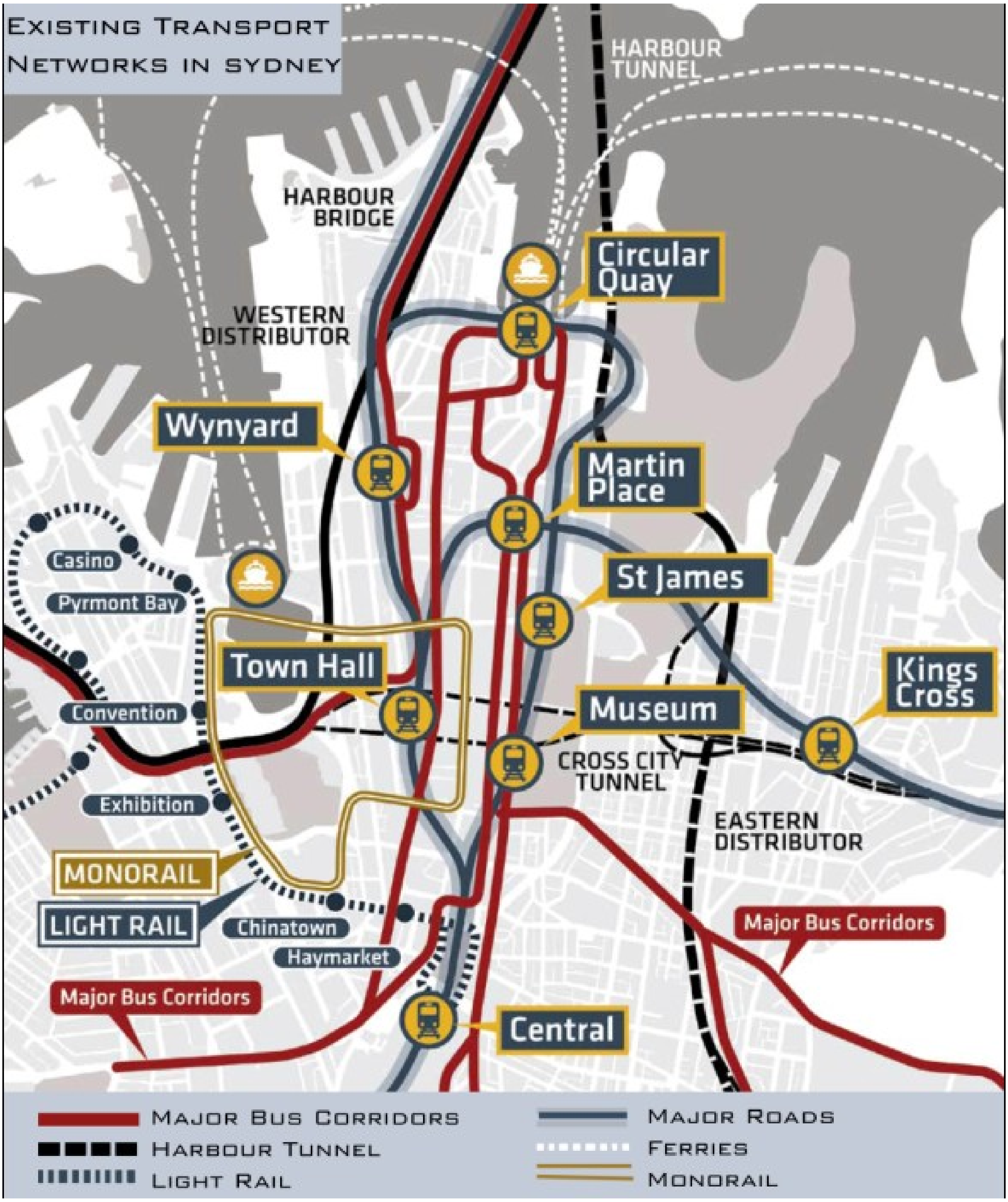

Figure 2.27 Transport Networks

Figure 2.28 Sydney Bus Routes

Presently the Barangaroo precinct receives only limited bus service because of the low level of generated demand in the area. Sydney buses covers the metropolitan area, with approximately 300 routes extending to Parramatta in the west, Palm Beach and Chatswood in the north, Miranda in the south, and the eastern suburbs. The main bus terminals are located at Circular Quay, Wynyard, Town Hall and Central Station. The existent close bus-stop to Barangaroo site is located on Millers point and the number 431,433 of buses arrive to this stop.

As seen from existing transport networks figure, Circular Quay, Wynyard, Town Hall, Central Museum, St James Stations, and Martin Place are the train stations on Sydney. Besides these train stations connected to all cities around Sydney, the city circle makes up the heart of the Sydney passenger railway network. The constituent stations of the Circle are (clockwise): Central, Town Hall, Wynyard, Circular Quay, St. James, Museum and back to Central. Owing to the rail providing airport link, to get to the airport from all city circle railway stations takes 15 minutes. From an accessibility perspective, the link between the precinct and the Wynyard transport is crucially important to provide benefits for the Barangaroo development.

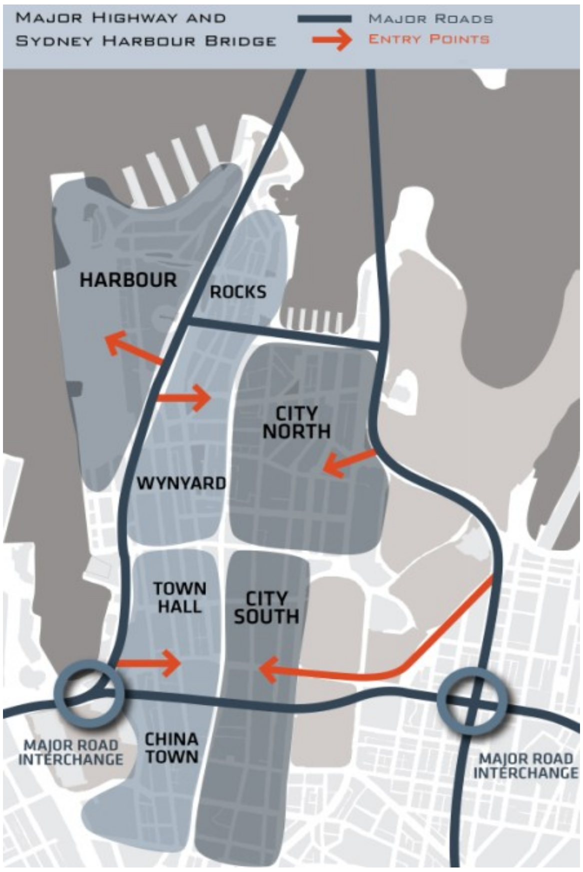

Figure 2.29 Major roads and entry

Referring to major highway and entry points in Sydney, traffic that does not have a destination in the City Centre should not have to travel on surface streets through the City Centre. Roads such as the Cross City Tunnel play a big role connecting two south part of Sydney city. Connecting the Eastern Distributor to the Sydney Harbour Bridge and Sydney Harbour Tunnel.

The 2.3 kilometer Sydney Harbour Tunnel connects the Warringal Freeway on the northern side of Sydney Harbour to the Cahill Expressway, south of the harbor. The connection from these major roads are being provided by using by-pass routes after entry points of city center. The principle vehicular roads for the Barangaroo site are Sussex Street/Hickson Road and Kent/York Street.

Figure 2.30 Sydney Ferries

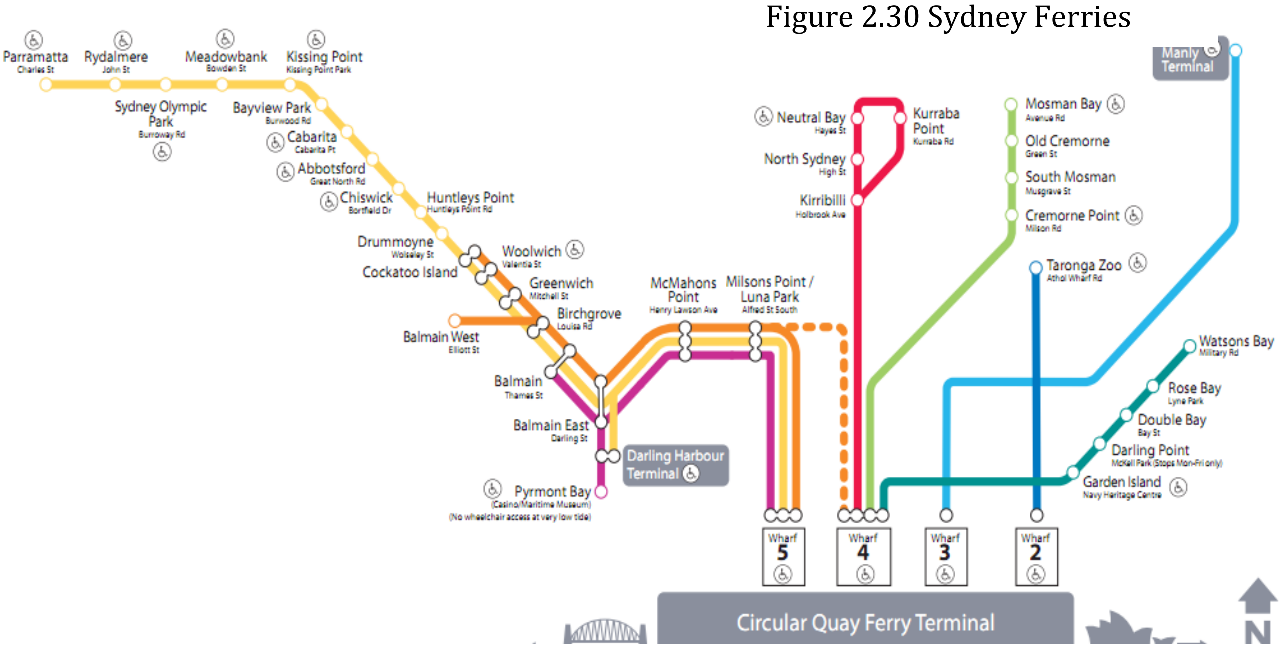

Figure 2.31 Sydney's Ferries network

Sydney Ferries make transportation more than 14 million people across Sydney Harbour and the Parramatta River each year. The extensive network connects 39 destinations and spans approximately 37 kilometers from Parramatta in Sydney's west, manly in the north and Watsons Bay in the east. Circular Quay, the hub of the Sydney Ferries network, is located in Sydney Cove between the recognized Sydney Harbour Bridge and the Sydney Opera House. The Ferries destinations are shown on figure. The destinations are: Balmain, Double Bay, Manly, Parramatta, Taronga Zoo, Darling Harbour, and Cockatoo Island.

King Street wharf of Darling Harbour is the commuter wharf serving the Sydney locality of Darling Harbour located closely end of Barangaroo site.

2.1.7 SWOT Analysis

Strength

- ✓ City center proximity
- ✓ No existing building in site
- ✓ Surrounding waterfront
- ✓ Wide area for a large scale project

Weakness

- ✓ Poor link with the rest of the city
- ✓ Steep topography
- ✓ Pressure of population growth
- ✓ Transportation network
- ✓ Lack of Green Space

Opportunities

- ✓ Historical and cultural values
- ✓ Adjacent to Sydney's Central Business District
- ✓ Touristic and cultural activities
- ✓ Transportation network

Threats

- ✓ Noise and ecological pollution
- ✓ Poor connection for pedestrians
- ✓ Preservation of heritage buildings

Once the S.W.O.T. Analysis has been listed out it gives us the framework to lay down our goals and objectives, our concepts and visions. This analysis is considered one of the final steps before the objectives, goals,

2.1.8 Comparative analysis.

Now that we have set the foundation for what the various opportunities, strengths, threats and weaknesses are, we are now poised to run a comparative analysis of Barangaroo in terms of size and area in order to be able to develop a sense of the dimensions of the project area. Barangaroo has an area of 220000 m2 which is roughly ten times the area of Duomo in Milan. The following figure compares area of Duomo in Milan and Barangaroo.

Figure 2.32 Barangaroo, Sydney

Figure 2.33 Piazza Duomo in Milano

2.2 Vision

Our vision considered for Barangaroo site is to recognize the opportunity to renew Barangaroo as a vibrant commercial and mixed use precinct with significant foreshore parkland. A mixed use development zone, with the remainder of Barangaroo dedicated for waterfront public recreation space as part of the process to renew Barangaroo.The Barangaroo precinct will achieve a new and significant foreshore open space for Sydney. In addition publicly accessible areas can be provided by, through private development sites within the mixed use zone, in the form of squares, streets, footpaths, and pe destrian lanes and connections. The strong connection will be provided with the rest of the City Centre.

The scope of the completion of a 14-kilometre foreshore promenade will make Sydney Harbor's foreshore one of the most publicly accessible in the world. Barangaroo renewal will promote the sustainable development of Sydney – economically, socially and environmentally. A balance between the commercial and recreational opportunities at Barangaroo will be critical to both the social and economic success of the renewal program.

2.3 Concept Plan

As part of the process for concept plan to renew Barangaroo, our concept plan contains the ideas as follows;

- The site will include three precincts including Headland Park, public domain and mixed-use precinct.

- The two main axes used to arrive the main focus points on the site (Through King Wharf to Millers Point to Headland Park). These axes will provide strong connections in terms of pedestrian way.

- It has been decided to have the Headland Park as a 'natural 'form, providing continuous public foreshore promenade to connect King Street Wharf and Walsh Bay to have a vibrant urban waterfront.

- North cove acting as a transition between the green headland and central part to define the headland of Barangaroo.

- Southern cove will have a vibrant contemporary urban waterfront providing connections to Hickson Road and the city beyond.

- From an accessibility perspective the Barangaroo-Wynyard pedestrian link is provided for adequate capacity and to improve the access for mobility

- As Wynyard station is the one of the busiest station, after Barangaroo development, and due to the easy way to access to Miller points via the bridges

- The proposed rail station in Argyle Cut. Therefore people coming to the Barangaroo will be able to use the rail station close to the area.

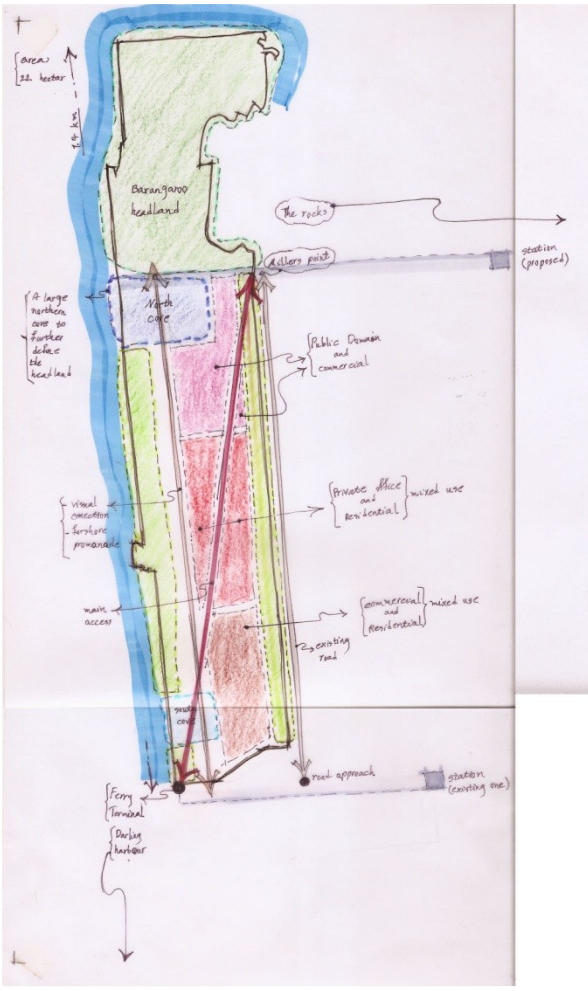

Figure 2.34 Rough concept plan

- Due to the lack of public transport to the Barangaroo, light rail loop will improve north-south access in the City. To provide the bus route on the Hickson road will make the area more accessibility from city center so that we proposed the bus-stops on Hickson Road.

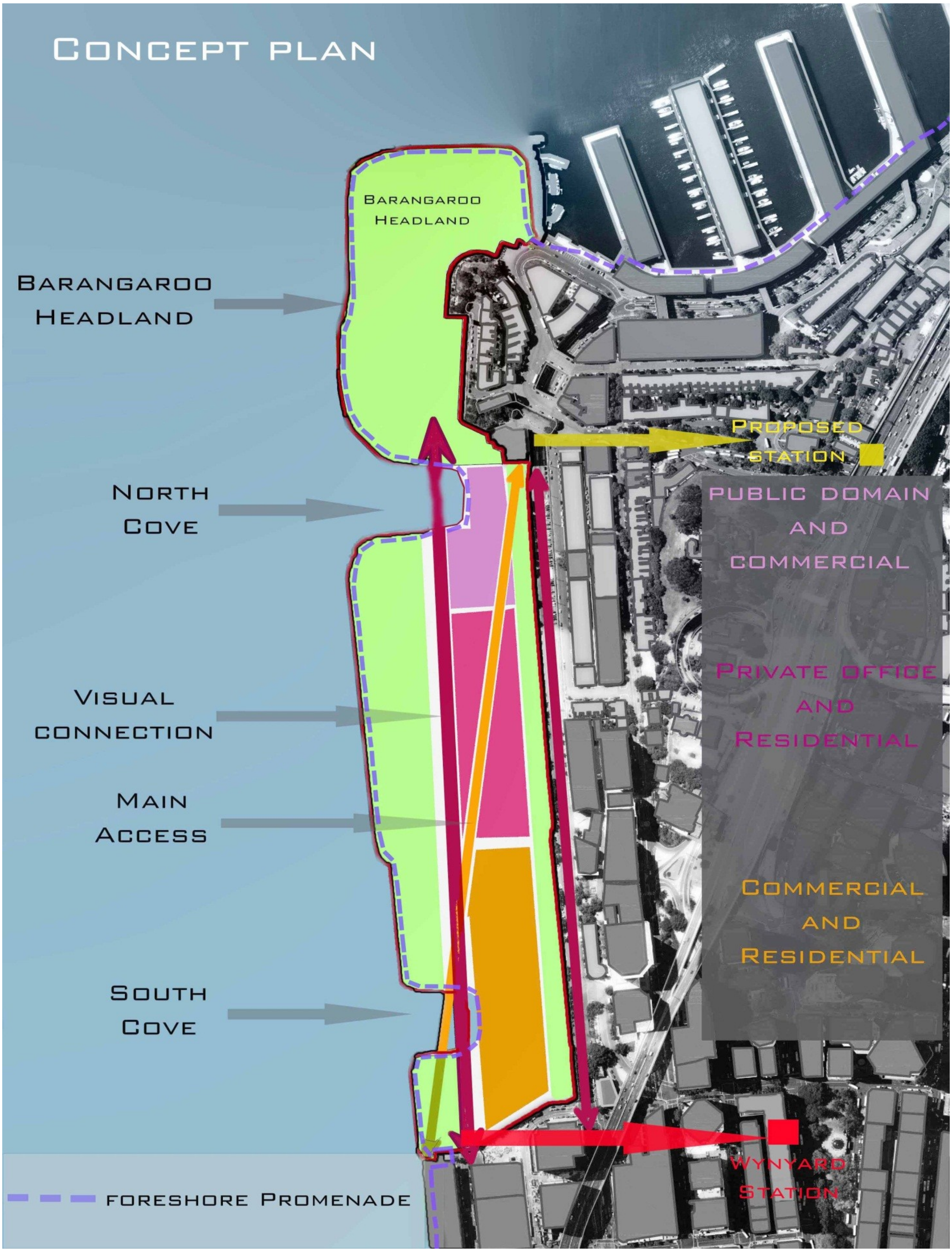

Figure 2.35 Concept plan

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2.4 Master Plan

The master plan of Barangaroo is based on a unique vision for 'completing the western edge of the city' by creating:

- A new civic boulevard connecting East Darling Harbour to Walsh Bay and King Street Wharf.
- A grand harbour side park along the entire length of the waterfront.
- A vibrant new commercial quarter integrated with the CBD.
- Land spaces are created adjacent to the water's edge in a variety of shapes and sizes. These spaces allow ease of circulation to the waterfront they connect the buildings near the waterfront to the water and they provide visual links throughout the development.
- Barangaroo will complete and enhance Sydney's waterfront promenade.
- Hickson Road will be one of the key transport arteries; allowing people to move easily from the city's north to south Hickson road will accommodate a tramway together with a dedicated bus service.
- Hickson road will accommodate a tramway together with a dedicated bus service.

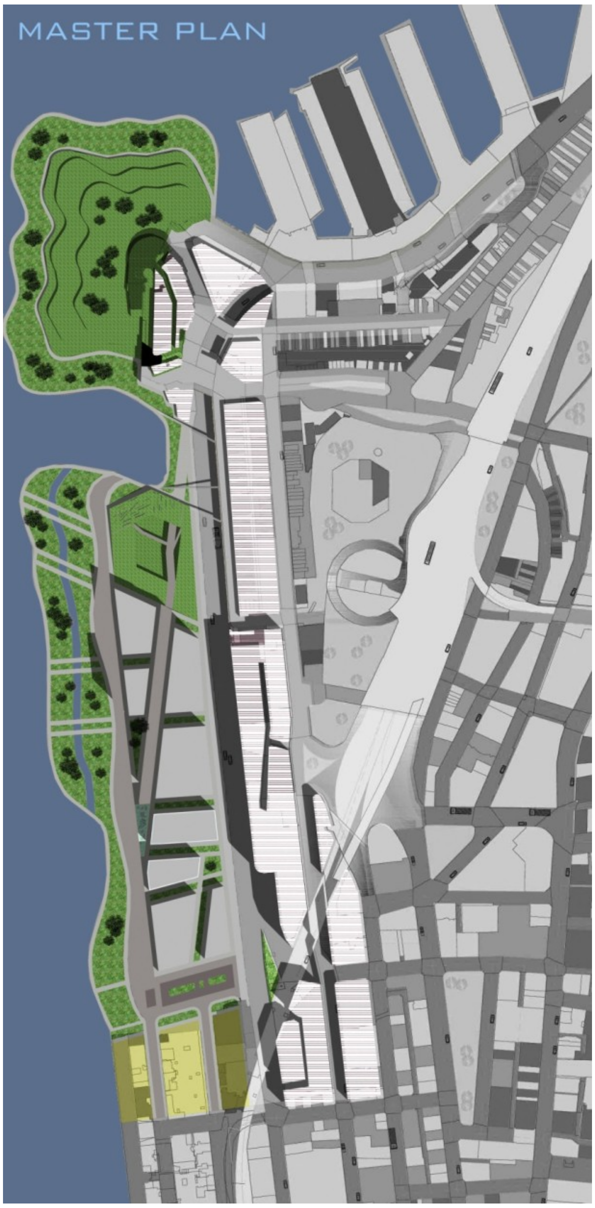

Figure 2.36 Master Plan

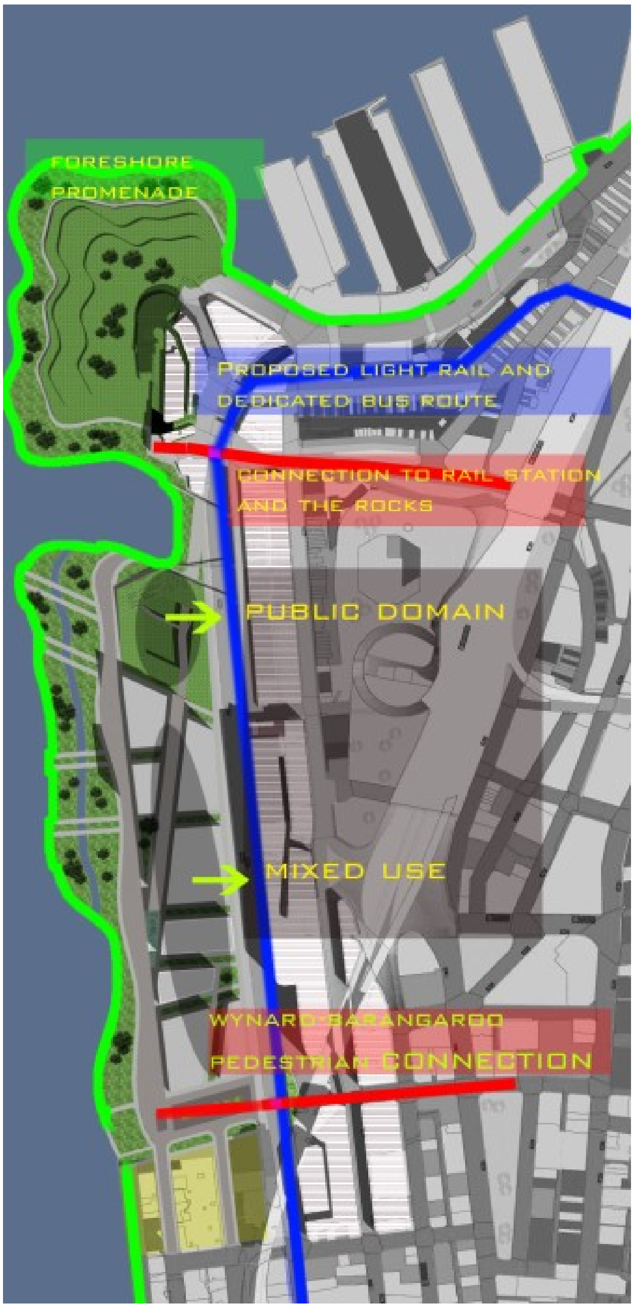

Figure 2.37 Master Plan Information's

- With provided connection from the Barangaroo site to Millers Point, this connection will allow us to exploit links to Rocks through Argyle Street.
- The link on Margaret Street is the principal connector from Wynyard to the commercial core of Barangaroo.
- The High Street bridge connection provides an opportunity to invite current low-cost housing residents of Millers Point and artisan businesses along Hickson Road to Barangaroo community.

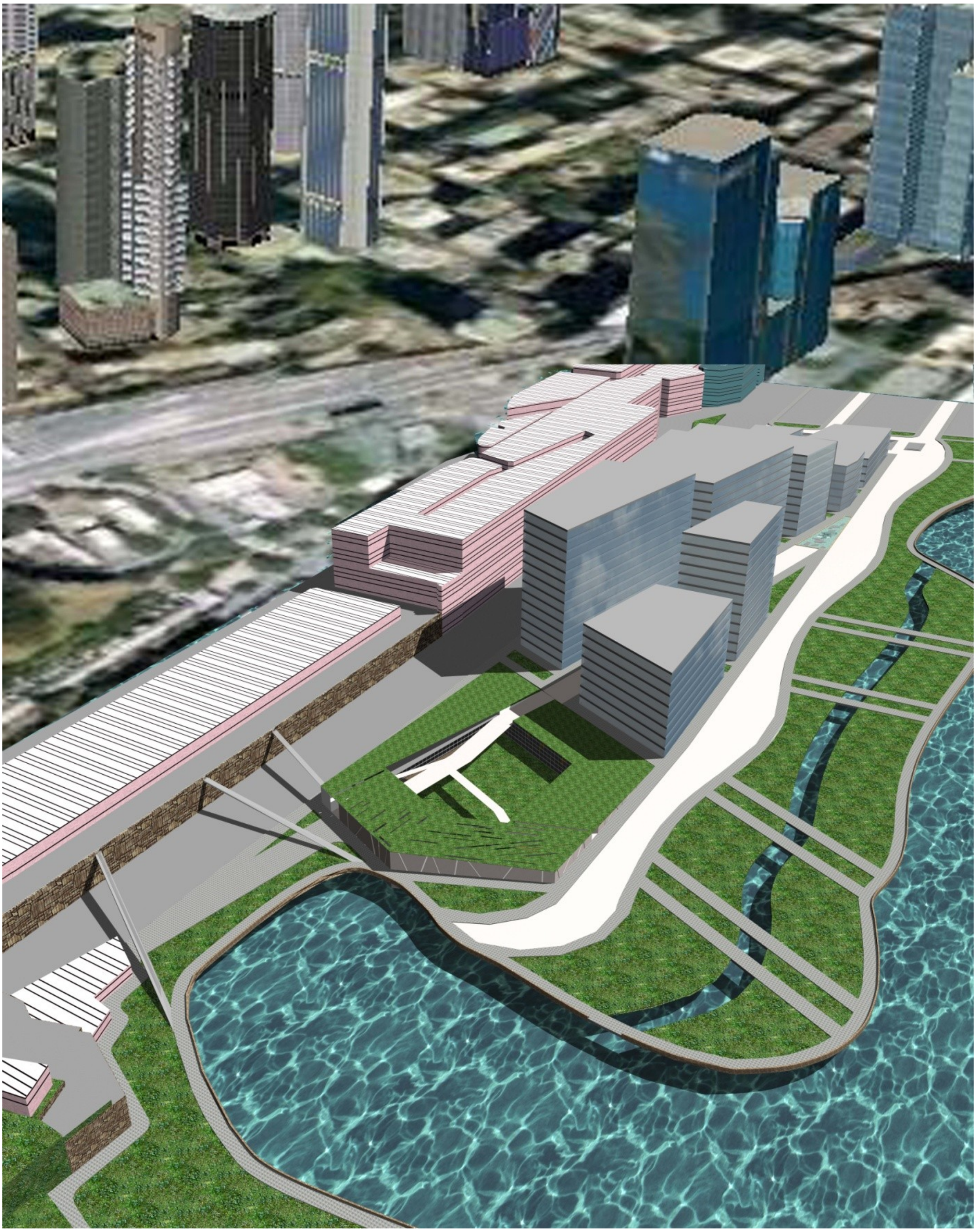

Figure 2.38 Master Plan Area

Chapter 3

Architectural Design.

3.1 Design Goals

After master plan design of our site, we decided to work on individual building block to define more detailed space inside. According to our master plan design, we decided to design Exhibition Center in Public domain zone. The reason why we chose this area of the Barangaroo site is to have main intersection point to make this place to be more attractive. Exhibition center in the public domain zone will attract many people because of the focal point of the site located near Headland Park and waterfront .The design goals are as follows;

-To create a place where people can gather,

-To make strong axes connection around the area

-To focus on more green and open space in and around the building to make people to enjoy space around the building.

-To give priority natural lighting.

- To remain in the memory becoming urban icon in the collective.

-To create a transparence space between inside and outside to make it more visible and user friendly

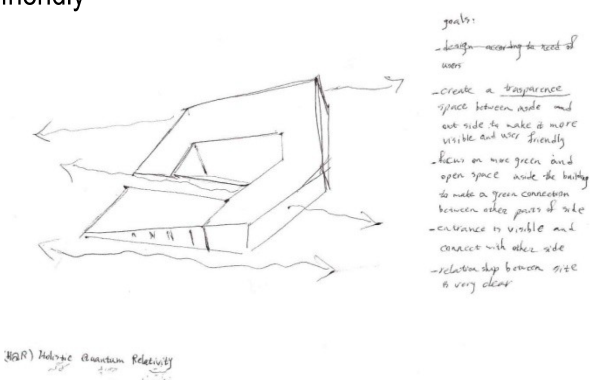

Figure 3.1: Design idea

-To have a visible and attractive entrance.

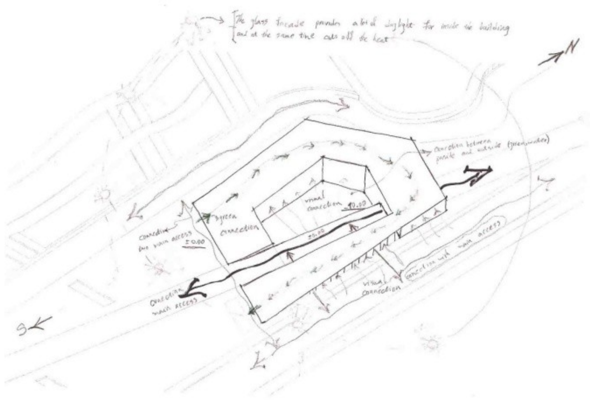

Figure 3.2: The main and secondary connections

-To provide visual connection interior part of building.

-To connect the main axis to the pedestrian pathway

-The whole concept is made out of; one main line, two secondary line.

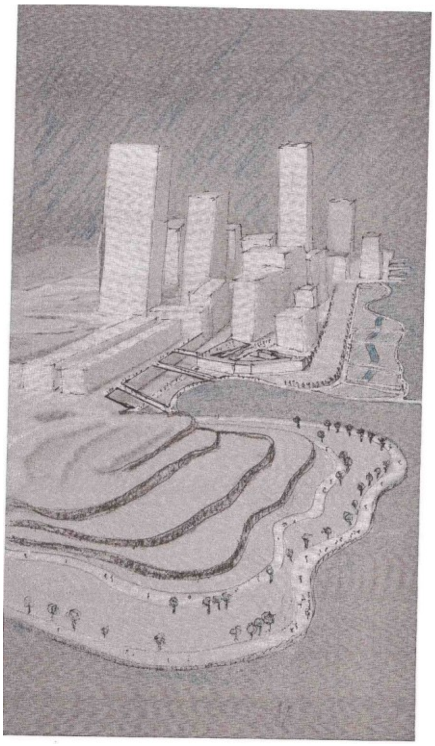

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Figure 3.3:Barangaroo view

3.2 About Building

We wanted to create a building, which is harmonious with surrounding area.It is provided the pedestrian walkway through our building connecting the green space, so that people coming to the building not only the users enjoy the building but also people who are passing also can enjoy the space around the building area. Under pedestrian pathway there is sunken garden

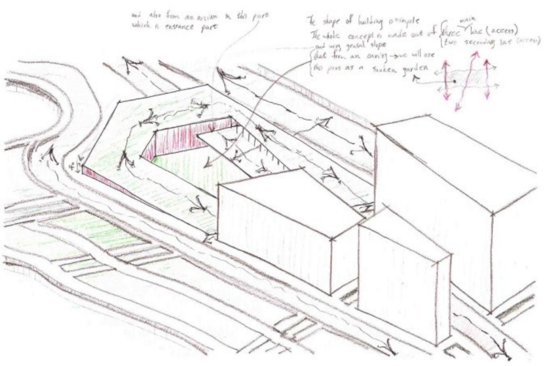


Figure 3.4: The shape of Building

The building is like a stone covered by grass, exactly like the same one that we can find in the green area. There will be two ramps to connect the ground level and the green roof. The longer and thinner slice openings on the green roof will provide skylight.

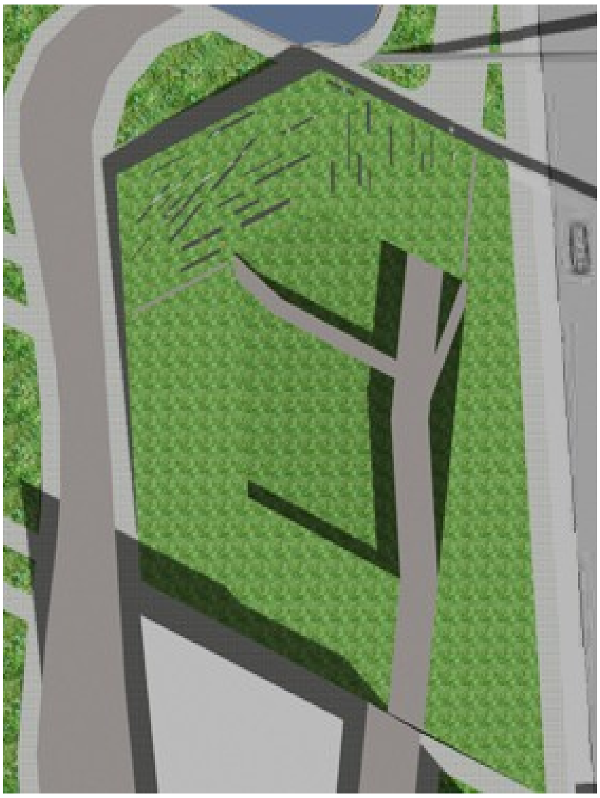


Figure 3.5: Top view of Green Roof

The external facade is covered by concrete wall at north and west side by including deeper some slices part so as to make it more interesting. At east side of building has a passage under green roof to connect main axis to the pedestrian pathway. The interior part of building, the glass facade provides lot daylight for inside and the same time cuts off the heat. Same time cuts off theheat.

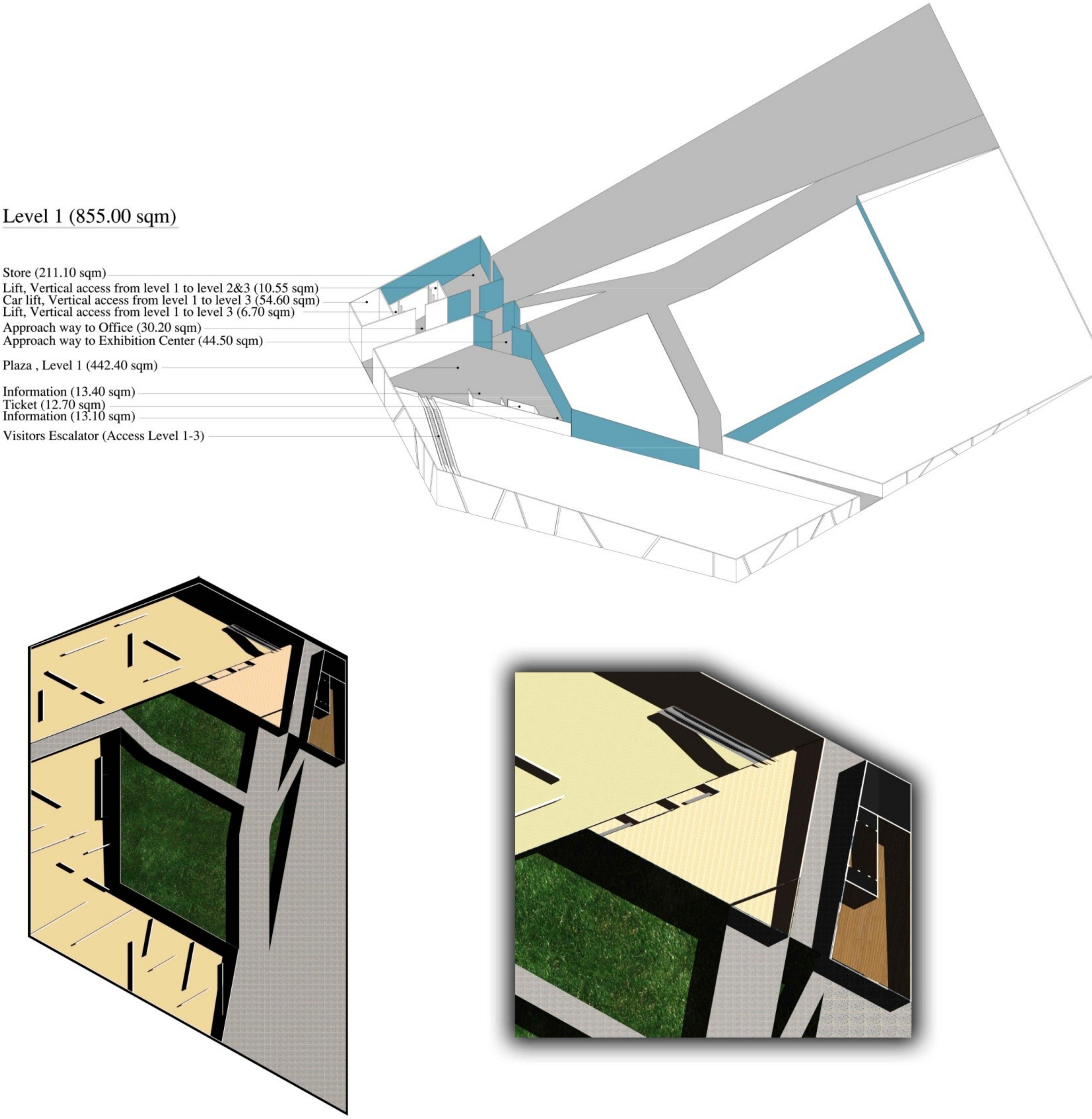


Figure 3.6; Level 1 Floor Plan

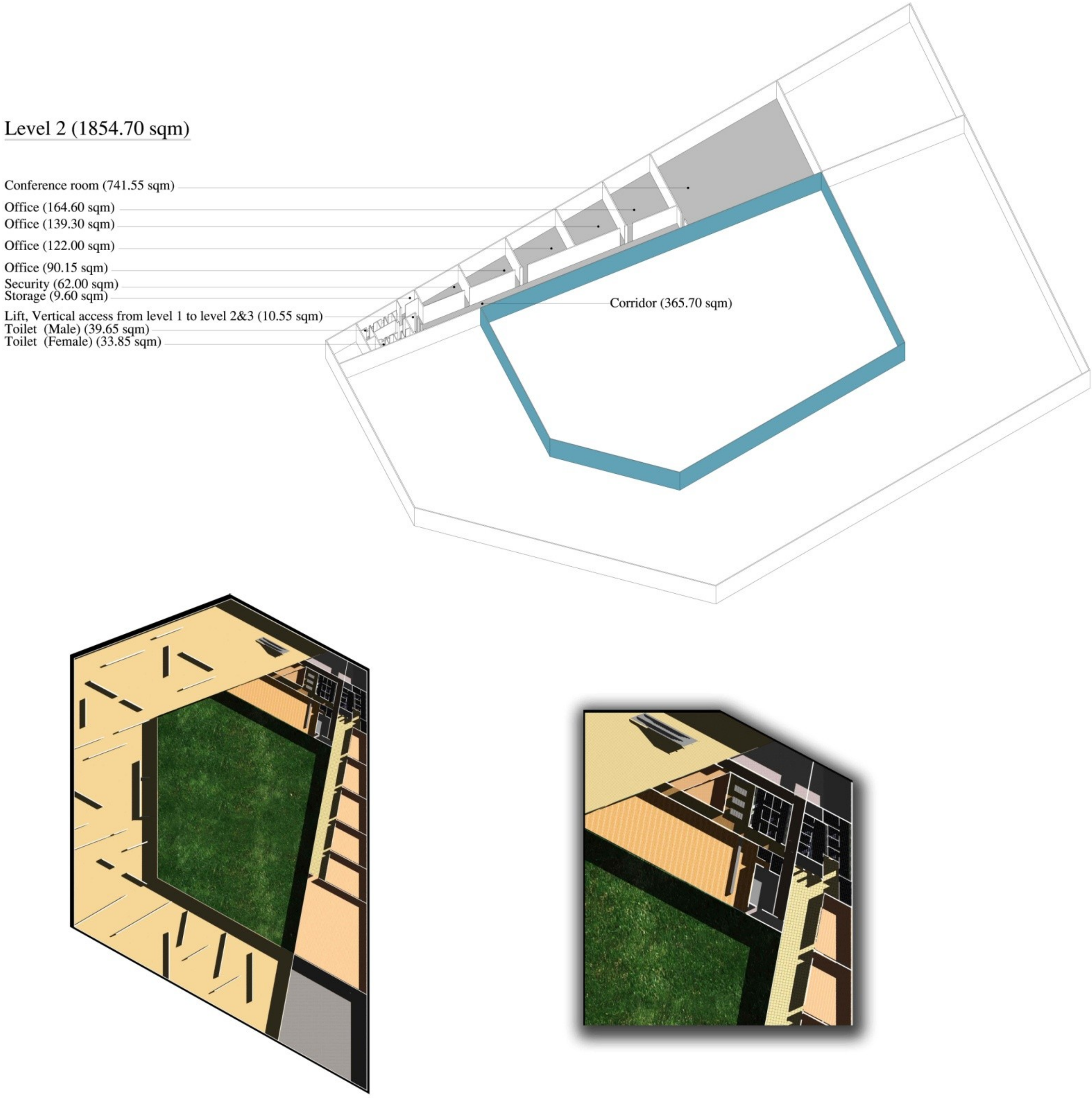
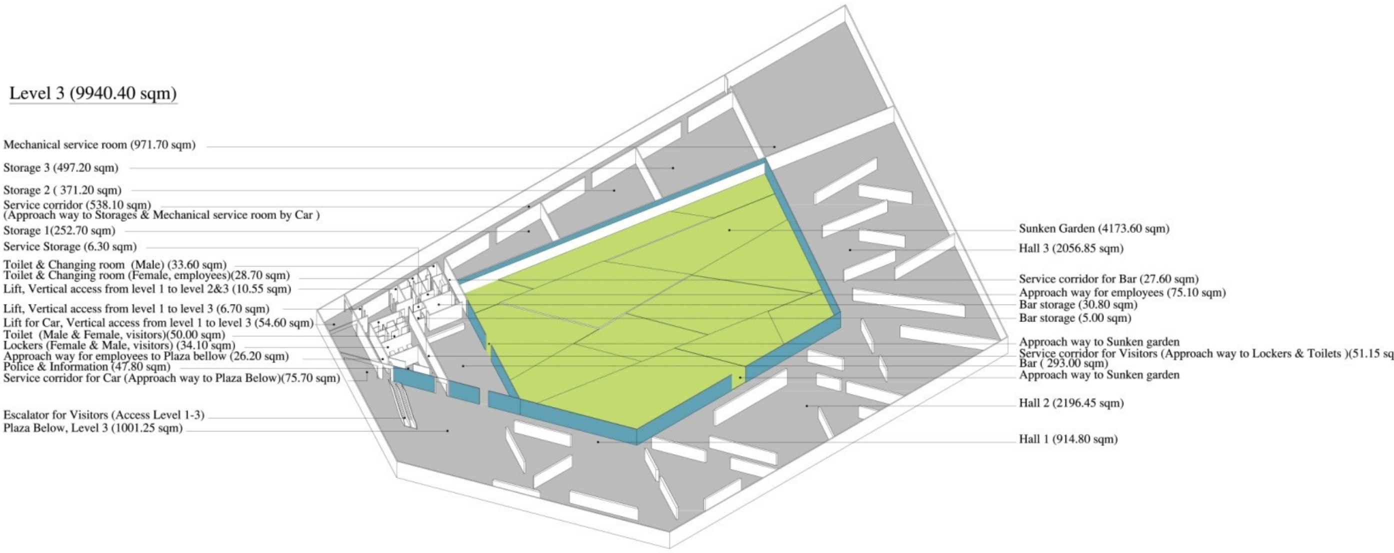
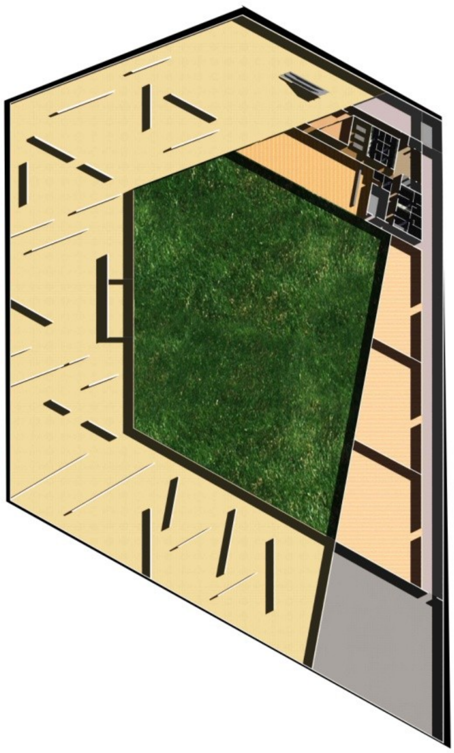


Figure 3.7; Level 2 Floor Plan





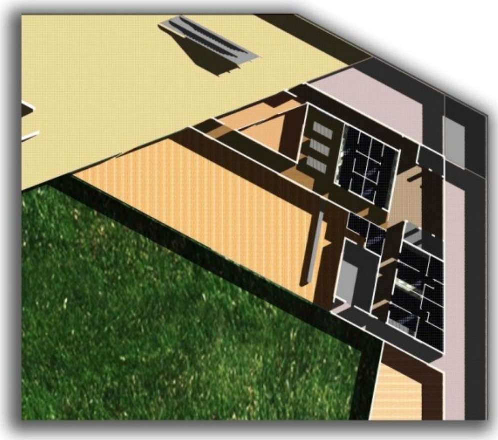


Figure 3.8 ; Level 3 Floor Plan

Figure 3.9 ; North Elevation of Exhibition Center

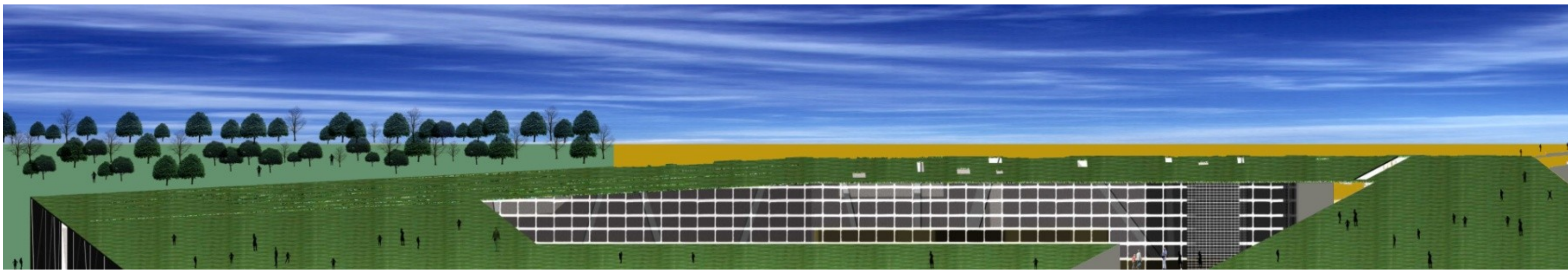


Figure 3.10 ; South Elevation of Exhibition Center

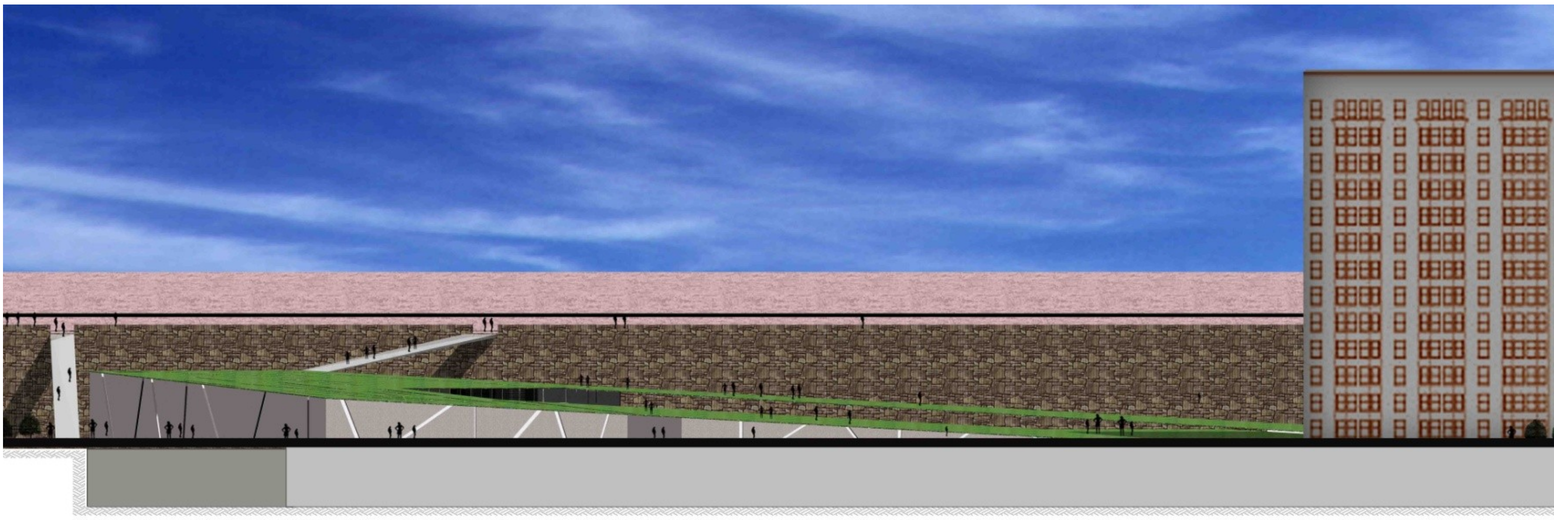


Figure 3.11 ; West Elevation of Exhibition Center

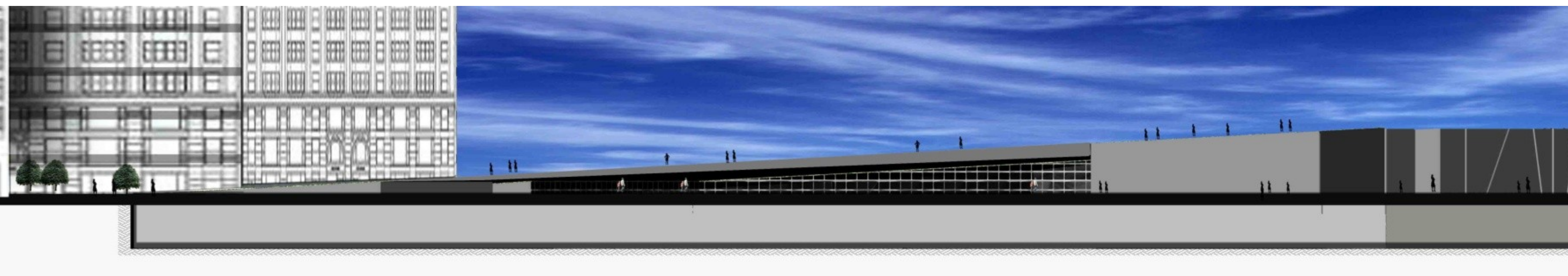


Figure 3.12 ; East Elevation of Exhibition Center

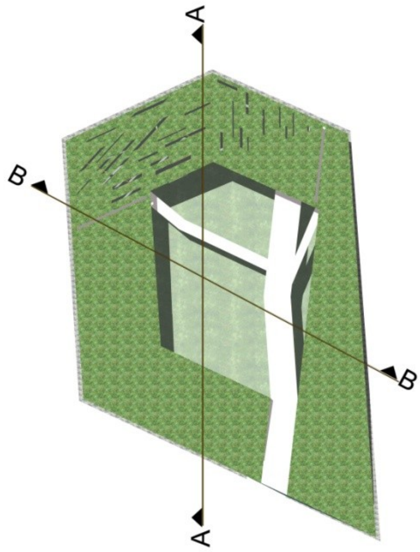
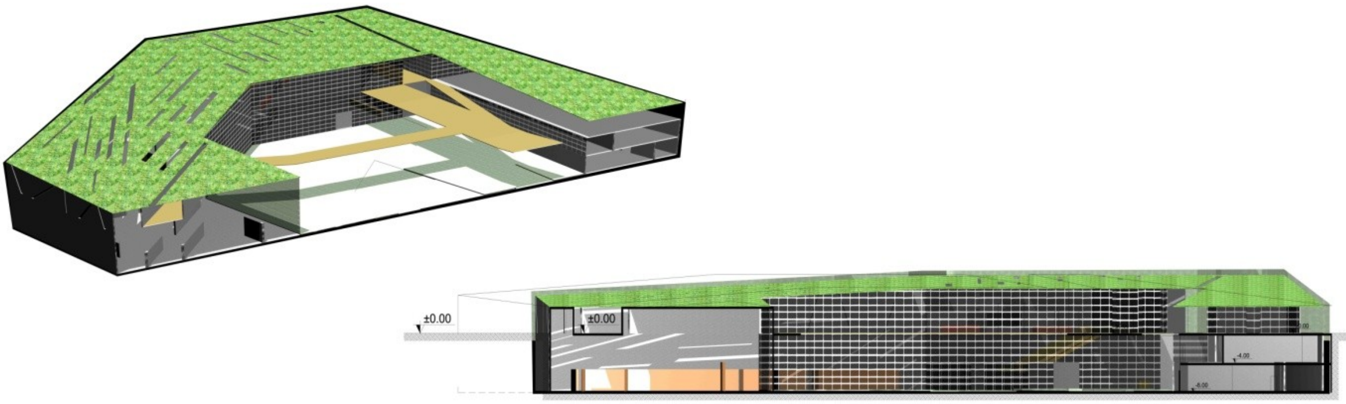


Figure 3.13; Section A-B;B,B



Section B-B

Figure 3.14; Section B-B

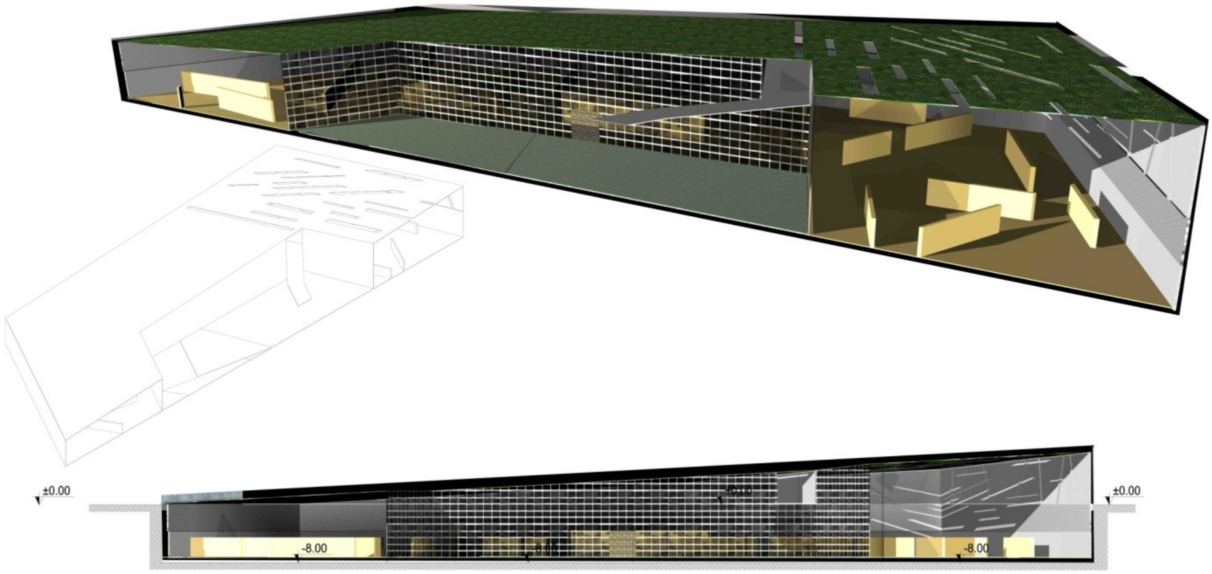


Figure 3.15; Section A-A

Chapter 4

Structural Design

4.1 Introduction

We have chosen steel frame structure based on the fact we need a light weight structure, compared to the reinforced concrete.

Due to the shape of building, the building has been divided into seven structurally sound parts by providing the required dilatations between them. For the purpose of covering the big span for the exhibition center, we used single-span half step-up truss system. The continuity of the columns and the structure are kept as regular as possible.

4.2 The Steel Frame Advantages and Disadvantages

Advantages;

1. Steel frames are extremely strong and durable, able to withstand extreme natural occurrences such as hurricanes and earthquakes.
2. Due to the ease of working with steel, the time of construction is reduced.
3. Steel frame buildings offer significant advantages with increased strength, durability, and stability.
4. Steel creates longer lasting structures that require little maintenance.
5. Due to the lower self-weight, the steel-framed building can reduce the vertical load and earthquake effect which are transferred from the structure to the foundation.
6. Steel frames are precise and predictable (excellent quality control)

Disadvantages;

1. The cost of making steel is very high and much more expensive than masonry or concrete.
2. The Steel Frame needs fire protection as a result of lower resistance of fire: the beam, column, bracing and the trapezoidal metal sheeting should be covered by fire resisting dope. In addition to this, the cost of fire protection is approximately 30% of the total cost of a steel structure.
3. Insulation is a large-scale difficulty with steel buildings. Steel buildings require the insulation as steel on its own is not a very good insulator.

4.3 Design Assumptions

In conformity with steel-frame construction with truss roof system, it is assumed that resistance to lateral wind loads is provided by a system of localized cross-bracing, and the main steel frame is designed to support gravity loads only. The connections are designed to transmit vertical shear, and to be capable of transferring a horizontal tying force to preserve the integrity of the structure in the event of accidental damage. With these assumptions, the frame is classified as 'simple', and the internal forces and moments are determined using a global analysis which assumes the members to be effectively pin-connected.

4.4 Truss Geometry, Loading, Analysis

All the design choices, calculations and choice methods have been thoroughly calculated by hand. The most common use of trusses in buildings are 32 m span. The design of single-span roof trusses at 6-m centers has been assumed. The roof purlins are used to provide the lateral restraints. The purlins are positioned at node points and are assumed to provide lateral restraint to the top boom at 4-m centres.For the purposes of the analysis, it is assumed that all the joints in the truss are pinned.

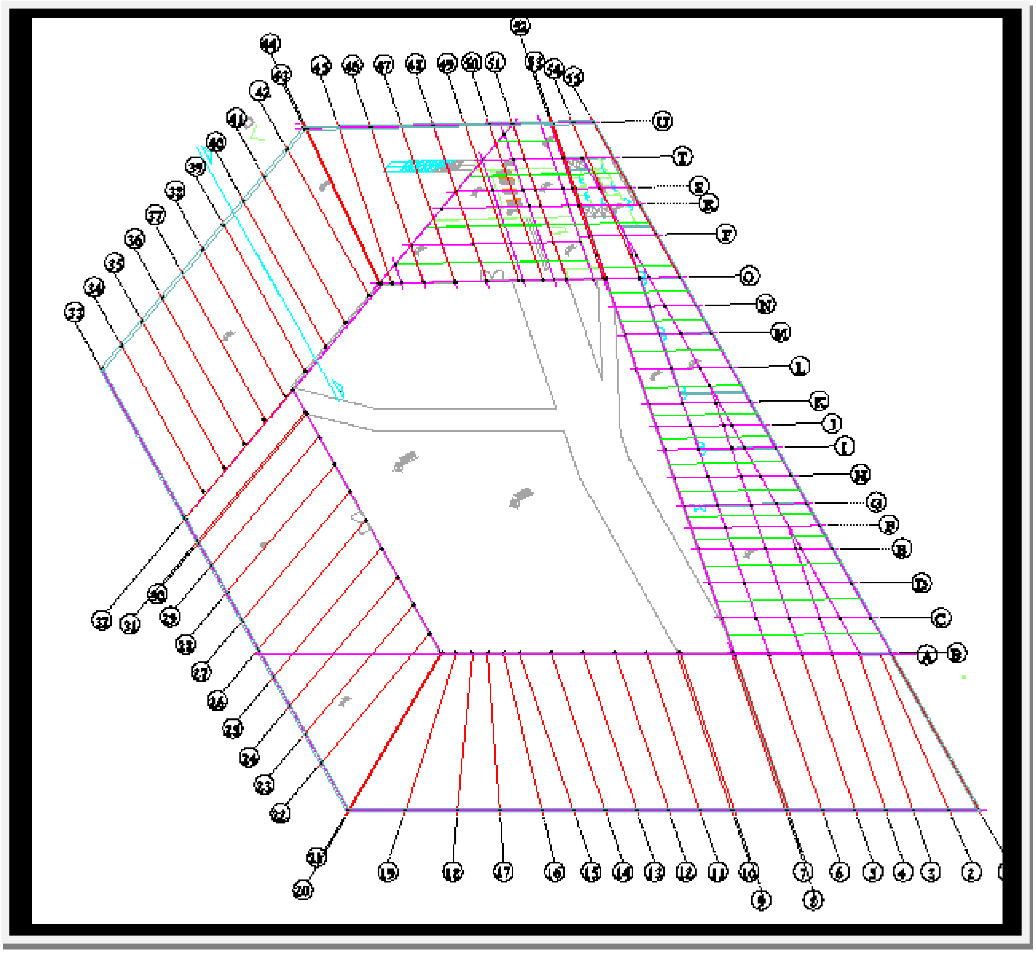


Figure 4.1: Structural Plan

4.4.1 Variable Actions

It is assumed that the roof is accessible with occupancy, giving a characteristic imposed load of $4\ kN/m^2$ by considering snow load as well. "Snowfall was last reported in Sydney City area in 1836."

Determine wind speeds and design wind pressure in Sydney

Wind speed; $V_{sit,\beta} = V_R . M_d . (M_{z,cat} . M_s . M_t)$

$V_{sit,\beta} = 48{,}3\ m/sn$

Design wind pressure;

p=(0,5. $p_{air} . [V_{des,Q}] . C_{fig.} C_{dyn}$ $C_{fig.}$=$C_{p,e.} K_{a.} K_{c.} K_{l.} K_P = 0{,}8.0{,}8.1.1.1 = 0{,}64$ p=$0{,}895\frac{kN}{m^2}$

4.4.2 Permanent Actions

Table 3.1 Load Calculation of Green Roof	kN/m^2
Vegetation Growth Medium(Lighter Soil Medium) Drainage Composite -Drainage -Aeration -Water Storage -Root Barrier(To retard plan growth)	1,1
Insulation(Extruded Polystyrene)	-
Membrane Protection and Root Barrier	-
Roofing Membrane	-
Concrete With Reinforcement(6mm)	1,44
Corrugated Steel	0,1
C Profile	-
Plasterboard	0,1
Service	0,3
Total	3,04 kN/m^2

Table 3.2 Load Calculation of Floor

	kN/m^2
Pavement	0,1
Adhesive Mortar	-
Concrete Screed	0,9
Expanded Polystrene	-
Concrete with Reinforcement	1,4
Corrugated Steel	0,1
Mineral Wool Insulation	-
C profile	-
Plasterboard	0,1
Service	0,3
Total	2, 9 kN/m^2

4.4.3 Design Action

It is assumed that the roof loading is applied at the nodes on the top chord of truss. The design loads are derived as follows;

		Roof	Floor
Variable Actions	;	4x 1,5=6 $\mathrm{kN/m^2}$	4x1,5= 6 $\mathrm{kN/m^2}$
Permanent Actions	;	3,04x1,35 = 4,1 $\mathrm{kN/m^2}$	2,9x1,35=3,9 $\mathrm{kN/m^2}$
Total	;	10,1 $\mathrm{kN/m^2}$	9,9 $\mathrm{kN/m^2}$

The forces applied to each node will be 10,1x6x4=242,4 kN

Wind Uplift

Since there is full wind coming uplift on the truss, the service loading will not be present. 3,04-0,3=3,01 kN/m^2

Wind Uplift ; 3,01x4x6x1,5=108,36 kN

Restraining permanent action ; 3,01x4x6x1=72,74 kN

Total Uplift =35,6 kN

4.4.4 Member Forces

As a general rule the spacing should be between 5m and 10m for the economic range of truss spans. The spacing between two truss systems has been chosen 6m.The shorter side of truss depth is 1m and the longer side is assumed 3.85m with a span-to-depth ratio between 10 and 20 depending on the intensity of the applied loads.

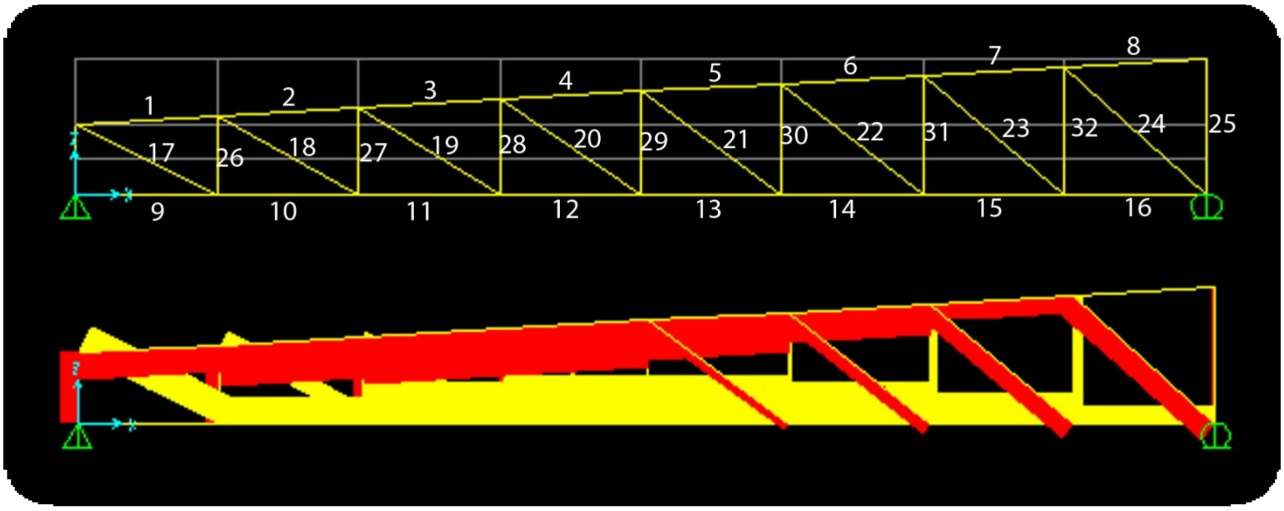


Figure 4.2: Truss Member Force Diagram

Table 3.3 Truss Member Forces (compression negative)

	Force(Kn)			Force(Kn)	
Member	**Vertical**	**Wind**	**Member**	**Vertical**	**Wind**
1	-1523	223	17	1700	-249
2	-2471	347	18	1006	-141
3	-2824	397	19	413	-58
4	-2774	390	20	-59	8
5	-2411	339	21	-449	63
6	-1797	253	22	-780	109
7	-981	138	23	-1066	150
8	0	0	24	-1320	186
9	0	0	25	-126	17
10	1587	-223	26	-794	111
11	2467	-347	27	-490	68
12	2819	-397	28	-216	30
13	2770	-290	29	33	-4
14	2407	-338	30	265	-37
15	1794	-252	31	483	-67
16	979	-138	32	689	-96

4.4.5 Design Using Double-angles

Design assumption allows for bolted splice at mid-span.

4.4.5.1 Top Chord

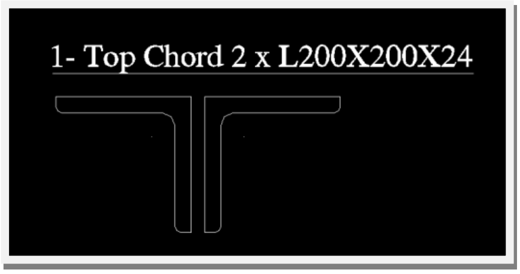


Figure 4.3: Top Chord 2XL200x200x24

Design Forces compression; 2705 kN

Tension caused by wind reversal; 397 kN

Length between restraints; 4,0m both axes

b=420 mm

h=200 mm

t=24 mm

i_z=60,6 mm(radius of gyration)

A=18120 mm^2

Material Properties

$t \leq 40mm$

$f_y = 275 N/mm^2$

$f_u = 430 N/mm^2$

Section Classification

$\varepsilon = \sqrt{(235/f_y)}$ $\varepsilon = \sqrt{(235/275)}$=0,924

c/t_f=8,75 15 ε = 13,86

The flanges satisfy the requirements for class 3 element.

h/t_w=200/48=4,16 15 ε> h/t_w

13,86>4,16

The stem is a class 3 element.

Section in compression

N_{sd}=2705 kN

The buckling length,L=4000 mm

λ_z=l/i_z=66

λ_1=93, 9x0,924=86,7

$\bar{\lambda}$=λ_z/λ_1 .$\beta_A^{0,5}$=0,761

Buckling curve,c

χ =0,699

The design buckling resistance of a compression member shall be taken as;

N_{sd}= χ. $\beta_A^{0,5}$.A. f_y/γ_{m_1}=3317 kN≥ N_{sd}=2705 kN satisfactory√

Section in tension

Under wind uplift max.tension on top chord ; 397 kN

N_{Rd}=$A. f_y/\gamma_{m_o}$=18120x275x10^{-3}/1,05=4745kN≥ N_{sd}=397kN satisfactory√

4.4.5.2 Bottom Chord

Design forces for bottom chord;

Tension ; 2701 kN

Compression; 390 kN

There will be bolted splice at the point of max force.

Resistance of M27 bolts,grade 4,6

A_s=460mm^2

f_{ub}=400N/mm^2

γ_{M_b}=1,35

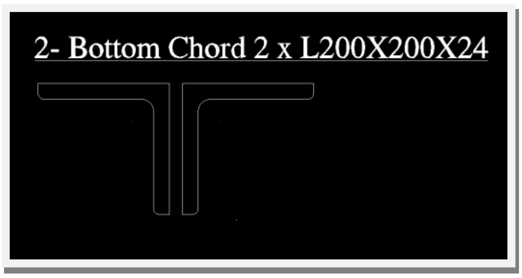


Figure 4..4: Bottom Chord 2XL200x200x24

Shear resistance per shear plane

$$F_{V,Rd} = \frac{0{,}6.\,f_{ub}.\,A_s}{\gamma_{M_b}}$$

$F_{V,Rd}$=81,7 kN

d_o=27+3=30mm

e_1=60 mm for plates

$e_1/3.\,d_o$=0,666 for plates 0,555 for section

$$\frac{p_1}{3.\,d_0} - \frac{1}{4} = 0{,}583$$

f_{ub}/f_u=400/430=0,930

α=0,555(the smallest one)

Bearing Resistance

$$F_{b,Rd} = \frac{2{,}5.\,f_u.\,d.\,t}{\gamma_{M_b}} = 477\ kN$$

477Kn for stem,238 kN for flange

For bolts in four each shear;

$F_{v,sd} \leq 4x81{,}7$

$\leq$326,8kN

The resistance of the bolts is provided by four each shear.

Number of bolts required = $N_{sd}/F_{v,sdmax}$

=2701/326,8=9 bolts

9 bolts are used to provide the required resistance.

To carry the shear resistance of the bolts in bearing

Minimum plate thickness;

$$\frac{F_{V,Rd} . \gamma_{M_b}}{2,5. \alpha . f_{ud}} = 6,84 \text{ mm}$$

20 mm splice plates between back to back profile have been placed.

Limiting stress to limit deformations;

0,85.(430+275)/1,35=444 N/mm^2

Maximum bearing stress(in stem)

$$\frac{2819}{9} \text{x} \frac{10^3}{27\text{x}40} = 290 \text{N/mm}^2 \leq 444 \text{ N/mm}^2$$

<u>Check tension resistance of member</u>

The checks required for the tension resistance of the member are as follows;

-the resistance of the whole section ($N_{pl,Rd}$), and

-the resistance of the section where bolts are located

Resistance of the whole section;

$$N_{pl,Rd} = \frac{A. f_y}{\gamma_{M_0}} = \frac{18120\text{x}275}{1,05\text{x}10^3} = 4745 \text{ kN}$$

-Resistance at bolt holes at any section allowing four 30mm diameter.

A_{net}=A minus area of all bolt holes

A_{net}=18120-30x(2x20)=16920 mm^2

γ_{M_2}=1, 25

$$N_{u,Rd} = \frac{0,9. A_{net} . f_{ud}}{\gamma_{M_2}} = \frac{0,9\text{x}16920\text{x}430}{1,25\text{x}10^3} = 5238 \text{ kN} \geq 2701\text{kN} \surd \text{ satisfactory}$$

Section in compression

N_{Sd}=397 kN

$N_{b,Rd}=\chi.\beta_A.A.f_y/\gamma_{m_1}$

The buckling length = 4000 mm

λ_z=l /i_z=66 λ_y=l /i_y=4000/39=102

λ_1=93, 9x0,924=86,7

$\bar{\lambda}_z=\lambda_z/\lambda_1 .\beta_A^{0,5}$=0,761 $\bar{\lambda}_y=\lambda_y/\lambda_1 .\beta_A^{0,5}$=1,17

Buckling curve,c,

$\bar{\lambda}_{eff,z}$=0,5+0,7x0,761=1,03

$\bar{\lambda}_{eff,y}$=0,35+0,7x1,17=1,17

χ_{min} =0,45

$N_{b,Rd} = \chi.\beta_A.A.f_y/\gamma_{m_1}$

$= 0{,}45x1x18120x275/1{,}05/10^3 = 2135kN \geq 397kN$ √ satisfactory

4.4.5.3 Diagonal Brace Members

The critical member is that adjacent to the support.

Design forces for diagonal brace member;

Tension ; 1700 kN

Compression; 1265 kN

b=420 mm

h=200 mm

t=20 mm

i_z=61,12 mm(radius of gyration)

A=15270 mm^2

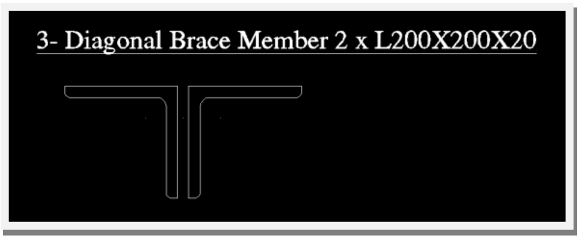


Figure 4.5: Diagonal Brace Member 2XL200x200x20

The connections between top and bottom chord are provided by 20 mm gusset plate. There will be bolted splice at the point of max force.

M27 bolts, grade 4,6

A_s=460mm^2

$\mathrm{f_{ub}}$=444 $\mathrm{N/mm^2}$

γ_{m_b}=1,35

$$\mathrm{F_{v,Rd}} = \frac{0{,}6.\mathrm{f_{ub}}.\mathrm{A_s}}{\gamma_{\mathrm{M_b}}} = 81{,}7\mathrm{kN} \qquad \text{(Shear resistance)}$$

$\mathrm{d_o}$=27+3=30mm

$\mathrm{e_1}$=50mm for section = 60mm for plate

$\mathrm{e_1/d_o}$=0,555 for section=0,667 for plate

$$\frac{\mathrm{p_1}}{3\mathrm{d_o}} - \frac{1}{4} = 0{,}583$$

$$\frac{\mathrm{f_{ub}}}{\mathrm{f_u}} = \frac{400}{430} = 0{,}930(< 1{,}0)$$

α=0,555 for section=0,667 for plates=40 mm

$$\mathrm{F_{b,Rd}} = \frac{2{,}5.\alpha.\mathrm{f_u}.\mathrm{d}.\mathrm{t}}{\gamma_{\mathrm{M_b}}} = 447\ \mathrm{kN\ for\ stem\ ,238\ kN\ for\ flange}$$

For bolts in four shear;

$$\mathrm{F_{v,sd}} \le 4\mathrm{x}81{,}7 = 326{,}8\ \mathrm{kN}$$

Number of bolts required; 1775/326, 8=6 bolts

Minimum plate thickness;

$$\frac{\mathrm{F_{v,Rd}}\cdot\gamma_{\mathrm{M_b}}}{2{,}5.\alpha.\mathrm{f_u}} = 6{,}84\ \mathrm{mm} < 20mm\ gusset\ plate$$

Limiting stress=0,85(430+275)/1,35=444 $\mathrm{N/mm^2}$

Max bearing stress(in stem);

$$\frac{1775}{6} \mathrm{x} \frac{10^3}{27\mathrm{x}30} = 365\mathrm{N/mm^2} \leq 444\ \mathrm{N/mm^2}$$

Section in Tension

$$N_{t,Rd} = N_{pl,Rd} = A.\frac{f_y}{\gamma_{M_0}} = \frac{15270\mathrm{x}275}{1{,}05\mathrm{x}10^3} = 4000\mathrm{kN} \geq N_{sd} = 1700\mathrm{kN}$$

Section in Compression

$N_{sd} = 1320\ \mathrm{kN}$

Section Classification; class 3

$\varepsilon = \sqrt{(235/f_y)}$ $\varepsilon = \sqrt{(235/275)}$=0,924

h/t_w=150/42=3,57 15 ε = 13,86

The flanges satisfy the requirements for class 3 element.

The buckling length = 5000 mm, $\beta_A^{0,5} = 1$

λ_z=l /i_z=5000/61,12=81,8 λ_y=l /i_y=5000/39,2=127

λ_1=93, 9x0,924=86,7

$\bar{\lambda}_z=\lambda_z/\lambda_1\ .\beta_A^{0,5}$=0,94 $\bar{\lambda}_y=\lambda_y/\lambda_1\ .\beta_A^{0,5}$=1,46

Buckling curve,c,

$\bar{\lambda}_{eff,z}$=0,5+0,7x0,94=1,16

$\bar{\lambda}_{eff,y}$=0,35+0,7x1,46=1,37

χ_{min} =0,36, $\gamma_{M_1} = 1{,}05$

$N_{b,Rd}=\chi.\beta_A.A.f_y/\gamma_{m_o} = 0{,}36\mathrm{x}1\mathrm{x}15270\mathrm{x}275/1{,}05/10^3 = 1439\mathrm{kN} \geq 1265\mathrm{kN}$ √ satisfactory

4.4.5.4 Vertical Brace Members

Design forces for vertical brace members;

Maximum Tension ; 660 kN

Maximum Compression; 760 kN

b=320 mm

h=150 mm

t=15 mm

i_z=45,7 mm(radius of gyration)

A=8600 mm^2

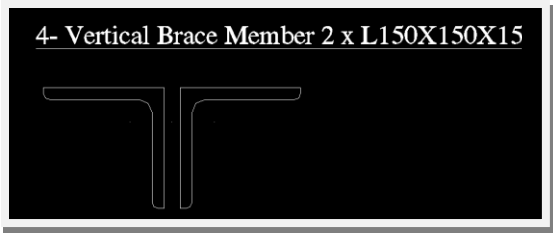


Figure 4.6: Vertical Brace Member 2XL150x150x15

<u>Section in compression</u>

$\mathrm{N_{sd}} = 760\ \mathrm{kN}$

Section Classification; class 3

The buckling length = 3600 mm, $\beta_A^{0,5} = 1$

λ_z=l /i_z=3600/45,7=78,7 λ_y=l /i_y=3600/29,3=122,8

λ_1=93, 9x0,924=86,7

$\bar{\lambda}_z$=λ_z/λ_1 .$\beta_A^{0,5}$=0,9 $\bar{\lambda}_y$=λ_y/λ_1 .$\beta_A^{0,5}$=1,42

Buckling curve,c,

$\bar{\lambda}_{eff,z}$=0,5+0,7x0,9=1,13

$\bar{\lambda}_{eff,y}$=0,35+0,7x1,42=1,34

χ_{min} =0,36, $\gamma_{M_0} = 1,05$

<u>Section in tension</u>

$\mathrm{N_{b,Rd}} = \chi.\beta_A.A.f_y/\gamma_{m_0} \quad = 0,36x1x8600x275/1,05/10^3 = 810\ \mathrm{kN} \geq 660\mathrm{kN} \surd$ satisfactory

4.4.6 Column Design

We assume that the connection between columns and end of truss system are connected as a nominally pinned connection. The pinned connection is capable of transmitting the calculated design forces, without developing significant moments.

4.4.6.1 Selection of column

Steel truss members weight have been added to permanent values.

Loading;	Variable Action	Cumulative	Permanent Action	Cumulative
Roof	384 kN		331 kN	
		384 kN		331 kN

Partial Safety Factors for Loading

Permanent Action

$\Upsilon_{G,sup} = 1,35$

Variable Action

$\Upsilon_{G,sup} = 1,50$

Section Properties

305x305x198 universal column has been chosen.

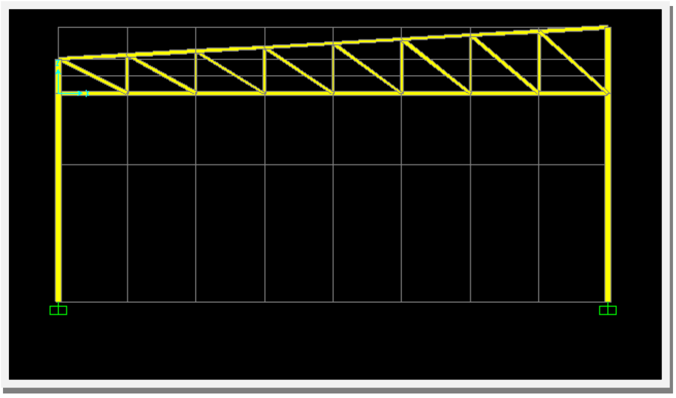


Figure 4.7: 305x305x198UC Universal Columns

h =406,4 mm   b=403 mm

t_w=26,6 mm t_f=42,9 mm

d/t_w=10,9 mm   c/ t_f=4,7 mm

A=$433 cm^2$ I_y=$1225x10^6 mm^4$

I_w=$15500x10^9 mm^6$ I_z=$468,5x10^6 mm^4$

I_t=$23430x10^3 mm^4$ $W_{p,ly}$=$6999x10^3 mm^3$

$W_{el,y}$=6031x$10^3 mm^3$

i_z=104 mm

i_y=168 mm

$i_z = \left(\frac{I_z.I_w}{w_{pl,y}{}^2}\right)^{0,25}$ =110 mm

$a_{LT} = \left(\frac{I_w}{I_t}\right)^{0,5}$ =813 mm

Classification of Cross Section

The section is designed to withstand to small moments in addition to axial force. The section is always in compression.

$\varepsilon = \sqrt{(235/f_y)}$ $\varepsilon = \sqrt{(235/275)}$=0,924

Flange	Web
10ε=10x0,924=9,24	33ε =33x0,924=30,5
c/t_f=4,7	d/t_w=10,9
c/t_f<10ε	33ε > d/t_w

In accordance with the limiting value of c/t_f and d/t_w ,the classification of cross section is a class 1 section.

Design Value of Actions

The column supports the load from the roof.

G_k=292 kN

Q_k=384 kN

=$\Sigma\gamma_{Gj}.G_{kj} + \gamma_{Qi}.G_{Qi}$

=1,35x331+1,5x384

=1023 kN

The effect of unbalanced loading on either side of the column must be taken into account.

h/2+100mm=406,4/2+100=303 mm

$M_{y,sd}$=$1023x303/10^3$ =310 kNm

<u>Resistance of Cross-section</u>

For a class 1 section without bolt holes, the reduced design plastic moment, allowing for the axial force is;

$$M_{Ny,d} = \frac{M_{ply,Rd}.(1-n)}{(1-0,5a)}$$

Where,

n=$N_{Sd}/N_{pl,Rd}$

a=(A-2xbxt$_f$)/A

$M_{ply,Rd} = W_{pl}.f_y/\Upsilon_{Mb}$

=6999x10^3x275/1,05/10^6

=1833 kN

Applied force;1023 kN

For a member subject to axial compression,the design plastic resistance of the cross section is;

$N_{pl,Rd}$=A. f_y/Υ_{M0}

=43300x275/1,05/10^3=11340 kN

n=1023/11340=0,1 , a=(43300-2x403x42,9)/43300=0,2

$$M_{Ny,d} = \frac{M_{ply,Rd}.(1-n)}{(1-0,5a)} = 1833.\frac{1-0,1}{1-0,5x0,2} = 1833kNm > M_{sd} = 254kNm$$

Buckling Resistance of The Member

A class 1 member subject to axial compression is checked for the following modes of failure;

-Flexural buckling

-Lateral torsinal buckling

$$M_{Ny,d} = \frac{N_{sd}}{\chi_{min}.A.f_y/\Upsilon_{M1}} + \frac{k_y.M_{y,sd}}{W_{pl,y}.f_y/\Upsilon_{M1}} \leq 1{,}0$$

Applied axial force,

$N_{sd} = 1023kN$

χ_{min} is of χ_y,where χ_y is the reduction factor for y-y axes.

λ_y=l /i_y=16000/168=95,2

λ_1=93, 9x0,924=86,7

$\bar{\lambda}_z$=λ_z/λ_1 .$\beta_A^{0,5}$=95,2/86,8x$1^{0,5}$=1,1 buckling curve a

χ_y=0,596

To calculate ky

$$M_{Ny,d} = 1 - \frac{\mu_y.N_{sd}}{\chi_y.A.f_y} \quad \text{but } k_y \leq 1{,}5$$

μ_y=$\bar{\lambda}_y(\beta_{\mu y} - 4) - (W_{pl,y} - W_{el,y})/W_{el,y}$ μ_y ≤0,9

$\Psi = 1{,}0$, $\beta_{\mu y}$(Moment factor)=1,3

μ_y=1,1x(2x1,3-4)+(6999x10^3-6031x10^3)/(6031x10^3)

= -1,37

$M_{Ny,d} = 1— 1{,}37x1023x10^3 0{,}596x43300x275 =$

1,2≤1,5

$M_{Ny,d}$=0,354≤1,00 is satisfied for flexural buckling.

Lateral Torsional Buckling

$$\frac{N_{sd}}{\chi_z . A . f_y / \Upsilon_{M1}} + \frac{k_{Lt} . M_{y,Rd}}{\chi_{Lt} . A . W_{pl,y} / \Upsilon_{M1}} \leq 1{,}0$$

Applied axial force; N_{sd}=1023 kN

Applied moment ; $M_{y,Rd}$=310kNm

$$k_{LT} = 1 - \frac{\mu_{LT.} N_{sd}}{\chi_z . A . f_y} \qquad k_{LT} \leq 1{,}0$$

μ_{LT}=0,15.$\bar{\lambda}_z$. $\beta_{\mu,LT}$-0,15

=0,14 $\leq$ 0,9

λ_y=l /i_z=16000/104=153

λ_1=86,7

$\bar{\lambda}_z$=λ_z/λ_1 .$\beta_A^{0,5}$=153/86,7x$1^{0,5}$=1,76

χ_z=0,253

k_{LT} =0,99≤1

For a nominally pin-ended I section with end-moment loading only the value of λ_{LT} can be obtained from;

$$\lambda_{LT} = \frac{L/i_{LT}}{C_1^{0,5} . \left[(1 + \frac{(L/a_{LT})^2}{25{,}66})\right]^{0,25}} = \frac{16000/110}{1^{0,5} . \left[(1 + \frac{(16000/813)^2}{25{,}66})\right]^{0,25}} = 72{,}6 \text{ using curve a}$$

$\bar{\lambda}_{LT}$=λ_{LT}/λ_1 .$\beta_A^{0,5}$=72,6/86,8x$1^{0,5}$=1,1 buckling curve a

χ_{LT}=0,77

$$\frac{N_{sd}}{\chi_z . A . f_y / \Upsilon_{M1}} + \frac{k_{Lt} . M_{y,Rd}}{\chi_{Lt} . A . W_{pl,y} / \Upsilon_{M1}} \leq 1{,}0$$

0,574 $\leq$ 1,0 is satisfied for lateral buckling.

4.4.7 Bracing design

According to the design actions obtained from frame imperfections and wind loading on bracing system,2LX200X200X24 steel profile has been used. These forces are distributed equally between each bracing system. The cross-braced system has been used in each of the two end-walls into seven sound parts. As the longitudinal bracing is provided by external shear walls, interior part of structures are supported by cross-braced system in each of the two ends.

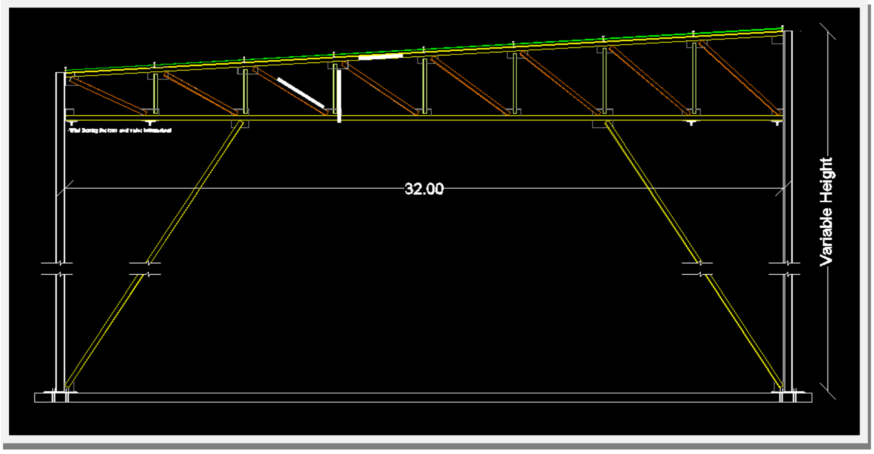


Figure 4.8: 2XL200x200x24 Equal angle steel profiles for transverse bracing

In accordance with the design load obtained from sap2000, 2LX200X200X24 steel profile is used for bracing.

Section Classification

$\varepsilon = \sqrt{(235/f_y)}$ $\varepsilon = \sqrt{(235/275)}$=0,924

c/t_f=8,75 15 ε = 13,86

The flanges satisfy the requirements for class 3 element.

h/t_w=200/48=4,16 15 ε> h/t_w

13,86>4,16

The stem is a class 3 element.

Resistance of cross-section

$N_{c,Rd} = A.f_y/\gamma_{M0}$=18120x275/1/$10^3$=4983kN >360kN

Buckling resistance

λ_1=86,7

λ_y=l /i_z=14500/60,6=240

$\bar{\lambda}_z=\lambda_z/\lambda_1\ .\beta_A^{0,5}$=240/86,7x$1^{0,5}$=2,76

$N_{b,Rd}=\chi.\beta_A.A.f_y/\gamma_{M1}$=0,12x1x18120x275/1,05/$10^3$=570kN >260 kN

Figure 3.8 shows roof trusses in place in a building with the purlins providing lateral support to the top chord, and a lower chord bracing system providing lateral support to the bottom chord.

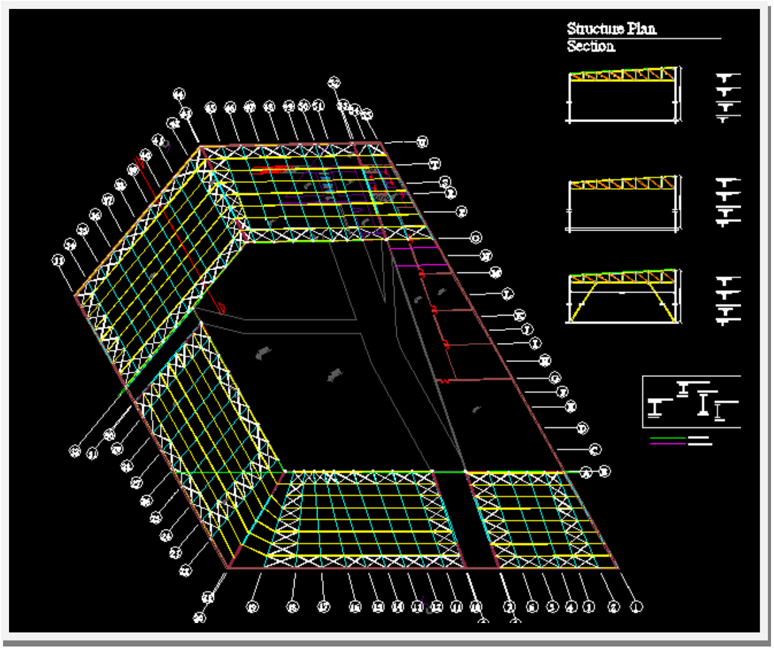


Figure 4.9: The purlins and bracing systems.

4.5 Two Storey Steel Frame Structure Analysis

The design choices, calculations and choice methods have been thoroughly calculated by hand. The frame is classified as 'simple' and internal forces and moments are determined using a global analysis which assumes the members to be effectively pin-connected. The connections are designed to transmit vertical shear, and to be capable of transferring a horizontal tying force to preserve the integrity of the structure.

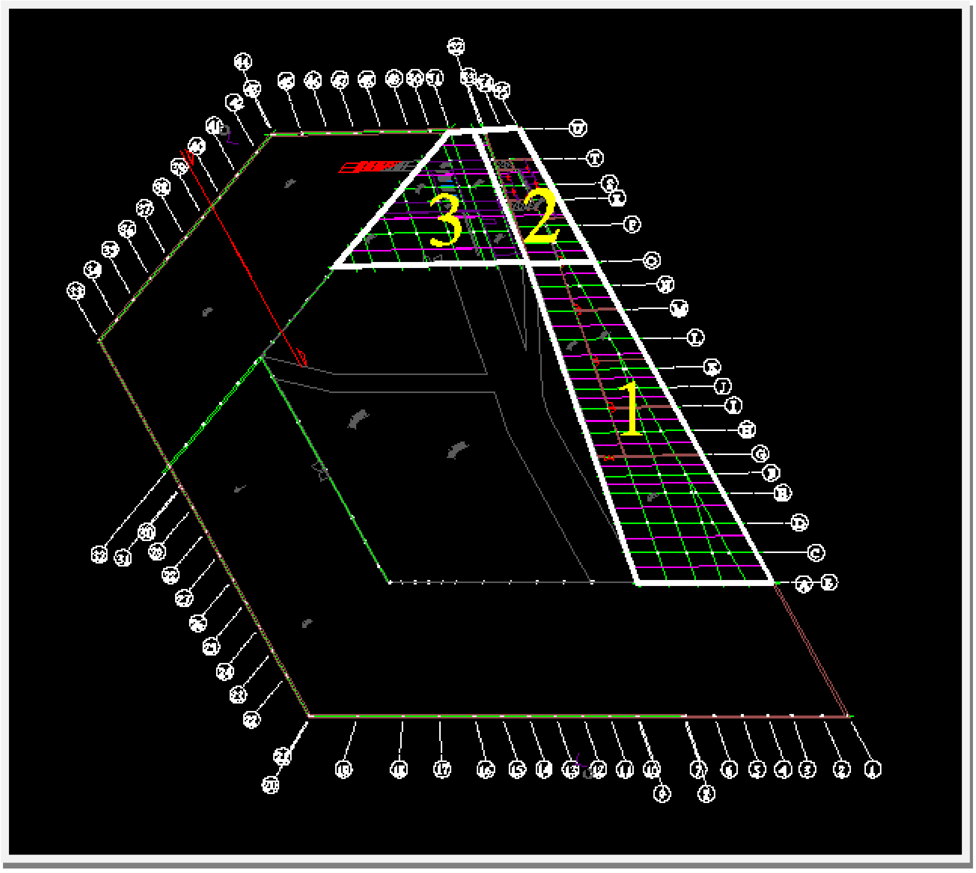


Figure 4.10: Two storey's braced frame structure blocks..

4.5.1 Selection of the Beams

4.5.1.1 The Secondary Beam

The secondary beam is supported at both ends and is fully restrained along its length.

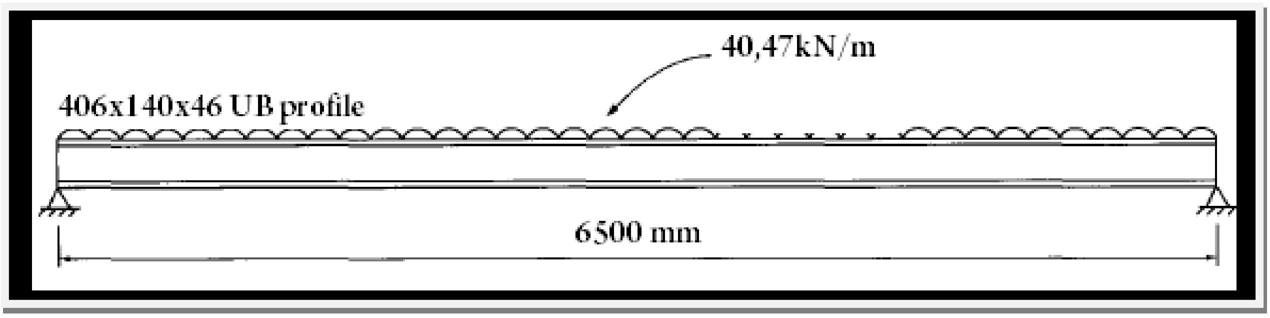


Figure 4.11: The secondary beam 406x140x46UB

Variable action ; Q_k=4x4kN/m=16kN/m

Permanent action ; G_k=3,04x4kN/m=12,20kN/m

Partial Safety Factor

Variable action ; $\Upsilon_{Q_{sup}}$=1,50

Permanent action ; $\Upsilon_{G_{sup}}$=1,35

Design Values

$F_d = \Upsilon_{G_{sup}}.G_k + \Upsilon_{Q_{sup}}.Q_k$

=1,35x12,2+1,5x16

=40,47 kN

Design Moment

$$M_{sd} = F_d.\frac{L^2}{8} = \frac{40{,}47x6{,}5^2}{8} = 213{,}7\ kNm$$

Design Shear Force

$$V_{sd} = F_d.\frac{L}{2} = \frac{40{,}47x6{,}5}{2} = 131{,}5\ kN$$

The section size is determined in accordance with $W_{pl,required}$, $M_{sd} \leq M_{c,Rd}$ flange thickness less than 40mm.

$$W_{pl} = \frac{M_{c,Rd}}{f_y}.\Upsilon_{Mo} = \frac{213{,}7}{275}.1{,}05 = 815{,}9\ cm^3$$

We chose 406x140x46 UB profile.

Classification of Cross Section

As a simply supported beam ,the section to develop plastic resistance has been chosen.

Flange buckling ;

$\varepsilon = \sqrt{(235/f_y)}$ $\varepsilon = \sqrt{(235/275)}$=0,924

c/t_f=6,36 11 ε = 10,16 6,36≤10,16

The flanges satisfy the requirements for class 2 element.

Web buckling ;

d/t_w=52,1 , 83 ε =76,7

52,1≤76,7

The stem is a class 2 element.

<u>Deflection Check</u>

The calculated deflection for an unit load of 1 kN/m

$$\delta = \frac{5}{384} x \frac{F_L . L^3}{E . I_y} = \frac{5}{384} x \frac{10^3 . 6{,}5 . 6500^3}{210000.15690 . 10^4} = 0{,}705$$

δ_1 is the deflection due to permanent action

δ_2 is the deflection caused by variable action, which should be less than L/300

δ_{max} is the total deflection caused by permanent and variable action, which should be less than L/250

		Deflection Limit
$\boldsymbol{\delta_1}$ permanent action	0,705x12,20=8,6 mm	L/300=21,6 mm
$\boldsymbol{\delta_1}$ variable action	0,705x16=11,28 mm	L/250=26 mm
Total	19,88 mm	

<u>Shear on Web</u>

$V_{sd} < V_{pl,Rd}$

The design plastic shear resistance of the web is given by;

$$V_{pl,Rd} = A_v . \frac{f_{y/\sqrt{3}}}{Y_{Mo}} =. \frac{1{,}04x402{,}3x6{,}9x275}{\sqrt{3}x1{,}05x10^3} > V_{sd} = 127 \text{ kN}$$

Local shear check on the web of the beams, where it is connected to column.

$$A_v . \frac{f_{y/\sqrt{3}}}{Y_{Mo}}$$

$$A_v = t_w . d$$

$$V_{pl,Rd} = \frac{6,9x250x275}{\sqrt{3}x1,05x10^3} = 260,8\ kN > V_{sd=}131,5\ kN$$

4.5.1.2 The Primary Beam

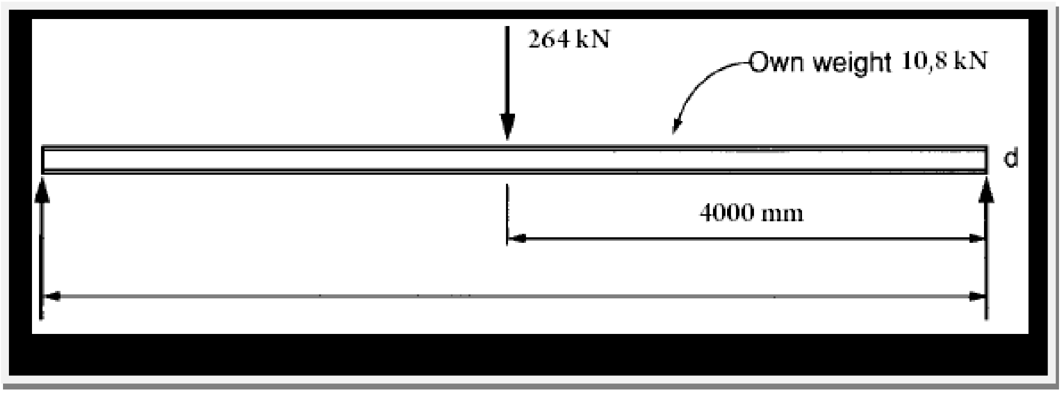


Figure 4.12: The primary beam 533x210x122UB

<u>Characteristic Values</u>

The point loads are taken as the end reactions from beam B1.

Variable actions at point load ; $Q_{k,1} = 4x4x6,5 = 104\ kN$

Permanent action at point load ; $G_{k,1} = 3,07x4x6,5 = 79,8\ kN$

For self-weight of primary beam = 8 kN

<u>Partial Safety Factor</u>

Variable action ; $Y_{Q_{sup}}$=1, 50

Permanent action ; $Y_{G_{sup}}$=1,35

<u>Design Values</u>

F_d=$Y_{G_{sup}}.G_k + Y_{Q_{sup}}.Q_k$

=1,35x79,8+1,5x104

=264 kN

<u>Self-weight</u>

$F_{d2} = 1{,}35x8$

$= 10{,}8\ \text{kN}$

<u>Reactions</u>

$V_{sd} = F_{d1} + F_{d2}/2$

$= 264 + 10{,}8/2$

$= 137{,}4$ kN (at supports)

$$M_{sd} = \frac{F_{d1}.L}{4} + \frac{F_{d2}.L^2}{8}$$

$$= \frac{264X8}{4} + \frac{(10{,}8/8).8^2}{8}$$

$= 538{,}8\ \text{kN}$

$W_{pl,required} = 2057\ \text{cm}^3$

The beam is unrestrained between the point loads, the design resistance ($M_{c,Rd}$) of the section will be reduced by lateral torsional buckling.

533x210x122 UB section is chosen.

<u>Design Buckling Resistant Moment</u>

$M_{b,Rd} = \chi_{LT}.\beta_w.W_{pl,y}.f_y/\gamma_{M1}$

$a_{LT} = 114{,}2\ \text{cm}$

$i_{LT} = 5{,}27$

$$\lambda_{LT} = \frac{L/i_{LT}}{C_1^{0,5}.\left[(1 + \frac{(L/a_{LT})^2}{25{,}66})\right]^{0,25}} = \frac{400/527}{1^{0,5}.\left[(1 + \frac{(400/114{,}2)^2}{25{,}66})\right]^{0,25}} = 68{,}8 \text{ using curve a}$$

$\lambda_1 = 93{,}9\varepsilon = 86{,}8$

$\bar{\lambda}_z = \lambda_z/\lambda_1\ .\beta_A^{0,5}$=68,8/86,8x$1^{0,5}$=0,79

$\chi_{LT} = 0{,}80$

The design buckling resistance moment

$M_{b,Rd} = 0{,}80x1x3196x275/1{,}05/10^3$

$= 669$kNm > 538,8kNm satisfactory√

<u>Shear on Web</u>

The effect of shear will be checked for where there are point loads.

$V_{sd} = 264 \text{ kN}$

The design shear resistance for a rolled I section is;

$$V_{pl,Rd} = \frac{1{,}04.\, t_{w.} b.\, f_y/\sqrt{3}}{\Upsilon_{Mo}} =. \frac{1{,}04x544{,}5x12{,}7x(275/\sqrt{3})}{1{,}05x10^3} = 1097\text{kN} > V_{sd} = 264 \text{ kN}$$

$V_{sd} < V_{pl,Rd}$,so there is no reduction in moment resistance due to shear in the web is sufficient.

<u>Deflection Check</u>

The point –load-deflection is carefully considered by calculating the deflection from unit load and then multiplying by the applied loads.

The serviceability loads are used for deflection check.

Maximum deflection;

δ_1 for variable actions=0,067x104=6,97 <L/300=32mm

δ_2 for permanent actions=0,067x79,8=5,34

$\delta_1 + \delta_2$ =12,31mm<L/250=26,6mm

4.5.1.3 Selection of Column

We designed the column subject to loads from the roofs and first floor.

Loading for Column(kN)

	Variable(kN)	Cumulative(kN)	Permanent(kN)	Cumulative(kN)
Roof(2x)	52		39,9	
	52		39,9	
	104		79,9	
	104		79,8	
		2x312		2x239,4
First Floor	52		37,7	
	52		37,7	
	104		75,4	
	104		75,4	
		312		226,2
Total		936 kN		705 kN

Partial Safety Factor

Variable action ; $\Upsilon_{Q_{sup}}$=1,35

Permanent action ; $\Upsilon_{G_{sup}}$=1,50

Section properties

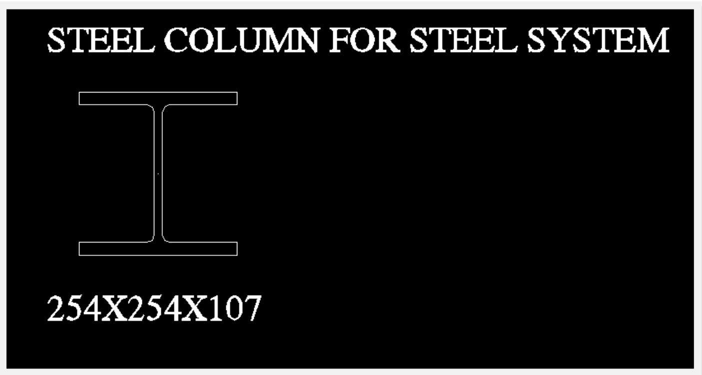


Figure 4,13: The column 254x254x107UC

h =267 mm b=259 mm

t_w=12,8 mm t_f=20,5 mm

d/t_w=15,6 mm c/ t_f=6,31 mm

A=13600mm^2 I_y=175x$10^6 mm^4$

I_w=898x$10^9 mm^6$ I_z=59x$10^6 mm^4$

I_t=172x$10^3 mm^4$ $W_{p,ly}$=1484x$10^3 mm^3$

$W_{el,y}$=1313x$10^3 mm^3$ Fe 430 UC

i_y=113 mm i_z=65,9 mm

Classification of Cross-section

The column is designed to withstand small moments together with axial force.

$p_y = 275\ N/mm^2$

$\varepsilon = \sqrt{(235/f_y)}$ $\varepsilon = \sqrt{(235/275)}$=0,924

c/t_f=6,31 10ε = 9,24 6,31≤9,24

The flanges satisfy the requirements for class 1 element.

Web buckling;

d/t_w=15,6 , 33 ε =30,5

15,6≤30,5

The stem is a class 1 element.

Design Value of The Action

N_{sd}=$\Sigma Y_{G_j}. G_{kj} + Y_{Q_i}. Q_{ki}$

=1,35x705+1,5x936

=2356kN

The effect of unbalanced loading on either side of the column mu =h/2+100mm=233,5mm

st be taken into account;

All moments of end of beams connected to column are in balance each other.

Resistance of Cross-section

Applied axial force ;

N_{sd}=2356 kN

$$N_{pl,Rd} = \frac{A. f_y}{Y_{m1}} = \frac{13600x275}{1,05x10^3} = 3562kN \geq 2356kN\ satisfactory\surd$$

Buckling Resistance of The Member

Flexural Buckling

A class 1 member subject to moment about the major axis only, should satisfy the following;

$$\frac{N_{sd}}{\chi_{min}.A.f_y/\Upsilon_{M_1}} \leq 1,0$$

The buckling length = 4000 mm, $\beta_A^{0,5} = 1$

λ_z=l /i_z=4000/65,9=60,7 λ_y=l /i_y=4000/113=36

λ_1=93, 9x0,924=86,8

$\bar{\lambda}_z$=λ_z/λ_1 .$\beta_A^{0,5}$=6,07/86,8x1^{0,5}=0,69 use buckling $\bar{\lambda}_y$=λ_y/λ_1 .$\beta_A^{0,5}$=36/86,8x1^{0,5}=0,41 use buckling, a

$$\frac{N_{sd}}{\chi_{min}.A.f_y/\Upsilon_{M_1}} = \frac{2356x10^3}{0,85x13600x275/1,05} = 0,78 \leq 1,0 \text{ satisfactory for flexural buckling}$$

Lateral Torsional Buckling

$$\frac{N_{sd}}{\chi_z.A.f_y/\Upsilon_{M_1}} = \frac{2356x10^3}{0,85x13600x275/1,05} = 0,78 \leq 1,0 \text{ satisfactory for lateral torsional buckling}$$

4.6 Structural Integrity

Tying Forces

The beams and their connection should be designed to resist tie forces, so that they will limit the progressive spread of damage in the event of an accident. These forces are defined as;

0,5.w_f. s_f. L_S for internal beam

0,5.w_f. s_f. L_S for edge beam

The forces should not be less than 75kN for floors or 40kN for roofs

For the floors; 1,35x2,9+1,5x4=9,9kN/m^2

For the roof ; 1,35x3,04+1,5x4=10,1kN/m^2

Column Tie Forces

The columns must be restrained at the periphery of the structure.The restraints should be capable of resisting a tie force of not less than 1% of the axial force in the column.

The area supported by external column=8x4=32m^2

The column load at roof level

$w_f$xarea=10,1x32=323,2kN

The restraint force=3,23kN

Column load at 1st floor

2xRoof	2x323,2 kN
1st floor	316,8 kN
Edge beams	237 kN
Cladding	230 kN
Total	1430,2 kN

1% of the total axial force=14,3 kN

Roof Tie Forces

Edge beam=0,25x10,1x8x6,5=131,3 kN

Secondary beam=0,5x10,1x4x6,5=131,3 kN

Main Beam = 0,5x10,1x8x6,5=262,6 kN

All of tie forces are greater than 40kN and 1%of the column load(3,13kN)

Floor Tie Forces

Edge beam=0,25x9,9x8x6,5=131,3 kN

Secondary beam=0,5x9,9x4x6,5=128,7 kN

Main Beam = 0,5x9,9x8x6,5=257,4 kN

Both the calculated tie forces are greater than 40kN AND %1 of the column load(11,07kN)

4.7 Frame Imperfection

Appropriate allowances should be made to cover the effects of practical imperfections, including residual stresses and geometrical imperfections such as lack of verticality, lack of straightness, lack of fit and the unavoidable minor eccentricities present in practical connection. The effects of imperfections shall be allowed for in frame analysis by means of an equivalent geometric imperfection in the form of an initial sway imperfection determined from;

Roof;10,1 kN/m^2

Floor;9,9 kN/m^2

The design load for the weight of columns and beam casings,0,3 kN/m^2,for the floor and roof.

The cladding has a characteristic 0,8kN/m^2 and design load of 1,0 kN/m^2.

The area of building=1570m^2

The perimeter of the building is 200m

The weight of the cladding 4,8x200=960 kN/m^2

Total Design Loads on Each Floor(kN)

Roof(2x)	2x10,4x1570	32656
First Floor	10,2x1570+2x960	17934
Total		50590

To obtain the equivalent horizontal forces for checking the frame, the total floor load is multiplied by the imperfection angle ϕ which is obtained from;

$$\phi = k_c.k_s.\phi_o$$

$k_c = (0,5 + \frac{1}{n_c})^{0,5} = (0,5 + \frac{1}{6})^{0,5} = 0,81$ The value for transverse imperfection

$k_c = (0,5 + \frac{1}{n_c})^{0,5} = (0,5 + \frac{1}{15})^{0,5} = 0,75$ The value for longitudinal imperfection

The value of n_s in both direction is the same 2,

$k_c = (0,2 + 1/2)^{0,5} = 0,84$

The final imperfections will be;

Transverse 0,8x0,84x1/200=1/298

Longitudinal 0,75x0,84x1/200=1/317

Equivalent horizontal forces at each floor(kN)

	Design Load	Transverse	Longitudinal
Roof(2x)	16328	54,8	103
First Floor	10,2x1570+2x960	60,1	56,6

Wind Loading on Bracing System

$q_p = 0,895\ \mathrm{kN/m^2}$

The force on each of the transverse braced bays;

$= q_p.C_f.\mathrm{length}/2 = 0,895x0,8x80/2 = 28,6\ \mathrm{kN/m}$

The total force to be resisted by the longitudinal bracing

$= 0,895x0,8x30 = 21,5\ \mathrm{kN/m}$

The force in the transverse bracing resulting from wind acting on the end-bays is determined by multiplying the total force on the longitudinal bracing by ratio of the half the width of the building by its length.

Multiplying factor; 30/(2x80) =0,1875

Design Actions on Transverse Bracing

	Wind on front elevation	Resultant couple from wind on ends	Transverse Imperfection	Longitudinal Imperfection	Design Action
Roof	57,2	8,06	27,4	8,58	101,2
1st Floor	114,2	16,13	30,05	4,72	165,3

As the structure is more than one storey high, in each direction two system of bracing is required. Two braced bays have been built into the rear elevation.

As the longitudinal bracing is provided on two elevation,Plan bracing will be provided by the floors acting as a diaphragms.

4.8 Beam to Beam Connection

Initial Design Information

The connection between the secondary (406x140x46 UB) and primary beam(533X210X122 UB) is designed.For a secondary beam the design ultimate reaction is;

V_{sd}=131,5 kN

The connection is pinned so that the significant moments in the primary beam doesn't occur.The connection has been designated as (Category A; Bearing Type) shear connection using a partial depth flexible end-plate.It can result in increased erection effort.

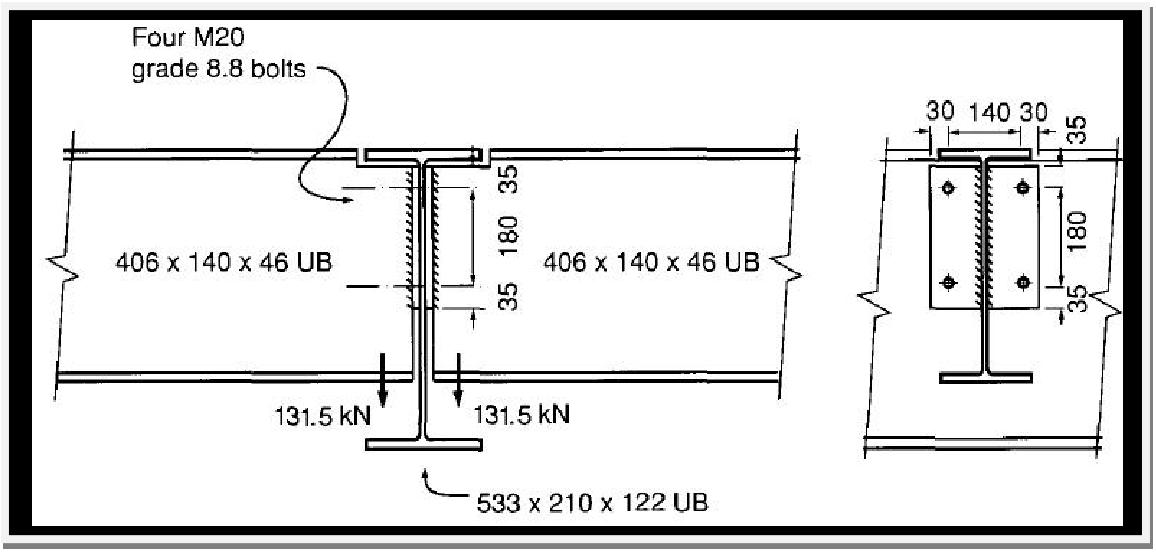


Figure 4.14: Beam to beam connection detail (dimensions mm)

The proposed end plate 200mm(wide)x250mm(deep)x8mm(thick).The four-bolt connections will be sufficient.The end distance=35mm,the bolt pitch is 180mm

Minumum end distance,e_1=1,2. d_o=1,2x22=26,4mm<35mm

Normal edge distance, e_2=1,5. d_o=1,5x22=33mm>30mm

Shear Resistance of Bolt Group

The force on each shear plane individually;

Shear per bolt=131,5/4=32,9kN

Shear resistance of bolt= $F_{V,Rd}$=0,6xf_{ub}xA_s/γ_{Mb} where;

γ_{Mb} is the material factor=1,35

f_{ub} is the ultimate tensile strength of the bolt=800 N/mm^2

A_s is the tensile stress area of the bolt=245mm^2

$F_{v,Rd}$=0,6x800x245/1,35/1000=87,1kN/plane>32,9kN satisfactory√

Check Shear Resistance of The End-plate

In accordance with the presence of fasteners, the reduced shear resistance can be ignored if;

A_{vnet}/A_v=0,824

f_y/f_u=275/430=0,640≤0,824

Design-Plastic Shear Resistance

$$V_{pl,Rd} = \frac{A_v . f_y}{\sqrt{3} . Y_{Mo}}$$

f_y=275N/mm^2

$Y_{Mo} = 1,05$ A_v=2x8x250=4000mm^2

$V_{pl,Rd} = 604,8kN > 131,5kN$ the plates are adequate in shear.

Design End-plate Weld

The end-plate is connected to the beam web by two full depth fillet webs;

Fillet weld shear strength, $f_{vw,d} = f_u/(\beta_w x Y_{Mw} x \sqrt{3})$

where, f_u=430 N/mm^2

β_w =0,85

Y_{Mw}=1,35

$$f_{vw,d} = \frac{430}{0{,}85x1{,}35x\sqrt{3}} = 216 N/mm^2$$

Total length of weld=250x2=500mm

Resistance required/mm =131,5x10^3/500=263 N/mm

Design resistance, $F_{vw,Rd}$=$f_{vw,d}.a$

-throat thickness required,a≥263/210=1,21mm

-leg lengths required=a/0,7=1,73mm

-use of 6mm fillet weld as practical minimum

Shear Resistance of Secondary Beam Web

Influence of notch to the top flange

For restrained beams in grade Fe430 steel,the stability of the web is not to be checked if provided;

$V_{sd}.(t_p+c) < M_{c,Rd(reduced)}$

Check Bearing Resistance of Supporting Beam

The bearing resistance of the secondary beam end-plates.

The actual bearing stress;

$f_{b,sd} = 2xV_{sd}/(4xdxt_w) = 2x131{,}5x10^3/(4x20x12{,}7) = 258{,}8 N/mm^2$

The four M20, grade 8,8 bolts and a 200x250x8 mm grade Fe430 end-plate welded to the beam with a full-length 6 mm fillet weld(eachside).

4.9 Beam to Column Connection

Initial Design Information

The connection between the main beam 533x210x122UB and an external column 254x254x107UC at the first-floor level.The connections is nominally pinned.The rotation of the beam can occur without significant moments.The connection is designed as a 'Category A;Bearing type'shear connection.

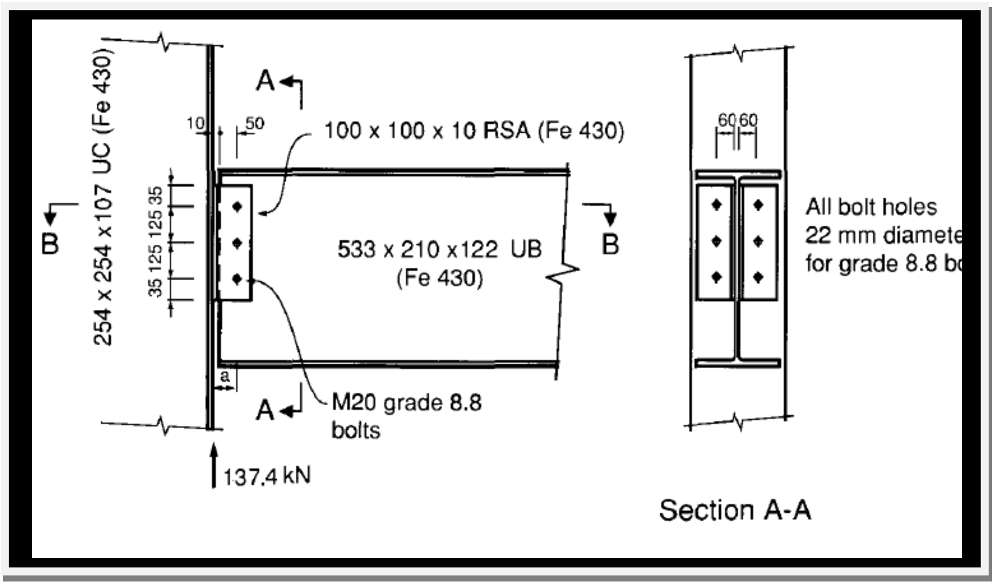


Figure 4.15: Beam to beam connection detail (dimensions mm)

Checl

The design shear force is the vector sum of vertical and horizontal components.

$F_{v,sd} = \left(F_v{}^2 + F_m{}^2\right)^{0,5}$

Where F_v is the vertical shear component per beam web bolt;

$F_v = V_{sd}/3$=137,4/3=45,8kN

F_m is the horizontal shear component per beam web bolt;

$F_v = V_{sd}$.a/$F_v = Z_b$ $Z_b = n(n+1)p/6 = 250$ a=60mm

$F_v = 33\text{kN}$

$F_{v,sd} = 56{,}4\text{kN}$

Shear resistance of bolt per shear plane;

$F_{v,Rd} = 0{,}6.f_{ub}.A_s/\gamma_{Mb}$

γ_{Mb}=1,5

f_{ub}=800 N/mm^2

A_s=245mm^2

$F_{v,Rd}$=87,1kN per shear plane

For double shear,bolt resistance

=2x87,1

=174,2kN>110kN satisfactory√

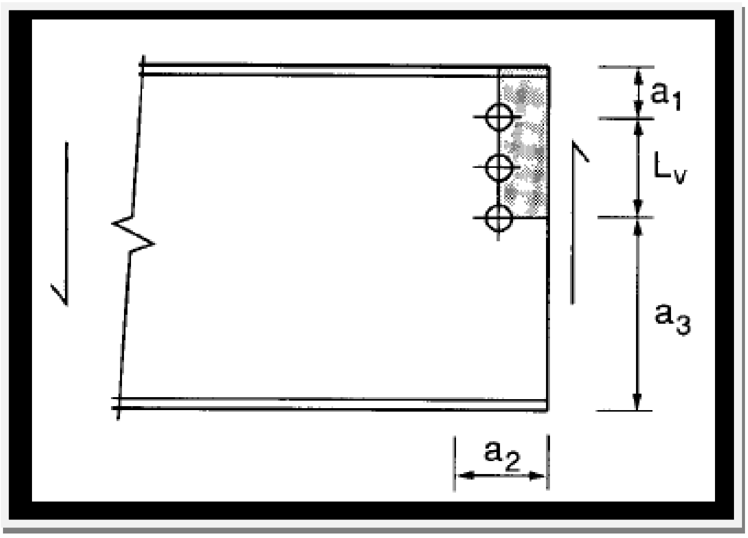


Figure 4,16; Block shear failure of web

$V_{eff} = (f_y/\sqrt{3}).A_{v,eff}/\Upsilon_{Mo}$

$\Upsilon_{Mo} = 1{,}05$

$A_{v,eff} = t.L_{v,eff}$

$L_{v,eff} = L_v + L_1 + L_2$

$L_v = 250mm$

$L_1 = 70mm$<5d

$L_2 = (a_2 - k.d_{o,t})(f_u/f_y)$,k=61

$L_3 = L_v + a_1 + a_2$

$= 250 + 70 + 216{,}7$

$= 536{,}7\text{mm}$, should not be greater than $(L_v + a_1 + a_3 + n.d_{o,v}).({}^{f_u}/_{f_y}) = 736\text{mm}$

$L_{v,eff} = 250 + 70 + 61 = 381\text{mm}$

$$V_{eff,Rd} = \frac{\left(\frac{275}{\sqrt{3}}\right)x12{,}7x381}{1{,}05x10^3} = 731\text{kN} > 269{,}4\ kN \quad satisfactory\surd$$

Check Bearing Resistance of The Bolts

$$F_{b,Rd} = \frac{2{,}5.\alpha.f_u.d.t}{\Upsilon_{Mb}}$$

$\Upsilon_{Mb} = 1{,}35$

t=12,7mm

d=20mm ,α is the lesser of $\left(\frac{e_1}{3do}\right), \left(\frac{e_1}{3d_o} - \frac{1}{4}\right), \left(\frac{f_{ub}}{f_u}\right)$ or 1,0

p_1 is the bolt pitch=125mm

e_1 is the distance of a bolt from a free edge in the direction of the applied load. e_1=85,4mm

$$f_{b,Rd} = \frac{2{,}5x1x430}{1{,}35} = 796\ \text{N/mm}^2$$

$$\text{Limiting stress} \leq \frac{0{,}85(f_u + f_y)}{1{,}35}$$

$$\leq \frac{0{,}85(430 + 275)}{1{,}35} = 443{,}9\text{N/mm}^2$$

$F_{b,Rd} = (\text{limiting stress}).d.t$

$= 443{,}9x20x12{,}7/10^3$

$= 112{,}75\text{kN} > F_{v,sd}(56{,}4\text{kN})$

Chapter 5

Conclusion

In this project urban design of Barangaroo site will help make sustainable living area to recognize the opportunity to renew Brangaroo as a vibrant commercial and mixed use precinct with significant foreshore parkland.In addition the most efficient solutions are provided to the area with the publicly accessible ensuring integration and inclusion with Sydney city as a whole.These are the proposed light train system, new buses routes on Hickson Road, the scope of the completion of a 14-kilometre foreshore promenade connecting all city to the Barangaroo site.

For architectural design, the exhibition center is proposed on public domain area. Exhibition center in the public domain zone will attract many people because of the focal point of the site located near Headland park and waterfront. From the technological point of view, green roof with the smaller opening to provide skylight and glass façade providing daylight for interior part of center are some ideas to be taken into consideration in sustainable design.

For structural design of exhibition center, in order to cover big span for the center, the single-span half step-up truss roof has been used. The building has been divided into seven structurally sound parts by providing the required dilatations. Since we need a light weight structure, compared to the reinforced concrete it is chosen steel frame structure. The design choices, calculations and choice methods have been thoroughly calculated by hand and Sap2000 structural analysis program.

Chapter 6

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Chapter 7

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