Appendix A4.2
Spencer Dock Station Design Report

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Executive Summary

This report was prepared for DART+ West by IDOM Consulting, Engineering, Architecture, to document the Spencer Dock Station Preliminary Design.

In the Multi-Criteria analysis developed for Docklands Station and included in the Docklands Station Options Study Report (MAY-MDC-ARC-RS01-RP-A-0001), two options were assessed on location A (Docklands) and three options on location B (Spencer Dock).

As the MCA process results did not identify an option that clearly outperformed all other options, the option to be taken forward was selected by the NTA on a strategic basis. The option selected was Option B2, from now on called Spencer Dock Station.

This option was developed further in the Concept Design report (MAY-MDC-ARC-RS01-RP-A-0002), which is the basis of the station design.

The main issues that the Spencer Dock Station Design report will address are:

- The integration with the North Lotts SDZ planning scheme
- The integration with the transport network
- The urban regeneration
- The intermodality with the Luas and Bus systems
- The functionality of the station
- The materials and finishes
- The structural design
- The MEP design
- The sustainability approach

Abbreviations, acronyms and definitions

The following definition of acronyms and abbreviations shall apply within this document:

TERM	DEFINITION
ACB	Air Circuit Breaker
BEMS	Building Energy Monitoring System
BMS	Building Management System
B&F	Buildings and Facilities
CAF	Common Appraisal Framework
CIÉ	Córas Iompair Éireann (Ireland's National Public Transport provider)
DART	Dublin Area Rapid Transit
DCC	Dublin City Council
DCDP	Dublin City Development Plan
EMC	Electromagnetic Compatibility
EMDB	Essential Main Distribution Board
FE	Functional Earthing
GDA	Greater Dublin Area
GRC	Glassfibre Reinforced Concrete
GSWR	Great Southern & Western Railway
HVAC	Heating, Ventilation and Air Conditioning
IÉ	Iarnród Éireann / Irish Rail
IFSC	Irish Financial Service Centre
IRCC	Irish Rail Control Centre
JCBRA	Joint City Block Roll Out Agreement

MCA	Multi-Criteria Analysis
MDB	Main Distribution Board
MEP	Mechanical, Electrical and Plumbing
MGWR	Midlands Great Western Railway
NTA	National Transport Authority
LSF	Life Safety
OSD	Over Station Development
PE	Protective Earthing
ppmm	Passengers per minute per metre width
RC	Reinforced Concrete
SCADA	Supervisory Control And Data Acquisition
SET	Signalling Electrification and Telecoms
TER	Telecommunications Equipment Room
TGD	Technical Guidance Document
TSS	Train Service Specification
TSI	Technical Specifications for Interoperability
tphpd	Trains per hour per direction
TIW	Ticket Issuing Window
TVM	Ticket Vending Machine
WHO	World Health Organization
ZEB	Zero Energy Building

Codes and Standards

General Architectural

- Irish Building regulations. Technical Guidance Documents.
- CCE-TMS-312. Design Guidance Document for Accessibility of Railway Stations. TECHNICAL GUIDANCE NOTES. CCE DEPARTMENT. Iarnród Éireann. September 2020

Station design and sizing

- Station Design Guide. Iarnród Éireann. November 2004.
- Station Capacity Planning Guidance. Network Rail. November 2016.

Fire risk assessment

- Irish Building regulations. Technical Guidance Document. Part B. 2006
- Guidance for fire precautions on existing British rail surface stations. February 1993.

Accessibility

- The Disability Act: 2005;
- Irish Building regulations. Technical Guidance Document. Part M. 2010
- Technical Specifications for Interoperability (TSI) relating to accessibility of the Union's rail system for persons with disabilities and persons with reduced mobility (PRM)
- CCE-TMS-312 Design Guidance for Accessibility of Railway Stations

General MEP

- EN European Standards
- IEC International Electrotechnical Commission. Applicable if an EN does not exist for a specific matter.
- ISO International Standards. Applicable if any EN applicable for a specific matter does not exist.
- BS British Standards. Applicable if any EN and ISO applicable for a specific matter do not exist.
- IEEE Institute of Electrical Engineers. Applicable if an EN, IEC, ISO and/or BS do not exist for a specific matter.
- ETCI Electro Technical Council of Ireland. Guidelines.
- DIT Dublin Institute of Technology. Guidelines.
- BR Building Regulations Ireland.
- EEC Applicable Directives
- IS Insurance Institute of Ireland. If an EN IS exists for a specific topic it will be applied instead of the equivalent EN.
- CIBSE Chartered Institute of Building Service Engineers.
- Safety, Health and Welfare at Work Act 2005
- Any other requirements of the Industrial Inspectorate of the Department of Labour of the Irish Government.

Structure

General Standards:

- I.S. EN 1990:2002 (Eurocode 0) – Basis of the structural design.
- I.S. EN 1990:2002/A1:2005 (Eurocode 0) – Basis of the structural design.
- I.S. EN 1991-1-1:2002 (Eurocode 1, Part 1-1) – Actions on structures – General actions - Densities, self-weight, imposed loads.
- I.S. EN 1991-1-2:2002 (Eurocode 1, Part 1-2) – Actions on structures – General actions – Actions on structures exposed to fire.

Material Standards:

- I.S. EN 1992-1-1:2005 (Eurocode 2, Part 1-1) – Design of concrete structures – General rules and rules for buildings.
- I.S. EN 1992-1-2:2005 (Eurocode 2, Part 1-2) – Design of concrete structures – General Rules. Structural Fire Design
- I.S. EN 1993-1-1:2005 (Eurocode 3, Part 1-1) – Design of steel structures General Rules and rules for buildings.
- I.S. EN 1993-1-2:2005 (Eurocode 3, Part 1-2) – Design of steel structures. General Rules. Structural Fire Design
- I.S. EN 1996-1-1:2005 (Eurocode 6, Part 1-1) – Design of masonry structures. General Rules for reinforced and unreinforced masonry structures.
- I.S. EN 1996-1-2:2005 (Eurocode 6, Part 1-2) – Design of masonry structures. General Rules – Structural fire design.
- I.S. EN 1996-2:2006 (Eurocode 6, Part 2) – Design of masonry structures. Design considerations, selection of materials and execution of masonry.
- I.S. EN 1996-3:2006 (Eurocode 6, Part 3) – Design of masonry structures. Simplified calculation methods for unreinforced masonry structures.

Earthquake Standards:

- I.S. EN 1998-1:2004 (Eurocode 8, Part 1) – Design of structure for earthquake resistance – General rules, seismic actions and rules for buildings.

Geotechnical Standards:

- I.S. EN 1997-1:2004 (Eurocode 7, Part 1) – Geotechnical Design – General rules.

Irish Building Regulations:

- Technical Guidance Document A. Structure 1997 (2005).

Firefighting

- BR doc. B Fire safety
- EN 3 Portable fire extinguishers
- BS 5306 Fire extinguishing installations and equipment on premises

HVAC

- BR doc. F Ventilation
- BR doc. L Conservation of fuel and energy - buildings other than dwellings
- CIBSE Guide B Heating, ventilation, air conditioning and refrigeration
- CIBSE Guide J Weather, solar and illuminance data
- CIBSE TM 21 Minimising pollution at air intakes

Public Health

- EN 12056 Gravity drainage systems inside buildings
- BR doc. G Hygiene
- CIBSE Guide G Public health engineering
- CIBSE Guide W Water distribution systems
- Joint HSE and DoH Working Group on legionellosis HSG (92)45 – November 1992
- HPSC National Guidelines for the control of legionellosis in Ireland, 2009-10-06
- NDSC The Management of Legionnaires' Disease in Ireland.
- HTM 04-01 and HTM 2027" Recommendations for the Prevention of Legionella"
- Solar Heating Design and Installation Guide

Gas

- IS 820 Non-domestic gas installations

Electrical Installation design

- EN 60364 Electrical installations for buildings
- BS 7671 Requirements for electrical installations. IET Wiring Regulations

Earthing&Bonding and lightning

- BS EN 62305 Protection against lightning
- BS 7430 Code of practice for protective earthing of electrical installations
- EN 50522 Earthing of power installations exceeding 1 kV a.c.
- EN 50122-1 Railway applications – Fixed installations – Electrical safety, earthing and the return circuit – Part 1: Protective provisions against electric shock
- EN 50162 Protection against corrosion by stray currents from D.C. systems
- EN 50310 Application of equipotential bonding and earthing in buildings with information technology equipment
- IEC 61000-5-2 Electromagnetic Compatibility (EMC) – Part 5: Installation and mitigation guidelines – Section 2: Earthing and cabling
- IEEE 80 IEEE Guide for Safety in AC Substation Grounding

Electrical Installations

- ET 101:2008 National Rules for Electrical Installations & Amendments (2011, 2016)
- EN 60364 Electrical installations for buildings
- BS 7671 Requirements for electrical installations. IET Wiring Regulations
- EN 61439-1 Low-voltage switchgear and control gear assemblies.

Lighting

- IS EN 12464 Light and Lighting, Lighting of Workplaces; (all parts)
- CIBSE – The SLL Code for Lighting, (current edition), and applicable CIBSE / SLL Lighting Guides, (LG1 to LG12).
- ErP Directive (European Union Energy Related Products). Luminaire operating devices.
- ET 101:2008 National rules for Electrical Installations
- EN 13201-2:2003 Road Lighting Performance Requirements
- CIE 115-2010 Lighting of Roads for Motor and Pedestrian Traffic
- CIE 126-1997 Guideline for minimising skyglow
- CIE 150-2003 Guide of limitation of the obtrusive light from outdoor installations
- BR - L2 Lighting
- ETCI Part 714 Reference document for Public Lighting Installations

Emergency lighting

- IS 3217 Code of Practice for Emergency Lighting Installations
- IS EN 1838 Lighting applications – Emergency lighting.
- IS EN 50171 Central power supply systems
- IS EN 50172 Emergency escape lighting systems.
- IS EN 62034 Automatic test systems for battery powered emergency escape lighting
- IS EN 60598-2-22 Luminaires for emergency lighting
- CIBSE LG12 Emergency Lighting Guide

Stray currents

- BS 7631 Cathodic protection. Code of practice for land and marine applications
- EN 50122-1 Railway applications – Fixed installations – Part 1: Protective Provisions Relating to Electrical Safety and Earthing
- EN 50122-2 Railway applications – Fixed installations – Electrical safety, earthing and the return circuit – Part 2: Provisions against the effects of stray currents caused by D.C. traction systems

- IEC 62128-2 Railway applications - Fixed installations - Electrical safety, earthing and the return circuit - Part 2: Provisions against the effects of stray currents caused by d.c. traction systems.
- EN 50162 Protection against corrosion by stray current from direct current systems

Fire alarm

- EN 54 Fire detection and fire alarm systems
- EN 3218 Code of practice for fire alarm systems (where EN 54 is not defined)
- CIBSE GUIDE E Fire Engineering

SCADA

- CIBSE Guide H Building Control Systems
- Automatic Controls Application Manual Commissioning Code C – Automatic Controls
- Applications Handbook Vols 1 & 2 Guide to BEMS Centre Standard Specification
- SMG 90c. HVCA 1992. Standard maintenance specification

1. Introduction

Spencer Dock station is part of the DART+ Programme[1], a transformative programme of projects which aims to modernise and improve existing rail services in the Greater Dublin Area (GDA). It will provide a sustainable, electrified, reliable and more frequent rail service to improve capacity on the rail corridors serving Dublin.

The DART+ Programme is included within the following Government policy strategies:

- The National Development Plan 2018-2027;

- Transport Strategy for the Greater Dublin Area 2016-2035; and

- The Climate Action Plan 2019.

Passenger capacity and train service frequency will be significantly increased as a result of the project. This will help to deliver a more efficient transport system, allowing more people to travel to more places in a sustainable way. The DART+ Programme will provide a viable, sustainable alternative to private car use, therefore helping users reduce their carbon footprint.

The DART+ Programme is a programme of work comprising several constituent projects to create a full metropolitan DART network with all lines linked and connected. Docklands station is part of the DART+ West.

It comprises of, inter alia, the following actions:

- Electrification of the Maynooth line from City Centre to Maynooth (40km approx.).

- City Centre enhancements at Connolly (platforms, junctions & station modifications) to increase train numbers per hour.

- The relocation of Docklands Station to a location adjacent to Spencer Dock Luas Stop to better serve all routes entering the City Centre.

1.1 Context and site

1.1.1 Dublin City Development Plan 2016-2022

Spencer Dock Station is aligned with the strategic approach of the Dublin City Development Plan 2016-2022.

One of the principles of the plan is achieving a more sustainable and resilient city by creating a connected and legible city based on active streets and quality public spaces with a distinctive **sense of place**. Placemaking is particularly important in the strategic development and regeneration areas (SDRAs).

Spencer Dock Station is placed within the **North Lotts & Grand Canal Dock** strategic development zone (SDZ) in the strategic development and regeneration area (SDRA) 6 established in the Dublin City Development Plan 2016-2022 (see figure below).

[1] Information obtained from DART Expansion brochure 17th August 2020.

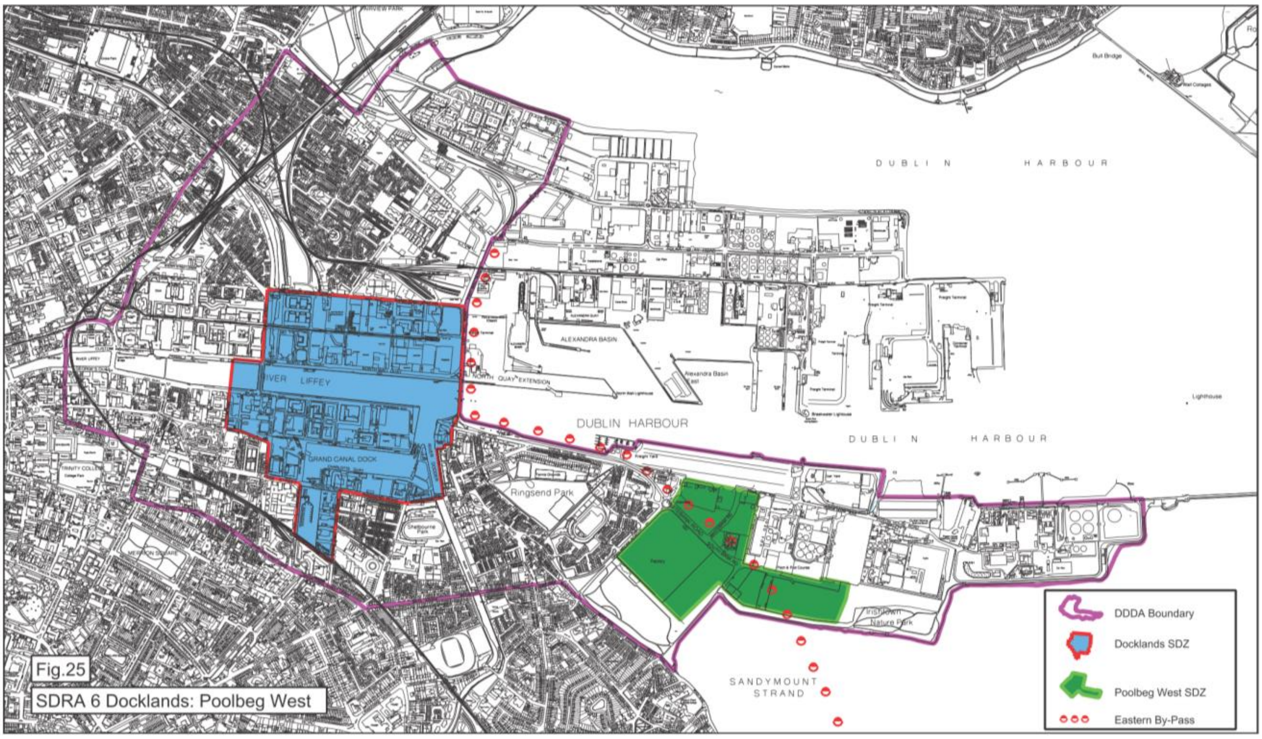


Figure 1. SDRA 6. Docklands. Poolbeg West. Dublin City Development Plan 2016-2022

The new Spencer Dock Station will play a key role in improving citizens wellbeing and enhancing life, thus meeting the DCDP 2016-2022 vision goals. The project will reduce car use and traffic congestion, and it will also improve the quality of the city environment. These improvements should encourage the use of the public transport network. The connection of DART+ West with the Luas system at Spencer Dock will provide a more equitable city.

1.1.2 North Lotts & Grand Canal Dock SDZ Planning Scheme

Spencer Dock Station is integrated into the North Lotts and Grand Canal Dock Planning Scheme 2014. The publication of the Planning Scheme sets the ambition for the redevelopment of the Docklands Strategic Development Zone (SDZ) as “a model of sustainable inner-city regeneration incorporating socially inclusive urban neighbourhoods, a diverse, green innovation economy contributing to the prosperity of the locality, the city and country, all supported by exemplary social and physical infrastructure and a quality public realm integrated with the wider city.”

The North Lotts & Grand Canal Dock Planning Scheme establishes five main hubs in the SDZ. One of these is located at Spencer Dock.

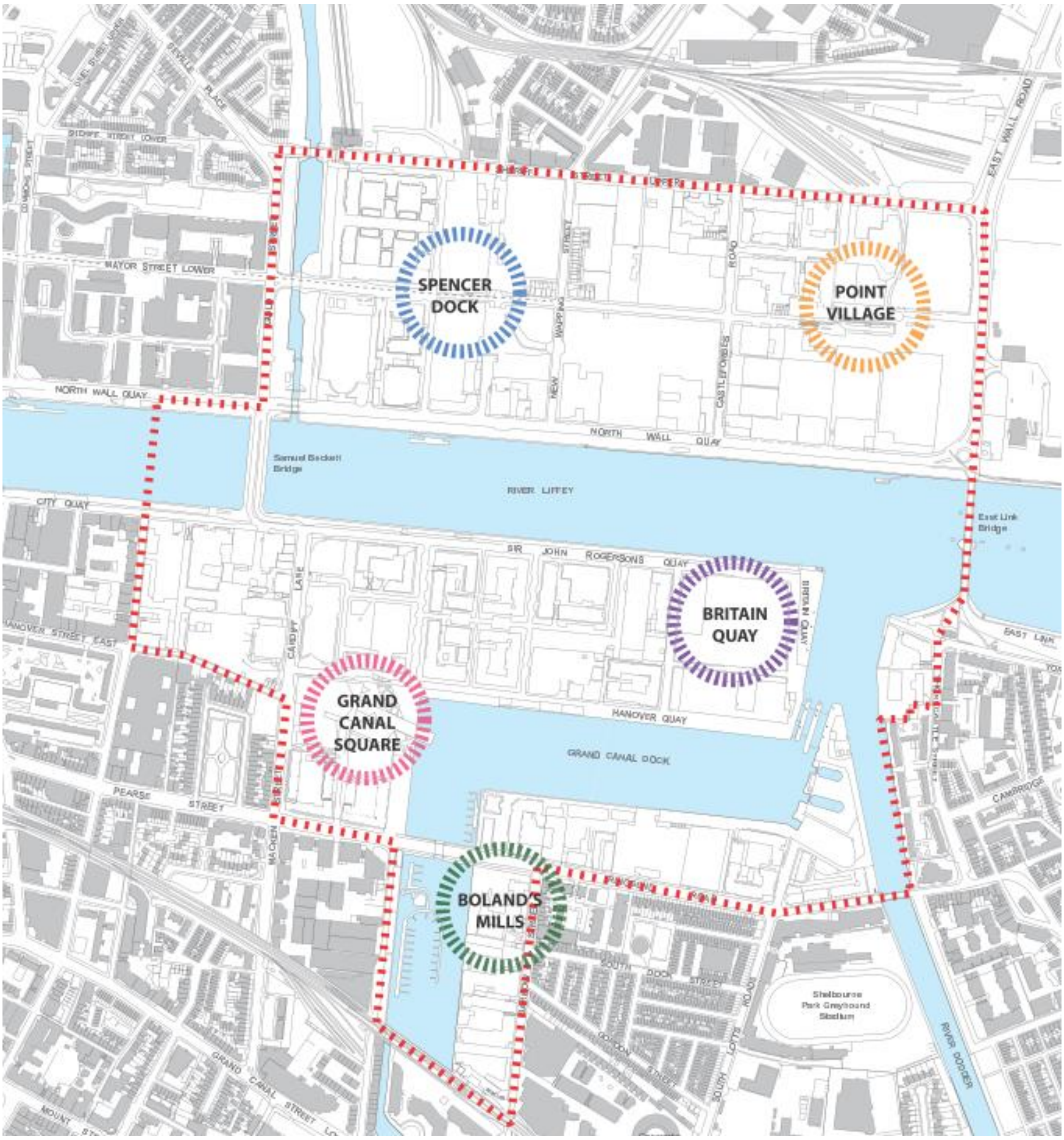


Figure 2. The Hubs. North Lotts and Grand Canal Dock Planning Scheme 2014

The objective for the SDZ Planning Scheme is that all of the hubs achieve their own character through a combination of mixed-use, landmark buildings, significant open space and a unique public realm.

ROLE OF SPENCER DOCK HUB

Even more so than The Point Village Hub, Spencer Dock Hub has a City and Regional role outside of the footprint of the SDZ. The key aspects of this role include:

- Primary economic driver; this is where the big floor-plates could cluster in a 'Business District'.
- Transport role connected to the regional network.

- The combination of economic role and transport role is likely to be reflected in some element of increased intensification and scale.

- Home to Convention Centre Dublin and the synergies that this brings in the future.

CITY BLOCK 2

Spencer Dock Station is located in the west part of **City Block 2 (blocks 2A and 2C).** North Lotts and Grand Canal Dock SDZ Planning Scheme describe the main objectives for this plot:

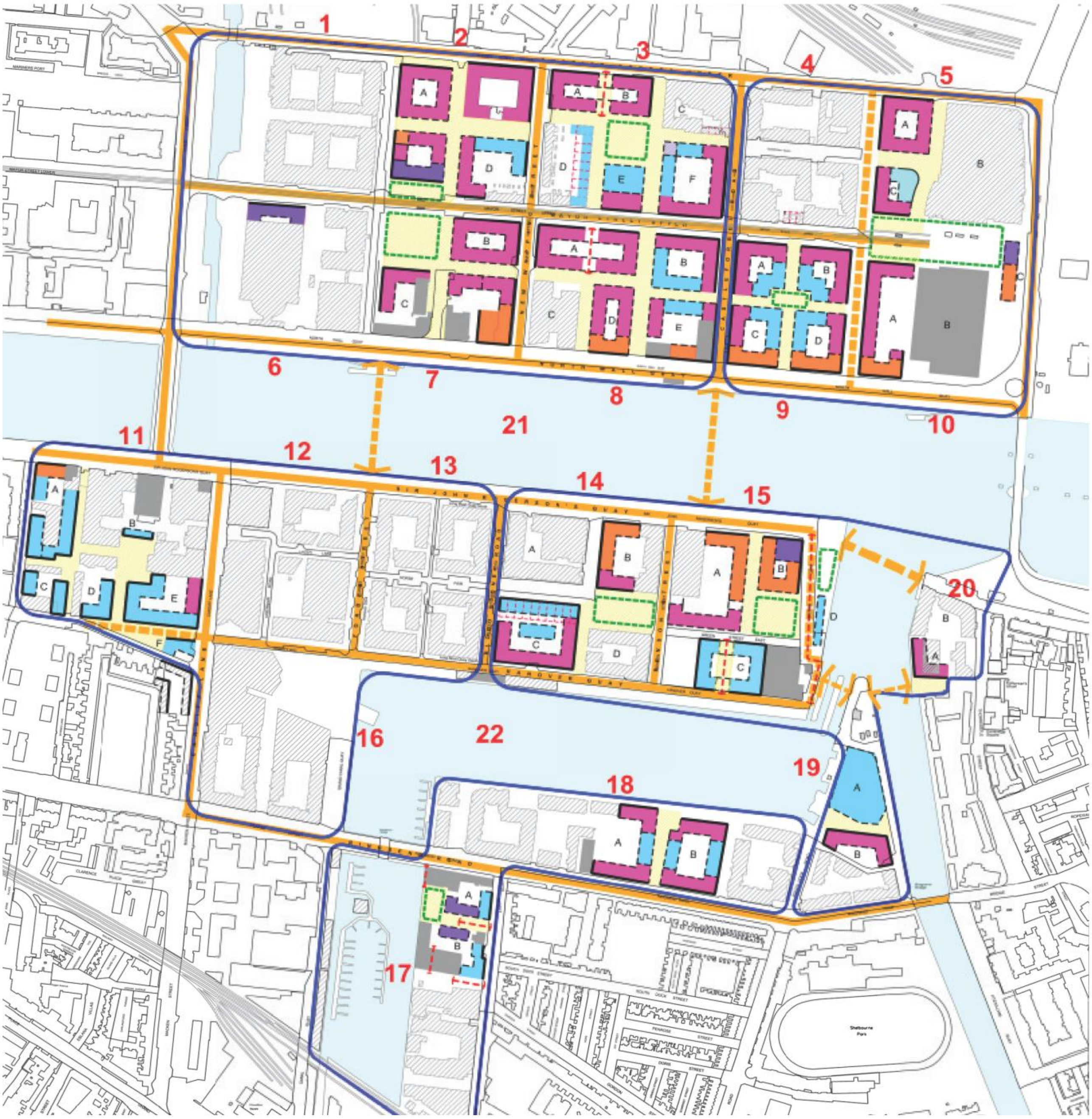


Figure 3. Development code for City Blocks. North Lotts and Grand Canal Dock Planning Scheme 2014

- 40 Residential / 60 Commercial mix-use over the City Block.

- Commercial uses to be concentrated on 2C, fronting Station Square, and west side of 2D to form a commercial hub at confluence of Luas line and DART Inter-connector.

- Residential to be concentrated to east side of 2D.
- Blocks 2A and 2C on DART Underground line shall be used as location for temporary pavilion structures.
- Ground floor active uses to be provided fronting Station Square.
- Block 2C to be a 12 storey commercial building and remaining blocks to range between 5 storey commercial / 6 storey residential and 6 storey commercial / 7 storey residential. According to the "Review of Building Height & Proposed Amendments to North Lotts and Canal Dock Planning Scheme" published in October 2019, the remaining blocks could go up to 10 residential storey / 8 storey commercial at some points, as illustrated in the image below. The amended scheme is under review and has not yet been approved.

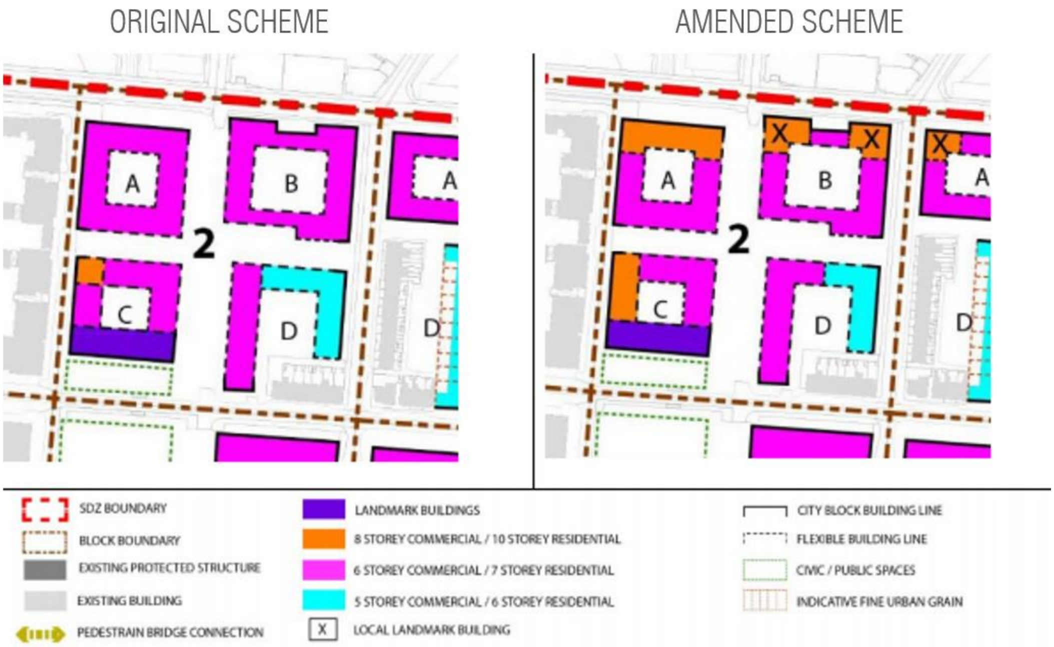


Figure 4. Review of Building Height & Proposed Amendments to North Lotts and Canal Dock Planning Scheme

- City Block 2 is to include East-West street linking existing pedestrian street in STUV block to New Wapping Street approximately mid-way along the block.
- City Block 2 to include landscape plaza fronting Block 2C to provide for an attractive space adjacent to the Luas stop.

JOINT CITY BLOCK ROLL OUT AGREEMENT (JCBRA)

According to the North Lotts Planning scheme, City block 2 shall be 40 Residential / 60 Commercial mixed-use over. However, following the Planning application submitted for the City Block 2 (DSDZ259020), 2B and 2D Blocks will be converted into fully residential use, while 2A and 2C (where Spencer Dock Station is located) remain commercial.

The JCBRA was submitted on March 2020 in respect of Block 2 and 7 Spencer Dock, prepared by John Spain Associates, on behalf of Spencer Place Development Company Limited. This JCBRA revises the land use mix location within Blocks 2 and 7 to facilitate a full residential scheme within Block 2B and 2D. As a consequence, blocks 2A and 2C will have full commercial use.

EXISTING CONTEXT

The existing context of the development includes the residential development at City Block 1, located to the west of the site as well as the Spencer North residential blocks located to the east within City Block 2.

City Block 1, STUV. Built

City Block 2B & 2D, Spencer North. Underconstruction

City Block 7, Spencer Place. Underconstruction

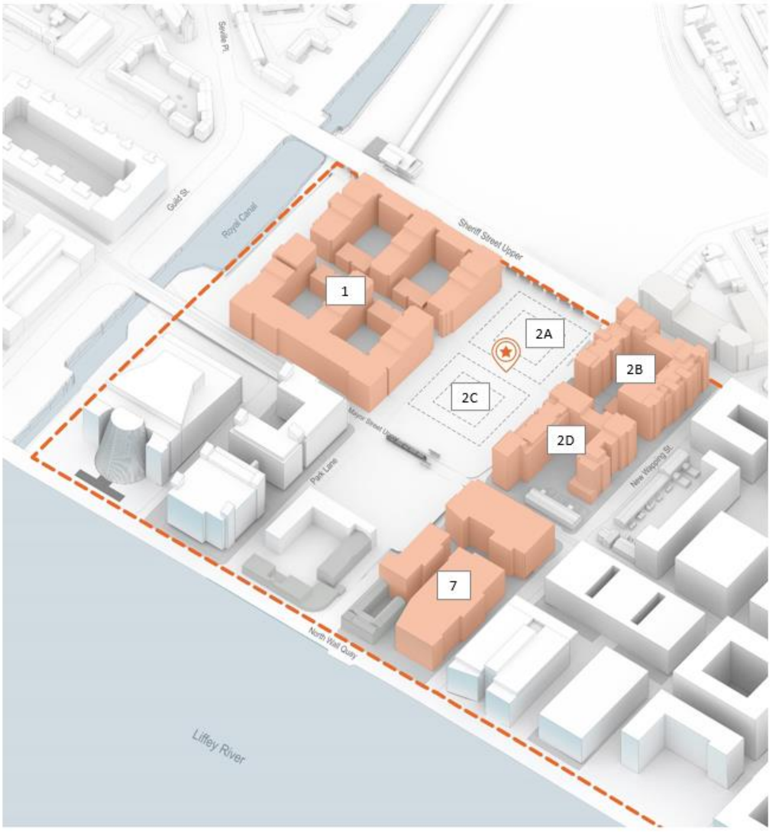


Figure 5. Spencer Dock Station. Existing context

The North Lotts & Grand Canal Dock Planning Scheme also describes the distance requirements of the streets and public spaces:

• East-west street linking existing pedestrian street in STUV block to New Wapping Street approximately mid-way along the block. (Laneway: 10-14 metres wide).

• North-south street mid-way along block linking Sheriff Street Upper with Mayor Street and Station Square. (Local Street: 14-18 metres wide).

• A landscaped plaza fronting the new station.

The requirement for the new streets/lanes and civic spaces are fixed, and their location and general alignment indicated are fixed on the Overall Development Code.

The precise alignment of the new lanes and streets shall form part of the City Block Rollout Agreement, in order to guide subsequent planning applications.

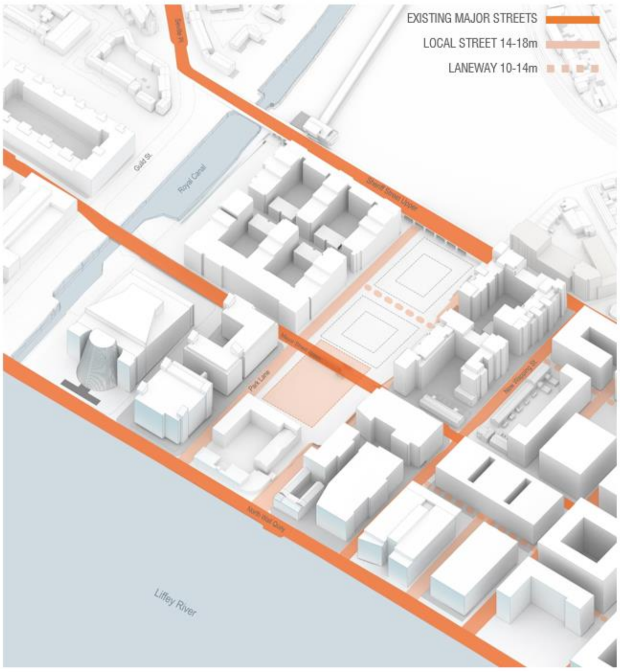


Figure 6. North Lotts and Canal Dock SDZ Block 2 streets and laneways

DART UNDERGROUND

There is an existing project to locate at Spencer Dock a station of the future DART Underground line and to convert the plot that is north of Sheriff Street Upper in the portal tunnel for the TBM during the construction phase of the project.

As advised by Iarnród Éireann, the DART Underground project has not been considered in the development of the design for Spencer Dock Station.

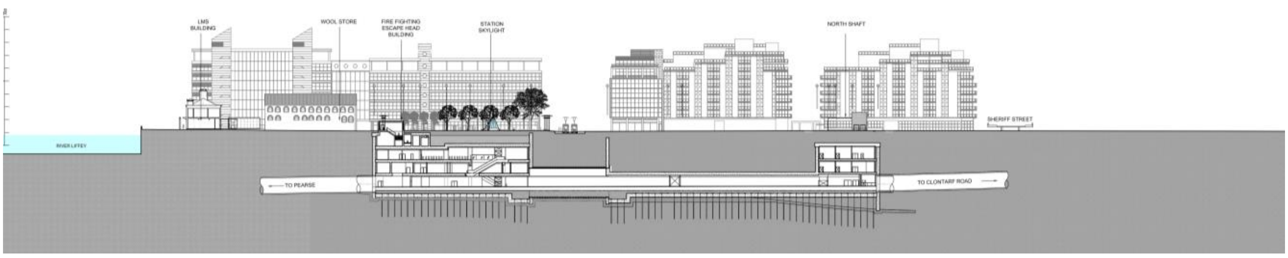


Figure 7. DART Underground station project. Longitudinal section

1.1.3 Integration with the transport network

Spencer Dock Station will have a wide variety of public transport services and pedestrian/cycling facilities in the vicinity: Luas, Bus services, as well as a bicycle parking, making the site highly accessible by more sustainable means of transport.

The figure below illustrates the potential for DART+ commuter and Luas tramway integration. The illustration serves to highlight the significant value of maximising the potential for interchange between railway lines and modes of transport in the Docklands Development Area.

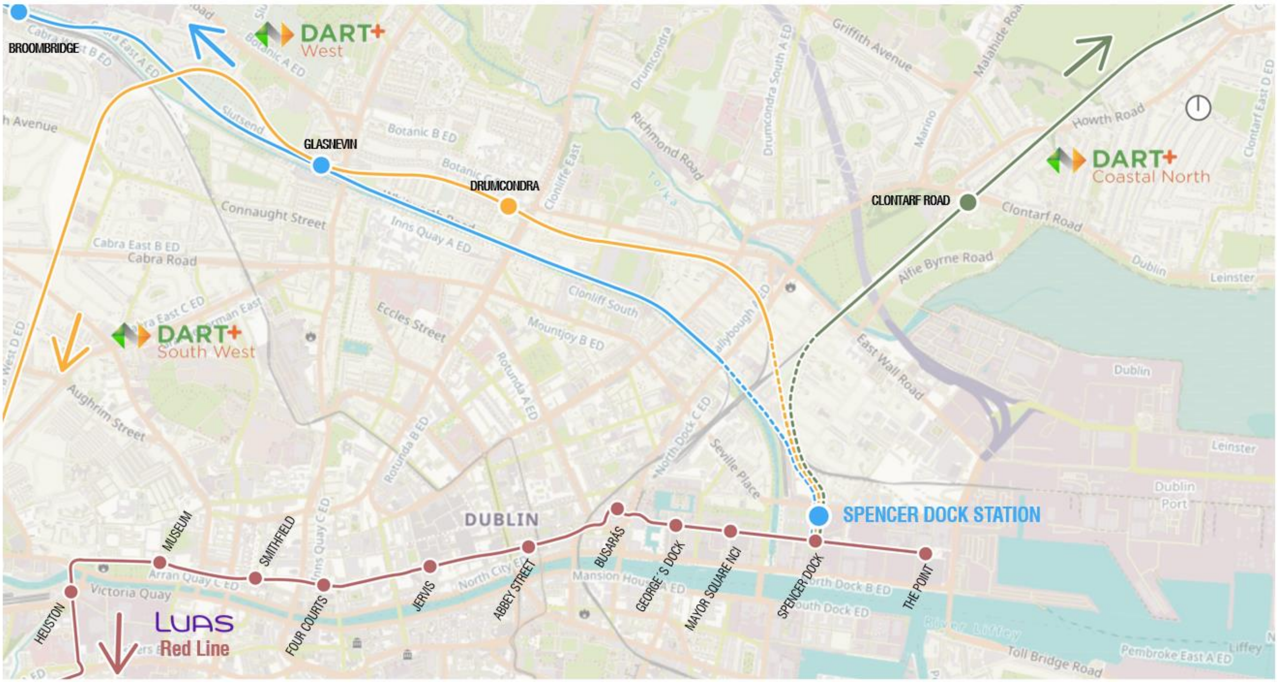


Figure 8. Integration of Spencer Dock station with Dublin transport Network

LUAS

The Luas Red Line commenced operation in 2004, introducing the light rail services from Connolly Station to Tallaght and serving the city centre, Heuston Station, a number of hospitals and residential areas in the south-west of Dublin. The Red Line has provided a new high capacity public transport link and has contributed to a significant increase in the proportion of people travelling to and from Connolly by rail. The Luas is so well used that a programme to extend the Red Line trams by 10 metres was initiated to provide an additional 40% passenger capacity.

The Luas Red Line has one stop at Spencer Dock in the location where the new DART+ station will be placed, thus easing the connection of the railway system with Dublin city centre.

BUS

There are several Dublin Bus stops operating in the area. The routes serving the stop on Sheriff Street Upper are detailed below:

ROUTE	DESCRIPTION
151	From Docklands (East Rd.) To Foxborough (Balgaddy Rd.)
903	North Wall, The Green Room - Dundalk (County Louth Hospital)

Figure 9. Dublin Bus routes stopping at Sheriff Street Upper

BICYCLES

There is a covered parking area for 60 bicycles at Spencer Dock to the south of the Luas station. The inclusion of the DART+ station in the area will increase the demand for bicycle parking in the area. The enlargement of the existing parking is contemplated in the DART+ West project with the addition of 120 new parking spaces.

PEDESTRIANS

With regard to pedestrians, there are good quality footways with dedicated pedestrian crossing facilities at all major junctions near the station, and there are numerous bridges providing pedestrian access across River Liffey, including the Samuel Beckett and Sean O'Casey bridges.

1.1.4 Cultural and industrial heritage

The North Lotts and South Lotts where the Grand Canal Docks are situated were largely developed during the eighteenth century. New land was reclaimed in stages from the Liffey estuary as the city's expansion moved eastward beyond the Royal and Grand canals. Dublin's modernising economy demanded a new port for the import and export of goods as well as space for industrial development. Gasometres, chemical and cotton factories sprung up to respond to the needs of a quickly expanding population, as well as for trade with Britain and worldwide. The wide streets of the North Lotts were used to shuttle cargo back and forth from the factories to the docks. The Campshires were wide undesignated open spaces along the quays, populated with cranes and the bustle of dock workers moving goods to and from the ships. During this time, the East Wall formed the boundary of the city and the sea; Ringsend remained a fishing village at the mouth of the estuary until the tidal flats were in filled to form the South Lotts. The geographical trend in port cities has been progressive, in Dublin's case, easterly development of the docks over time, which results in the creation of a zone of transport and industry between the city and the sea. A 1693 map shows a broad sweep of the Liffey and Dublin Bay beginning just east of what is now O'Connell Bridge, with mud-flats and sand-banks making the maritime approach to the city difficult. The absence of a natural harbour in Dublin by the late seventeenth century had become a preoccupation of both merchants and the city fathers, and artificial quays such as 'Wood Quay', 'Blind Key' and 'Customs House Key' were constructed during this period. The idea of re-engineering and straightening the Liffey's braided banks so that it would scour a deep but narrow navigation channel took hold at the beginning of the eighteenth century.

(Source: PUBLIC REALM MASTERPLAN for the NORTH LOTTS & GRAND CANAL DOCK SDZ PLANNING SCHEME 2014)

Figure 10. Image taken from *The Port of Dublin, Official Handbook* (Dublin, Wilson Hartnell, 1926).

The vibrant transport hub, the most important on the island, was formed when the canal and road system was later extended to include rail and road networks to create a fully operational docklands for the city.

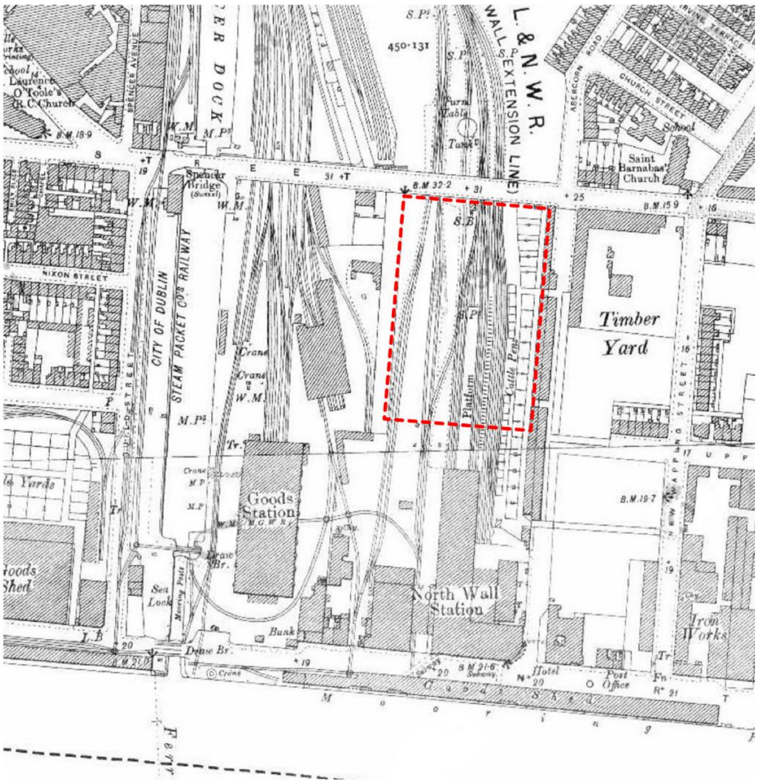


Figure 11. Historic map (1888-1913). Image taken from map.geohive.ie. Spencer Dock Station plot marked off with a red dashed line

1.1.5 Urban regeneration. The site

The plot has an approximate area of 1.1 hectares, and it is bounded by Sheriff Street Upper to the north, Mayor Street Upper to the south, Park Lane to the west and a 'New Street' running north-south proposed in the Spencer North new development.

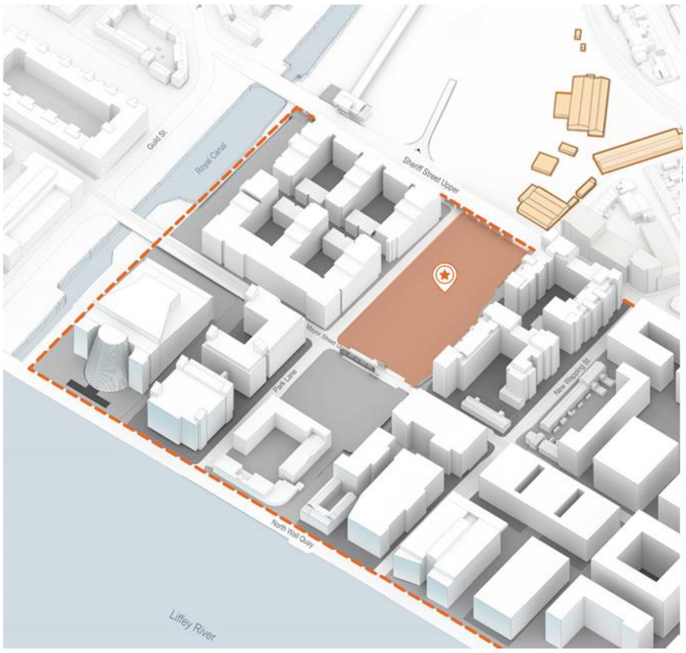


Figure 12. Location of the plot within the North Lotts and Grand Canal Dock SDZ Planning Scheme

Major Street is approximately at level +3.00 m. The plot has a slope down towards Sheriff Street Upper, with a level of +0.30 m below the overbridge.

Figure 13. Longitudinal section of the plot

The majority of the site is owned by CIÉ, as represented with a green hatch in the figure below. It includes Mayor Street Upper and Sheriff Street Upper bridge, including the land it is on. The unhatched area to the north-east of the plot is a land parcel still in the ownership of Spencer Dock Development Company Limited, previously acquired from Green Sunrise Waste management.

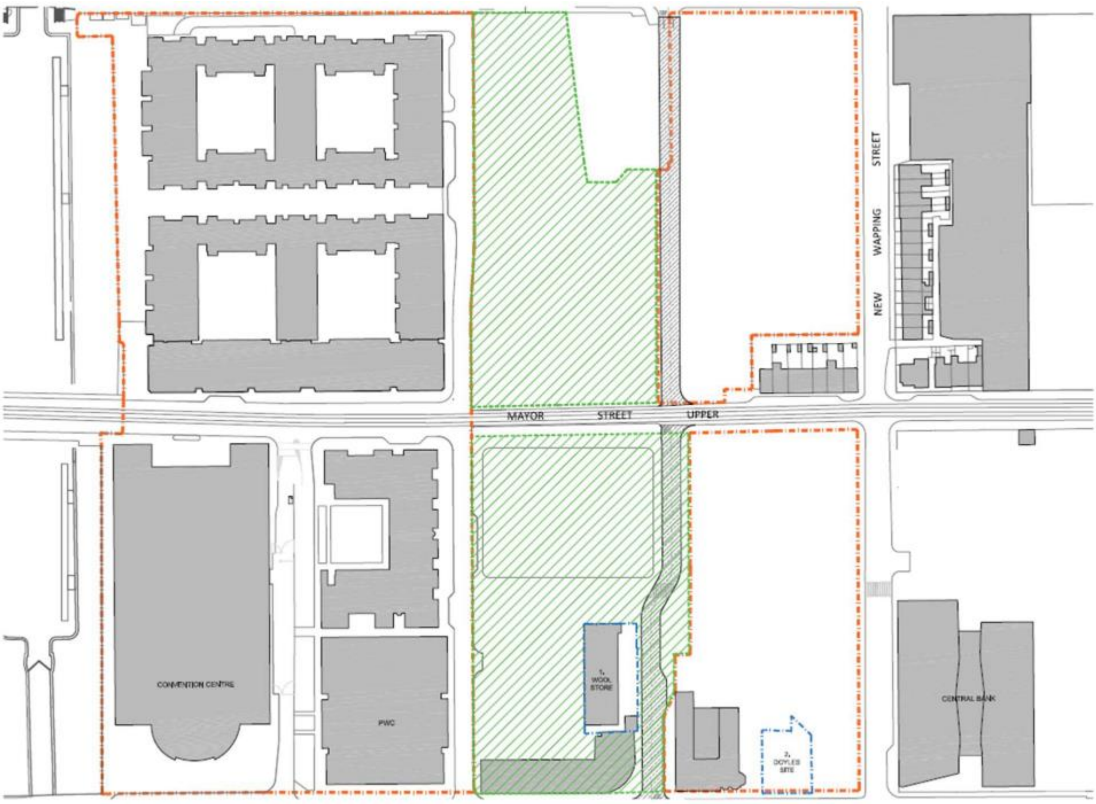


Figure 14. Extract of Spencer Dock MDA Lands - Overall boundary site plan

The new Spencer Dock Station will provide a smooth, safe and seamless access to the planned new developments and the major areas of interest in the North Lotts area.

The new hub will have its epicentre in the public space facing the Spencer Dock Station entrance. This public space will be a combination of economic and transport role (as an interchange between Luas, DART, cycle and pedestrian routes) and the synergies that this brings in the future.

The figure below provides detail on commercial residential and public services planned or present in the immediate vicinity of the proposed station.

Figure 15. Main buildings located close to Spencer Dock Station

2. Station design

With the aim of achieving a high-level passenger experience, a state-of-the-art station is proposed with two key ideas:

- To foster interchange with other means of transport. The connection with Spencer Dock Luas Station will be the most important one, but there will also be direct access to buses, to a cycle parking, and to a drop-off for cars and taxis.
- To provide a seamless connection between the city and the platforms, thus achieving a safe and pedestrian-friendly passenger experience.

Figure 16. Sketch of the station's main entrance

Spencer Dock Station has been designed with two island platforms serving four tracks. The size of the platforms and the station facilities provide a significant capacity to the station.

2.1 Integration with the North Lotts and Grand Canal Dock SDZ Planning scheme

Spencer Dock Station provides good integration with the surrounding buildings by aligning the platform of the station to the North Lotts planning scheme gridlines. This alignment also makes the layout more compatible with the structure of the buildings above. The platforms need to be pushed south by lowering the top of rail level so the tracks can pass under the Sheriff Street Upper overbridge and the Spencer Dock Plaza with sufficient structural and OHLE clearance. The resulting level for the platforms is -2.39 metres.

Sheriff Street Upper overbridge must be altered over the proposed station to accommodate the new track layout.

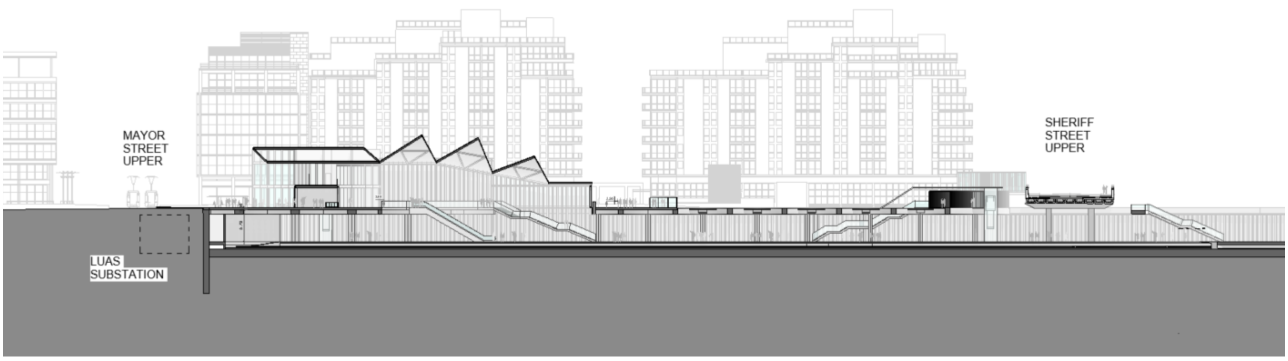


Figure 17. Schematic section of the station

Access to the proposed station is located fronting Spencer Dock Luas station, thus fostering the interchange between the DART and the Luas. The access to the station is placed at a prime urban location due to the existence of the Spencer Dock plaza acting as an urban hall for the station.

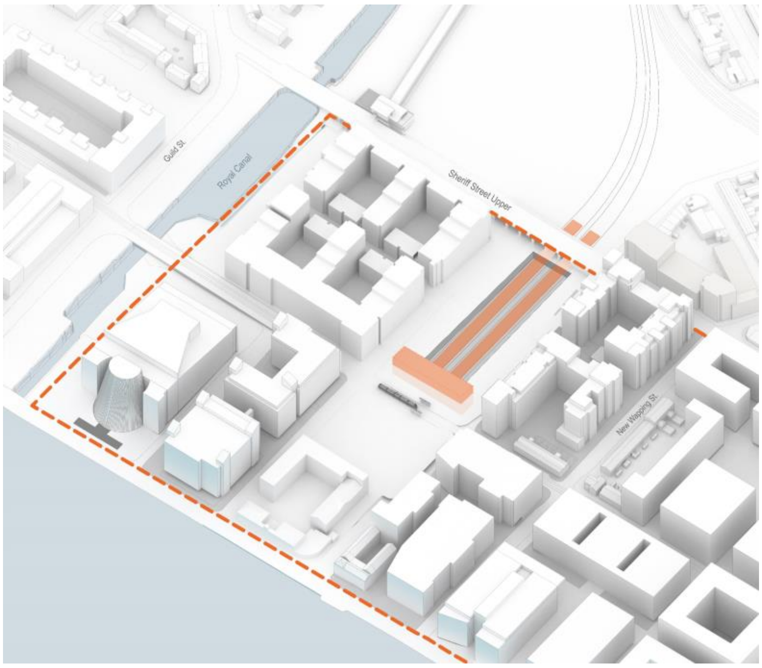


Figure 18. Graphic Representation of the proposed station

The construction of the two building blocks (2A & 2C) described in the North Lotts planning scheme is compatible with the stations' layout. The landmark building and the building fronting Sheriff Street Upper would need to have challenging structures to avoid locating any support in the footprint of the station.

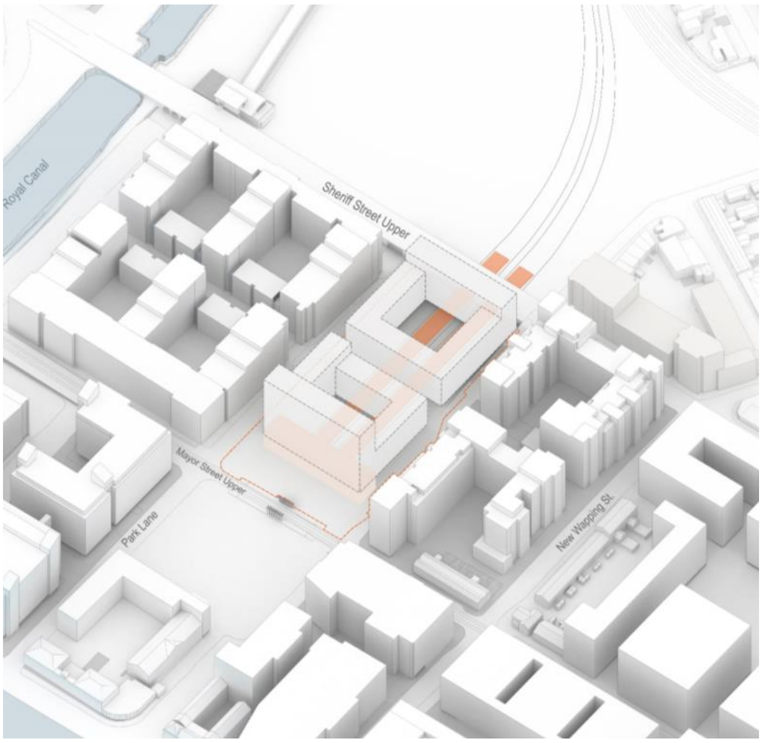


Figure 19. Graphic representation of proposed station including the OSD

The design and construction of the Over Station Development (OSD) is out of the DART+ West scope. The proposal shown in this report presents the OSD for a complete understanding of the works that will be needed to develop the site optimally.

The alignment of the station is based on the North Lotts and Grand Canal Dock planning scheme. A possible configuration of the Over Station Development, integrated with the station design, is represented below, together with the alignments of the different levels of the station.

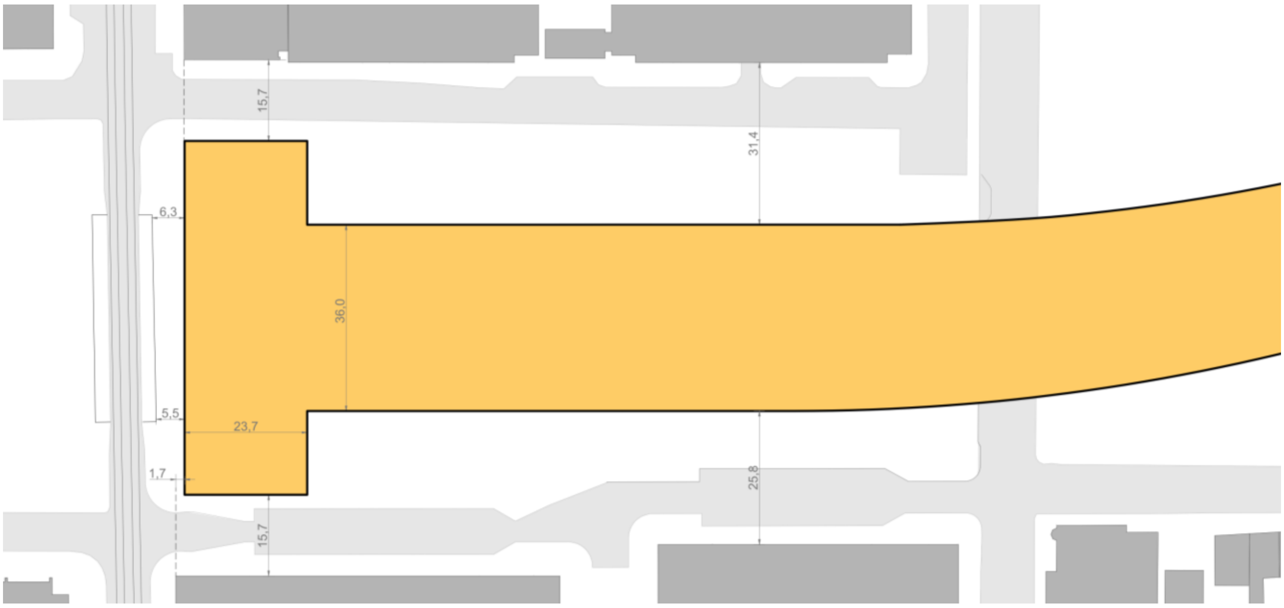


Figure 20. Spencer Dock Station alignments. Below ground station footprint.

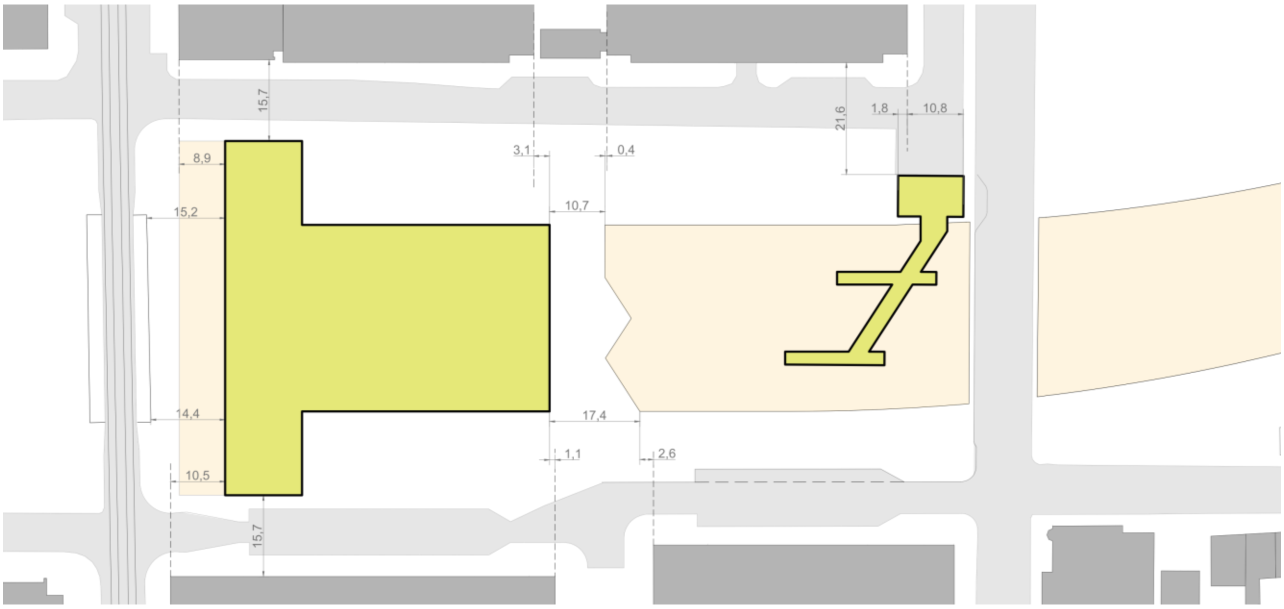


Figure 21. Spencer Dock Station alignments. Above ground station footprint

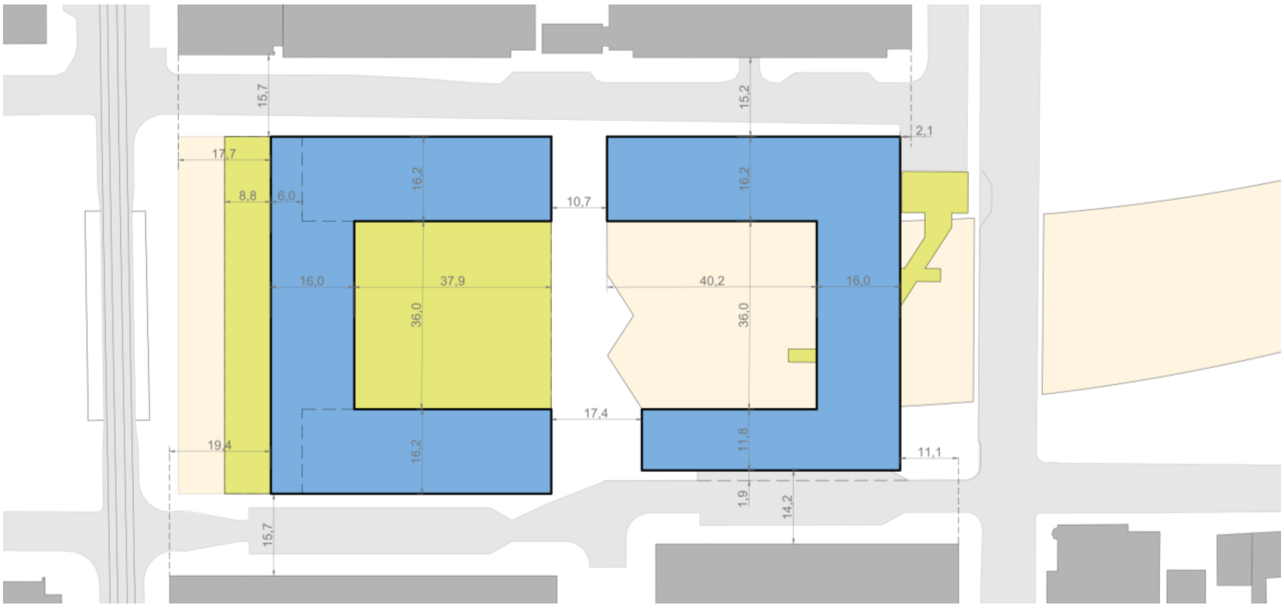


Figure 22. Dimensions and alignments of a possible configuration of the OSD (blue) integrated with the station design (green).

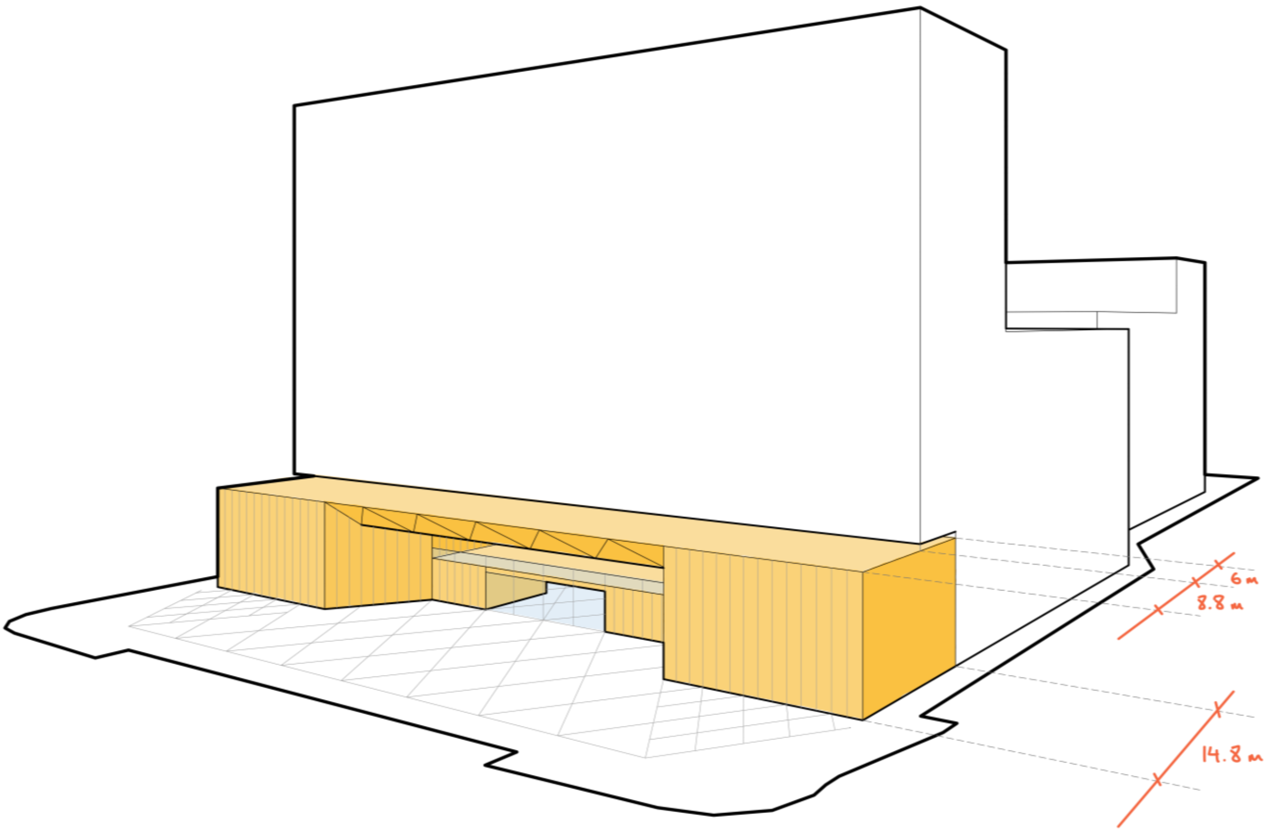


Figure 23. Dimensions of the alignment of the station with the alignment of the future landmark building.

An intermediate pedestrian laneway will be constructed between blocks 2A and 2C of the planning scheme to give continuity to the pedestrian laneways existing in the surrounding blocks.

INDEPENDENT STATION AND OSD STRUCTURES

The future overhead structure design can be found within the areas on either side of the proposed platforms, thus minimising the interference between the structure of the station and the structure of the overhead structure design buildings.

This approach has some important consequences:

- It allows the construction of the station structure independently of the future Over Station Development structure.
- The future OSD structure will need to be solved with two bridges over the station. One of the bridges needs to support ten levels and the other one eight levels. The distance between the cores at both sides of the station entrance will need to have a structural span of more than 36 metres.

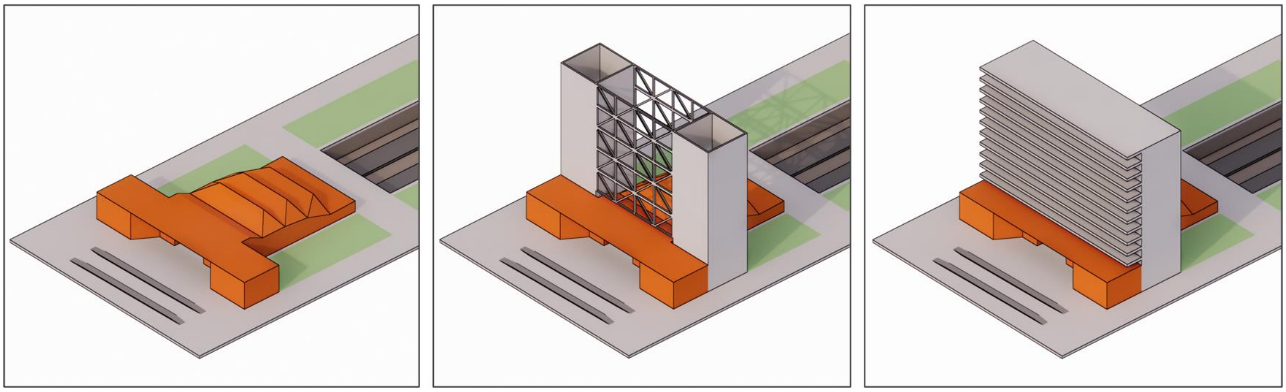


Figure 24. Schematic representation of the landmark building structure that will be needed to bridge the station entrance

The part of the station corresponding to Block 2A of the North Lotts planning scheme will not be covered as part of the station project, except for the area corresponding to the platforms, which will be covered to protect the passengers from the rain. A structural provision of columns and beams will be constructed to reduce the size of the retaining walls and the depth of the piling. This structural provision would ease the construction of a plaza between buildings in the case that the Over Station Developers are required to cover that space. Also, the drainage provision for the platform canopies will be oversized to collect the rainwater of all the areas of the plaza.

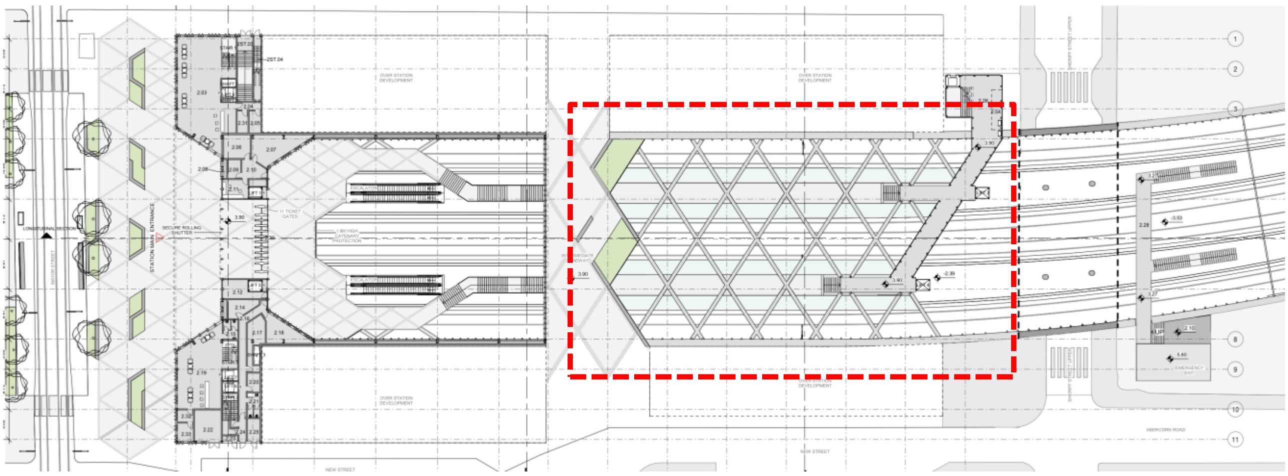


Figure 25. Area corresponding to Block 2A of the North Lotts planning scheme

2.2 Intermodality and accesses

One of the main objectives of moving the station from Docklands to Spencer Dock is to foster pedestrian accessibility and intermodality with other means of transport.

The station is proposed with two entrances:

- The **main entrance** is at Mayor Street Upper, fronting the Spencer Dock Luas Station. This access will receive the greatest passengers flow due to the intermodality with the Luas station, the proximity of significant pedestrian flows and the existence of a covered cycle parking.
- The **secondary entrance** is placed at Sheriff Street Upper. It is much easier to access this point by road users than to enter the North Lotts and get to Mayor Street Upper. This access will receive the passengers coming to the station by taxi, private cars and, especially, by bus. There is an opportunity to increase the number of spaces for buses to stop at this location.

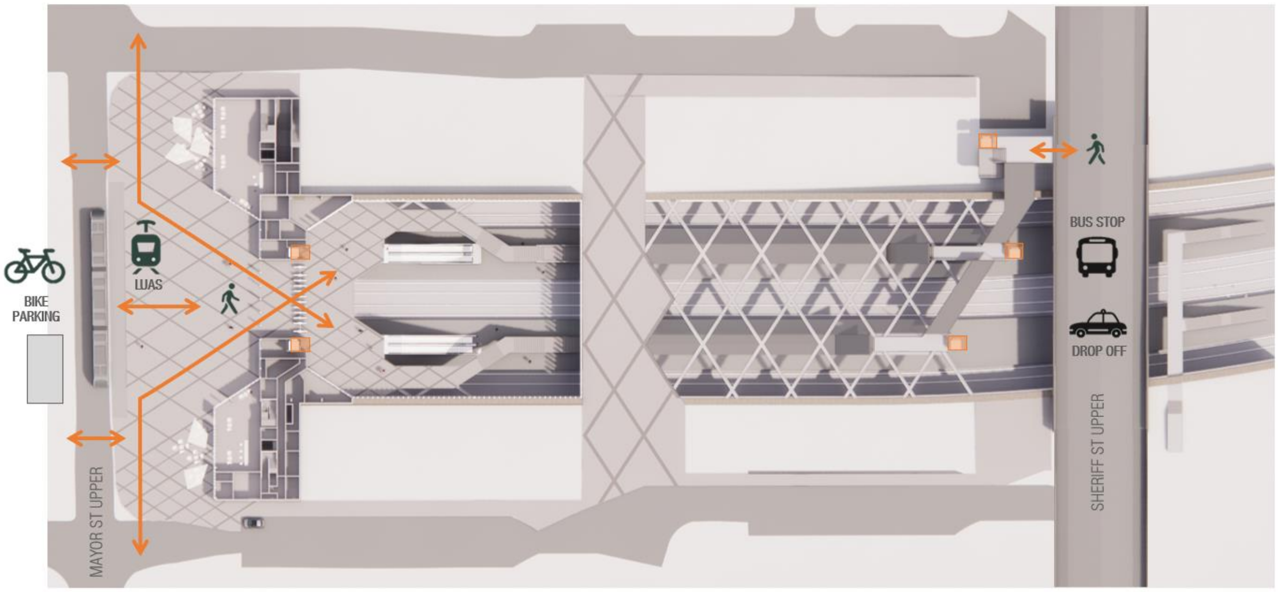


Figure 26. Diagram showing the intermodality and accesses to Spencer Dock Station

The illustration below shows the longitudinal section through the station with the main access and the secondary access at both ends of the platforms. They provide the desired intermodality with a significant number of means of transport.

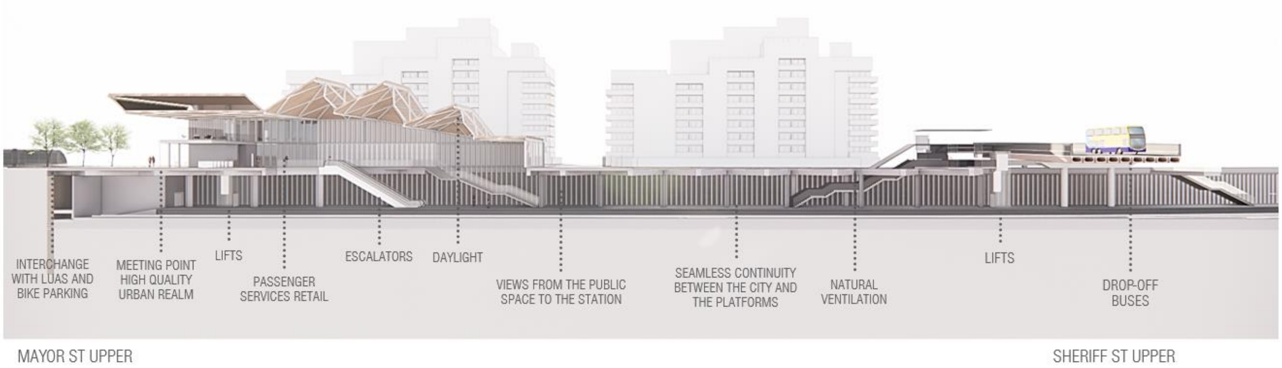


Figure 27. Graphic Illustrating the section and the primary elements of the proposed station

2.3 Required facilities

According to the demand estimate for the station (see MAY-MDC-ARC-RS00-RP-A-0003_Station Capacity report), and following the accessibility requirements, the vertical communication elements to be included at each island platform are:

- Two escalators
- Two lifts
- Two staircases 2.4 metres wide

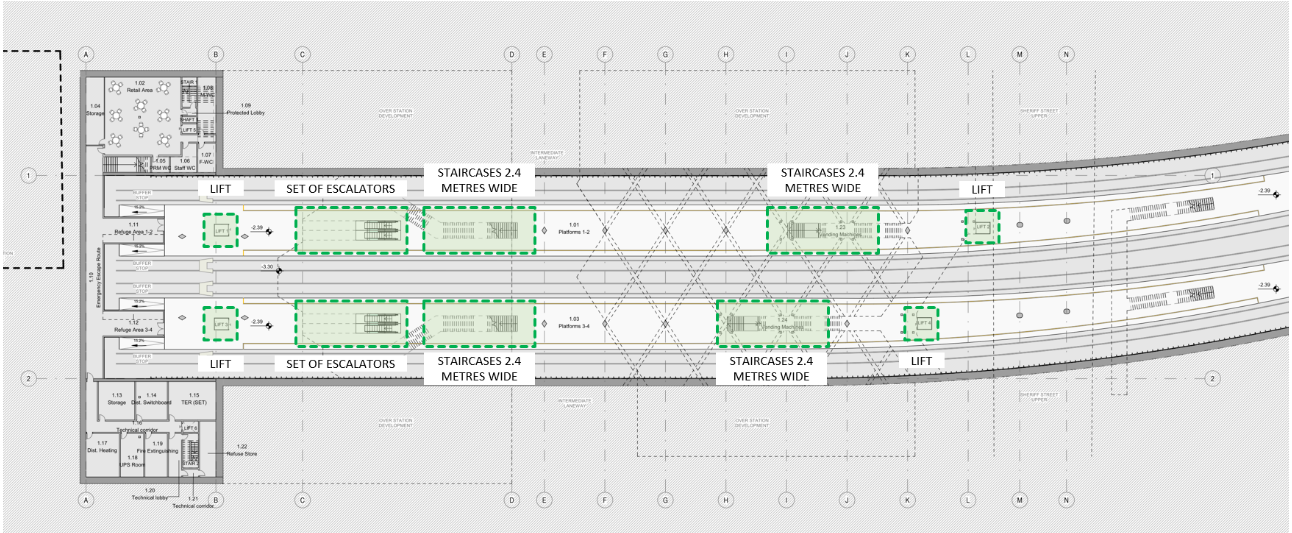


Figure 28. Platform level plan showing the vertical communication elements

Due to evacuation requirements in case of fire (see MAY-MDC-FFF-RS01-RP-A-0001_Spencer Dock Station Fire Safety strategy), two additional means of egress need to be provided:

- One staircase 2 metres wide per island platform at the northern end of the platforms.
- An evacuation corridor at the southern end of the platforms that converge on a 2.4 metres wide staircase.

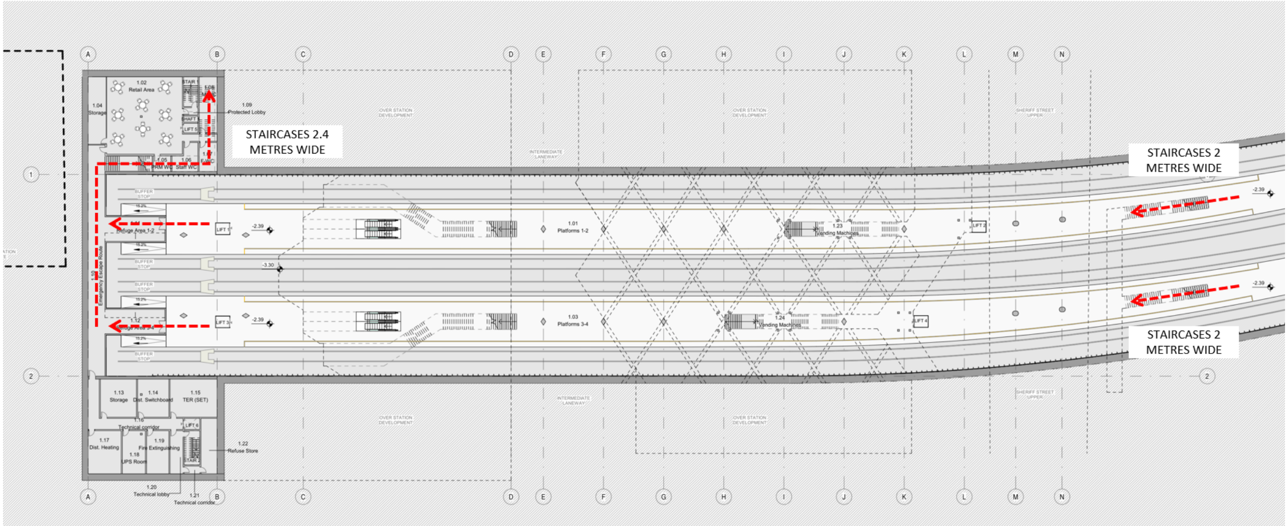


Figure 29. Platform level plan showing the emergency exit routes

These emergency routes lead to the public space at Abercorn Road and Park Lane, respectively:

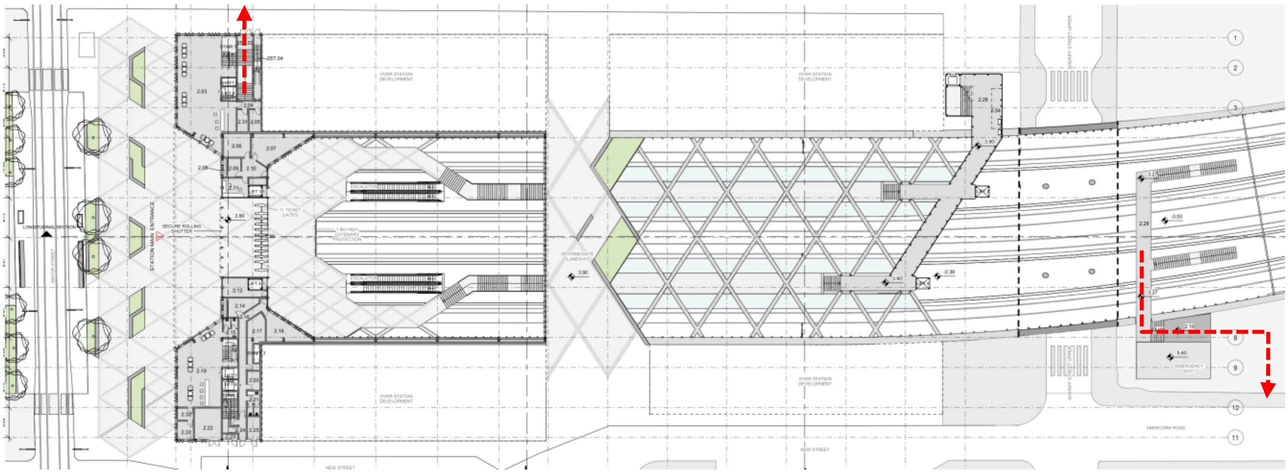


Figure 30. Street level plan showing the emergency exits to Park Lane and Abercorn Road.

The calculations provided on the Station Capacity report also highlights the necessity of:

- Twelve access validation gates
- Four ticket vending machines

In addition to the vertical communication and access facilities, some other facilities for passengers and staff need to be provided. They are listed below:

- Ticket vending facilities
- Staff facilities
- Train drivers facilities
- Retail units
- Control room and storage for the Dublin Fire Brigade
- Cleaning and storage facilities
- Technical rooms

2.4 Architectural design

2.4.1 Station concept

The station main access design intends to achieve the following objectives:

- The access from Mayor Street will be the entrance gate to the DART+ system for Dublin citizens. The building will need to be representative as it will be the image of IÉ company and the new DART+ system to the public. The architectural design of the access as a big opening fronting the Spencer Dock plaza highlights the idea of the station being the gate to the DART+system within the city.

Figure 31. View of the station's main entrance

- The new entrance will also be the gate to Dublin for the passengers arriving by train. The entrance gate will also be the welcoming point for those people accessing the city by train. The first impression of a city is essential in terms of tourism, business and international image.

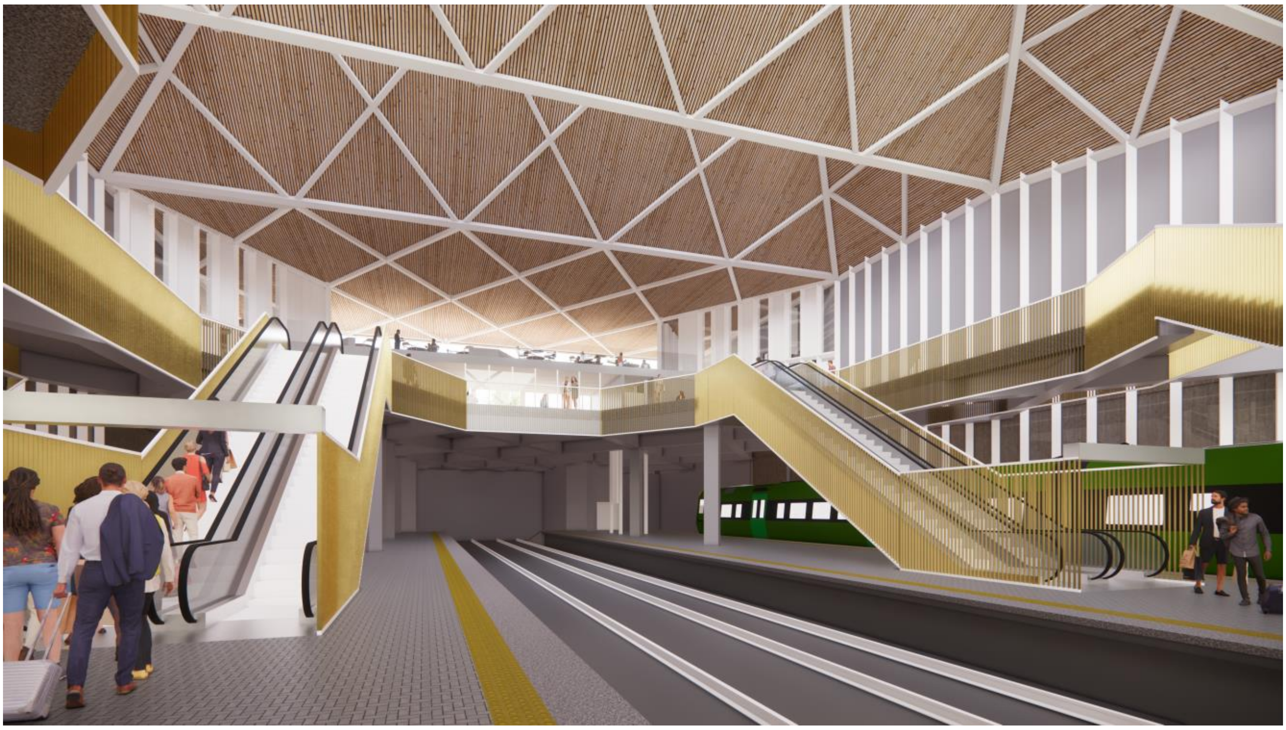


Figure 32. View from the platforms

Figure 33. View from the concourse

- The station building fronting Spencer Dock plaza is also envisaged as the basement for the future landmark building planned over the station in the North Lotts and Grand Canal Dock planning scheme. The building formed by the access to the station and the two lateral retail units has been designed considering the future condition of it being the basement of the twelve storey landmark building.

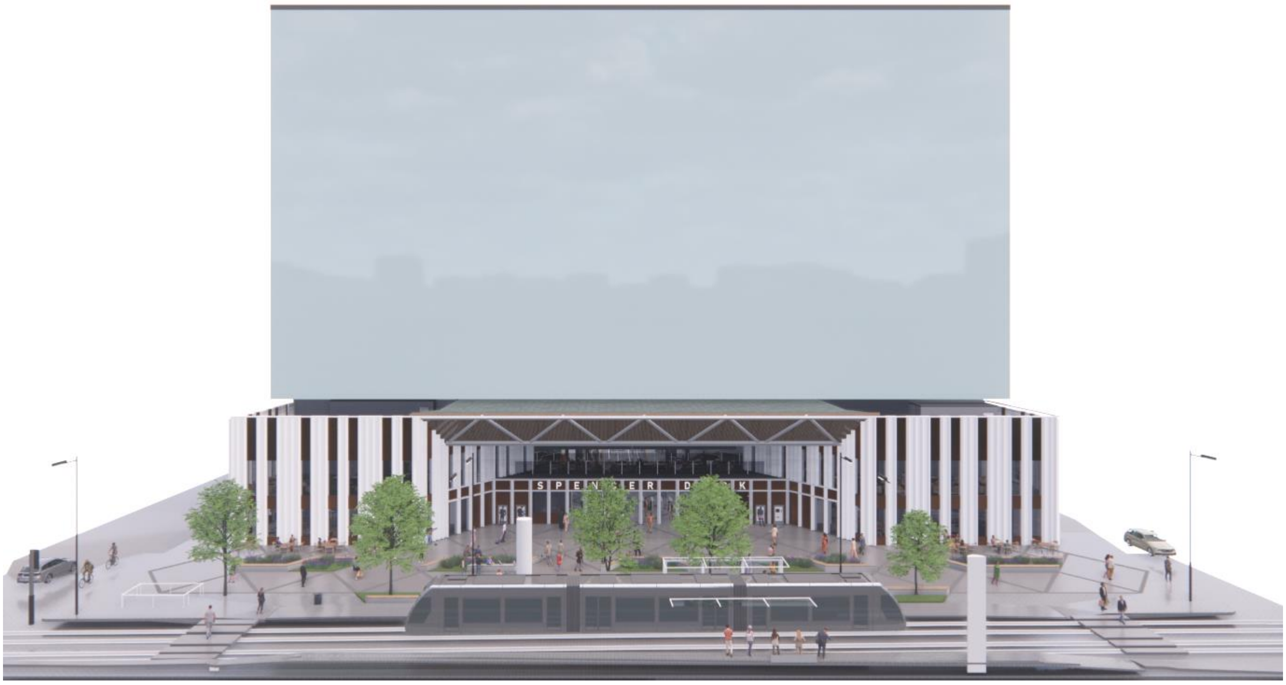


Figure 34. Representation of the station as the basement of the future Landmark building

- In order to highlight the importance of intermodality, the area between the access to the station and the Spencer Dock Luas station will be transformed into the station public concourse. The access to both transportation systems (Luas and DART+), the ticket vending facilities and the retail units will be organised around this concourse plaza.

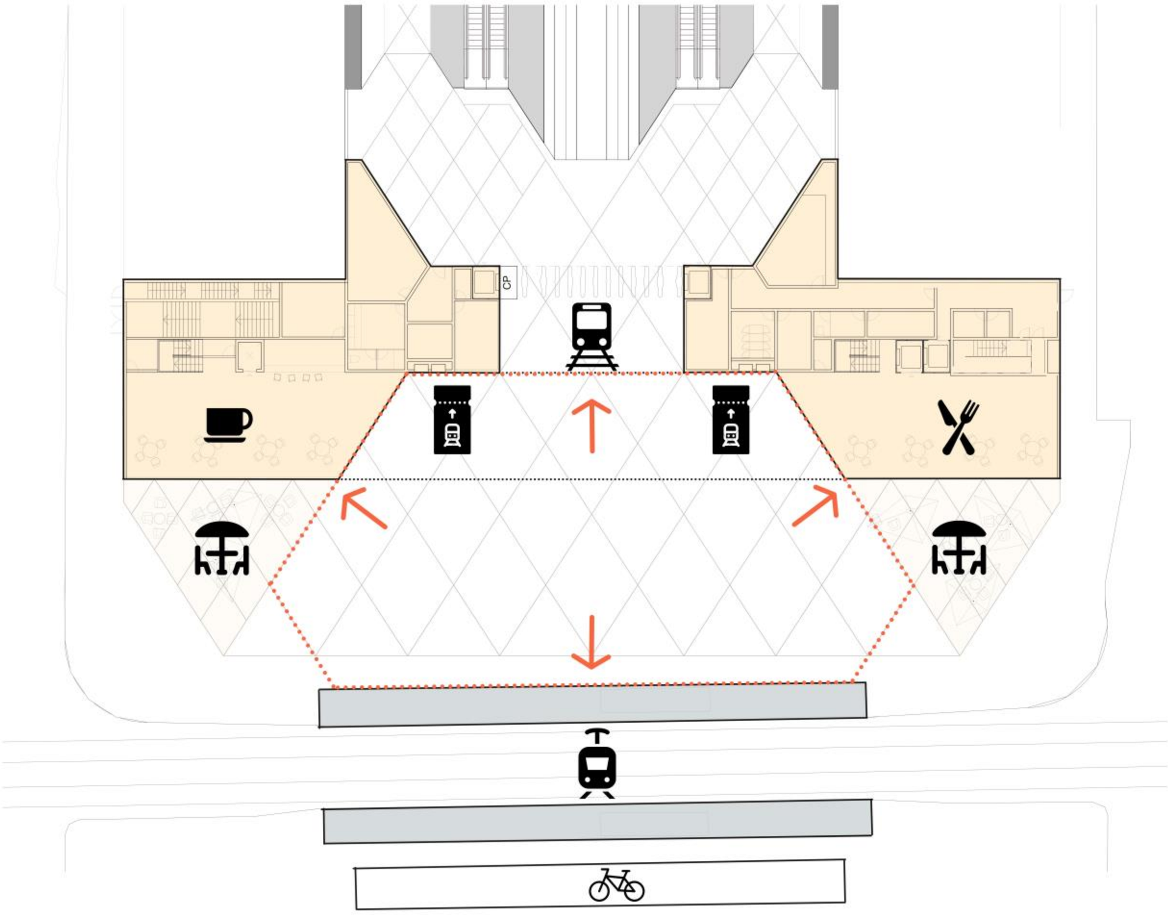


Figure 35. Diagram of the station's public concourse

2.4.2 Station layout

The station layout is divided into three main levels:

1. The **platform level** is where the connection with the railway system is produced. This level mainly contains the platforms and tracks. At the southern end of the platforms, there is also a technical area and the basement level of one of the retail units.

   The figure below shows the proposed station plan at platform level. Two island platforms that give service to four tracks are provided.

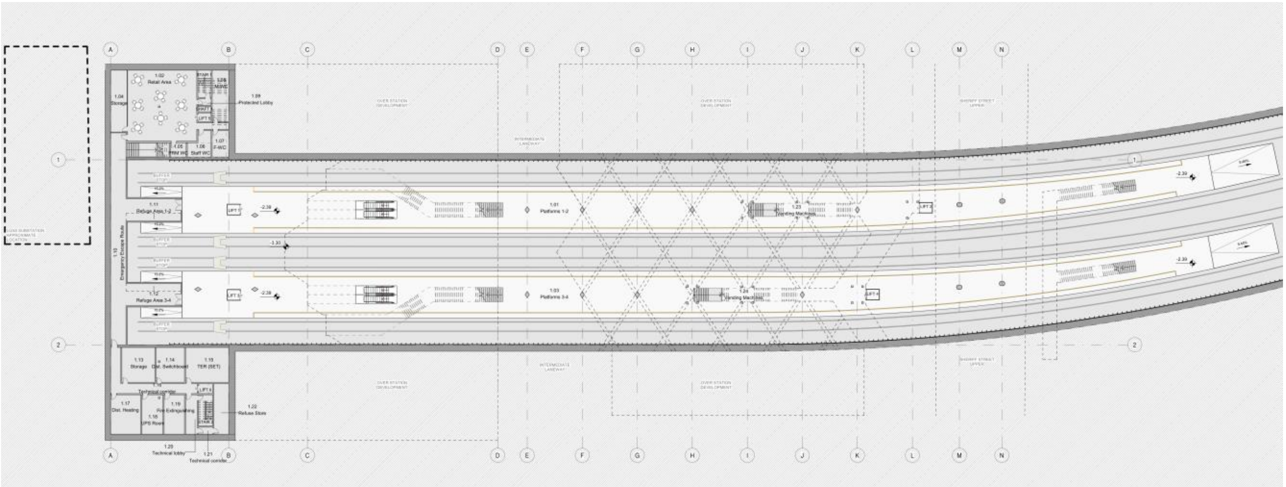


Figure 36. Functional layout of the proposed station at platform level

2. The **street level** is where the main access is placed for pedestrians and Luas users. There are two retail units at both sides of the entrance, with a privileged location fronting the Spencer Dock plaza. All the staff facilities are placed at this level. At the eastern side of the building, there is an access to the technical areas of the station together with the supplies rooms and cabinets. The intermediate laneway that crosses the station connecting Park Lane with the continuation of Abercorn road is also located at this level.

   The figure below shows the functional layout of the station at street level.

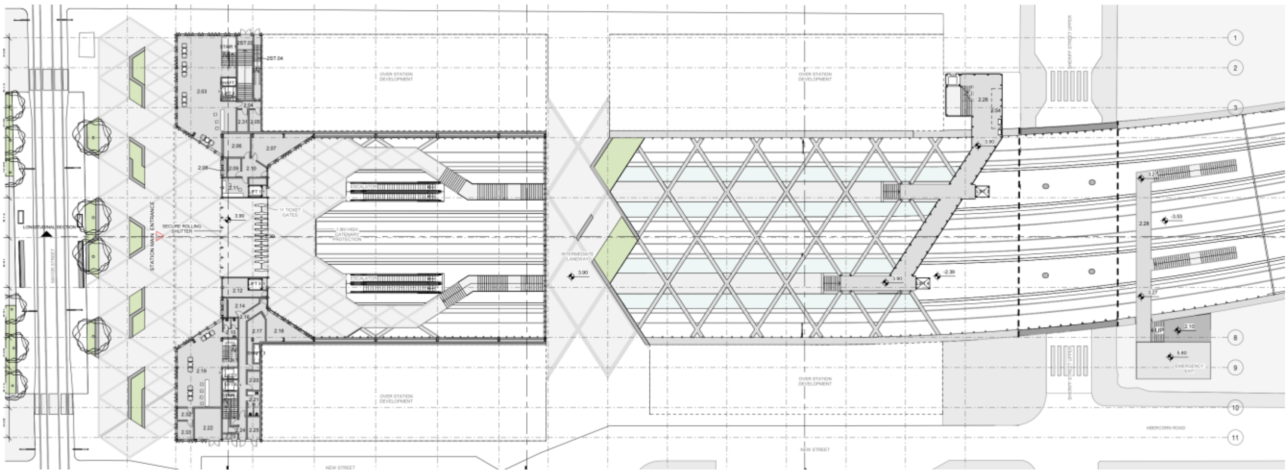


Figure 37. Functional layout of the proposed station at street level

3. The **first floor level** is where the connection with the Sheriff Street Upper drop-off is located. The secondary entrance at the northern end of the station is directly connected with the overbridge that needs to be reconstructed over the tracks at Sheriff Street Upper. A drop-off area for buses and private vehicles can be provided over the bridge that will connect directly with the platforms through this secondary entrance.

   This level also houses the first floor of the retail units at the southern end of the station. Both retail units share an exterior covered terrace that is placed over the main access.

   The figure below shows the functional layout of the station at first floor level.

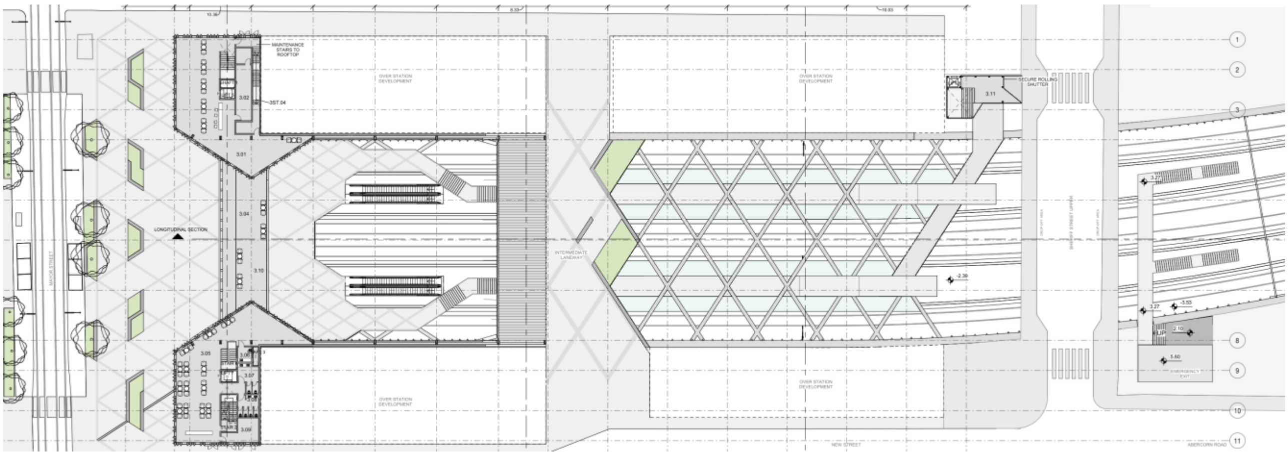


Figure 38. Functional layout of the proposed station at first floor level

2.4.3 Entrance canopy

The interior concourse of the station is covered by a canopy that has been designed with the purpose of solving different issues:

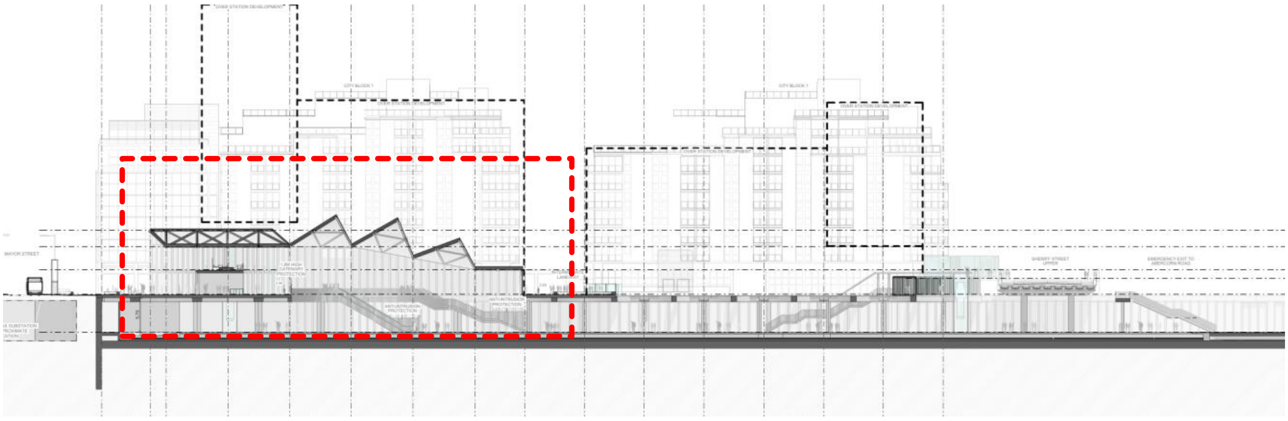


Figure 39. Spencer Dock Station longitudinal section

The canopy is supported in the two lateral walls to avoid any intermediate columns in the central space of the station, thus preventing any interference with the staircases and escalators. This means that the span of the structural trusses is around 34 metres. In order to solve this structural requirement, a three-dimensional structure has been provided to cover the entrance and a series of inclined trusses to cover the staircases and escalators area.

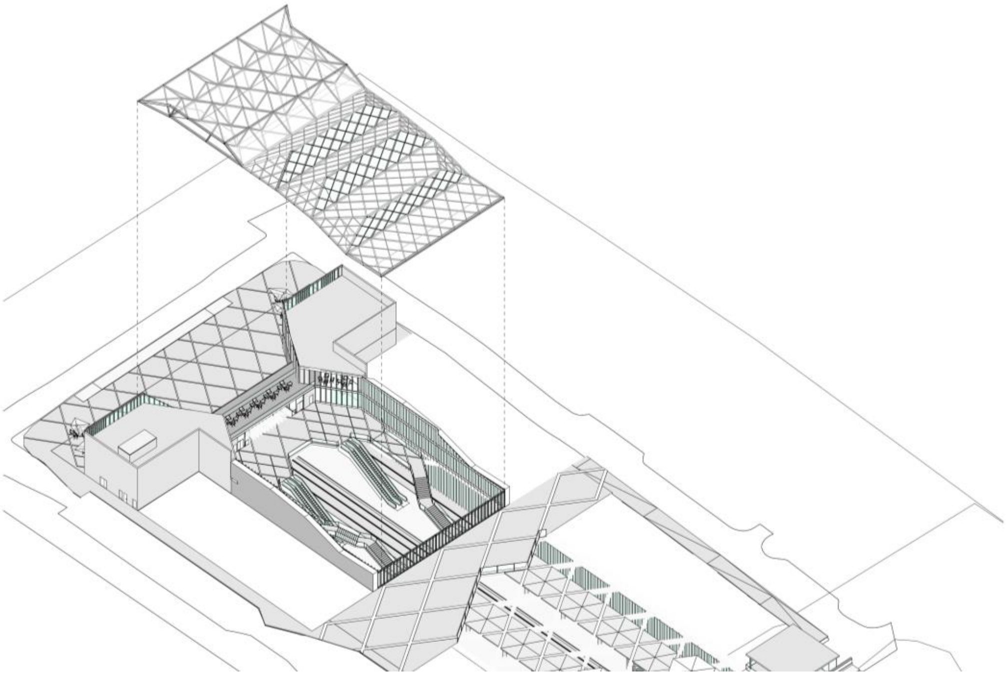


Figure 40. Diagram of the entrance canopy

The inclination of the canopy gables adapts to the perspective that the passengers will have when arriving at the station from the city. This will ensure a great view permeability to the sky and a significant amount of natural light flooding the station’s entrance and platforms, thus minimising the need for artificial lighting.

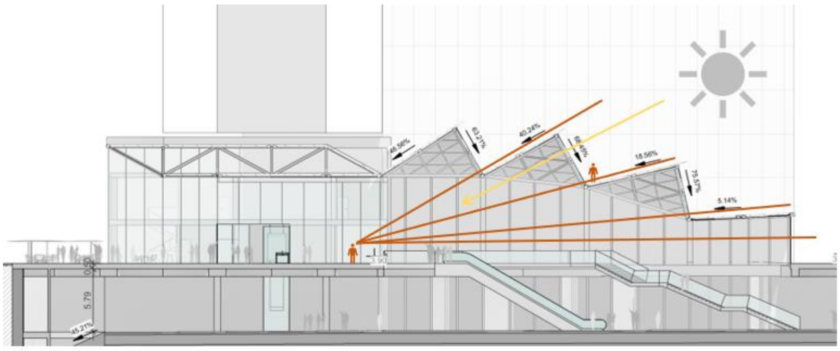


Figure 41. Diagram showing the gables adaptation to the passengers' views.

In case of fire, the design of the canopy allows greater retention of smoke. Smoke exhaust vents would be located in the opaque gables of the canopy to release the smoke.

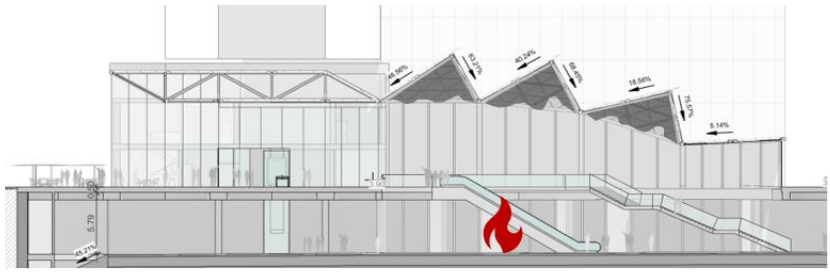


Figure 42. Diagram showing the smoke retention in the canopy gables.

The design of the canopy will follow the diagonal lines provided by the structure. These lines will continue towards the exterior façade fostering the diagonal flows that the passengers need to follow to reach the station's interior area. These lines are also reflected in the concourse floor with the same purpose of easing the passenger movements.

The materiality of the canopy will provide warmth to the station since the ceilings are proposed to be wooden slats separated between them. In addition, an acoustic absorption material will be placed on the back of the slats to provide acoustic comfort to the interior concourse of the station.

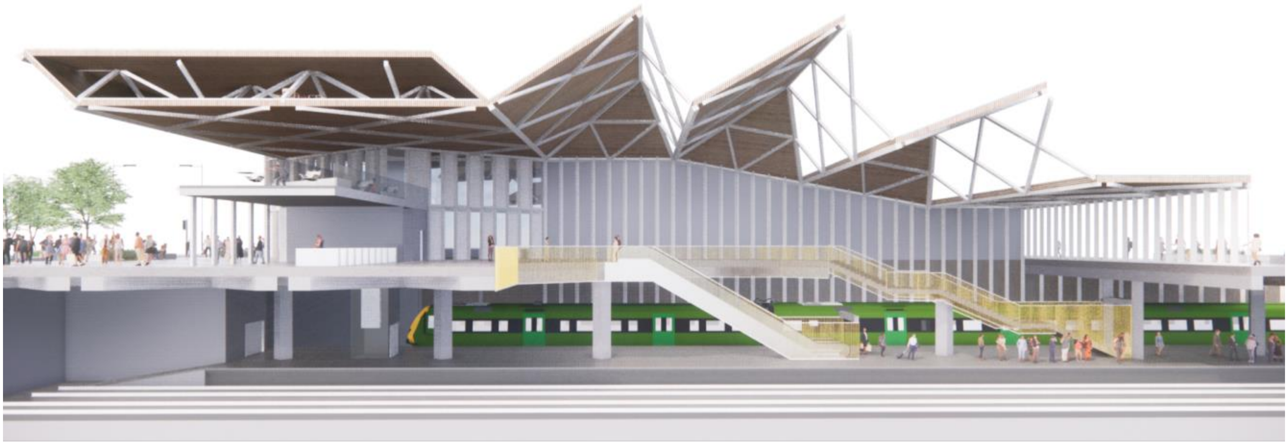


Figure 43. Section of the entrance canopy area

For maintenance purposes, all the glazed gables will be accessible from the rooftop. The exterior faces of the glass can be cleaned from the maintenance paths provided on the roof.

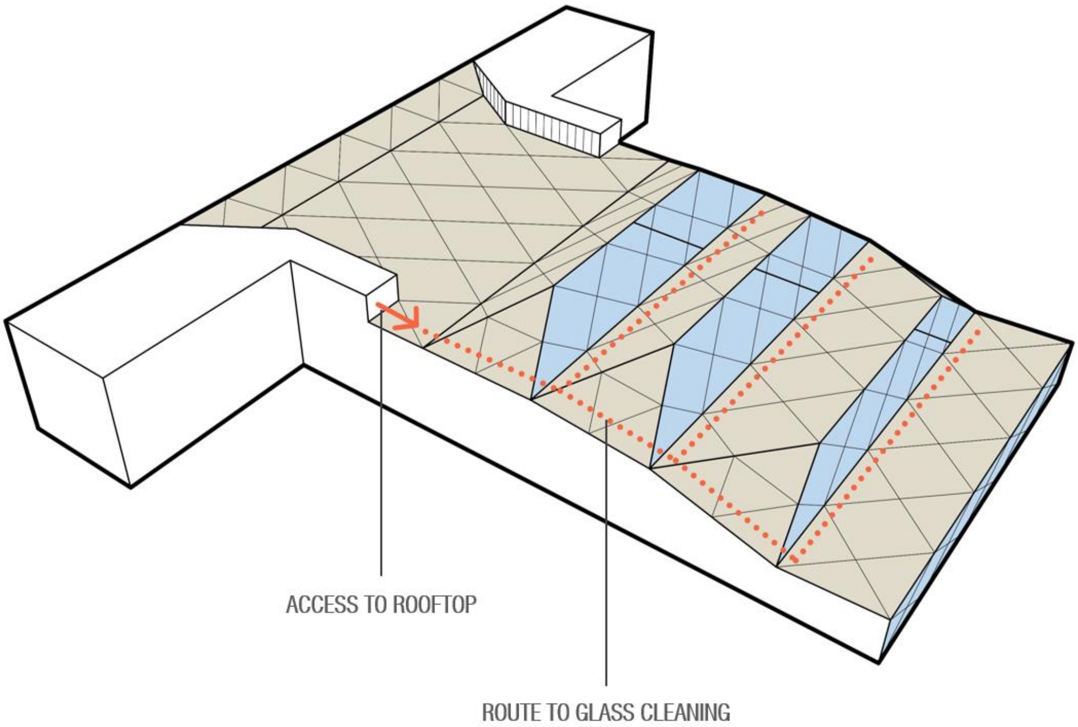


Figure 44. Diagram of the roof maintenance routes

2.5 Materials and Finishes

This chapter explains the main finishes proposed for Spencer Dock Station. A minimal palette of materials is proposed for the new station to convey a modern and cool aesthetic. The use of high-quality finish materials is of particular importance and will significantly improve the passenger's perception of the space, creating a safe and comfortable passenger experience.

2.5.1 Interior Finishes

The interior finishes will be chosen according to their **quality, comfort performance, durability, low maintenance and easy cleaning**. The finishes are selected following the requirements of the different areas of the station:

2.5.1.1 Entrance, concourse and public staircases

- FLOOR
  - Local light grey granite bush-hammered stone floor placed on a concrete slab with a layer of cement mortar screed, on interior and exterior concourses and staircases. Darker grey granite stone to be used for the diagonal stripes.

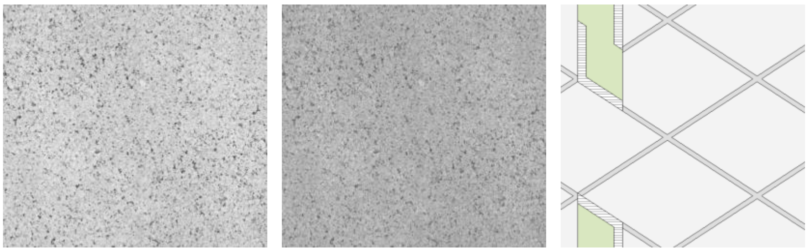


Figure 45. Granite stone samples and pavement layout

  - Ribbed rubber aluminium matting (between access doors and lifts).

    Aluminium profiles with rubber inserts for the external area. Profile 22mm. For external area applied with aluminium dirt collection well below heavy traffic area. Well to be connected to the drainage system.

Figure 46. Aluminium matting with rubber inserts

- WALLS
  - GRC panels with vertical GRC lamellas.

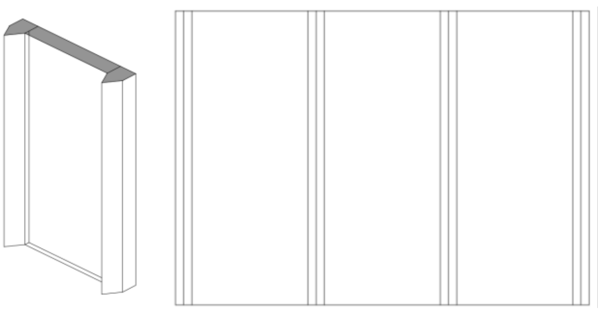


Figure 47. Axonometric and elevation view of the panels and lamellas

- CEILING
  - Wooden slats with acoustic absorption layer, over the main entrance area.
  - Wooden slats with acoustic absorption layer on opaque gables, over the staircases and escalators area.

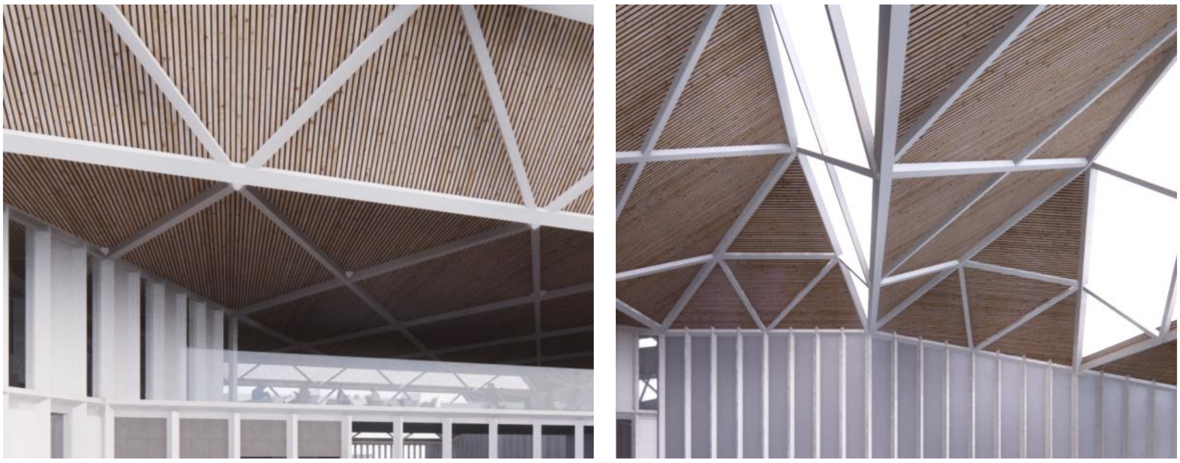


Figure 48. Wooden slats ceiling on main entrance area (left) and opaque gables (right)

Timber ceilings offer the natural aesthetic of wood, as a key design influence within on-trend interiors, whilst offering acoustic control, service integration and meeting the rigorous demands of fire safety.

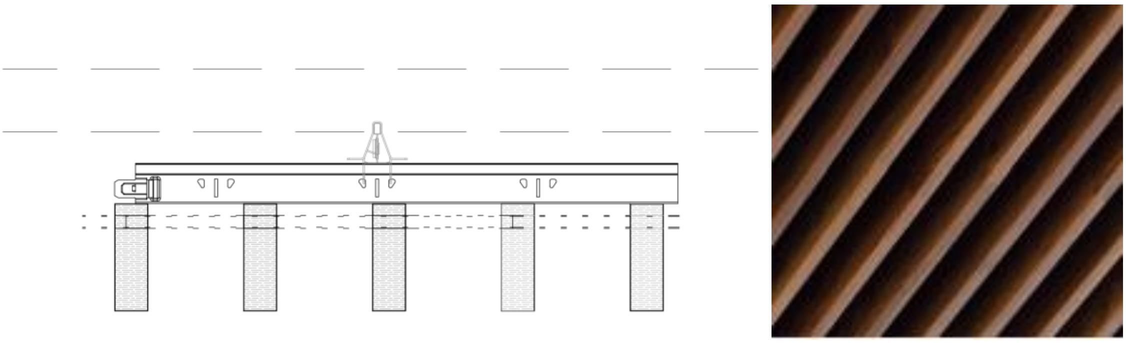


Figure 49. Section detail of timber ceiling. Photo of timber ceiling

- BALUSTRADE
  - Vertical steel profiles hiding the edge of the staircase. Steel profile handrail welded to the guardrail. The profiles will be placed every 10 cm, and they will be finished by a top and bottom rail. The vertical profiles will be welded to the handrail.

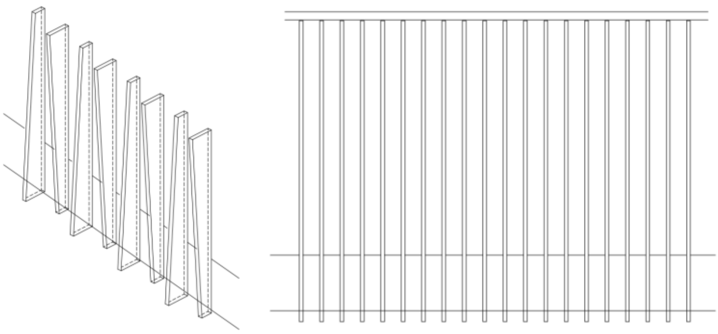


Figure 50. Axonometric and elevation view of the balustrade design

The height of the balustrade is raised at platforms level, and a roller shutter is proposed to enclose at night the staircases and escalators that lead to the main concourse.

Figure 51. View of the balustrade and the roller shutter that encloses the staircases and escalators at night

2.5.1.2 Platforms

- FLOOR
  - Precast concrete pavers.

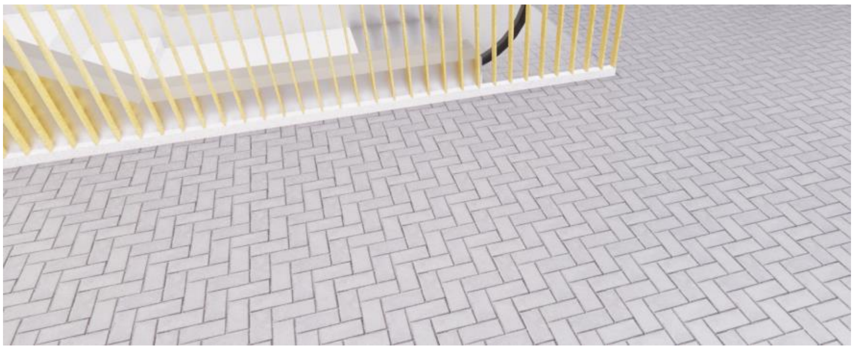


Figure 52. Precast concrete pavers at platform level

- WALLS
  - GRC panels with vertical GRC lamellas.

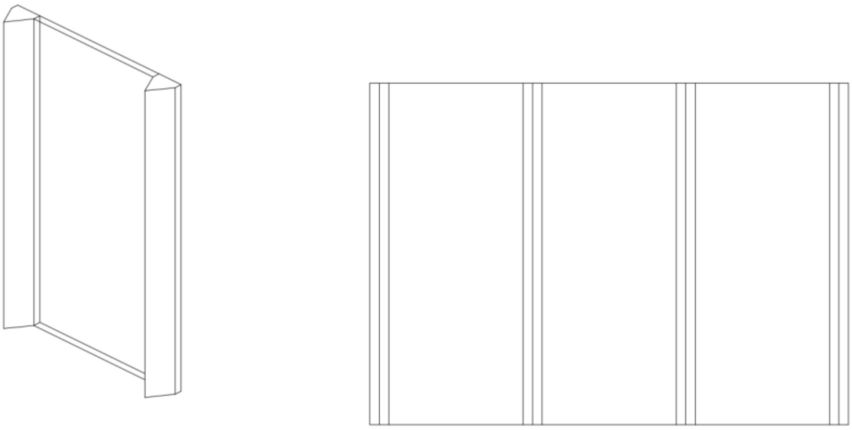


Figure 53. Axonometric and elevation view of vertical lamellas

- Acoustic wall panels. Applying acoustic wall panels reduces reverberation levels by absorbing sound, reducing the level of sound which is reflected back into the environment.

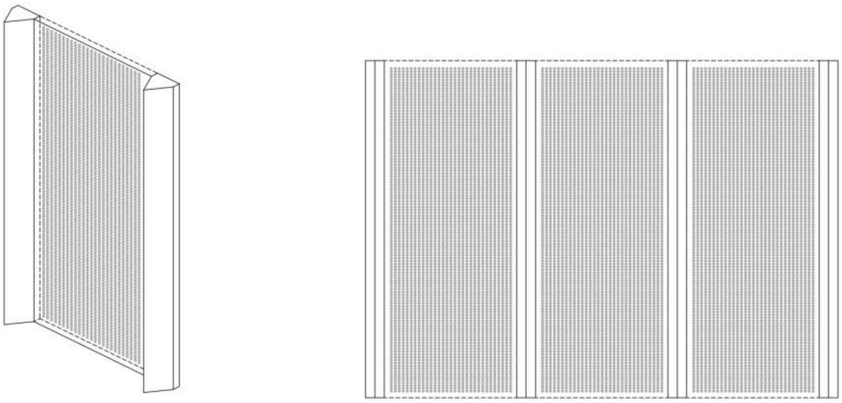


Figure 54. Axonometric and elevation view of vertical acoustic panels between lamellas

2.5.1.3 Staff areas

- FLOOR
  - Ceramic tile 8 mm thickness. 1200x600mm. Dark grey, light-textured.

Figure 55. Ceramic tile sample.

- WALLS
  - Acrylic paint on plasterboard lining.

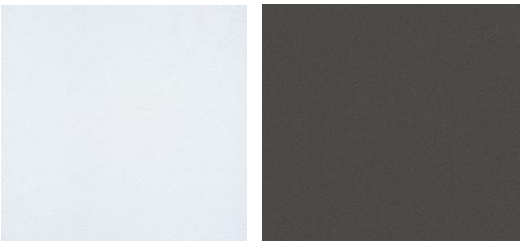


Figure 56. Paint samples.

- CEILING
  - Removable acoustic modular ceiling (60x60 cm). At first, removable acoustic ceilings stand out for the perforations on their surface, which provide the different levels of sound absorption in the different models. Normally these ceilings are made of plasterboard.

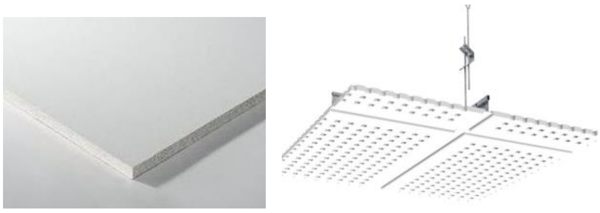


Figure 57. Plasterboard ceiling sample and perforation ceiling

2.5.1.4 Technical rooms

- FLOOR
  - Electrical/ Signalling rooms: rubber flooring.
  - Cleaning Room, Trash Room and Staff toilets: ceramic tiles.
  - Other MEP rooms: traffic bearing multicomponent epoxy paint.
- WALLS
  - Acrylic paint over masonry block wall or gypsum board.
  - Cleaning Room, Trash Room and Staff toilets: ceramic tiles.
- CEILING:
  - Modular moisture resistant suspended ceiling tile to provide future access for services & modifications.

The modularity of construction systems is one of the objectives of the project when selecting station finishes (e.g. partitions, raised floors, suspended ceilings, ceiling fittings, etc.). Furthermore, the availability of local and national suppliers for the proposed construction systems is also a key factor. The benefit of these criteria is that they will ease daily maintenance and repair work as well as reducing the carbon impact.

Regarding the interior illumination system, linear LED lighting will provide a good level of illuminance to the concourse area.

Wayfinding and advertising elements will be sympathetic with the station design and will be integrated into opaque wall panels suspended from the ceiling. Wayfinding and advertising elements will be backlit. They will have a powder-coated casing with a front flushed glass cover, keeping a minimalist, clean appearance. All fixings will be concealed.

The doors giving access to 'back of the house' areas or to technical rooms will be flushed doors with concealed frames. The doors' finish should match the finish of the wall where it is placed. The Ticket Issuing Window will be laminated tempered glass, included in a laminated curtain wall that will allow station staff to control the station entrance and provide information to incoming passengers.

In order to facilitate the complete maintenance of the installations, all the **suspended ceilings** of the building will be registrable.

2.5.2 Outer Envelope

Considering the nature and function of the building, it is appropriate to have a construction system suited to its use. It must meet constructive and economic parameters, such as durability, maintenance, local sources, cost, etc.

2.5.2.1 Façade

There are two different facades in the station:

- The facades that separate the interior of the building with the street or with the concourse area. This façade has been designed to allow the possibility of being either opaque or transparent to respond to the requirements of the interior spaces.

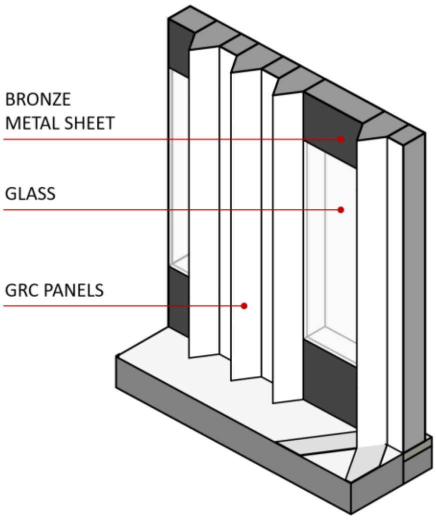


Figure 58. Exterior facade

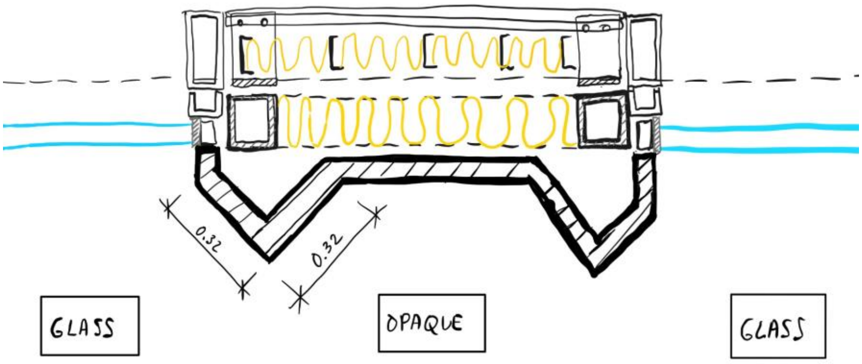


Figure 59. Diagram of the façade system

- Opaque GRC modules. Composition:
  - Opaque precast GRC (Glassfibre reinforced concrete/cement).
  - The aesthetic characteristics of precast concrete are determined by two factors: the shade or colour and the texture.

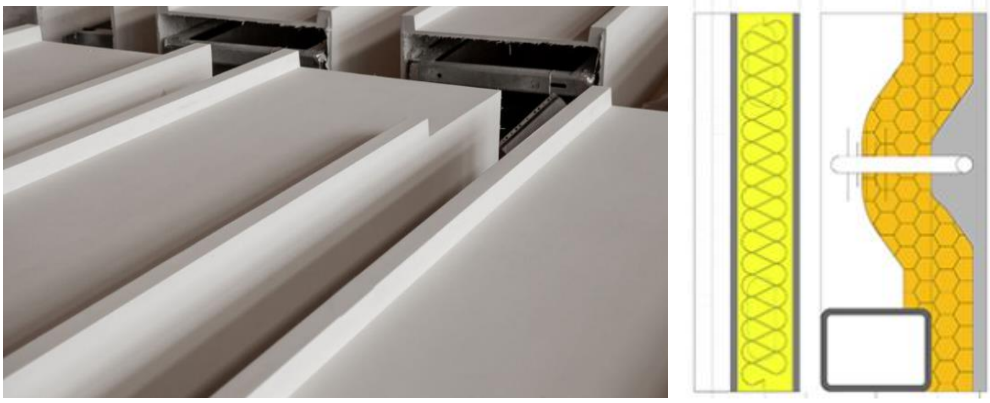


Figure 60. Mockup of GRC façade. Section detail of GRC wall

- There are three different types of panels, with 2, 3 or 4 vertical elements.

Figure 61. Different types of GRC panels

- Glass and metal modules. Composition:
  - Curtain wall system with horizontal and vertical mullions.
  - The glazed panels will have a glass with a different solar factor depending of their location and solar incidence. The glass panels facing the entrance plaza will have a high solar factor.

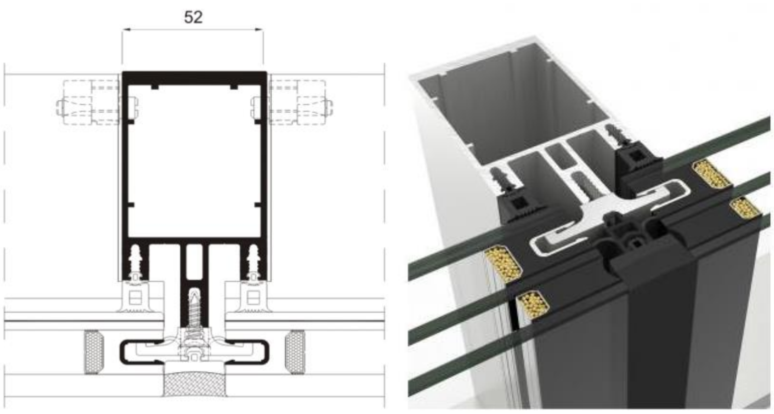


Figure 62. Section and photo detail of curtain wall.

  - Brushed bronze colour stainless steel composite panels. These metal panels provide continuity to the grass reflections to achieve the vertical rhythm of the façade, while avoiding having glass in the areas closer to the ground.

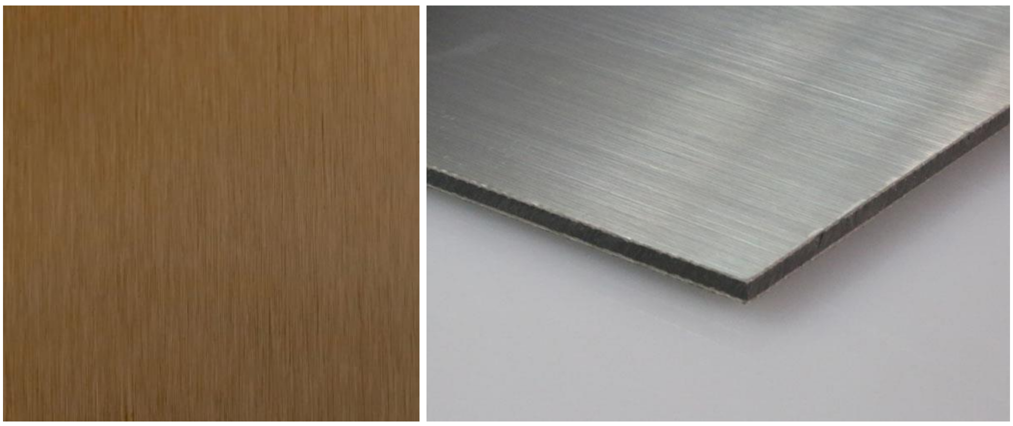


Figure 63. Brushed bronze stainless steel composite panels

- The facades that separate the interior of the building with the areas where the future Over Station Development will be placed. This façade has been designed as an opaque element since no sight of light permeability is allowed through these elements.

  Composition (interior to exterior)
  - GRC panels with vertical GRC lamellas.
  - Metal frame
  - Insulation
  - Vertical metal sheet system

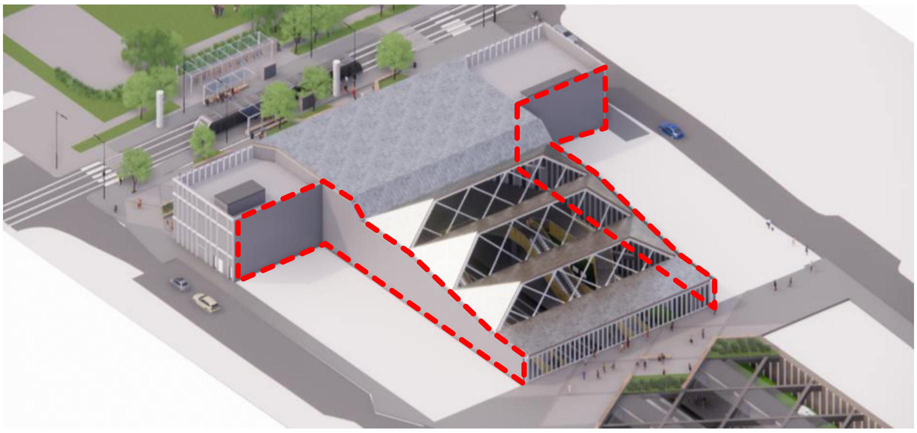


Figure 64. Location of façade

2.5.2.2 Roof

There are two types of roofs. On the one hand, a flat one that covers the retail units and is solved with a traditional system of concrete slab, waterproofing membrane (bituminous membrane, PVC, etc), isolation and concrete floor.

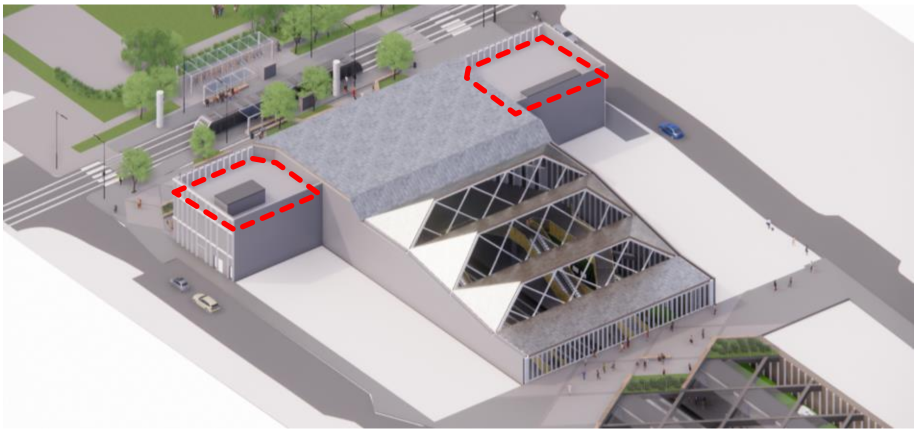


Figure 65. Location of traditional roof

On the other hand, the roof that covers the public areas of the station is solved with a metal sheet finish.

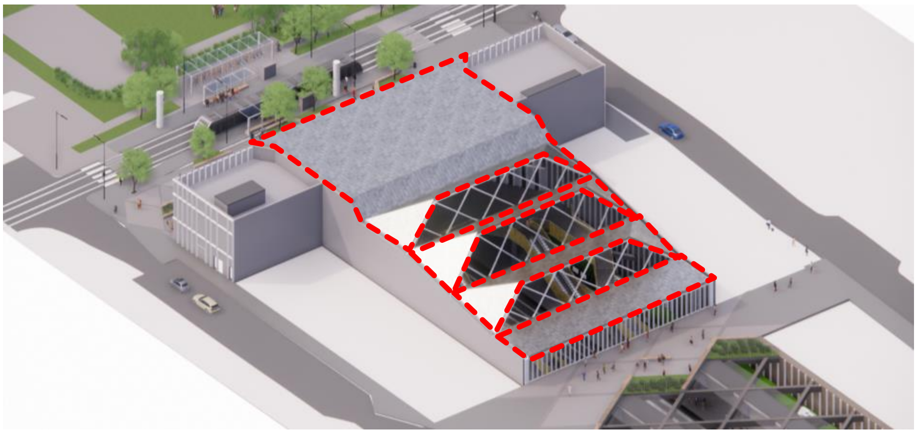


Figure 66. Location of metal sheet roof

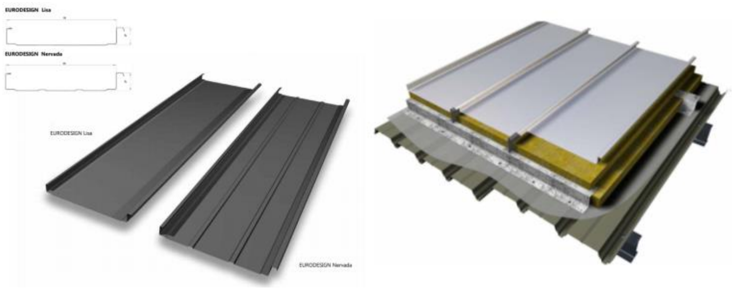


Figure 67. Metal sheet system in roof

2.5.2.3 Retaining walls

The excavation will be carried out with a secant pile system. The diameter of these piles will be around 1 meter, and they will be under a coronation beam. In front of the pillars, there will be a concrete wall to create a continuous surface as the interior finish of the platforms level. During the detailed design stage the possibility of using tapial blocks instead of concrete will be studied as an alternative solution for the concrete wall.

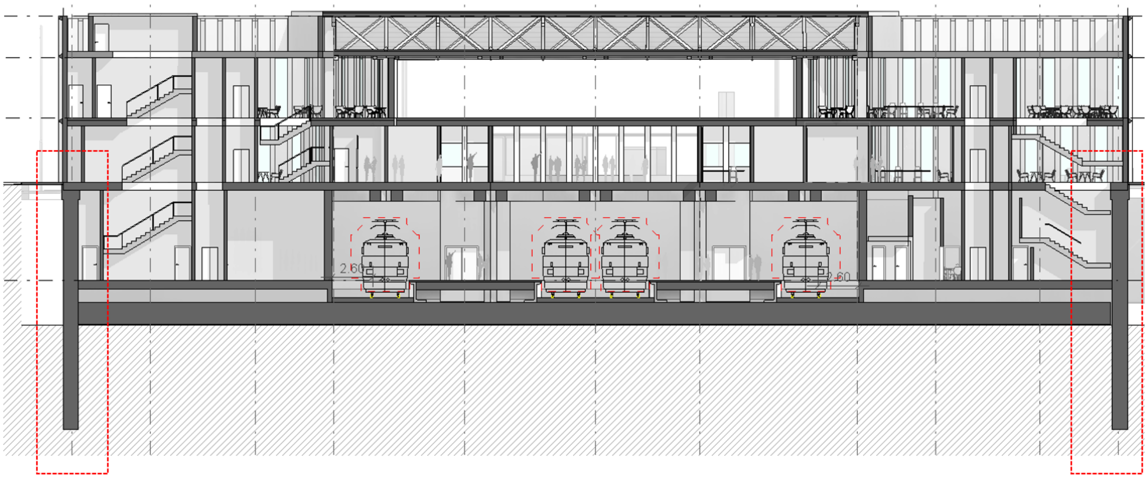


Figure 68. Cross Section

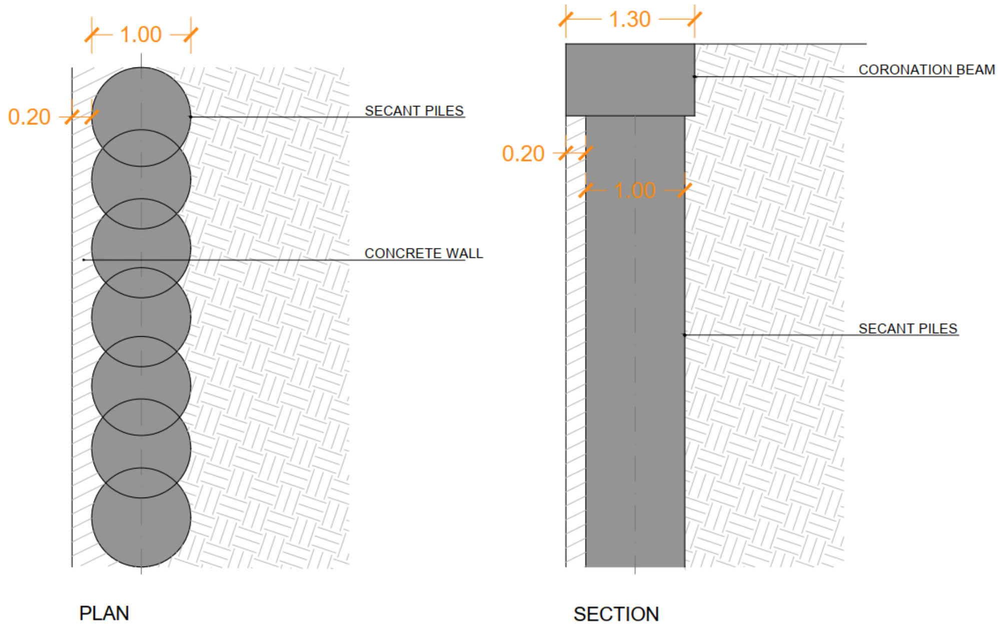


Figure 69. Sketch of secant piles

2.6 Schedule of uses and areas

The table below shows the main uses and net areas of Spencer Dock Station:

Room No	Room Name	Level	Net Area	
BACK OF HOUSE			**179.53**	**m^2**
2.06	Chang. Room	Street Level	17.79	m^2
2.07	Train Driv. Fac. & Canteen	Street Level	37.46	m^2
2.09	Storage	Street Level	6.91	m^2
2.1	Secure Lobby	Street Level	11.02	m^2
2.11	Ticket Office	Street Level	13.88	m^2
2.12	Retail	Street Level	17.10	m^2
2.16	BOH Corridor	Street Level	25.78	m^2
2.18	ICR/CR	Street Level	24.89	m^2
2.2	Clean. & Water	Street Level	6.62	m^2
2.21	Staff WC	Street Level	8.57	m^2
2.24	Secure Lobby	Street Level	6.26	m^2
2.29	Ticket Office Room Storage	Street Level	3.25	m^2
EMERGENCY EXITS			**300.51**	**m^2**
1.1	Emergency Escape Route	Platform Level	185.07	m^2
2ST.01	Emergency Exit Staircase 1	Street Level	28.57	m^2
2ST.02	Emergency Exit Staircase 2	Street Level	73.69	m^2
2ST.03	Emergency Exit Staircase 3	Street Level	13.18	m^2
PUBLIC AREAS			**3816.07**	**m^2**
PLATFORMS			2792.96	m^2
1.01	Platforms 1-2	Platform Level	1403.79	m^2
1.03	Platforms 3-4	Platform Level	1389.17	m^2
PUBLIC AREA MAIN ACCESS			739.35	m^2
1.11	Refuge Area 1-2	Platform Level	13.54	m^2
1.12	Refuge Area 3-4	Platform Level	13.54	m^2
1.23	Vending Machines	Platform Level	46.02	m^2
1.24	Vending Machines	Platform Level	44.81	m^2
LIFT 1	Platform Lift 1	Platform Level	4.53	m^2
LIFT 2	Platform Lift 2	Platform Level	4.40	m^2
LIFT 3	Platform Lift 3	Platform Level	4.64	m^2
LIFT 4	Platform Lift 4	Platform Level	4.40	m^2
2.01	Unpaid Concourse	Street Level	100.65	m^2
2.08	Ticket Vending Machine	Street Level	2.42	m^2
2.13	Ticket Vending Machine	Street Level	2.42	m^2
2.3	Paid Concourse	Street Level	480.77	m^2
2L.01	Platform Lift 1	Street Level	4.07	m^2
2L.02	Platform Lift 2	Street Level	4.37	m^2
2L.03	Platform Lift 3	Street Level	4.37	m^2
2L.04	Platform Lift 4	Street Level	4.40	m^2
PUBLIC AREA SECONDARY ACCESS			283.76	m^2
2.26	Unpaid Concourse	Street Level	40.49	m^2

2.27	Paid Concours	Street Level	143.47	m²
2.54	Ticket Vending Machine	Street Level	18.07	m²
2ST.08	Stairs	Street Level	21.49	m²
3.11	Concourse	First Floor Level	60.24	m²

RETAIL AREAS			**1310.75**	**m²**
RETAIL UNIT 1			839.92	m²
1.02	Retail Area	Platform Level	166.85	m²
1.04	Storage	Platform Level	32.85	m²
1.05	PRM WC	Platform Level	8.37	m²
1.06	Staff WC	Platform Level	10.27	m²
1.07	M-WC	Platform Level	21.75	m²
1.08	F-WC	Platform Level	25.21	m²
1.09	Protected Lobby	Platform Level	14.88	m²
1L.05	Retail Lift 5	Platform Level	3.84	m²
1S.01	Shaft	Platform Level	3.02	m²
2.03	Retail Area 01	Street Level	135.49	m²
2.04	Lobby	Street Level	4.85	m²
2.05	Storage	Street Level	7.38	m²
2.31	Waste	Street Level	6.68	m²
2.34	Retail Area 01-Bar	Street Level	14.05	m²
2L.05	Retail Lift 5	Street Level	3.84	m²
2S.01	Shaft	Street Level	1.26	m²
2ST.01	Retail Stair	Street Level	18.72	m²
3.01	Retail Area 01	First Floor Level	222.18	m²
3.02	Kitchen	First Floor Level	24.31	m²
3.03	Storage	First Floor Level	6.89	m²
3.04	Retail Terrace 01	First Floor Level	43.62	m²
3L.05	Retail Lift 5	First Floor Level	3.30	m²
3S.01	Shaft 1	First Floor Level	3.09	m²
3ST.01	Retail Stair	First Floor Level	18.66	m²
3ST.04	Emergency Exit Staircase	First Floor Level	29.92	m²
3ST.07	Retail Stair	Roof Level	8.64	m²
RETAIL UNIT 2			470.83	m²
2.15	Staff WC	Street Level	7.96	m²
2.19	Retail Area 02	Street Level	76.29	m²
2.32	Lobby	Street Level	5.86	m²
2.33	Waste	Street Level	9.61	m²
2.36	Retail Area 02-Bar	Street Level	18.14	m²
2L.07	Retail Lift 7	Street Level	4.82	m²
2S.02	Shaft	Street Level	3.02	m²
2S.03	Shaft	Street Level	3.12	m²
2ST.05	Retail Stair	Street Level	13.17	m²
3.05	Retail Area 02	First Floor Level	202.13	m²
3.06	PRM WC	First Floor Level	5.83	m²
3.07	M-WC	First Floor Level	14.28	m²
3.08	F-WC	First Floor Level	12.57	m²

3.09	Kitchen	First Floor Level	20.46	m^2
3.1	Retail Terrace 02	First Floor Level	47.46	m^2
3.13	Retail Corridor	First Floor Level	7.29	m^2
3L.07	Retail Lift 7	First Floor Level	4.94	m^2
3ST.06	Retail Stair	First Floor Level	13.88	m^2
TECHNICAL ROOMS			**424.62**	**m^2**
1.13	Storage	Platform Level	37.48	m^2
1.14	Mechanical Room	Platform Level	32.49	m^2
1.15	TER (SET)	Platform Level	49.62	m^2
1.16	Technical corridor	Platform Level	41.18	m^2
1.17	Sewage Room	Platform Level	37.30	m^2
1.18	Fire Extinguishing	Platform Level	27.93	m^2
1.19	UPS Room-EL	Platform Level	30.01	m^2
1.2	Technical lobby	Platform Level	15.69	m^2
1.21	Lobby	Platform Level	3.65	m^2
1.22	Refuse Store	Platform Level	24.94	m^2
1L.06	Technical Lift 6	Platform Level	4.56	m^2
1ST.02	Technical Stair	Platform Level	14.18	m^2
2.14	Telecom Room	Street Level	12.38	m^2
2.17	TER (SET)	Street Level	18.31	m^2
2.22	MV Subs.	Street Level	24.76	m^2
2.23	Utilities	Street Level	2.92	m^2
2.25	Gas & Water supply	Street Level	8.51	m^2
2L.06	Technical Lift 6	Street Level	4.56	m^2
2ST.02	Technical Stair	Street Level	15.48	m^2
3S.03	Shaft 3	First Floor Level	3.29	m^2
3ST.02	Technical Stair	First Floor Level	15.38	m^2
TOTAL			**6031.48**	**m^2**

3. Structural Design

3.1 Structural criteria

Spencer Dock Station has a shallow station configuration. The final integration of the station, between and under the OSD buildings, determines a semi-underground station. Added to all this is a very high-water table, almost at street level.

The first action is to determine how the station's lower land boundary containment basin is designed:

- North: Bridge under Sheriff Street Upper
- South: Mayor Street Upper (Luas underground substation)
- East and West: Over Station Development buildings

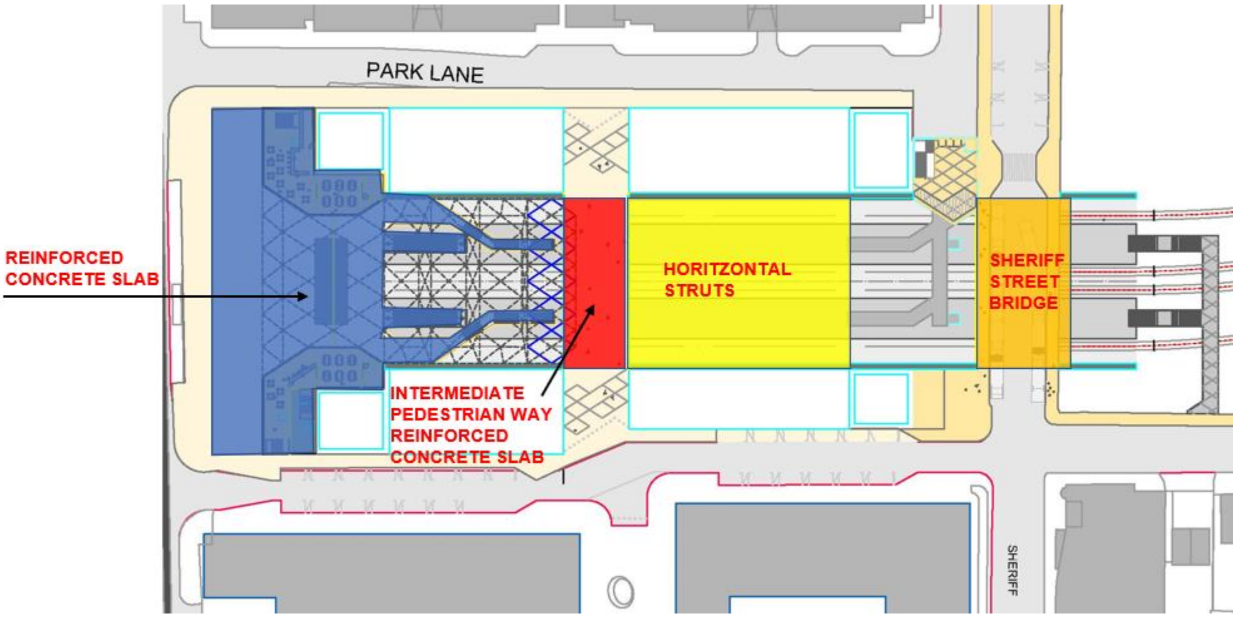


Figure 70. Ground Level slabs typologies

The station boundaries at the platform (-2.39) and concourse (+3.90) levels will be built with an alignment of reinforced concrete secant pile walls with struts at the top to improve their work during construction and in its final state. This will limit the containment of lands subject to a very high water table.

The station will have a lower sub-pressure slab at the base of the secant piles.

Parallel to the alignment of secant piles, there will be a line of concrete walls anchored to the subpressure slab, which will allow the support of the different typologies of slabs and temporary and permanent struts. This situation will allow, in all cases, the placement of waterproofing sheets between the two structural alignments.

The possibility of constructing concourse level structures at the ground floor based on precast floor units or in situ reinforced concrete is envisaged. These could be supported by the interior concrete walls and the columns arranged in the axes of the central platforms, as well as in the location where the architectural special plan dictated it.

The slab of the upper level of the retail area (+8.00 m) will be supported only on column alignments.

The roof structure of the station is based on a Steel Truss solution, spanning over the concourse area as a series of triangulated trusses, incorporating large skylights over the platform area. The roof finish will be of the light insulated metal panel type.

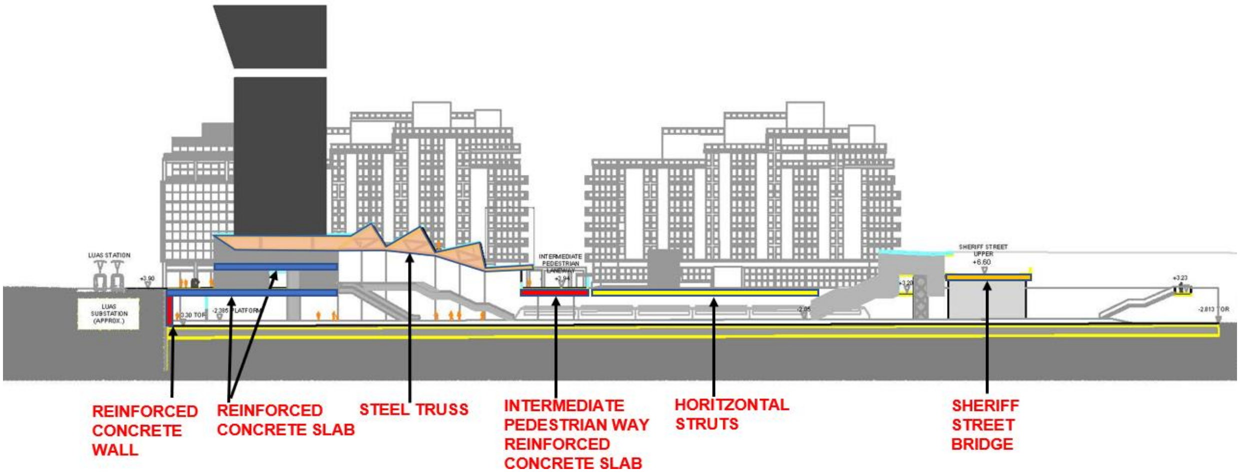


Figure 71. Longitudinal section. Structural systems

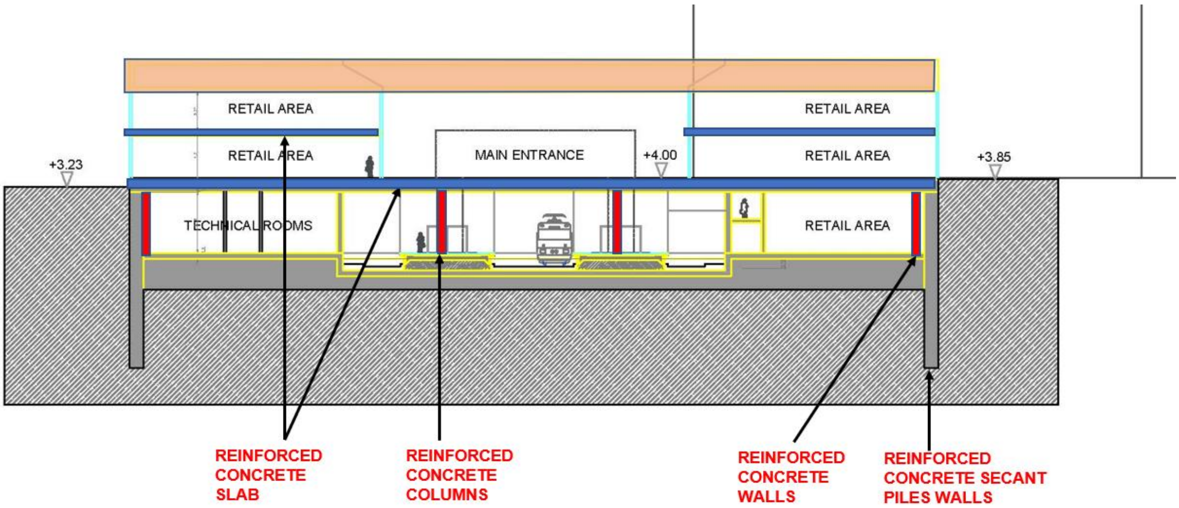


Figure 72. Cross section. Structural systems

There are three types of structures transversal to the station alignment located at the ground level, with different characteristics:

- Intermediate pedestrian way (+3.90). The intention of this walkway is the east-west connection of the street level. This concrete structure is expected to be supported between the station's perimeter walls and vertical supports located on the axis of the central platforms.
- Sheriff Street Upper bridge. Demolition of sections of the existing Sheriff Street Upper bridge and a new Sheriff Street Upper bridge must be made to allow the train to pass. This structure will be supported on vertical supports located in the axis of the island platforms and new supports close to the perimetral walls of the station.
- It is envisaged the placement of Horizontal Struts in the uncovered area of the station on the tracks to improve the work of the reinforced secant piles and thus reduce their dimensions. This will also allow for possible station coverage quickly in the future when this decision has been made.

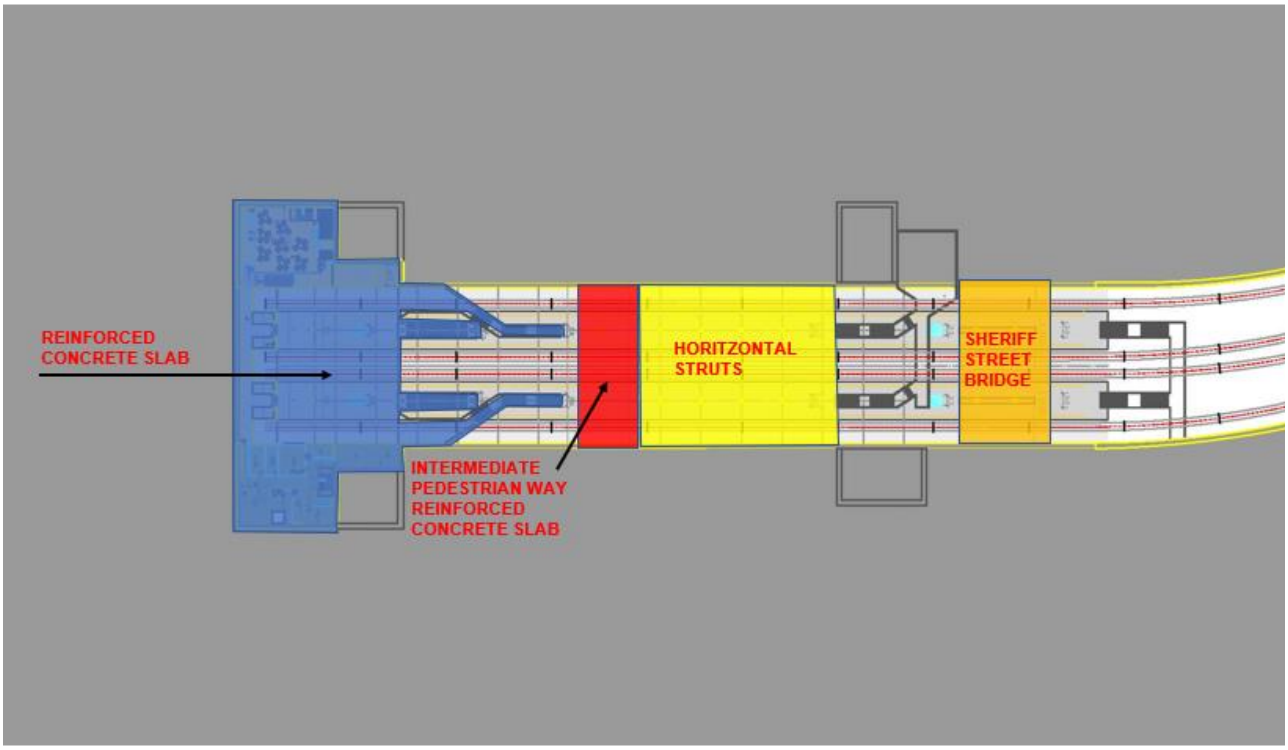


Figure 73. Platform Level. Slabs typologies

3.2 Site Conditions

3.2.1 Introduction

The purpose of this preliminary advanced geotechnical study is to provide a preliminary approach and understanding of the results of the available historical field investigations, lab testing and ground interpretation carried out by the previous site historical GI at Spencer Dock location. Please note that this advanced geotechnical study is solely for concept design purposes, therefore this is a preliminary report based on initial assumptions.

These preliminary results should be contrasted with the specific site investigation designed in the GI contract, which will confirm the previous assumptions.

3.2.2 The Site

The site is within the vicinity of city center of Dublin, where the intersection between the Royal Canal and the Liffey River is formed. This an area with ancient urban and railway development close to the Docks; landfills, contaminated land and made ground materials placed irregularly on alluvium and superficial soft peaty estuarine deposit.

The plotsite is located at Spencer Dock South of Sheriff Street Upper and north of the current Spencer Dock LUAS station. The site is part of the North Lotts & Grand Canal Dock Planning Scheme.

3.2.3 Sources of Information

The main sources of information that have been consulted in this assessment of the site are listed below as shown in the figure below. The red polygon marks the area of influence of available historic report.

Figure 74. Historic GI extracted from the Irish Geological Survey on the vicinity of Docklands

- Report GI. Plot B. Ref.239 Site investigation. North wall development. Dublin city. 7no BH Shell and Auger. February 1976.
- Report GI Plot A. Ref.344. Sheriff street Bridge. Spencer Dock. Dublin city. This a draft by hand with poor geotechnical description and confusing terminology.
- Report GI. Plot A. Ref.5831. North Quays ESB 110Kv Substation report. Dublin city. Building Consultancy group. 9no Trial Pits. January 1992.
- Report GI. Plot B. Ref.164. Well locations drilling. Sheriff street. Dublin city. 3no BH for groundwater survey. February 1998.
- Report GI. Plot A. Ref.785. Seville Place development/Spencer Docks. Dublin corporation Dublin city. 3no BH, lab testing and chemical analysis. August 2004.
- Engineering Services Report. CS Consulting Group for Spencer Place Development company limited. Job NoR043 Spencer Place Residential. Block 2, Spencer Dock Dublin. August 2019
- Irish Geological Survey Historical Borehole Logs which have been consulted within this viewer, as shown above (Fig.1) specifically from previous ground investigation contracts carried out in the area from 1976 to 2009. https://www.gsi.ie/en-ie/data-and-maps/Pages/Geotechnical.aspx

3.2.4 Ground Conditions

3.2.4.1 Conceptual Ground Model

A conceptual ground model has been developed based on the review of the available historic ground investigation data within the vicinity of the site and GSI information. This identifies the likely ground conditions solely for conceptual design purposes with faintly grade of accuracy.

Regarding the available historical ground investigations, the ground conditions seem to vary significantly vertically along the subsurface profile from one plot to the other which should be noted for engineering purposes. Historic landfills and urban development related to the royal canal and rail infrastructures occurred, and in addition ground profile shows variation in just a few metres as a consequence of alluvium sedimenthology history overlying the Dublin glacial Boulder clay (DBC). Then a separate ground model is expressed below in which shall be used as a guide until further precise information is obtained within the immediate location of the proposals.

Conceptual Ground Model		
Stratum Number	**Material**	**Approximate Thickness (m)**
1	Made ground and landfills, tarmac, clays, ash material and bricks	0.90-2.75
2	Loose (Nspt 10) Fine to medium sandy gravel with shells	1.20-1.55

3	Soft grey silty clay	0.30-0.65
4	Dense to very dense medium to coarse very sandy gravel with cobbles and boulders	3.95-6.85

Table 3 - Conceptual Ground Model

According to the historical GI and based on that assumptions performed by others, the surface and subsurface ground materials within the study area can be divided into the following types from top to bottom, Quaternary soils and bedrock, summarised as follows:

- **Made ground.** The thickness of this material is ranging between 0.90 and 2.75 metres. Heterogeneous made ground was pervasively referred at the site where anthropogenic action and even contaminated land by urban development is extended. This material is unsuitable and shall be removed in all cases for foundations purposes, even considering the pernicious effect as a consequence of permeable behaviour been underlie by soft clayey peat estuarine deposit.
- **Quaternary Estuarine Alluvium.** Identified on site boreholes, and in detail along the trial pits Report 5831. It comprises superficial soft deposits into two (2) stratum levels underneath the made ground and landfills. In the plot this stratum 2 and 3 varies significantly in elevation and in some cases does not appear likely removed by landfills. Boreholes describes the stratum 2 and 3 between 0.90 to 1.55 and 3.95 to 4.55m BGL respectively where soft grey silty clay (stratum 3) overlies dense medium to coarse very sandy gravel with cobbles and boulders (stratum 4)
- **Quaternary Coarse Gravel Alluvium**. Upper gravel. This stratum is considered the ideal founding level – named stratum 4 - It comprises dense to very dense medium to coarse very sandy gravel with some cobbles and boulders, which identified at 2.80mBGL (Plot A) to 2.75-4.55mBGL (Plot B). Occasionally this level of upper gravel can be underlie by soft grey sandy silt.

3.2.4.2 Laboratory Testing Results

- This Section describes the preliminary classification and engineering properties of soil stratum recovered during the previous ground investigation, as determined by field and laboratory testing of available historic GI. This section also suggests typical strength parametres for soils taken by comparison from literature as a generic approach to the site as a whole for the proposed concept design:

Stratum Number	Material	Young modulus Es (MPa)	Poisson Coefficient √	Coefficient compressibility *mv* (m2/MN)	Modulus of subgrade reaction *ks*350mm plate dia (MNxm-3)
2,3	Estuarine Alluvium. Soft to loose, clayey peat , grey silt and sandy gravel with shells	2,4-10	-	High 0.3-1.5	5-20
4	Quaternary Alluvium. Dense to very dense coarse sandy gravel with cobbles and boulders	75-100	0,3-0,4	-	120-150
(*) Based on the historical site data within the vicinity and recommended parametres in literature by correlation.					

Table 4 - Lab test results (*)

3.2.5 Groundwater

Groundwater regime has been assessed from boreholes and trial pits data. Water table elevations were highlighted as metres below ground level (BGL) which represents the depth to boreholes elevation at the time.

Groundwater shows similar patterns where levels were recorded at boreholes between 1.45 to 2.45 m BGL. However there should occur some other reasons as the well drilling report 164, dated February 1998, highlighted water level between 2.5m to 5mBGL underneath the made ground and contained within the grey silt with loose gravel and shell fragments level.

Water table will likely interfere with the open excavations and the stability of the soils. If basement is proposed, selected granular blanket shall be disposed underneath platforms and foundations to alleviate up lift water pressure, and temporary support for excavation should require. The granular blanket to the underside of the slab will facilitate pumping of the groundwater and hence dissipate the up-lift pressures.

3.2.6 Geotechnical Considerations

From the desk study information, the following geotechnical considerations may be inferred for the concept design of this project.

3.2.6.1 Subgrade Materials

It is anticipated that three superficial material types may be encountered along the developments at Docklands plots:

i. Made ground and historical fills. These heterogeneous materials are unsuitable for engineering purposes and it is advised to be removed until completion. Also the presence of contaminated land recommends the execution.
ii. Soft estuarine alluvium deposits, clayey peat and fine loose sand bands with shells. These superficial deposits underlying the fills are subject to settlement, and low bearing capacity. Due to the fact of organic peat and clayey content, the expected California Bearing Ratio (CBR) value should result inadequate lower than 3. It is recommended the substitution of such material until the upper gravel alluvium stratum 4 and 5, backfilled by selected well graded granular material SHW Class 6A - below water level - until design level. This backfill material should be compacted until the required design density.
iii. Alluvium, dense fine to coarse sandy gravel with occasional cobbles and boulders and very few silt content. This material resulted with SPT values between 30 and 74 blows, in some cases refusal. For concept design purposes the expected CBR should range in between 20 to 30.

3.2.6.2 Earthworks and Excavation

3.2.6.2.1 Earthworks

Embankments, where required for rail construction, should be constructed of engineering fill placed and compacted in accordance with Standards for National Roads of Ireland (TII Transport Infrastructure Ireland publications), NRA of Ireland Vol.4 geotechnics and drainage and Specifications for Road Works Series NG600 Earthworks, read in conjunction with UK Specification for Highways Works (SHW) Highways agency.

For capping selected granular material SHW Class 6F is recommended. If flooding areas are expected selected well graded granular material SHW Class 6A (below water) shall be disposed.

3.2.6.2.2 Excavations

Where works require excavation, they should be carried out in accordance with the requirements of Irish Specifications for Road Works Series NG600 Earthworks (Transport Infrastructure Ireland TII publications) and Specification for Roads Works Series 600 Vol 1. British standards.

Consideration should be given to the temporary / permanent stability of the sides of excavations. The type of support required is a function of a number of factors including, material type, depth of excavation, groundwater level and tidal in the area of excavation, available space/imposed spatial restrictions, surroundings buildings and sequence of construction work.

For superficial made ground and fill deposits, 1V to 3H are considered appropriate slope for permanent open excavations. Sandy gravelly material with cobbles and boulders shall dispose to 2V to 3H. If additional measures are required, reinforced wire mesh and soil nailing shall be placed.

For excavations where expected chiselling, instability or insufficient excavation room, temporary support (king post wall, sheet pile walls, etc..) shall be advised. Where it requires the substitution of unsuitable material, landfills or made ground, immediate backfilled by SHW Class material 6A - below water level - shall follow the excavation until design level. This levelling should be compacted to admit foundations on top where admissible moderate loads are accommodated.

Should deeper excavations or trenches be required, or even unattractive control of groundwater, it is anticipated that temporary support shall dispose with the execution of sheet pile wall/ props (groundwater cut off), or even contiguous pile wall.

For permanent excavations contiguous secant pile wall hard-soft shall be recommended. The assessment of tie-back anchored reinforcing the capping beam shall be disposed at design stage. Piles shall be carried out in accordance with Irish ICE Specification, for piles and embedded retaining walls.

3.2.6.2.3 Filling and Compaction

It is anticipated that the majority of the superficial deposits, stratum 1 (made ground, fills), 2 (clayey peat) and 3 (soft silt), will be unsuitable for re-use as general fill, even with the presence of slightly contaminated land (diesel, grey ash, PAH, Pb and Cu).

For rail embankment, general granular fill SHW Class 1A/1B and selected granular SHW Class 6A/6B shall be advised. However, detailed assessment will be required based on further site precise investigation and earthworks volume to confirm the initial assumptions.

Compaction requirements shall be advised in accordance to Irish Specifications for Road Works Series NG600 Earthworks (TII publications) and Clause 612 and table 6/4 Specs SHW end product 95% of maximum dry density of BS 1377: Part 4.

3.2.7 Preliminary Foundations Results

The development involves the construction of new rail platforms, service buildings and associated infrastructures, underground station, and residential with key commercial buildings.

Groundwater is an issue which shall be investigated along the selection of standpipe piezometres installed in boreholes to precise water regime and elevation. Open excavations for foundations purposes should execute in accordance with natural groundwater level interference and expected incoming flows to excavation at designed elevation.

Where deep excavations or basements are to be executed beneath the structures, an analysis of earthworks stages shall be carried out. It is considered that a safe temporary slope of 1V to 2H for the made ground and superficial deposits shall provide that sufficient de-watering measures are put into place. Where the distance between the excavation and site boundaries is not adequate it will be necessary to support the excavation by some form of retaining structure. The retaining structures may take the form of temporary sheet pile walls in Stratum 1 and 2, and secant pile walls (hard-soft) would be appropriate for deeper excavations. If significant water incoming flows are expected a retaining system shall be considered for made ground replacement and backfilled by SHW Class material 6A selected well graded granular material - below water level -.

Spread foundations are considered a feasible foundation solution for some of the proposed structures founded on stratum 4. A list of development and preliminary foundation types according to the engineering purposes are given below:

- Type A. Light service steel buildings and new rail platforms

  Made ground, fills and superficial estuarine deposit (stratum 1 and 2) are not adequate material for foundations support. Conventional strip or pad foundations can be placed on the dense coarse sandy gravel with cobbles (stratum 4) underneath the soft surface material. However as those stratum lie deep and water table will interfere prompt open excavations, it is recommended the removal of soft clay/made ground material until completion and backfilled by compacted structural fill Class 6N Selected granular fill SHW - end product 98% of maximum dry density of BS 1377:part 4 (vibrating hammer method) - until above water level, placing the strip footings on top. Allowable bearing capacity lower than 100kN/m2 should be admitted. This will be in compliance with the control of stiffness/density testing during the construction (in situ CBR, Load plate test).

In the case of rail platforms, ground improvements shall be advised replacing the made ground material and backfill by general granular fill SHW Class 1A/1B or selected granular SHW Class 6A/6B according to the imposed dynamic loads. If this not the case or suitable option, ground improvements (stone columns) should be executed capped by top selected and compacted granular blanket from the top surface, being the columns embedded in pervious dense sandy gravel.

- Type B. Key buildings and heavy infrastructures

  Raft slabs are considered adequate foundations for heavy infrastructure development at the site where higher bearing pressures are required. Dense to very dense coarse very sandy gravel with cobbles - stratum 4 - encountered at depth of roughly 3.00 metres BGL can be considered as an acceptable founding layer. This stratum - expected thickness between 3.50 to 7.10 metres - should readily support loads of the order between 300-350kN/m2. However, cautions will be recommended if soft clays layers underlie this dense material before reaching up the underlying Dublin Boulder clay Glacial where interface likely weathered.

Note that dewatering activities can have a significant impact on material bearing capacities and retaining wall design. It is recommended that a detailed hydrogeological study is carried out before the groundwater management plan is agreed at construction stage and any excavation is commenced to assess the degree of groundwater drawdown and potential for generation of any settlements on the surroundings buildings. Temporary retaining walls can frequently be used within the groundwater management system to provide groundwater flow inhibitors. Consequently the dewatering design and the detailed geotechnical design should be progressed in an integrated manner.

The soil consolidation and settlement under the designed loads mentioned above will be subject to assessment of groundwater levels and the thickness of soft clay material encountered interlayered in gravelly clay horizons.

Those preliminary recommendations given above are based on assumptions. The final selection of foundation type and some others geotechnical inputs (e.g strip footings, raft foundations, pile foundations, ground improvements, drainage design, etc) will be confirmed once the site specific data becomes available as indicated.

3.3 Seismic Condition

Following established engineering practice, the Republic of Ireland is deemed to be in an area of very low seismicity and as such national annexes are not considered necessary for adopted I.S. EN 1998 .

In the event that I.S. EN 1998-1 is considered for the design and construction of buildings and civil engineering works in the Republic of Ireland, the recommended values for NDP´s given in I.S. EN 1998-1 should be employed.

The design seismic action, AEd, is expressed in terms of: (a) the reference seismic action, AEk, associated with a reference probability of exceedance, PNCR, in 50 years or a reference return period, TNCR.

The values considered are PNCR = 10% and TNCR = 475 years as the recommendation of the I.S. EN 1998-1:2004 and I.S. EN 1998-2:2005.

No onshore seismic zonation map with peak ground accelerations is currently available. Recently a map of seismic intensity (EMS scale) for 475 years mean return period has been published. Although the correlation between intensity and ground acceleration is rather weak. In areas with intensities less than 6 or 7 the 475-year return period PGA should not be exceeding the 0.04g, a level considered as a very low seismicity region.

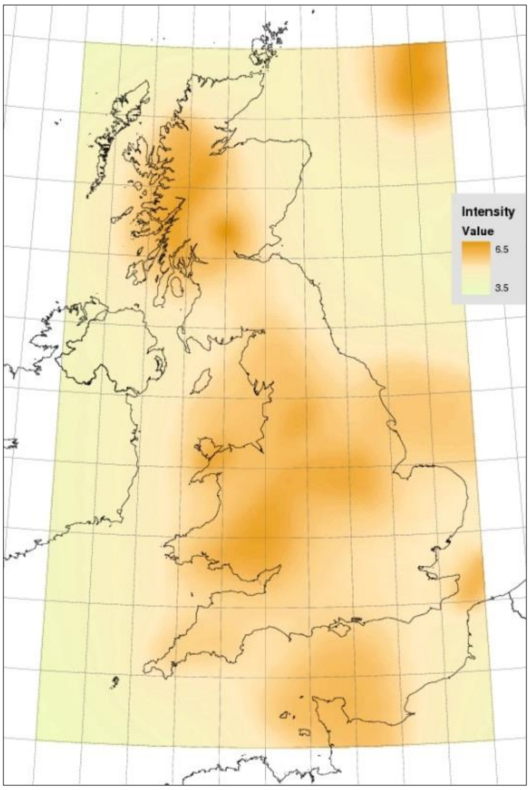


Figure 75. The expected intensity (EMS) of earthquake shaking with a 10% probability of being exceeded over 50-year period in the UK. (Source: Musson and Winter (1996))

Another reference is the Seismic Hazard Harmonization in Europe (SHARE), supported by the EU-FP7 to deliver the first state of the art reference hazard model for Europe, replacing older maps. The SHARE hazard contributes to the Global Earthquake Model (GEM) and serves as input for risk mitigation policies such as the design of earthquake-resistant multi-storey buildings and critical infrastructures such as bridges or dams. The SHARE seismic hazard is assessed with time-independent, probabilistic approach. Models of future ground shaking are based on the history of earthquakes over the past 1000 years, on the knowledge of active faults mapped in the field, on the style and rate of deformation of the Earth´s crust from GPS measurements, and on the instrumental recordings of strong ground shaking generated by past earthquakes.

The SHARE results do not replace the existing national design regulations and seismic provisions, which must be obeyed for today´s design and construction of buildings.

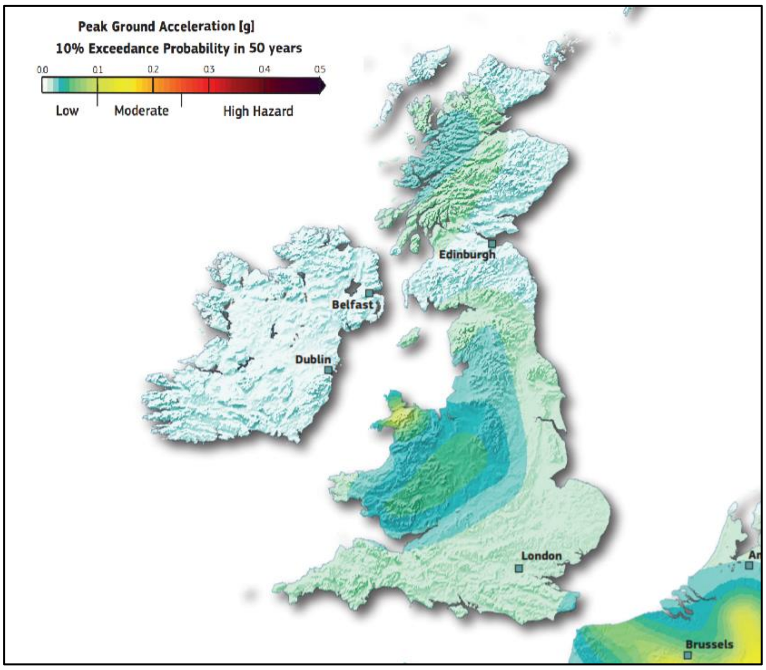


Figure 76. Peak ground acceleration [g] 10% exceedance probability in 50 years. (Source: SHARE European Seismic Hazard Map for Peak Ground Acceleration, 10% Exceedance in 50 years)

Therefore, no special provision for seismic design is required for this project.

3.4 Materials

3.4.1 Concrete

The concrete adopted for the structural design is included in the following table, depending on the element type:

Concrete specification according to I.S. EN-1992-1-1:2004				
Element type	**Exposure Class**	**f_{ck} min (MPa)**	**Max w/c**	**Min. Cement (kg/m3)**
Lean concrete	N/A	C15	N/A	N/A
Spread Footings	XC2; XA1-2-3(1)	C35/45	0,50	360
Piles Caps	XC2; XA1-2-3(1)	C35/45	0,50	360
Piles	XC2; XA1-2-3(1)	C35/45	0,50	360
Interior Columns	XC3	C35/45	0,50	360
Exterior Columns	XF1; XS1; XA1-2-3(1)	C35/45	0,50	360
Interior slabs	XC3	C35/45	0,50	360
Exterior slabs of buildings	XF4; XS1	C35/45	0,50	360
Exterior slabs of roads	XF4; XS1	C35/45	0,50	360
Interior beams	XC3	C35/45	0,50	360

Exterior beams	XF3; XS1	C35/45	0,50	360
(1) Aggressive conditions for the soil and water to be confirmed				

Table 5 – Concrete specification according to I.S. EN-1992-1-1:2004

All concrete is to be normal weight concrete. Concrete shall have low permeability, high strength, and the ability to resist chloride penetration into the concrete by diffusion, absorption, or hydraulic pressure. The exposure classes and the structural classes have been defined following the Eurocode methodology.

Concrete covers have been defined for each element according to the exposure conditions as per the following table:

Concrete specification according to NA to I.S. EN-1992-1-1:2004							
Exposure conditions							
	Class Designation	**Description of the Environment**	**Indicative Concrete Strength**	**Max. w/c**	**Min. Cement (kg/m3)**	**Min. Cover to steel (mm)**	**Nominal cover to steel**
Carbonation induced corrosion	XC1	Dry or permanently dry	C25/30	0.65	270	25	$25 + \Delta c_{dur,\gamma} + \Delta c_{dev}$
	XC2	Wet, rarely dry	C28/35	0.60	290	35	$35 + \Delta c_{dur,\gamma} + \Delta c_{dev}$
	XC3	Moderate humidity	C30/37	0.55	310	35	$35 + \Delta c_{dur,\gamma} + \Delta c_{dev}$
	XC4	Cyclic wet and dry	C30/37	0.55	310	40	$40 + \Delta c_{dur,\gamma} + \Delta c_{dev}$
Seawater induced corrosion	XS1	Airborne salt but no direct contact	C30/37	0.55	310	35	$35 + \Delta c_{dur,\gamma} + \Delta c_{dev}$
	XS2	Wet, rarely dry	C30/37	0.55	310	40	$40 + \Delta c_{dur,\gamma} + \Delta c_{dev}$
	XS3	Tidal, splash and spray zones	C35/45	0.50	360	45	$45 + \Delta c_{dur,\gamma} + \Delta c_{dev}$
Seawater induced corrosion	XS1	Airborne salt but no direct contact	C35/45	0.50	360	50	$50 + \Delta c_{dur,\gamma} + \Delta c_{dev}$
	XS2	Wet, rarely dry	C40/50	0.45	400	55	$55 + \Delta c_{dur,\gamma} + \Delta c_{dev}$
	XS3	Tidal, splash and spray zones	C30/37	0.55	310	45	$45 + \Delta c_{dur,\gamma} + \Delta c_{dev}$
Chloride induced corrosion excluding chlorides from seawater	XD1	Moderate humidity	C30/37	0.55	310	45	$45 + \Delta c_{dur,\gamma} + \Delta c_{dev}$

	XD2	Wet, rarely dry	C35/45	0.50	360	50	50 + $\Delta c_{dur,\gamma}$ + Δc_{dev}
	XD3	Cyclic wet and dry	C40/50	0.45	400	55	55 + $\Delta c_{dur,\gamma}$ + Δc_{dev}

NOTE 1 $\Delta c_{dur,\gamma}$ = 0mm for reinforced concrete and Factory controlled prestress precast concrete where fabrication is subject to a quality assurance system and with satisfactory history of previous use. Otherwise a value of 10 mm should be adopted

NOTE 2 Δc_{dev} = 10mm or 5mm for all factory controlled precast structures. This is based on fabrication being subjected to a quality assurance system in which the monitoring includes measurement of the concrete cover

NOTE 3 For cements assumed for use in this Table; refer to Notes 1 & 2 of Table NA.5 of the National Annex to I.S. EN 206

Table 6 - Concrete specification according to NA to I.S. EN-1992-1-1:2004

Minimum cover for concrete cast against prepared ground (including blinding) should be 50mm and for concrete cast directly against soil 75mm.

Concrete cover according to I.S. EN-1992-1-1:2004 (Reinforcing Steel)		
Element type	**Exposure class**	**Nom Cover (mm)**
Lean Concrete	N/A	N/A
Spread Footings	XC2; XA1-2-3(1)	55/75
Piles Caps	XC2; XA1-2-3(1)	55/75
Piles	XC2; XA1-2-3(1)	75
Interior Piers	XC3	45
Exterior Piers of buildings	XF1; XS1	55
Exterior Piers of roads	XF2; XS1	55
Diaphragm walls	XC2; XA1-2-3(1)	75
Vertical lining walls of Underground Stations	XC2; XC3; XA1-2-3(1)	45/55
Exterior Cut and Cover vertical lining walls	XF2; XS1; XA1-2-3(1)	55
Interior slabs	XC3	45
Exterior slabs of buildings	XF3; XS1	55
Exterior slabs of roads	XF4; XS1	55
Interior beams	XC3	45
Exterior beams	XF3; XS1	55

(1) Aggressive conditions for the soil and water to be confirmed

Table 7 - Concrete cover according to I.S. EN-1992-1-1:2004 (Reinforcing Steel)

3.4.2 Reinforcing Steel

Ribbed bars for concrete reinforcements will be weldable. Bars shall comply with Article 3.2 of Eurocode 2 (also according to UNE 10080), Class B or Class C and have the following characteristics:

- Characteristic yield strength of reinforcement: f_{yk} = 500MPa
- Ductile failure limit: f_s = 550MPa
- Design value of modulus of elasticity: E_s = 200,000MPa
- Rupture elongation = 12%

The nominal diametres of the corrugate bars will be selected from this series:

6 - 8 - 10 - 12 - 16 - 20 - 25 - 32mm

3.4.3 Grouting

Anti-shrinkage high resistance grout will be used over structural concrete, with a minimum characteristic compressive strength f_{ck} = 50N/mm^2.

3.4.4 Structural Steel

Structural steel to be S355 J0 in accordance with BS EN 10025, for all UC and UB members. Channel and angle shape members to be S275 J0.

Structural general properties will be:

- Modulus of elasticity: E = 210,000N/mm^2
- Shear Modulus: G = 80,000N/mm^2
- Poisson's Ratio: ν = 0.30
- Coefficient of linear thermal expansion: ε_t = 0.000012m/m °C
- Density: ρ = 7,850kg/m^3
- British sections profile or built up sections have been considered in the design.

The design value for the resistance of structural steel is defined by the expression: f_y/γ_i

Where the strength reduction coefficient γ_i will have the following values:

- γ_{M0} = 1.05
- γ_{M1} = 1.05
- γ_{M2} = 1.25

3.5 Loads

3.5.1 Dead Load

For permanent actions, a single representative value, coinciding with the characteristic value G_k, shall be considered.

The dead load includes the weight of all walls, permanent partitions, floors, roofs, finishes, foundations and structures, and all other permanent construction including services of a permanent nature.

It includes the gravitational action of all known and permanent elements which act on the structure, including equipment loads given by the suppliers.

The following values for dead loads of structures shall be taken into consideration:

Reinforced concrete	25kN/m^3
Mass Concrete	24kN/m^3

Structural steel	78.5kN/m³
Glass, in sheets	25.0kN/m³
Gravel	20kN/m³
Insulated claddings	0.2kN/m²
Roof cladding	0.2kN/m²
Single metal sheet claddings	0.1kN/m²

Others (piping, cable trays, …) should be considered the same way as equipment dead loads.

3.5.2 Live Loads – Imposed

Each of the variable actions can be considered with the following representative values:

- Characteristic value Q_k: Value of the action when acting alone.
- Combination value $\Psi_0 \cdot Q_k$: Value of the action when it acts together with another variable action.
- Frequent value $\Psi_1 \cdot Q_k$: Value of the action that is exceeded during a short period with respect to the life of the structure.
- Quasi-permanent value $\Psi_2 \cdot Q_k$: Value of the action that is exceeded during a large part of the life of the structure.

The values of the coefficients Ψ are as follows:

Recommended values of Ψ factors for buildings				
Actions		Ψ_0	Ψ_1	Ψ_2
Imposed loads in buildings, category (see I.S. EN 1991-1-1)				
Category A: domestic, residential areas		0.7	0.5	0.3
Category B: office areas		0.7	0.5	0.3
Category C: congregation areas		0.7	0.7	0.6
Category D: shopping areas		0.7	0.7	0.6
Category E: storage areas		1.0	0.9	0.8
Category F: traffic area, vehicle weight≤ 30kN		0.7	0.7	0.6
Category G: traffic area, 30kN<vehicle weight≤ 160kN		0.7	0.5	0.3
Category H: roofs		0.6	0.5	0.0
Railway traffic actions (LL; braking; nosing; centrifugal) (see I.S. EN 1991-2)		1.0	1.0	1)
Road traffic actions	TS; UDL; braking; skew (see I.S. EN 1991-2)	0.75	0.75	0.0
	Pedestrian and cycle-track loads	0.40	0.40	0.0
Snow loads on buildings (see I.S. EN 1991-1-3)		0.5	0.2	0.0

Horizontal earth pressure due to traffic load surcharge	0.7	0.7	0.6
Wind loads on buildings (see I.S. EN 1991-1-4)	0.6	0.2	0.0
Variable component of the water table	1.0	1.0	1.0
Temperature (non-fire) in buildings (see I.S. EN 1991-1-5)	0.6	0.5	0.0
Construction Loads	1.0	-	1.0
1) If deformation is being considered for Persistent and Transient design situations, $\Psi 2$ should be taken to 1.00 for rail traffic actions.			

Table 8 - Recommended values of Ψ factors for buildings

The values of the imposed loads considered are as follows:

- Roof load: 1 kN/m^2, as per EN-1991-1-1 Table 6.10
- Photovoltaic panels (if required): 2 kN/m^2
- Live load in administrative areas: 3 kN/ m^2
- Live load in public areas: 5 kN/ m^2
- Hanging installations: 0.6kN/m^2
- Floors loads of the building exposed to accidental vehicle traffic, as per EN-1991-1-1, chapter 6.3.3.
- Floor loads of the building that can be part of public roads, as per EN-1991-1-2.
- Train Loads on ground slab, as per EN-1991-1-2.
- Concentrated Loads should be taken into account, as per EN-1991-1-1 and EN-1991-2.

3.5.3 Snow Loads

The characteristic value of the snow load on the ground s_k=0.6kN/m^2 is taken from the following the national annex NA:2010 to I.S. EN 1991-1-3:2003 load map.

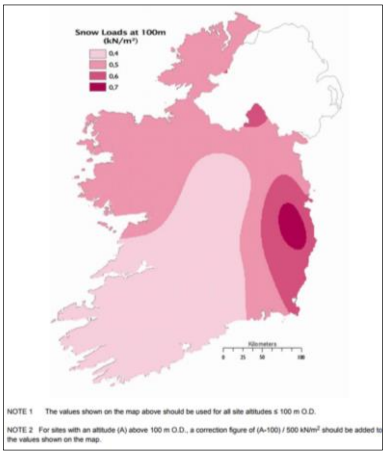


Figure 77. Irish Snow loads map (Source: annex NA:2010 to I.S. EN 1991-1-3:2003)

This load has been applied in all building roofs.

3.5.4 Wind Loads

Chosen from Figure below, the Basic Wind Velocity for the Dublin-Kildare area is 25m/s

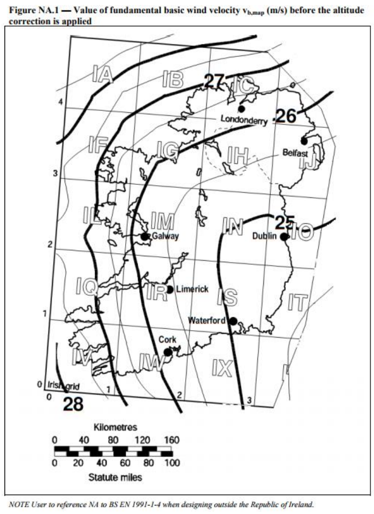


Figure 78. Value of fundamental basic wind velocity (Sourde: annex NA to I.S. EN 1991-1-4:2005)

To calculate wind loads the following input data are considered as per EN-1991-1-4:

- Terrain category II (Table 4.1)
- Air density: 1.25kg/m3
- Basic wind velocity vb: 25m/s (EC4.1)

Wind exposure coefficients for each surface (façade and roof) will be defined as per section 4.2.4 of EN-1991-1-4.

3.5.5 Water Forces

In accordance with Sections 5.2.2 of CCE-TMS-410, the effects of the effects of ground waters conditions present at the location of a proposed structure shall be considered in design. Appropriate allowance shall be made for the pressure and uplift likely to act on the structure as a whole or on parts of the structure. In general, actions due to water (free or ground water) shall be represented as:

- static pressures
- If relevant, hydrodynamic effects.

The variability of water pressure and of water-level shall be considered by means of the design situations. Where water level is considered as variable, design values shall be directly specified.

The proposed water-level in persistent load combinations shall be separated in two components as specified in IS EN 1997-1, Section 10.2:

- A permanent component that represents the standard water table in persistent situations.
- A variable component that represents the range of variation of the constant value.

Bridge structures over watercourses, rivers and other waterborne bodies shall comply with Sections 5.2.18 and 5.6.2 of CCE-TMS-410 and consider the following:

- Hydrodynamic loads on a structure with allowances for the effects of waterborne debris striking the structure, and requirements for taking scour into account shall be in accordance with EN 1991, Part 1-6: General actions - Actions during execution and EN 1991, Part 1-6: General actions - Actions during execution.
- For bridges over water, suitable protection shall be provided to the superstructure and substructure against the effects of hydraulic action, scour and, where relevant, the impact from flooding debris or waterborne vessels.

- Where necessary, the relevant Port Authority shall be consulted and the Bridge shall be designed for the load effects of a ship impact; provided in I.S. EN 1991: Eurocode 1, Action on structures, Part 1-7 General actions – Accidental Actions.
- Where substructures and/or foundations are located in or adjacent to flowing, tidal or navigable water, they shall be studied in accordance with CCE-TMS-410, Section 5.6.2.

3.5.6 Road Traffic

3.5.6.1 Vertical Loads due to Road Traffic

3.5.6.1.1 Lanes

The carriageway width, w, shall be measured between kerbs or between the inner limits of vehicle restraint systems, and shall not include the distance between fixed vehicle systems or kerbs of a central reservation nor the widths of these vehicle restraint system. The minimum value of the height of the kerbs to be taken into account is recommended as 75mm.

The width w_l of notional lanes on a carriageway and the greatest possible whole (integer) number n_1 of such lanes on this carriageway are defined in the following table.

Table 1. Number and width of notional lanes

Carriageway width *w*	Number of notional lanes	Width of a notional lane w_l (m)	Width of the remaining area (m)
w< 5.4 m	1	3	w-3
5.4≤w<6m	2	w/2	0
6m≤w	Int(w/3)	3	w-3n

The location and numbering of the lanes shall be determined in accordance with the following rules:

- The location of notional lanes shall not be necessarily related to their numbering.
- For each individual verification (e.g. for a verification of the ultimate limit state of resistance of a cross-section to bending), the number of lanes to be taken into account as loaded, their location on the carriageway and their numbering shall be chosen that the effects from the load models are the most adverse.

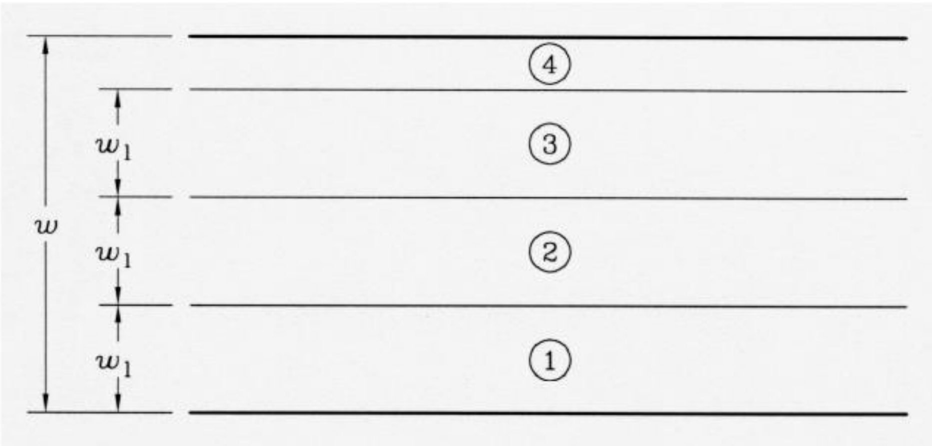


Figure 79. Example of the Lane Numbering in the most general cases

3.5.6.1.2 Load Model 1 (LM1)

Load model 1 (LM1) has been considered in the design. It represents concentrated and uniformly distributed loads, which cover most of the effect of the traffic of lorries and cars. This model shall be used for general and local verifications.

- Double axel concentrated loads (tandem system: TS), each axle having a weight of $\alpha_Q \cdot Q_k$. The following rules apply:
  - No more than one tandem system is taken into account per notional lane.
  - Only complete tandem systems are taken into account.
  - For the assessment of general effects, each tandem system is assumed to travel centrally along the axes of notional lanes.
  - Each axle of the tandem system is taken into account with two identical wheels, the load per wheel being therefore equal to $0.5 \cdot \alpha_Q \cdot Q_k$.
  - The contact surface of each wheel is taken as square and of side 0.40m.
  - For local verifications, a tandem system is applied at the most unfavourable location. Where two tandem systems on adjacent notional lanes are taken into account, they are brought closer, with a distance between wheel axles not below 0.50 m.

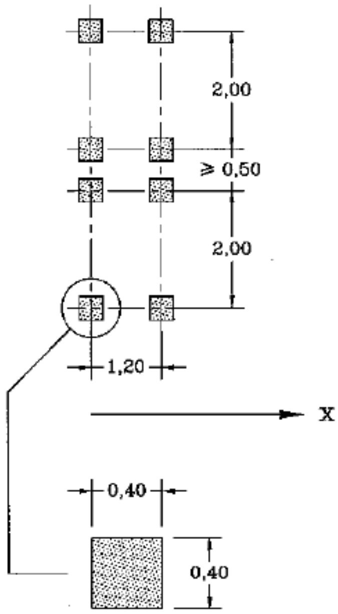


Figure 80. Application of tandem systems for local verifications. Source: IS EN 1991-2

- Uniformly distributed loads (UDL system), having the following weight per square meter of notional lane: $\alpha_q \cdot q_k$.
- The uniformly distributed loads are applied only in the unfavourable parts of the influence surface, longitudinally and transversally.

Load Model 1 is applied on each notional lane and on the remaining areas. On notional lane Number i, the load magnitudes are referred to as $\alpha_{Qi} \cdot Q_{ik}$ and $\alpha_{qi} \cdot q_{ik}$.

On the remaining areas, the load magnitude is referred to as $\alpha_{qr} \cdot q_{rk}$.

α_{Qi}, α_{qi} and α_{qr} are adjustment factors. The table below indicates their value:

Table 2. Load model 1: Adjustment factors for load model 1. Source NA to IS EN 1991-1

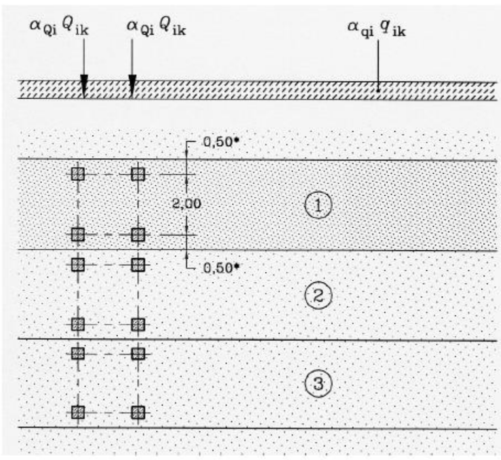
Location	α_Q for tandem axle loads	α_q for UDL loading
Lane 1	1	0.61 a)
Lane 2	1	2.2
Lane 3	1	2.2
Other lanes	-	2.2
Remaining area	-	2.2
a) should be taken as 1.0 for subclause 4.4.1 (2) of IS EN 1991-2		

The characteristic values of Q_{ik} and q_{ik}, dynamic amplification included:

Table 3. Load model 1: characteristic values. Source IS EN 1991-2

Location	Tandem system TS	UDL system
	Axle loads Q_{ik} (kN)	q_{ik} (kN/m^2)
Lane 1	300	9
Lane 2	200	2.5
Lane 3	100	2.5
Other lanes	0	2.5
Remaining area	0	2.5

The details of Load Model 1 are illustrated below:



Key
(1) Lane Nr. 1 : Q_{1k} = 300 kN ; q_{1k} = 9 kN/m^2
(2) Lane Nr. 2 : Q_{2k} = 200 kN ; q_{2k} = 2,5 kN/m^2
(3) Lane Nr. 3 : Q_{3k} = 100 kN ; q_{3k} = 2,5 kN/m^2
* For w_l = 3,00 m

Figure 81. Application of load model 1. Source: IS EN 1991-2. LM1 is derived from I.S. EN 1991: Eurocode 1, Action on Structures

3.5.6.1.3 Load Model 2 (LM2)

Load model 2 (LM2) has been considered in the design where relevant in local verifications. It represents a single axle load applied on specific contact areas that covers dynamic effect of the normal traffic on short structural members.

As an order of magnitude, LM2 can be predominant in the range of loaded lengths up to 3m to 7m.

Load model 2 consists of a single axle load $\beta_Q \cdot Q_{ak}$ with Q_{ak} equal to 400kN, dynamic amplification included, which should be applied at any location on the carriageway. However, when relevant, only one wheel of 200 β_Q (kN) may be taken into account.

β_Q is taken equal to unity.

The contact surface of each wheel shall be taken into account according to NA as a square of sides 0.40m and 0.40m instead of 0.35 and 0.60 as indicated in the general EN recommendations:

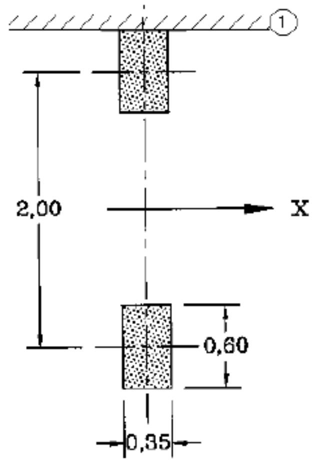


Figure 82. Application of load model 2. Source: IS EN 1991-2. LM2 is derived from I.S. EN 1991: Eurocode 1, Action on Structures

3.5.6.1.4 Load Model 4 (LM4)

Crowd loading should be represented by a Load Model consisting of a uniformly distributed load (which includes dynamic amplification) equal to 5kN/m^2.

3.5.6.2 Pedestrian Load on Footways

For road bridges supporting footways or cycle track, a uniformly distributed load q_{fk} shall be considered as follows:

- 5kN/m^2 (characteristic value) acting alone.

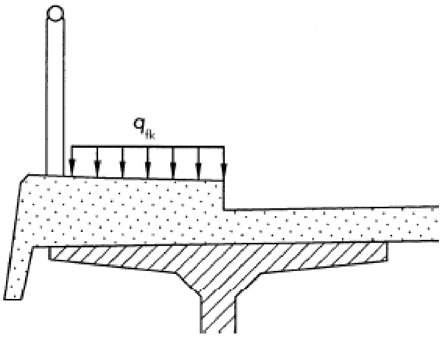


Figure 83. Characteristic load on a footway (or cycle track). Source: IS EN 1991-2

3.5.7 Load Combinations

Load combinations will be designed according to EN 1990 Eurocode 0 requirements.

- For persistent and transient design situations the combination action can be expressed as:

$$\sum_{j\geq 1}\gamma_{G,j}G_{k,j}+\gamma_P P+\gamma_{Q,1}Q_{k,1}+\sum_{i>1}\gamma_{Q,i}\Psi_{0,i}Q_{k,i} \qquad \text{(EC0 Eq. 6.10)}$$

Where:

- $G_{k,j}$ = representative value of each permanent action with constant values.
- $G^*_{k,j}$ = representative value of each permanent action with variable values.
- $Q_{k,1}$ = representative value (characteristic value) of the dominant variable action.
- $\Psi_{o,i}\cdot Q_{k,i}$ = representative values (combination values) of the variable actions concomitant with the dominant variable action.
- $\gamma_{Gj,sup}$ = 1.35
- $\gamma_{Gj,inf}$ = 0.9
- $\gamma_{Q1,sup}$ = 1.5
- $\gamma_{Q1,infj,inf}$ = 0.9

For accidental design situations the combinations of actions can be expressed as:

$$\sum_{j\geq 1} G_{k,j}+\sum_{j\geq 1} G^*_{k,j}+\psi_{1,1}\cdot Q_{k,1}+\sum_{I>1}\psi_{2,i}\,Q_{k,i}+A_d$$

Where:

- $G_{k,i}$, $G^*_{k,j}$ = representative values.
- $1{,}1\cdot Q_{k,1}$ = frequent value of the leading variable action concomitant with the accidental action.
- $\Psi_{2,i}\cdot Q_{k,i}$ = quasi permanent value of the rest of the variable actions concomitant with the accidental action.
- Ad = accidental action.

And for the serviceability limit state the next equation has been used (accidental situations will be excluded for these states):

- Characteristic combination:

$$\sum_{i\leq1}\gamma_{G,i}\cdot G_{k,i}+\sum_{j\geq1}\gamma_{G^*,j}\cdot G^*_{k,j}+\gamma_{Q,1}\cdot Q_{k,1}+\sum_{i>1}\gamma_{Q,i}\cdot\psi_{0,i}\cdot Q_{k,i}$$

- Frequent combination:

$$\sum_{i\leq1}\gamma_{G,i}\cdot G_{k,i}+\sum_{j\geq1}\gamma_{G^*,j}\cdot G^*_{k,j}+\gamma_{Q,1}\cdot\psi_{1,1}\cdot Q_{k,1}+\sum_{i>1}\gamma_{Q,i}\cdot\psi_{2,i}\cdot Q_{k,i}$$

- Quasi-permanent combination:

$$\sum_{i\leq1}\gamma_{G,i}\cdot G_{k,i}+\sum_{j\geq1}\gamma_{G^*,j}\cdot G^*_{k,j}+\sum_{i>1}\gamma_{Q,i}\cdot\psi_{2,i}\cdot Q_{k,i}$$

Where:

Calculation value of the actions "γ" (ELS)			
Action		Effect	
		Favourable	Unfavourable
Permanent. Constant value (G)	Dead load	1	1
	Superimposed dead load	1	1
Permanent. Variable value (G*)	Prestress load	1	1
	Rheological effects	1	1
	Earth pressure	1	1
	Settlement	0	1
	Friction in bearings	1	1
Variable (Q)	Loads due to traffic	0	1
	Pedestrian load	0	1
	Surcharge earth pressure	0	1
	Climatic actions	0	1
	Rail Structure Interaction	0	1
	Water	0	1
	Construction loads	0	1

3.6 Calculation Basis

The structure shall be designed and executed in such a way that it is able to sustain all actions and influences likely to occur during its execution and use, with appropriate degrees of reliability and in an economical way. The structure shall be designed to have adequate structural resistance, serviceability, and durability in accordance with EN Eurocodes.

To ensure the safety of the surface station structure, the Limit State design method will be used according to European Regulation. The states are classified as:

- Serviceability Limit States (SLS).
- Ultimate Limit States (ULS).

3.6.1 Serviceability Limit States (SLS)

This limit state concerns the functioning of the structure or structural members under normal use, which affects the comfort of users and the appearance of the construction works.

In the context of serviceability, the term “appearance” is concerned with criteria such as high deflection and extensive cracking, rather than aesthetics.

Serviceability limit states in buildings considers, for example, floor stiffness, differential floor level, storey sway or/and building sway and roof stiffness. Stiffness criteria may be expressed in terms of limits for vertical deflections and for vibrations. Sway criteria may be expressed in terms of limit for horizontal displacements. The following states are considered:

3.6.1.1 Deflection Limits

In general, the structures are designed to standard deflection limits indicated in British Standards and Eurocodes. The general principle for limiting deflections is to avoid damage to cladding, avoid damage or excessive and the overall appearance of the building.

The proposed limits are as follows in the table below:

Deflection limits			
Area	**Short term Imposed Load**	**Imposed and finishes load**	**Total Load**
Floors - general	Span/360	-	Span/250
Elements supporting cladding /brittle finishes	Span/500	Span/500	Span/250
Roofs – general	Span/360		Span/250
Horizontal storey drift	Storey height/300	-	Storey height/300
Horizontal building drift	Building height/300		Building height/300
Footbridges	Span/1200	-	-

Table 4 – Deflection limits

Deflections of a building shall not exceed the values that adversely affect its proper functioning or appearance. As specified in I.S. EN-1990-2002+A1-2005 A1.4.3, vertical and horizontal deformations should be calculated in accordance with I.S. EN 1992 to I.S. EN 1999, by using the appropriate combinations of actions.

3.6.1.2 Vertical deflection

Vertical deflection is represented schematically in the figure below:

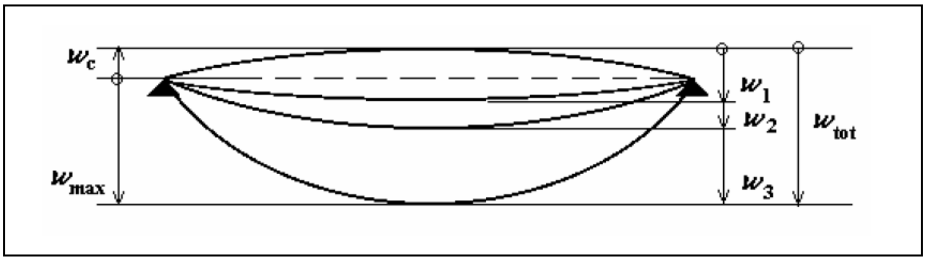


Figure 84. Definition of vertical deflections. (Source: I.S. EN-1990-2002+A1-2005, A.1.4.)

- w_c is the precamber in the unloaded structural member.
- w_1 is the initial part of deflection under permanent loads of the relevant combination of actions.

- w_2 is the long-term part of the deflections under permanent loads.
- w_3 is the additional part of the deflection due to variable actions of the relevant combination of actions
- w_{tot} is the total deflection sum of w_1, w_2, w_3
- w_{max} is the remaining total deflection considering the precamber.

For concrete structures, as specified in I.S. EN 1992-1-1:2004 7.4.1, the appearance and general utility of the structure could be impaired when the calculated sag of a beam, slab or cantilever subjected to quasi-permanent loads exceeds span/250. The sag is assessed relative to the supports. Pre-camber may be used to compensate for some or all of the deflection but any upward deflection incorporated in the formwork should not generally exceed span/250.

Deflections that could damage adjacent parts of the structure should be limited. For the deflection after construction, span/500 is normally an appropriate limit for quasi-permanent loads. Other limits may be considered, depending on the sensitivity of adjacent parts.

In the case of steel structures, since the Irish National Annexes do not recommend any specific deflection limit, the following criteria of the British Standard National Annex (NA to BS EN 1993-1-1:2005) will be considered in this design stage.

For structures supporting road traffic there is not a clear rule in the Eurocode for these structures. The proposed limit is under the frequent combination for conventional roads.

The suggested limits for calculated vertical deflections of certain members due to variable loads (permanent loads should not be included) are as follows:

- Cantilevers: Length/180
- Beams carrying plaster or other brittle finish: Span/360
- Other beams (except purlings and sheeting rails): Span/200
- Purlings and sheeting rails: To suit the characteristics of particular cladding.
- Road bridges: Span/1000 for the live loads under the frequent combination

If the function or damage to the structure, finishes, or non-structural members is being considered, the verification for deflections should take account of the effects of permanent and variable actions that occur after the execution of the member or finish concerned.

3.6.1.3 Horizontal displacement in building above ground

Horizontal displacements are represented schematically in the figure below:

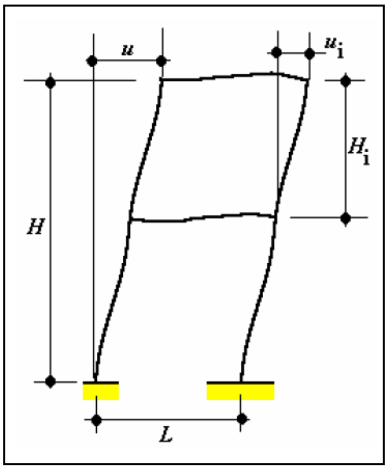


Figure 85. Definition of Horizontal displacements. Source: I.S. EN-1990-2002+A1-2005, A.1.4.3

- u is the overall displacement over the building height H
- ui is the horizontal displacement over a storey height Hi
- In general, for control and integrity of structural and non-structural elements under the Characteristic combination the following limits shall apply:
- u < H/500
- ui < Hi/300
- When only appearance of the structure is considered under the quasi-permanent combination the relative displacement in a storey shall be ui < Hi/250.

3.6.1.4 Horizontal displacement in structures below ground (U-Section and Retained Cut Structures)

In general, the analysis of the permissible horizontal displacement in diaphragm walls supporting above and belowground structures and buildings and excavations, is related to the level of settlements that adjacent buildings can sustain without failure in SLS and ULS. In this analysis the following factors are key parametres:

- Importance and categorisation of the buildings in respect to their significance and permissible limitations on damage i.e.monumental, public, private buildings etc.
- Plan location of the buildings relative to their excavations and taking account of the relationship between the settlement of the buildings, the distance to the excavation front and the lateral movements of the diaphragm walls.
- Structural typology of the buildings as including types of foundation. The type of structure, the number of floors as well as the foundation have implications on the capacity of a building to withstand a settlement.
- Characteristics of the ground.
- Construction process of the excavation.

This kind of geotechnical-structural analysis is developed more precisely during the detailed design of the project. Prior to the execution of the works, a dilapidation survey must be carried out to assess the existing conditions of the buildings and to be able to monitor their condition during the works.

At the current stage of the project, generic limits are proposed that we consider typical for the generality of concrete-steel buildings and conventional urban conditions.

The proposed maximum horizontal displacements allowed in diaphragm walls of the retain cut solutions under the characteristic combination of actions are:

- 20 mm, when buildings are up to 15 m from the diaphragm wall.
- Maximum horizontal displacement in diaphragm walls will never exceed 30 mm.

Diaphragm walls and props have to be instrumented during construction to check displacements and forces.

3.6.1.5 S.L.S. of vibration

To achieve satisfactory vibration behaviour of structures and their members under serviceability conditions, the following aspects, should be considered:

- The comfort of the user.
- The function of the structure or its structural members (e.g. cracks in partitions, damage to cladding and sensitivity of building contents to vibrations).
- For the serviceability limit state of a structure or a structural member not to be exceeded when subjected to vibrations, the natural frequency of vibration of the structure or structural member should be kept out of certain values which depend upon the function of the building and the source of the vibration.
- The analysis is not usually critical in concrete structures.

3.6.1.6 S.L.S. of cracking

The cracking of the concrete shall comply with Section 5.5 for durability of CCE-TMS-410.

The cracking of the concrete due to tensile stresses may affect the durability of the structure.

A limiting calculated crack width ωmax shall be established taking account of the proposed function and nature of the structure and the cost of limiting cracking. Due to the random nature of the cracking phenomenon, actual crack widths cannot be completely predicted. However, if the crack widths calculated in accordance with the models given in the Eurocode are limited to the values indicated hereinafter, the performance of the structure is unlikely to be impaired.

The following values are considered according to the exposure class of the elements.

Recommended values of ωmax for the building and relevant combination rules. Source: NA to I.S. EN 1992-1-1:2004. Section 7.3.1		
Exposure Class	**Reinforced members and prestressed members with unbonded tendons**	**Prestressed members with bonded tendons**
	Quasi-permanent load combination	**Frequent load combination**
X0, XC1	**0.3*1**	**0.2**
XC2, XC3, XC4	**0.3**	**0.2*2**
XD1, XD2, XS1, XS2, XS3		**0.2 and decompression*3**

Recommended values of ωmax for the <u>building</u> and relevant combination rules. Source: NA to I.S. EN 1992-1-1:2004. Section 7.3.1		
Exposure Class	Reinforced members and prestressed members with unbonded tendons	Prestressed members with bonded tendons
	Quasi-permanent load combination	Frequent load combination
*1 For X0, XC1 exposure classes, crack width has no influence on durability and this limit is set to give generally acceptable appearance. In the absence of specific requirements for appearance this limit may be relaxed. *2 For these exposure classes, in addition, decompression should be checked under the quasi-permanent combination of loads. *3 ωmax = 0.2mm applies to parts of the member that do not have to be checked for decompression		

Table 5 - Recommended values of ωmax for the building and relevant combination rules.

Source: NA to I.S. EN 1992-1-1:2004. Section 7.3.1

Recommended values of ωmax for the <u>bridges</u> and relevant combination rules. Source: NA to I.S. EN 1992-2 :2005. Section 7.3.1		
Exposure Class	Reinforced members and prestressed members with unbonded tendons	Prestressed members with bonded tendons
	Quasi-permanent load combination	Frequent load combination
X0, XC1	0.25	Decompression
XC2, XC3, XC4	0.25	Decompression
XD1, XD2, XS1, XS2, XS3	0.10	Decompression

Table 6 - Recommended values of ωmax for bridges and relevant combination rules.

Source: Table NA.2 in NA to I.S. EN 1992-2:2005. Section 7.3.1

The decompression limit should extend over 25mm for all parts of the bonded tendons or duct in buildings.

The decompression limit should extend over the complete area of the prestressed concrete section in bridges. Additionally, according to DN-STR-03012 October 2016, section 3.9,the maximum permissible top tension in a prestressed beam at transfer shall be limited to $0.75f_{ctm(t)}$.

3.6.2 Ultimate Limit States

Design for ultimate limit states shall be based on the use of structural load models for relevant limit states.

It shall be verified that no limit state is exceeded when relevant design values for actions, material properties or product properties and geometry data are used in the models.

The verifications shall be carried out for all relevant design situations and load cases.

The requirements shall be achieved by the partial factor method.

3.6.2.1 U.L.S. of equilibrium

The global balance, due to instability for a part or the overall structure shall be ensured.

3.6.2.2 U.L.S. against bending with or without axial force, shear and torsion.

This analysis is carried out on the structural element and cross sections. The development of the results is done by means of computer calculation software and supplementary hand calculations to guarantee the correspondence between calculation and reality.

3.6.2.3 U.L.S. of Fatigue

A fatigue verification shall be carried out for those structures and structural components, which are subjected to regular load cycles and fluctuation in accordance with I.S. EN 1991: Eurocode 1, Action on structures, Part 2- Traffic loads on bridges as amended by the Irish National Annex to Eurocode 1: Actions on structures – Part 2: Traffic loads on bridges.

For fatigue verification, it shall comply with Section 5.2.4, 5.2.5 and 5.2.16 of CCE-TMS-410, I.S. EN 1992-1-1-2004 and EN 1992-2:2005.

Aerodynamic Effects from the actions due from passing trains on surfaces of structures adjacent to or to near the track shall be considered as these could have sustainable effect on the elements of a structure. These may include elements such as footbridges, station canopy, parapets, cladding panels on structure, noise barrier etc. Aerodynamic effects can in turn induce cyclic loading in materials and induce fatigue failure.

The methodology indicated in sections 6.8.5 and 6.8.7 of I.S. EN 1992-1-1-2004 and EN 1992-2:2005 for passive/active steel and concrete respectively shall be followed to satisfy this ultimate limit state in the decks.

3.7 Structural description

The structure of the station is a continuous element with different structural solutions for each Zone. All the platform level is located below ground level and requires a retaining system, the entrance, and the retail area are located above ground level. All the structure below ground level is formed by reinforced concrete. The foundation of the station is formed mainly by a raft foundation connected to the retaining walls. The raft is designed to compensate the vertical water force under the station. The structure above ground level (mainly main entrance and retail area) is formed by reinforced concrete and a steel roof. For a better understanding of the structural design the station has been divided into 8 zones.

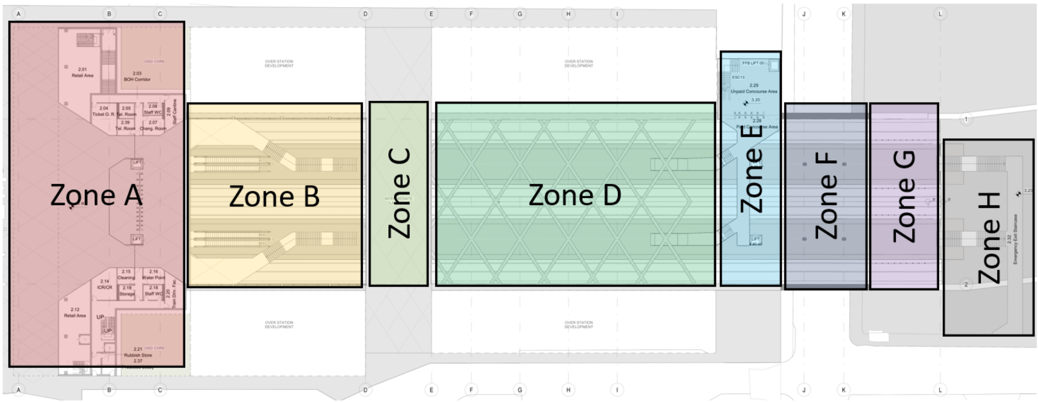


Figure 86. Spencer Dock division of structural zones

3.7.1 Zone A

The first zone is the main entrance of the station. This zone has 3 levels: platform level, entrance level, and roof level. Additionally, there is a mezzanine level between the entrance level and the roof. The foundation for the columns and walls is formed by pile caps which will allow having a high bearing capacity and low differential vertical movements. All the vertical structure is formed by reinforced concrete: the retaining system is designed with secant pile walls with columns rising from the retaining system and pile caps. The pile walls are supported by the raft and the slab. The slabs are a mixture of one-way and two-way slabs on beams. The roof is a singular structure formed by two different typologies. The roof over the retail area is formed by steel beams with composite deck and the roof over the public area is formed by steel trusses with lightweight cladding and only accessible for maintenance.

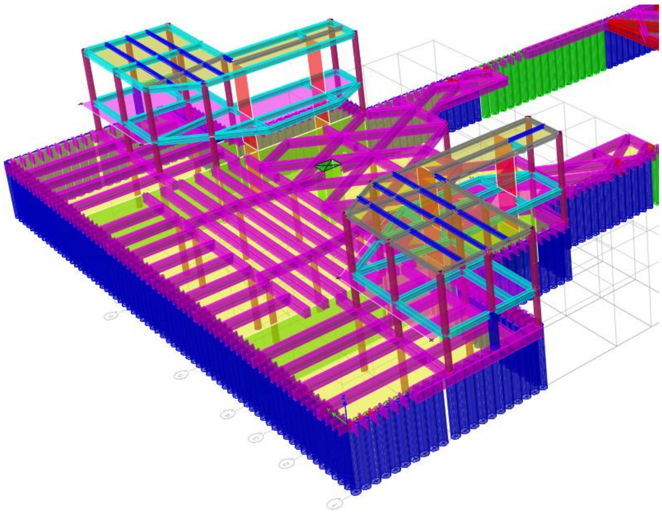


Figure 87. Structural numerical model of reinforced concrete structure of Zone A and B

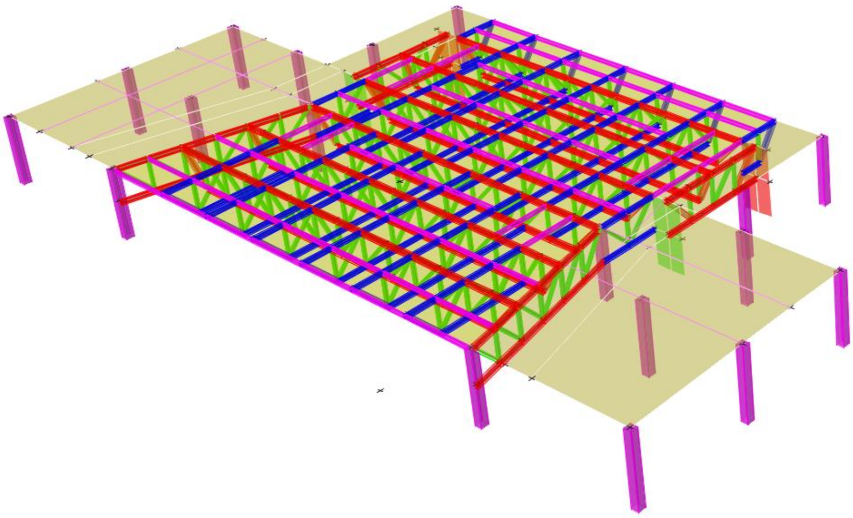


Figure 88. Structural numerical model of roof steel structure over Zone A

3.7.2 Zone B

The second zone is the part of the platform under the roof of the station. This zone has also 3 levels: platform level, entrance level, and roof level. All the vertical structure is formed by reinforced concrete: secant pile walls as retaining system and columns rising from the raft foundation as support for the stairs. The retaining walls have a cantilever system, being longer than the piles in Zone A. The slab at the entrance level is supported by cantilever beams, which are fixed to the retaining walls. The roof over the platforms is formed by steel trusses with lightweight cladding and glass only accessible for maintenance.

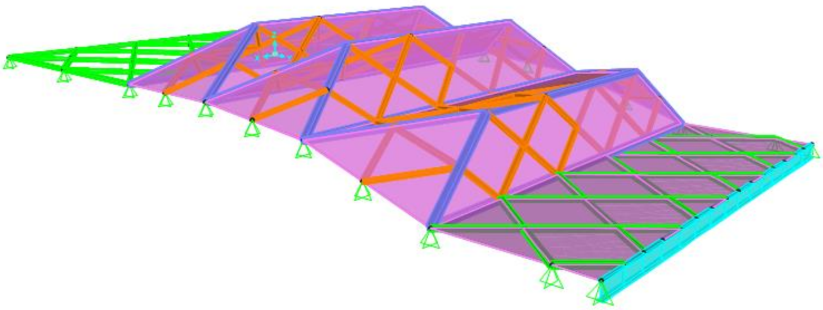


Figure 89. Structural numerical model of roof structure over Zone B

3.7.3 Zone C

The third zone is the part of the platform with a pedestrian bridge over it connecting both sides of the station. This zone has only two levels: the platform level and the pedestrian bridge. All the vertical structure is formed by reinforced concrete: secant pile walls as retaining system and columns rising from the raft foundation. The retaining system is considered to have two support points: the raft foundation and the slab of the bridge. The pedestrian laneway is a one-way slab on beams supported by the retaining system and the columns.

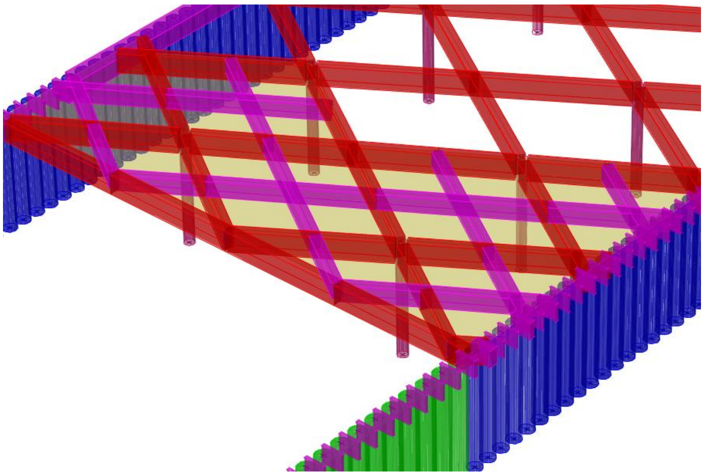


Figure 90. Structural numerical model of pedestrian bridge over Zone C

3.7.4 Zone D

The fourth zone is the biggest one, being located between the pedestrian laneway and the secondary building entrance. This zone has two levels: the platform and the beams working as shoring between the walls. All the vertical structure is formed by reinforced concrete: secant pile walls as retaining system and columns rising from the raft foundation. The retaining system is considered to have two support points: the raft foundation and the shoring system formed by beams connected to the capping beams of the piles. The shoring system is supported in the columns.

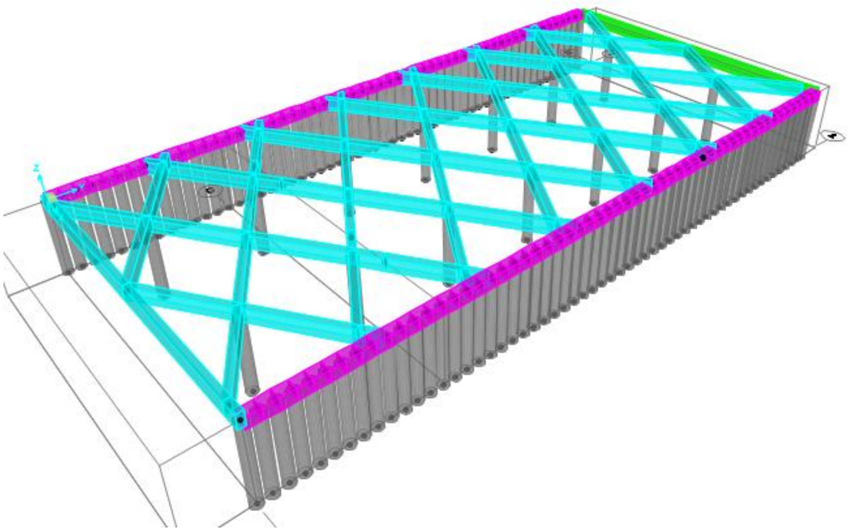


Figure 91. Structural numerical model of shoring system over Zone D

3.7.5 Zone E

The fifth zone is the one where the secondary building entrance is located. The building is independent of the structure of the station, having the retaining system of the station an extra load pressure due to the foundation of the building. All the vertical structure is formed by reinforced concrete: secant pile walls as retaining system and columns rising from the raft foundation. The retaining walls have a cantilever system. The secondary building is design as a reinforced concrete structure with columns rising from shallow foundations, two-way slabs on beams, and a steel roof.

3.7.6 Zone F

The sixth zone is the part of the station where the Sheriff Street Upper bridge is located. This zone has two levels: the platform and the Sheriff Street Upper bridge. All the vertical structure is formed by reinforced concrete: secant pile walls as retaining system and walls rising from the raft foundation. The retaining walls have a cantilever system and the walls are used as supports for the bridge.

3.7.7 Zone G

The seventh zone is located between the Sheriff Street Upper bridge and the emergency staircase. This zone has only one level, the platform. The only vertical structure is formed by the secant cantilever pile walls and is connected at the platform level by the raft foundation.

3.7.8 Zone H

The eighth zone is only formed by the emergency staircase. This staircase could be connected to one or both sides of the station. The vertical structure is formed by reinforced concrete columns and the slabs and stairs are all steel elements. The staircase is supported on the retaining wall and the columns, which rise from the raft foundation.

4. MEP Design

4.1 Fire Protection System

The proposal at Spencer Dock Station will be designed and built to achieve satisfactory protection against fire and the spread of fire. The design will be provided with appropriate means for rescuing people and for fighting fires.

4.1.1.1 Irish Building Regulations 2006 Groups

According to TGB Part B (2006), the Spencer Dock Station is catalogued as:

- Group 5: Assembly.

4.1.1.2 Fire extinguishers

Manual portable fire extinguishers will be provided throughout the station (platforms and plant rooms), in accordance with BS EN-3. The type of each fire extinguisher will be as follows:

- CO_2 type for electrical hazards (Electrical rooms and switchboards)
- Dry powder type for electrical and solid hazards.

4.1.1.3 Automatic Fire Detection System

An analogue addressable fire alarm system shall be provided to achieve automatic detection of fire in all enclosed areas of the station and plant rooms.

The station will have a Fire Alarm Control Panel located inside the Station Control Room (ICR/CR) with a graphic interface to monitor the system and it shall be linked to the local fire authority's system.

4.1.1.4 Automatic Fire Suppression System

A stand-alone automatic gas extinguishing system will be planned for the main electrical and telecom rooms (TER, Electrical Substation, etc.). Gas containers shall be located in a specific room for this purpose.

The gas to be used in this procedure should be an inert gas (e.g. FK-5-1-12). The standard used for the design and calculations is EN 15004, Part 1 & 2, "Fixed firefighting systems – Gas extinguishing systems".

4.1.1.5 Fire Mains

Dry internal fire mains (dry riser) will be provided at the platform level to ensure a 60m coverage. The Fire Department Connection (inlets) will be located at both entrances of the station.

Figure 92 Dry risers on the platform.

4.1.1.6 Fire Alarm System

Manual call points will be provided in all public areas, on platforms and concourse areas.

Fire Alarm System shall be in accordance with BS EN 54.

Figure 93 Fire extinguisher and fire alarm equipment.

4.1.1.7 Fire Hydrants

External fire hydrants will be provided in accessible places for Fire Fighting Services. They will be located to ensure a maximum distance from the station entrances of 46 m and not less than 6m.

4.1.1.8 Smoke Extraction System

A smoke extraction system will be provided in the platform covered area in order to remove the smoke and heat caused by a fire. A smoke and heat extraction system will be provided by means of natural vents located on the roof of the station. The system will be automatically operated and connected to the main fire alarm control panel. These natural vents will be also used for the daily ventilation of the station.

Automatic smoke barriers will be provided in the station to avoid smoke entering the entrance level. The smoke layer will be designed to maintain the means of egress free of smoke. A CFD analysis will be developed to ensure a safe evacuation of the station in case of a train in flames arrives at the station.

The smoke extraction system will be electrically operated and fed by an uninterruptible power supply. The smoke and heat extraction panel will be provided and located close to an exit door.

4.2 HVAC, Heating, Ventilation and Cooling System

4.2.1 Ambient conditions

Design outside temperatures taken into account shall be (as per ASHRAE 2017):

- DB 21.9º / MCWB 17º in summer
- DB -2.7º in winter

Regarding the setpoint temperature in the different rooms, the station can be divided into the following uses:

- Staff areas and ticket office: Heated to no less than 20ºC
- Telecom & server rooms; between 20ºC and 24ºC and 30%-70%

4.2.2 Ventilation

Natural ventilation shall be provided with openable windows or grilles, wherever it is feasible.

The public areas of the station will be ventilated by the natural vents on the roof.

Mechanical ventilation shall be provided for staff rooms, cleaning rooms, telecom rooms, retail areas, and toilets when natural ventilation will not be possible.

4.2.3 HVAC system per room

HVAC design shall comply with EN 16798 and Irish Building Regulations, Technical Guidance Part Fand it shall be designed and built for energy-efficient operation. The fresh air providing ventilation will be filtered in accordance with Building Standards requirements.

The HVAC system shall consider the internal and ventilation thermal loads calculated in accordance with criteria expressed in the ASHRAE Handbook of fundamentals and relevant EN standards.

	TEMPERATURE	HUMIDITY	HEATING	COOLING	MECHANICAL VENTILATION	NATURAL VENTILATION	HUMIDITY CONTROL	USE
Staff and ticket office rooms	>20ºC	-	YES	NO	YES	NO	NO	CONTINUOUS
Technical rooms	>5ºC	-	YES	NO	YES	YES*	NO	CONTINUOUS
Telecom and server rooms	20ºC-24ºC	30%-70%	YES	YES	YES	NO	YES	CONTINUOUS

Figure 94 - HVAC requirements

(*) When natural ventilation is not possible, mechanical ventilation will be provided.

The proposed systems will be selected based on a low energy consumption criterion.

4.2.4 Heating source

The station hot water generation for the Heating systems and Domestic Hot Water system will be obtained from a gas boiler located in a technical room at the roof level. This solution will be developed broadly in the detailed design phase.

Retail units will generate their hot water independently from the station services.

4.2.1 Cooling system

A split type system will provide the cooling necessary to maintain a constant temperature inside telecom and server rooms under 24ºC all the time.

4.3 Piping

4.3.1 General water treatment strategies

The following scheme explains the water treatment strategy for the area involved in the project of Spencer Dock Station.

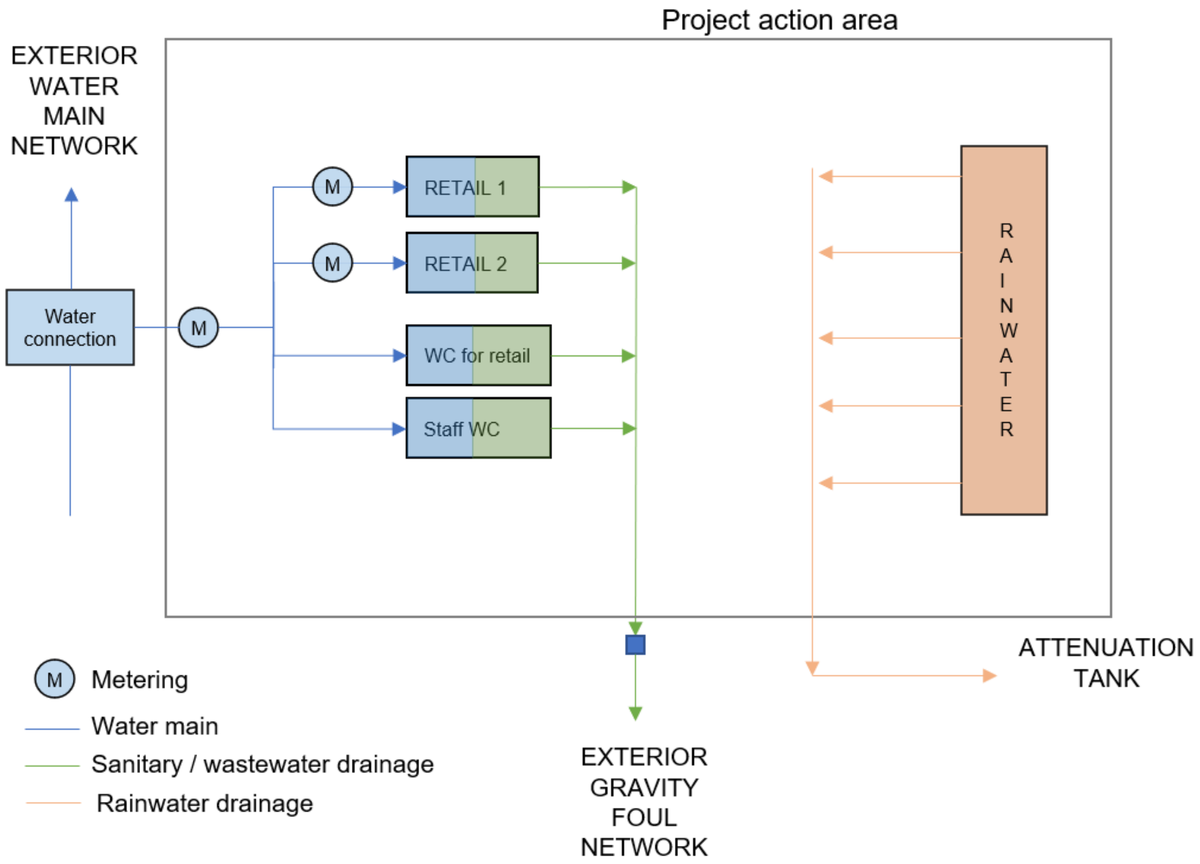


Figure 95 Water Drainage and Supply Strategy

The station rainwater system will discharge into an attenuation tank located in the exterior, which will be also used for the rainwater evacuation of the track.

The sanitary drainage will discharge into the existing exterior network.

4.3.2 Drainage and Sewerage System

The drainage and sewerage system shall comply with Irish Regulations. Connections with the Public Utilities are defined with the Utilities Companies.

Rainwater and wastewater systems shall be separate and independent systems.

4.3.2.1 Rainwater drainage

The rainwater collection in the new Spencer Dock Station building will be designed as a siphonic system operating at full capacity.

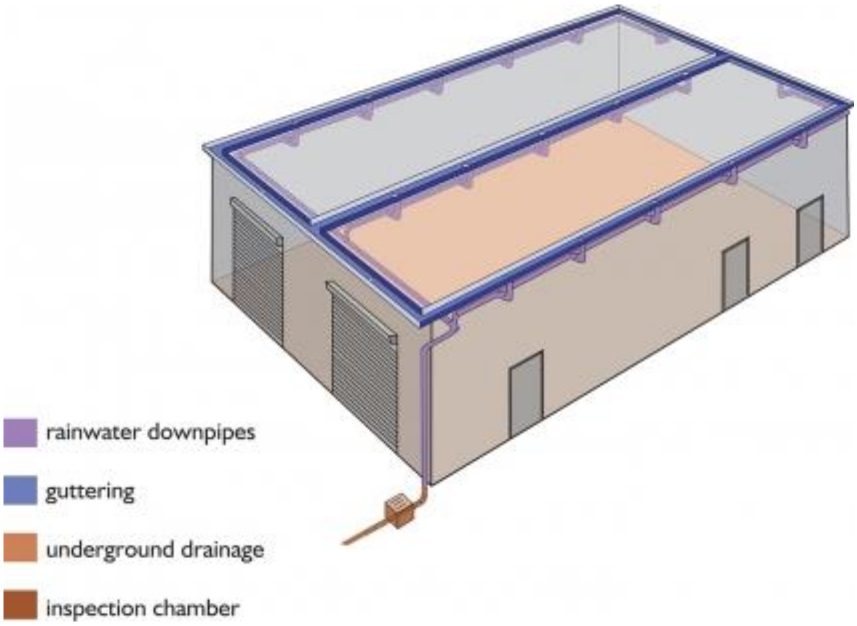


Figure 96 – Syphonic system

"*A syphonic system operates at full capacity, when water is sucked or syphoned from the roof down into the drain at high velocity". "Whereas a conventional outlet is simply a hole set into the lowest point on the roof, into which the water pours, the syphonic drain incorporates an anti-vortex plate that acts as a baffle, allowing only water to be drawn of the roof. During heavy rainfall the outlet drain fills to above the anti-vortex plate, cutting off airflow into the pipe. This lack of air coupled with the downward pull of the water creates a vacuum. The drainage pipes then flow at 100% full over the entire system*." (NOTE: information from Fullflow system)

All the pipes will be insulated against condensation.

As mentioned above, the stormwater gathered from the various roofs of the covered building, platforms and even the track leading into the station itself, shall be collected in an attenuation tank so as to pour it into the external network at a controlled flow rate.

4.3.2.2 Sanitary drainage

All sanitary drainage from the different spaces will be collected and discharged into the public sewage network.

All drain stacks will have adequate venting in order to protect the trap seals from siphonage, aspiration or back-pressure. In order to size the piping for the drain distribution system, the following criteria will be followed: the slope for horizontal drainage shall ensure a self-cleaning speed.

4.3.3 Water supply

Water supply to the new Spencer Dock Station staff areas, retails and toilets will be provided from the existing municipal water supply.

One main Water Meter will be provided inside the corresponding water intake space. From this point, separate water flow metres will be installed up to the retails in order to determine the water consumption of the different potential renters.

The material of the water supply pipes shall be plastic polymers, properly insulated.

4.3.4 Domestic Hot Water

DHW (Domestic Hot Water) will be provided using a gas boiler and will be stored in a thermally insulated tank.

Hot water piping including DHW recirculation shall be thermally insulated. Hot water tanks and pipework shall be arranged to prevent and protect against legionella bacteria:

· The hot water inside the tanks shall be stored above 55ºC.

· Heater system to rise hot water temperature up to 70ºC

· Thermally insulated tanks with drainage and access for cleaning.

· Tank material: Stainless steel.

4.3.5 Natural Gas

Natural Gas connection will be provided to each retail unit and the station services.

4.4 Electricity

4.4.1 Supply

The main electrical supply to the Spencer Dock station will come from an ESB distribution station, out of the boundary of the Station. This supply will feed the Main Distribution Board (CS-MDB1), which will feed the normal loads and the Essential loads. Essential Loads will have the additional backup of UPS. See section 4.4.2 for load type classification.

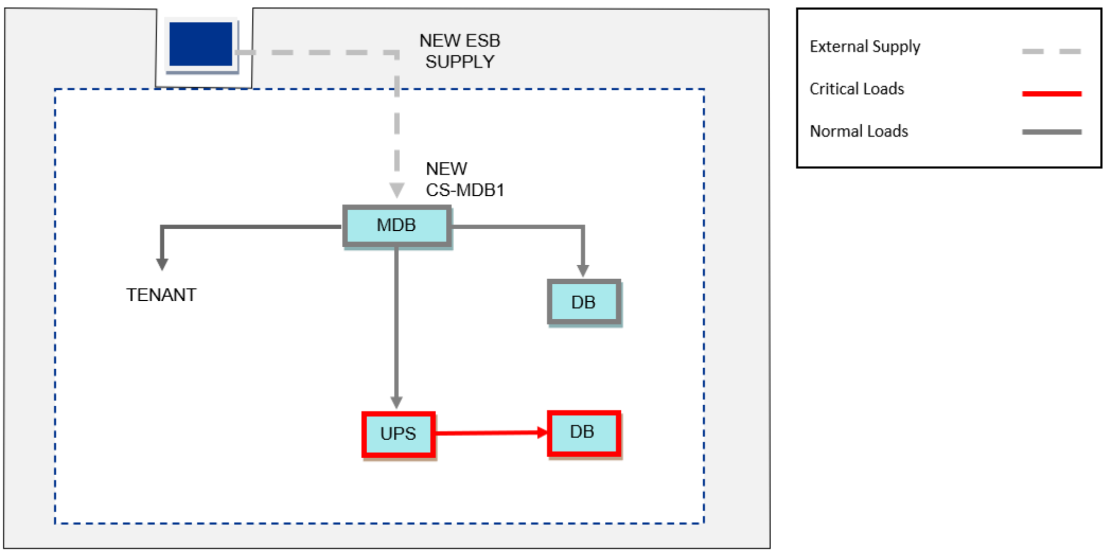


Figure 97 – Distribution scheme

The following equipment will be used for the electrical supply of the Spencer Dock Station:

- 1x 400V Main Distribution Board (MDB)
- 400/230V Distribution Boards.

Power factor capacitors

Power factor automatic capacitor banks shall be considered for the transformer in order to improve the power factor to at least 0.95. The power factor correction equipment will be located as close as possible to the MDB.

4.4.2 Type of Loads

According to their use, the loads that can be found in the Spencer Dock Station are building loads: office and general use small power, retail small power, HVAC, internal lighting, fire safety, escalators, elevators, etc. They are fed from dedicated Distribution Boards connected to the Spencer Dock Station MDBs.

On the other hand, according to the required redundant and uninterruptible supply, the following type of loads can be defined in the Spencer Dock Station design area:

- **Critical Loads**: Power supply to loads where a power break down is considered to be critical for life and safety of people or fire strategy, or that may notably impact the activity or economics of the railway, and thus requires back up energy source.
  - Fire alarm equipment nodes/panels
  - Escalators
  - Emergency lighting
  - TER HVAC loads
  - UPS feeding critical loads
  - TER workstation and technical room small power (10 minutes autonomy)
  - Data racks, security, and BMS (10 minutes autonomy)

  These loads are fed from Uninterrupted Power Systems (UPS) connected to the CS-MDB1, with enough batteries to provide the required autonomy in each case.

- **Ordinary Loads**: Power supply to all other loads, where power loss is not considered to impact in an important way the activity, economics, or safety of the Station.
  - General use Small Power
  - General lighting
  - General HVAC
  - Tenants
  - Water pumps

4.4.3 Power demand

The power demand estimation shall consider diversity factors and the minimum available spare capacity for future expansions shall be 20%.

The building's power demand will be based on different ratios (W/m^2) taking into account the activities and uses of each area.

4.4.4 Distribution Boards

Main Distribution Boards

The Main Distribution Boards (MDB) feeding the Spencer Dock Station services will be the CS-MDB1.

The loads considered ordinary loads shall be connected to the CS-MDB1 directly or through DBs. The loads considered Essential shall have UPS back-up. The retails areas will be fed through dedicated Distribution Boards connected to the CS-MDB1 and will be provided with energy metering equipment. Other Distribution boards will be installed in dedicated technical rooms and will be connected as it is shown in the schematic of Figure 97.

The MDB shall be type tested, factory-built assembly complying with IS EN 61439-2 with Form 4b with withdrawable feeders (in a rack) for fast replacement and maintenance. The cubicle construction of the main switchboard will consist of high-grade sheet steel of 2mm thickness. The enclosure degree of protection will be IP54. The neutral busbar will be of the same size and rating as the phase busbars.

The MDB will be arranged to enable the following to be carried out in the future:

- Extension by the addition of further cubicles at either end without disturbing the existing steelwork or busbars.
- Fit and cable additional circuit protection devices to spare equipped compartments.
- Change withdrawable outgoing units without disturbing adjacent units.
- Installation and termination of an outgoing cable.
- Inspection of switching devices, conductor connections, relays, etc.
- Adjustments of the settings of relays and other control/protective devices.
- Replacement of fuses, indicator lamps, etc.

In order to allow some not foreseen supplies, 20% of spare space will be provided within every new distribution board.

The MDB, and all DBs shall be design verified assemblies in accordance with EN 61439. Design verified assemblies shall be verified by testing, calculation, and/or design rules in accordance with EN 61439-1 and manufacturers shall provide evidence of compliance with that standard. All boards shall be installed with a minimum clearance of 1200mm from the front and 1000mm from the sides and rear if access to the back of the assembly is required in accordance with ET 201.

The maximum ratings of MCCBs shall be 630A. Breakers above 630A shall be ACBs.

All ACBs and MCCBs shall have integral power meters with communication modules. The meters shall be networked, and the wiring brought to an appropriate connector in the terminal section of the boards. The meters shall be compatible with the Building Management System (BMS).

Distribution Boards (DB)

Distribution Boards (DB) will be connected to the MDB, they shall feed other DB or directly the Building loads in the Station. They shall be located in LV electrical switchroom or a suitable area of the station.

DB will be form 3b in accordance with IS EN 61439-2. In order to allow some not foreseen supplies, 20% of spare space will be provided within every switchboard.

4.4.5 Cableways and Cables

Cable ladders and cable trays shall be used mainly for the ease of installation and maintenance of the electrical distribution.

Separate cabling systems will be used for different systems to ensure electromagnetic compatibility (EMC), which should be:

- Low voltage 400 V for production equipment, HVAC, small power, and lighting
- Very Low Voltage, ITC, and BMS cabling

For final or specific services, electrical conduits will be used: stainless steel or halogen-free (rigid and flexible).

There shall be at least 300mm between LV cableways and ITC cableways, according to EMC standards.

A spare space of 20% will be provided in order to allow future new circuits.

Cables

Bundles of single-core cables will be used typically for main feeders and machines, and multicore ones will be used mainly for small power and lighting. Low voltage cables to be considered shall be:

- Cables from MDB to Distribution Boards: CU/XLPE/LSZH/SWA/LSZH, 600/1000V Multicore, 90°C thermosetting insulated, armoured LSF Cu. If the installation is outdoors, CU/XLPE/PVC/SWA/PVC, 600/1000V cables shall be considered.

- Cables from Distribution Boards: Single-core or multicore, 90°C thermosetting insulated, non-arm, LSF Cu

- Cables for Life Safety Loads: Prysmian FP600S Fire resistant cable Cu

Low Smoke Fire Retardant will be used in general, and Low Smoke Fire Resistant will be used for safety feeders. In all cases, cables will be halogen-free.

Cables shall be sized considering ET101 standard fulfilling three criteria: current-carrying voltage drop below limits and short circuit withstand capability.

4.4.6 Small Power

Different small power connections shall be used depending on the area.

The sockets and electrical connections will be waterproof in wet areas, such as cleaning rooms, washrooms, outdoors, etc. Other supplies, such as fans or machinery, will be connected directly through an isolator switch beside the specific equipment. 230Vac socket circuits will be radial throughout with a maximum of eight twin sockets per circuit. The cleaner’s sockets shall be wired in separate circuits.

4.4.6.1 Technical rooms:

In technical rooms, power boxes shall be installed in order to connect maintenance, cleaning or other working equipment.

Power boxes shall be protected IP54 and IK09 generally.

4.4.6.2 Staff rooms:

In staff rooms, the following socket outlets will be combined in power boxes:

- Normal supply socket outlets, switched 230Vac – 13A (3 pins) P+N+E
- Normal supply USB socket outlet

Additionally, the following single or double socket outlets will be installed for equipment connection and scattered along the walls for cleaning purposes:

- Normal supply socket outlets, switched 230Vac – 13A (3 pins) P+N+E

4.4.6.3 Retail areas:

In the retail areas, the small power shall be developed and installed by the tenants. A junction box with a terminal block will be provided in each retail unit.

4.4.7 Lighting

4.4.7.1 Normal Lighting

Normal indoor lighting is intended to provide a comfortable environment with high-quality optical performances and high-efficiency energy consumptions.

According to this, indoor lighting shall be LED type, with the following features:

- High CRI, over 85 (4000K minimum will be selected), providing high comfort for the environment and optical quality.
- Suitable glare control for each working area according to CIBSE, e.g. UGR19 for offices and meeting areas.
- High energy efficiency (whole luminaire over 120lm/W).
- Minimum service life 50,000h (L80/B10) at = 25°C.
- Suitable dust and waterproofing: IP44 in showers, plant rooms, risers, and maintenance workshops; IP65 outdoors and in washing and cleaning wet areas.
- The capability of regulation for spaces where it can be combined with natural lighting, and according to the presence of people.

According to applicable standards and best practices, the minimum lighting levels shall be the following (horizontal illuminance unless otherwise stated):

Lighting Levels		
AREA	**ILLUMINANCE**	**U_0**
Entrance lobbies / Waiting areas	200 lux	0.4
Corridors / Circulation area	100 lux	0.4
Stairs	100-200 lux	0.4
Reception desk	300lux	0.6
Toilets / Changing room	200 lux	0.4
Rest rooms	100 lux	0.4
Storage/Service/Support Room	100-200 lux	0.4
Offices, task areas	500 lux	0.6
Offices, general areas	300 lux	0.4
Technical rooms	200 lux	0.4
Lift car	100 lux	0.4
Comms rooms	500 lux	0.6

Figure 98 – Lighting levels

4.4.7.2 Sustainability and control

The lighting sustainability strategies main concept shall be to allow reducing the luminance levels, or switching off the circuits in areas where artificial lighting is not needed, either because no work is being carried out or because natural lighting is enough to fulfil the task requirements.

An energy-efficient lighting control philosophy shall be used. Some points to be considered in the design of the lighting shall be:

- Passive Infra-Red (PIR) occupancy detection in toilets, stairs, stores
- Switches for plant rooms, technical rooms, and utility areas where maintenance staff are responsible for switching on /off. They may also be controlled by the Lighting Control System (BEMS)
- Turning off completely lighting circuits in order to cut off voltage and not maintain the "standby mode" in the luminaire when it has been switched off. This "standby mode" state implies a very low load.
- Fully programmable time functions to maximize energy savings within each Facility via a Lighting Control System

The lighting control of the Spencer Dock Station will be controlled via a fully addressable, programmable automated control system, which will be part of the Building Energy Monitoring System (BEMS). The system will use an open standard building automation lighting protocol to switch on and off the lighting in the rooms and to connect the field device to the BEMS. An open standard addressable dimming lighting control protocol will be used over it to set different scenes in rooms that require it. The combination of both protocols allows for a more robust and flexible control system.

4.4.7.3 Emergency Lighting

There will be two types of emergency lighting regarding its use:

- **Escape Lighting**: to ensure that the means of escape can be effectively identified and safely used by occupants of the building and allow a safe and organized evacuation. This can be further divided into Escape route, Open area and High-Risk Area lighting.
  Escape lighting luminaires shall be LED non-maintained, fed from a central power supply system.
- **Escape Signage:** This will mark and identify the directions of egress.
  Escape signage will be LED maintained, fed from a central power supply system.

Escape luminaires and signs shall be fed from un-switched branch circuits. Emergency luminaires will be a central power supply system, with an autonomy of at least 3 hours.

The schedule below shows the escape lighting levels in each space, as per the IS 3217:

Emergency Lighting Levels		
Room or area	**Type of lighting**	**Required minimum illuminance**
Defined Escape Routes (including out of the building near the exit)	Escape Route	1 lux (along the centre of the escape route) 0.5 lux (0.5 m around the centre)
Open areas over 60 m²	Anti-Panic Lighting	0.5 lux (excluding 0.5m around the perimeter)
Toilets over 8m²	Toilet Facilities	0.5 lux
Accessible Toilet or shower (any size)	Toilet Facilities	1 lux
Security and Plant Rooms	Plant Rooms	1 lux
Switchboards	Plant Rooms	5 lux (Vertical)
Disabled Refuges	Point of Emphasis	5 lux

Emergency Lighting Levels		
Room or area	**Type of lighting**	**Required minimum illuminance**
First Aid Posts and Fire Fighting Equipment: extinguishers, alarm call points, fire panels…	Point of Emphasis	5 lux (Vertical)
Other areas as per specification (e.g. lifts)	Anti-Panic Lighting	0.5 lux
High-Risk Area	High-Risk Area	10% of the normal illuminance

Figure 99 - Emergency lighting levels

At least an exit sign must be seen from any escape route, and additionally in any place where confusion may occur. They will be generally suspended, or surface mounted between 2 and 3m, always at the same height throughout the escape route, so far as it is reasonably practicable. Escape signs shall not be fixed to doors or in places where opening doors may obscure them.

4.4.7.4 Earthing and bonding

A copper underground mesh shall cover the full footprint of the Spencer Dock Station. The building will have its perimetric earthing grid, and it shall be connected with the buried mesh earthing grid. Vertical earthing rods will be connected to the grid to increase its performance.

All earthing systems shall be connected to the station earthing mesh, including:

- 400 Vac Low Voltage System.
- LPS – Lightning Protection system.
- Telecommunication System (ITC).

This mesh will be calculated according to IEEE 80:2000, to achieve less than 0.5 ohms, so all the earthing systems can be connected together and also the metal and steel-reinforced structures, metal pipes, cable trays, machinery, fences, façades, lighting columns, ... In this way, it is ensured that all those elements are at the same potential, and touch and step voltages will be acceptable. It is necessary to ensure the safety and reliability of the electrical supplies as a result of any fault in the low voltage network.

Separate earthing circuits will be used for protective earthing (PE) and functional earthing (FE), in order to prevent electromagnetic disturbances in the telecommunications and control systems. Earthing system will be designed according to IEC 61000-5-2.

4.4.7.4.1 Lightning protection

A risk assessment shall be done for the Spencer Dock Station considering IS EN 62305-2 in order to have a calculated risk lower than the tolerable risk and so minimise the possible lightning hazards.

The protection level used to achieve an acceptable risk will determine the air termination system arrangement according to the following table:

Protection Level				
Level / Class	**Efficiency**	**Rolling sphere radius (m)**	**Mesh width (m)**	**Down Conductor average distance (m)**
I	98%	20	5x5	10
II	95%	30	10x10	10
III	90%	45	15x15	15
IV	80%	60	20x20	20

Figure 100– Protection level

The protection level depends, among other things, on the lightning flash density, which in the Dublin area is 0.08 flashes/km2/year, based on the isokeraunic map of the BS 62305. This is quite a low value, typical to Ireland, which foresees low lightning protection needs.

Transient surge protection shall be provided in all incoming, outgoing and internal systems. This includes each Main Distribution Board, Distribution board, and Communications, Fire Alarm, Security, CCTV and BMS panels. It will be designed in accordance with IS EN 62305, IEC 61312-1 and ET101.

The Lightning Protection System (LPS) in the Spencer Dock Station shall be designed in accordance with the IS EN 62305. It will consist of the following parts:

- **Roof conductor**: The LPS at roof level will comprise a horizontal mesh of PVC sheathed 25mm x 3mm aluminium tape, which will be cross bonded to all metallic parts on the roof such as the structural steelwork, mechanical plant, metallic architectural features, satellite and terrestrial aerials and flag poles.

  The lightning protection system will be connected to the highest and lowest level of lift guide rail and the main electrical earthing point of the building, with further cross bonding to metallic rainwater pipes and selected curtain walling to avoid flashovers and voltage differentials between the various system components.

- **Down conductor**: The building pillar structural steelwork and reinforcement will be used as the primary down conductors if possible. A dedicated down conductor on the façade may be used as a down conductor in case the structural steelwork was not suitable.

  The specialist sub-contractor will coordinate with other specialists to ensure continuity in construction detailing and provision for studs and tabs for connecting to the lightning protection system.

  The Lightning Protection Specialist Contractor will ensure that all structural steel and reinforcement bar continuity bonds are made prior to concrete foundations, bases, columns and slabs being poured or enclosures being constructed and that all resistance readings are taken at this time to validate the performance of the steelwork.

  IS EN 62305 states that electrical/mechanical continuity should be adequately maintained between each floor level. The maximum electrical resistance for each column under the IS EN 62305 should be 0.2 ohms. It will be necessary to measure this resistance once the column is complete, should this value be exceeded external down conductors will need to be installed.

- **Earthing electrode**: The lightning protection earthing electrode for each down conductor will comprise of two elements: the pile foundation structural steel/re-bars and a 2.4m industry-standard copperbond earth rod. The rod will be contained within proprietary sealed earth pits, provided with concrete covers and cast-in the ground level slab out of the station. Test earth bars will be included within each earth pit.

4.5 BMS

The Building Management System (BMS) shall be capable of remote monitoring, supervision, and reporting on the operation and maintenance of systems and equipment. It shall also manage and control the status and performance of all the Electro & Mechanical equipment installed inside the station to optimise energy consumption whilst maintaining specified thermal comfort.

The controlled and monitored systems by BMS are the following:

- Heating, Ventilation, and Cooling System
- Electrical LV main switchboard Building Services
- Lighting System
- Emergency Lighting System
- Electricity and Water Metres
- Fire Alarm System

- UPS

The daily operation of the BMS shall be at the operator terminal, and it shall be possible to operate the BMS directly on the server. It shall be possible to access the BMS from a workstation/laptop/smartphone outside the station via a web browser. The BMS shall communicate with the SCADA.

4.6 Telecom (GroupIT, B&F)

The ticketing points shall be provided with induction hearing loops and with an Internet connection.

The station lifts shall be equipped with suitable loudspeakers with connection to the station Public Address System and the station lift alarm/system must be also fitted with a hearing loop. The CCTV installed inside the station lifts shall be managed by B&F and will be independent of the rest of the CCTV system which is controlled by SET.

The equipment of B&F and GroupIT shall not be located inside TER rooms which are only for SET services.

The voice alarm system will be in accordance with EN 54.

5. Sustainability Design

5.1 Passive architectural strategies to improve comfort conditions based on the specific climate conditions for Dublin

The first step in every sustainable building design consists of understanding the climate in order to adapt to its characteristics and respond to the external conditions providing design strategies capable of reducing the energy needs and maximise internal comfort.

The dominant influence on Ireland's climate is the Atlantic Ocean. Consequently, Ireland does not suffer from the extremes of temperature experienced by many other countries at a similar latitude. The warm North Atlantic Drift has a marked influence on sea temperatures. This maritime influence is strongest near the Atlantic coasts and decreases with distance inland. The hills and mountains, many of which are near the coasts, provide shelter from strong winds and from the direct oceanic influence. Winters tend to be cool and windy, while summers, when the depression track is further north and depressions less deep, are mostly mild and less windy (Irish Meteorological Service).

The bioclimatic charts reveal that the key strategies to achieve comfort are the **maximisation of solar radiation** (when possible) and the **protection from high-speed wind** conditions.

The main purpose of the design is to create a **shelter** that protects users from rain and winds while allowing solar access that provides solar radiation to improve thermal comfort for people.

The station is designed as an enclosed concourse but ventilated in a natural way, reducing mechanical ventilation systems that consume large amounts of **energy**.

This smart and **healthy** design manages to avoid possible concentrations of pollutants, suspended contaminating particles and viruses. Thus, the risk of diseases spread is minimised.

The project integrates and forms part of the urban fabric respecting the surrounding buildings, their shapes, widths and heights. The main virtue is that the proposal takes advantage of the existing resources in the environment, exploiting its possibilities. The free and open space located in front of the proposal is used to provide the best comfort conditions for citizens in terms of natural lighting, solar radiation and natural ventilation.

5.2 Shadow analysis & solar radiation

The shadow and solar radiation analysis have led to the design of a proposal that maximises the access of solar radiation to interior spaces. Thus, the building is designed facing south with a large opening at the entrance to allow solar access. In this way, several objectives are achieved simultaneously: on the one hand, the users' feeling of comfort is increased since solar radiation increases the heating sensation, and, on the other hand, the need for artificial lighting in the interior space is reduced. The OSD volumes do not have an impact on the results of this study.

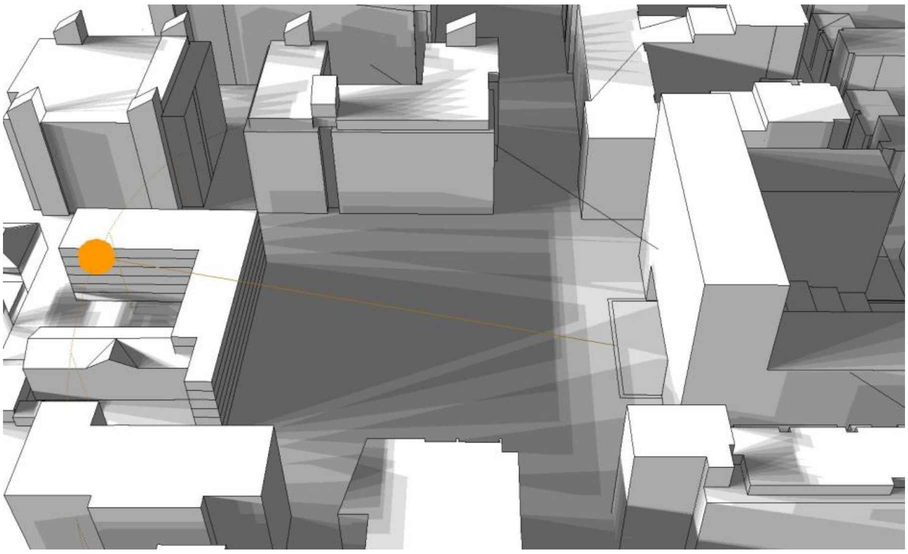


Figure 101. Side view of the proposal for the 21st of December, on the winter solstice, when the sun has the lowest height of the year.

The urban void created by the free space in front of the proposal allows solar access that provides natural light and radiation improving the energy performance of the design and thermal comfort sensation for the users.

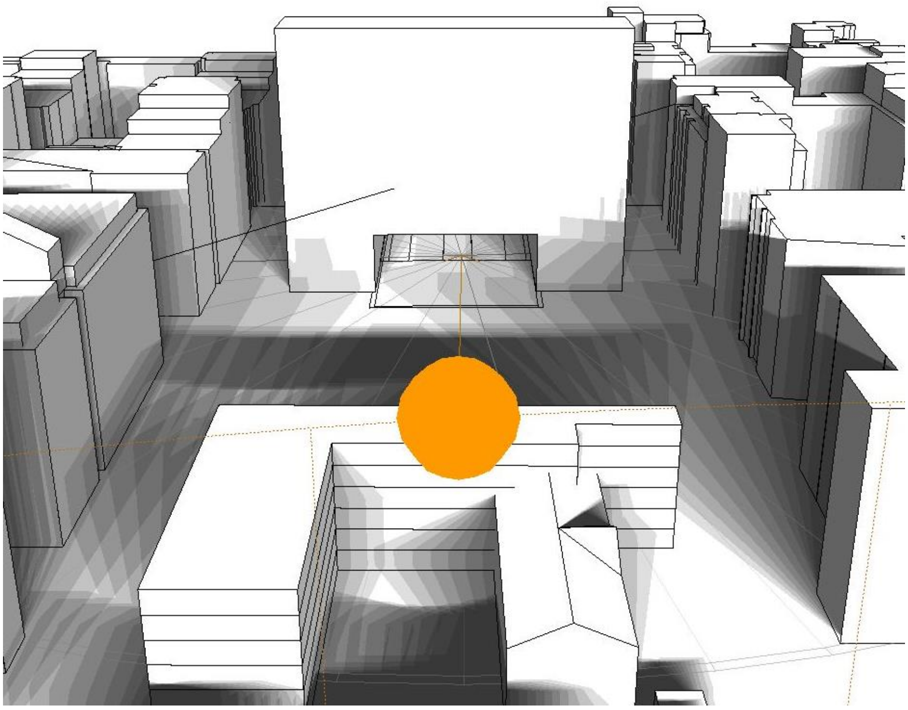


Figure 102. Front view of the proposal for the 21st of December, on the winter solstice, when the sun has its lower height of the year.

As shown on the diagram, solar radiation and natural lighting are available even during the worst-case scenario, on the winters' solstice when the day has fewer sun hours.

5.3 Towards the Zero Energy Buildings (ZEB)

5.3.1 Introduction

The main energy consumptions in stations tend to be due to lighting and ventilation needs, together with the heating requirements to achieve internal comfortable thermal conditions.

The proposed design works with a different concept, that aims to minimise the energy requirements of the stations, understanding the stations as a transition area between outdoors (the street) and indoors (the train cars). This strategy will allow for the reduction of the mechanical ventilation and heating needs, with their correspondent energy consumption and the maintenance needs and costs.

The bioclimatic design will permit the improvement of the comfort conditions in the stations compared to the external conditions by reducing air draughts and enhancing solar radiation.

Also, the station design enhances daylight, reducing the artificial lighting needs, that will be designed by LED technology that will dime in consonance with the daylight levels and the station occupancy and needs (light level reduction when there is no transport on the station).

Following the approach derived from the station’s concept design, some key strategies regarding sustainability have evolved within the station proposal.

5.3.2 Natural light income

In energy-efficient buildings, once the energy demands for heating, cooling and ventilation have been reduced to minimum values, the main energy consumption is due to artificial lighting. Therefore, the station’s layout incorporates natural light as an essential design element in several ways.

Around the station entrance, retail areas and back-of-the-house rooms are set to take advantage of the maximum amount of light. Glazed openings facing south seek to reduce the use of artificial lighting in these areas while incorporating shading systems that will eventually evolve in further stages of the project. In this regard, different strategies are being considered, ranging from fixed external elements that block solar radiation during the summer period but allow the free heat from the sun to be captured during the winter to solar control films integrated into the glazing composition itself.

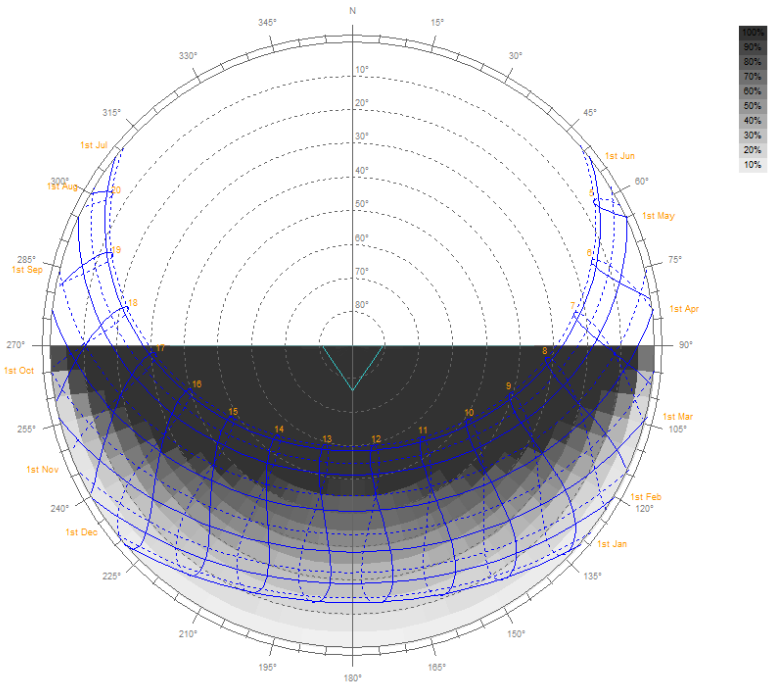
Leisure, transit or work places located behind these glazed surfaces will have a correct level of light, avoiding any blinding lights interfering with the activities taking place. Care has been taken to ensure that the occupied spaces receive the appropriate level of natural light.

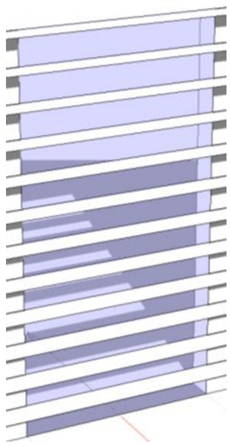
As the design is defined, checks will be made using daylight simulation software to ensure an adequate level of Daylight Factor.

The risk of overheating will be avoided thanks to specifically designed shading devices and thanks to reducing the amount of glass curtain walls on the southern facade. This strategy will reduce the cooling energy demand in the summers and also the heating demand in the winters while reducing the demand for artificial lighting throughout the year.

Sun path solar chart:

Equidistant Projection
Location: 53.2°, -6.2°
BRE VSC: 6.6%
Overcast Sky: 6.4%
Uniform Sky: 10.1%





Possible shading device: Horizontal blades

Figure 103. Shading devices study

In the main concourse area, passengers will experience a comfortable sensation while descending towards the platforms. Generous strips of light will guide them towards the lowest level of the station, illuminated by the canopy “creases” that cover this area. Since the canopy alternates opaque gables facing south with translucid gables facing north, light fills the space in an indirect way, reaching different points in the station platforms that are not necessarily located directly below these strips.

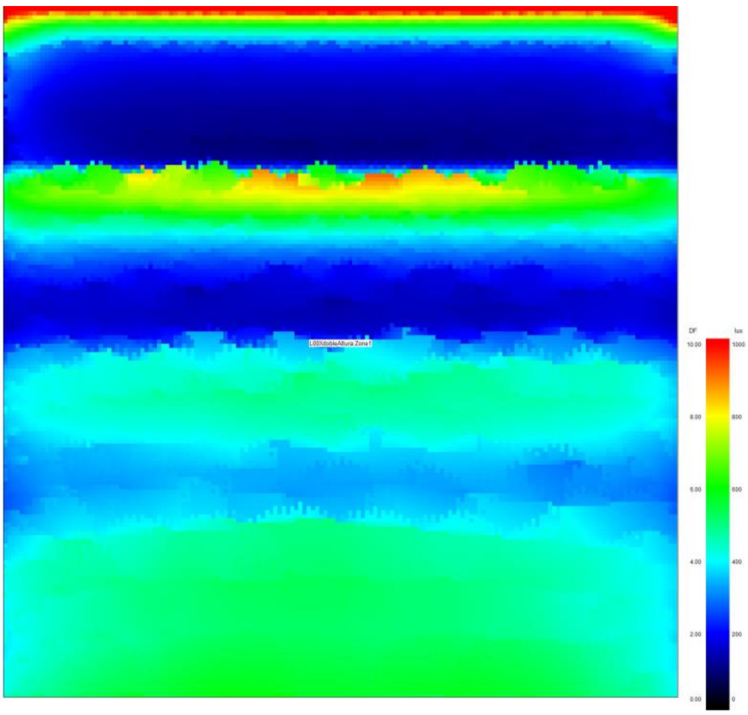


Figure 104. Station natural illumination study through the canopy skylights

The northern part of the platforms is open to natural light, filtered by the structural beams covering the span between the retaining walls of the station. The secondary access to the station linking Sheriff Street Upper is also designed following an open concept in order to reduce the artificial lighting needed in this access.

5.3.3 Thermal comfort

Linked to the natural light income, heat is also taken into account in the general station design.

The design allows solar access to inner space and provides an improvement of thermal comfort for the users by increasing their sensation of heat. Since it is a partially open station, the energy demands for heating and cooling are minimised.

Since natural light reaches most of the station areas, artificial lighting will be limited and will hardly contribute to increase the temperature inside the station.

This smart design provides different benefits:

- Increase of internal temperatures
- Improvement of the thermal comfort of the users

5.3.4 Air renewal

Airflow is ensured throughout the station. Specific measures have been implemented in order to ensure air renewal while limiting the impact of uncontrolled winds inside the station.

The smoke exhaust vents planned in the station canopy for use in case of a fire in the station are also intended to open whenever the conditions inside the station need an extra flow of air. These vents would avoid any improbable overheated situation in the enclosed area of the station. Openings in the main entrance of the station will contribute to the process of air renewal that may take place in the station.

In that sense, openings in opposite facades and orientations (in addition to the smoke exhaust vents mentioned above) facilitate natural cross ventilation without the need for energy-consuming mechanical installations.

The design promotes high indoor air quality passively, renewing the internal air, reducing particulate pollutants and the risk of spreading viruses.

5.3.5 Low environmental impact

Dublin's 30 year vision is for a **zero-carbon city** with all energy coming from renewable energy sources. All buildings will have to be built or retrofitted to near-zero energy building standards.

As mentioned before, the proposed design is based on a deep climate analysis to provide drastic energy savings to the stations while enhancing comfort, with the idea of achieving an exemplary transport system from a sustainable point of view.

Together with energy, there are other sustainable strategies to reduce the environmental impact of the stations:

- **Water**: reduce potable water needs by low consuming equipment, water recovery and reuse
- **Transport**: Prioritise facilities and paths for pedestrians and bikes nearby the stations.
- **Health**: Healthy environments with optimum Indoor Air Quality management, by maximising natural ventilated semi-exterior areas, and use of non-toxic and low - VOC materials
- **Security**: Safe design with open areas and adequate lighting. Protection of pedestrians in exits and cross-sections.

- **Modular & prefabricated construction design:** Traditional construction method requires extra material that leads to increase waste. In addition, using modular and prefabricated systems, less water is needed in the construction process; therefore, not only material is saved but also water. The generated material waste can be easily recycled in-house, avoiding sending the waste directly to a landfill.
  This kind of construction has other important benefits as:
  - financial savings,
  - shorter construction times, weather factor has less impact on construction, planning is more accurate and delays less likely.
  - safety, since the main work is carried out in a factory-controlled environment
  - flexibility, modular construction can be easily disassembled and relocated to different sites.
  - consistent quality, standards and quality checks throughout the entire process. In addition, the work is done indoors and in better conditions than in traditional construction
  - reduced site disruption, less truck traffic, less noise and dust and for a shorter time
- **Waste Management**: Minimise waste and enhance the use of recyclable materials.
- **Environmental friendly:** Use of environmentally friendly materials and provide the buildings with easy operation schemes to reduce environmental footprint.
  - Natural, Recycled & recyclable materials: The use of recycled and recyclable materials will be prioritized not only in main elements (steel, concrete, recycled aggregates) but also in furniture (seats made of sugarcane instead of PVC) and secondary elements (pipes, pavements…).
  - Sustainable wood: all the timber used in the project will be certified (PEFC, FSC or similar), ensuring sustainable provenance and management.
  - Materials with less CO2 emission and lower carbon footprint will be used,
  - Toxic-free materials: heavy metals, formaldehydes and VOCs will be avoided.
  - Local materials will be prioritised.
  - Designing for robustness. Appropriate design and material selection will avoid future reparation and maintenance costs. As well as it will minimise the frequency of replacement, maximising material’s optimisation.

5.4 Post-pandemic design. Passive and creative solutions

5.4.1 Contactless solutions

The post-pandemic era will be faced with innovations delivering a safe environment for the passengers using contactless devices and online operations, thus providing the passengers with a feeling of safety and making them more willing to use the DART+ network:

- Contactless turnstiles.
- Automatic doors.
- Holographic information systems and pushbuttons.
- Handrail sterilisers.
- Electronic sinks and sensors for urinals and toilettes, soap/steriliser dispensers, and paper hand towel dispensers.

The open and continuous design of the station will ease the crowd management tasks. Passenger supervision and social distance control can be done by someone located in the concourse area if necessary.

5.4.2 Use of technology

The use of technology will play a key role in the post-pandemic era:

- The Use of Big Data to realise targeted control measures, including traffic flow, operation monitoring, passenger and freight demand forecast, passenger flow tracing analysis.
- The use of technology to improve the operation efficiency and disease control: innovations such as mobile reservation of commute, droid and smart logistics.

5.4.3 Natural ventilation

The best way to fight the virus is to use natural ventilation. An open and ventilated design of the station would minimise the risk of contagion.

For enclosed areas, the following recommendations from the World Health Organization (WHO) will be followed when possible:

- For mechanical systems, increase the percentage of outdoor air, using economiser modes of HVAC operations and potentially as high as 100%.
- Increase total airflow supply to occupied spaces.
- Improve central air filtration:
- Consider running the HVAC system at maximum outside airflow for 2 hours before and after spaces are occupied, in accordance with manufactory recommendations.
- Generate clean-to-less-clean air movements by evaluating the positioning of supply and exhaust air diffusers and/or dampers and adjusting zone supply and exhaust flow rates to establish measurable pressure differentials. Have staff work in "clean" ventilation zones.

5.4.4 Antibacterial materials

During the development of the next stages of the project, materials and systems that prevent the build-up, spread and transfer of harmful bacterias and viruses will be proposed.

Copper and its alloys (brasses, bronzes, cupronickel, copper-nickel-zinc, and others) will be proposed for finishing materials within the station since they are natural antimicrobial materials that have intrinsic properties to destroy a wide range of microorganisms.

6. Drawing Index

FULL CODE	TITLE
MAY-MDC-ARC-RS01-DR-A-0001	Spencer Dock Station. Station Location
MAY-MDC-ARC-RS01-DR-A-0002	Spencer Dock Station. Platforms level plan
MAY-MDC-ARC-RS01-DR-A-0003	Spencer Dock Station. Street level plan
MAY-MDC-ARC-RS01-DR-A-0004	Spencer Dock Station. First floor level plan
MAY-MDC-ARC-RS01-DR-A-0005	Spencer Dock Station. Cross sections
MAY-MDC-ARC-RS01-DR-A-0006	Spencer Dock Station. Longitudinal sections
MAY-MDC-ARC-RS01-DR-A-0007	Spencer Dock Station. Elevations
MAY-MDC-ARC-RS01-DR-A-0008	Spencer Dock Station. Axonometric view
MAY-MDC-LAN-RS01-DR-A-0001	Spencer Dock Station. Landscape and urban integration