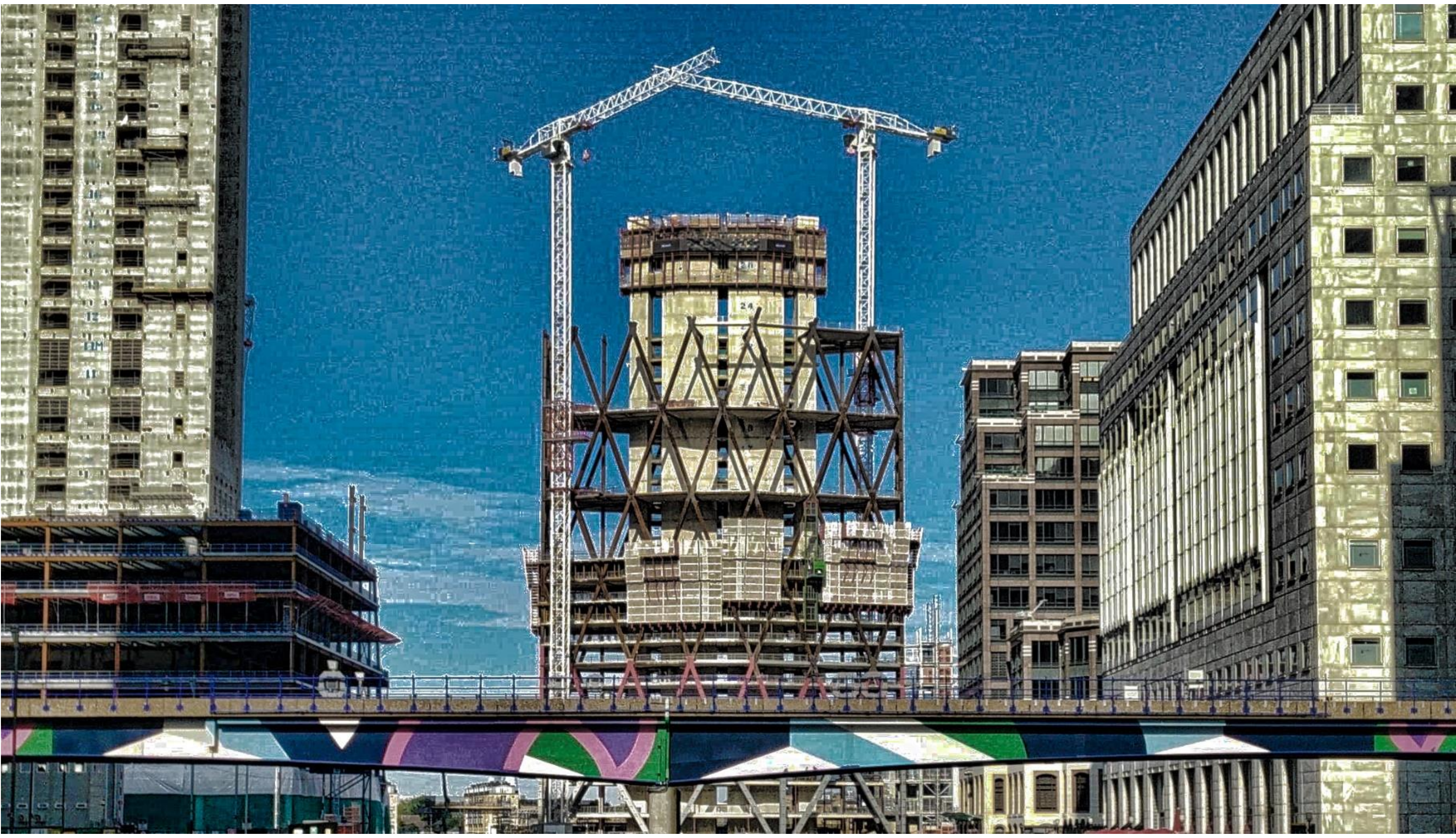
Figure 1. Newfoundland during construction.

Source: A. Denia Berrocoso.



Newfoundland at Canary Wharf

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Introduction

With 63 storeys providing around 630 apartments, Newfoundland will become the first residential tower on the Canary Wharf Estate. The 220m high-rise building is an outstanding feature of collaboration between architects, engineers and contractors. Achieving a tall light structure with two basement levels able to transfer high loads in a narrow site space and without disrupting the Jubilee Line Extension (JLE) tunnels running under it has become a challenge for WSP structural engineers.

The aim of this paper is to present the hybrid structural nature of the tower and how this has had a beneficial impact during construction making the building unique in its kind.

Architectural conception and site constraints

Newfoundland is located at the central axis of Canary Wharf's Middle Dock acting as a natural end to the water's edge. As a result of this, the tower's reflection on the water creates a distinct aura.

The exterior façade is formed by diagonal steel members that give the most distinctive feature of the building. These external members are not only aesthetic, but they also provide the main stability system for the tower. The set of these elements is called the diagrid which is also architecturally used as a separation for the private apartment balconies.

The narrow site constraints determined the use of a slim octagonal shape in plan which gives an outstanding elegancy to the slender prism.

Figure 2. Artistic recreation of the finished building. *Source: Horden Cherry Lee*

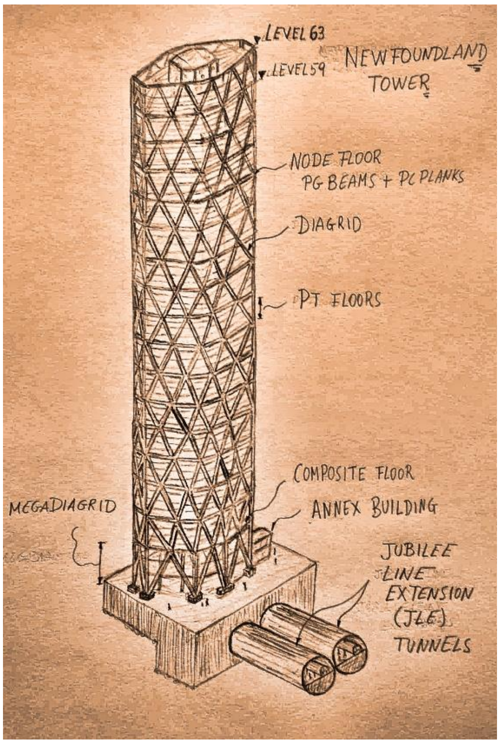
Newfoundland became the first construction project to pile into the Canary Wharf chalk bed due to the high loads in very limited founding locations. Secant pile walls were installed providing water-tightness to the substructure and additional load-bearing reinforced concrete piles were also poured with a maximum diameter of 2.4m. Since the tower sits above the JLE tunnels running under it, the largest diameter piles were located at each side allowing the raft slab to span over the underground tunnels and to reduce ground bearing pressure.

Stability and diagrid-core system

The tower superstructure consists of a structural combination of steel, precast concrete planks and post-tensioned concrete slabs as well as traditional reinforced concrete. The overall integration of these elements gives the building its hybrid nature.

In comparison to typical high-rise buildings that base their stability in concrete cores, Newfoundland's stability is provided by a combination of steel diagrid system (90%) and a reinforced concrete core (10%). This shared stability system is a result of the building geometry. Core walls thicknesses vary up through the tower with values from 500mm at basement levels to 300mm and 225mm at the structure higher levels.

During initial design stages, the limited area to support the building load became the main engineering challenge. The adopted solution of a steel diagrid allowed to transfer high loads through lighter elements and to optimize the overall weight of the concrete core sitting above the JLE tunnels.



From Level 03, every fourth floor is a node floor which has a different structural configuration compared to the three intermediate floors underneath it.

As the load increases from the upper to the lower levels, the diagrid members are sized using lighter sections at the top of the building and heavier plate girders at the bottom floors.

The diagrid bases are designed as stiffened steel grillages to avoid the load focusing on a small area leading to a crush of the concrete underneath if a small base plate was used. These grillages are essentially large base plates which distribute the load and combine with a more traditional reinforced concrete pile caps below them. These direct the load into the previously large diameter bearing piles.

Figure 3. Tower schematic view including JLE tunnels. *Source: A. Denia Berrocoso*.

From ground floor level, the vertical and diagonal members are unrestrained for three floors forming the mega-diagrid. In order to resist the large forces from the floors above, large fabricated steel box sections filled with concrete are used. The concrete fill helps to reduce the amount of steel required for the boxes and creates stiffness for the structure. The 500mm thick ground floor slab acts as a transfer slab for the first two tower levels columns due to the slab edge in these floors receding towards the building.

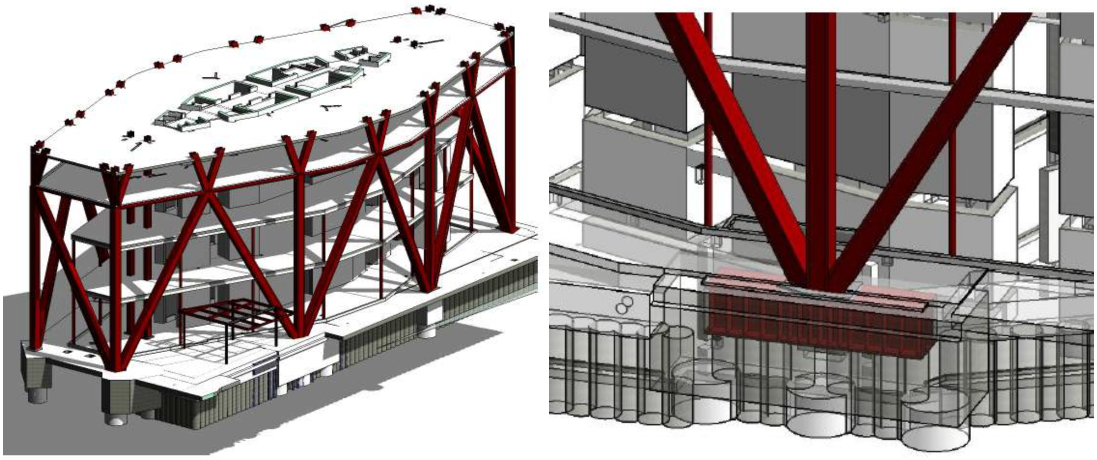


Figure 4. Mega-diagrid from GF to Level 3 (left) and concrete encased grillage (right). *Source: WSP Revit model.*

<u>Node and intermediate floors</u>

Apart from level 3 formed by a steel deck and composite beams, there are two typical floor slabs, the node floors and the intermediate floors. The second type of floor consists of a

250mm thick post-tensioned concrete slab. The adopted PT solution allowed the slabs to have large spans with shallow thicknesses. Special care was taken when designing slab to diagrid members supports to avoid punching shear issues using welded steel plates with holes to allow rebar passing through them to provide robustness to the floor system.

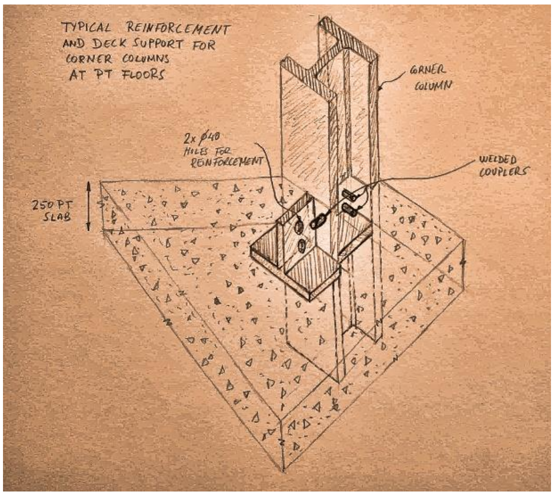
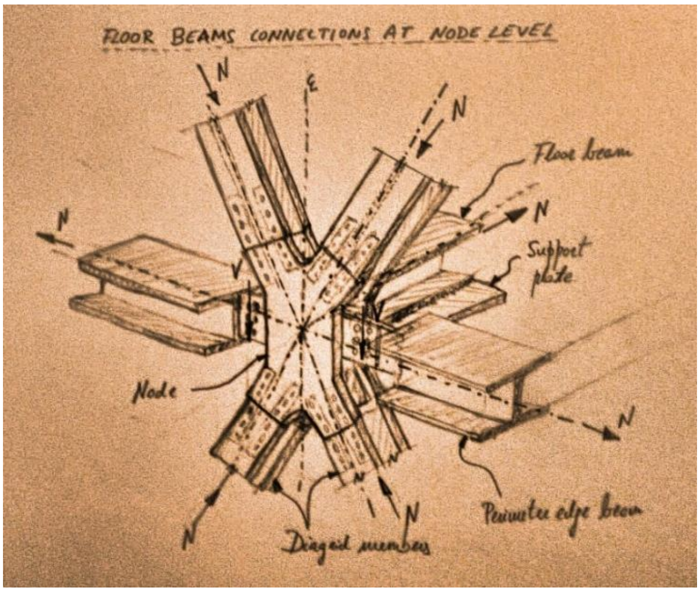


Figure 5. Corner slab support at PT level.

Source: A. Denia Berrocoso



While PT floors are only designed for gravity loading, node floors are conceived to behave differently. A combination of plated girders and box sections in conjunction with 200mm thick precast planks and 75mm reinforced concrete topping is the structural solution adopted for these levels. These are bespoke precast planks able to span 10m which have been specially designed for this project. This is a result of the close collaboration between consultant and concrete trade contractor with the aim of achieving a faster construction process.

Figure 6. Floor beams connecting at node slab edge. *Source: A. Denia Berrocoso*

Figure 7 shows the load path of the tying action at node levels. As the system wants to expand or kick outwards at the focal points due to the gravity and wind loads, the kicking force (in red) is restrained by the corner radial floor beam. This force is transferred in the slab (blue) and is restrained by the floor (green) by the tensile restraint of the structural topping reinforcement mesh allowing the resolution of the force into the floor.

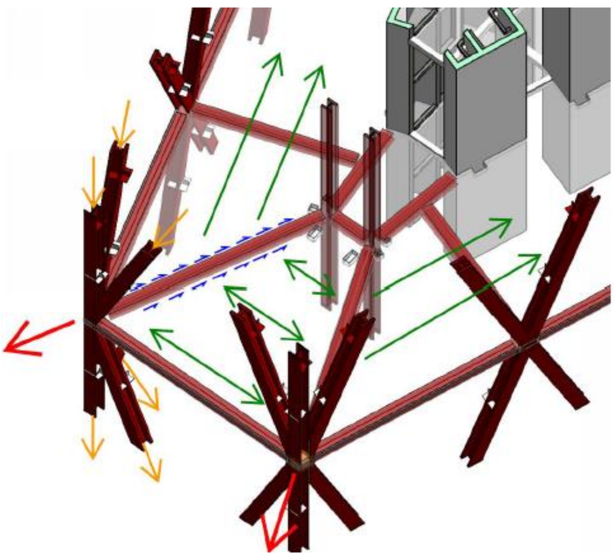


Figure 7. Load path of tying action at node floor types. *Source: WSP Revit model*

Optimising the construction sequence

Effective coordination between all the involved parties has been a key element when developing the construction sequence. During design stages, the sequence was simulated using Finite Element Analysis software to study the maximum height limit that the core could be constructed ahead of the diagrid, on which the tower's stability is shared. It was concluded that the maximum the core could progress above the top constructed node level was eight floors. This has allowed to erect the steel diagrid four floors prior to being tied into the core.

This way of construction allows both steel and concrete contractors to work simultaneously. While the diagrid is erected, the concrete contractor pours the post-tensioned concrete floors on the three intermediate levels making the construction process more efficient and faster. The choice of two different types of floors also allowed to create a natural division platform between vertical and horizontal construction providing a safe environment for workers.

Conclusion

Newfoundland will become one of London Canary Wharf's most iconic and distinctive residential building. After a vast time of planning, design and execution, this new high-rise tower will mean a breakthrough in structural engineering not only because of its particularities, but also because of the great level of multi-disciplinary collaboration carried out by architects, engineers and contractors.

The hybrid nature of the structure as a result of the successful integration of the different materials allows the building to achieve the most efficient design. The use of a diagrid structure has involved the development of a construction methodology that makes this tall building unique in its kind and sets a precedent to the construction community.

Newfoundland Project

Client: Canary Wharf Group

Structural and Façade engineers: WSP

Architect: Horden Cherry Lee with Adamson Associates

Fire Engineering, Geotechnical & Utilities/Infrastructure: Arup

Main contractor: Canary Wharf Contractors

Steelwork subcontractor: Victor Buyck Hollandia JV

Concrete subcontractor: Expanded Group