Figure 2: Typical tendon layout.

Figure 3: Tendon markings at the soffit of the slabs.

Newfoundland – an elegant tower

Newfoundland is an aesthetically appealing landmark residential building at Canary Wharf but the design of this had many challenges when combining steel diagrids, post-tensioned (PT) slabs and precast nodal floors. ***Nadarajah Surendran*** *from* ***Praeter Engineering*** *reports.*

The Newfoundland development is a 60-storey residential tower with around 636 apartments, two basement levels, an annex building and associated public realm. The tower is 220m in height and the slim diamond shape of the tower on plan is determined by the narrow footprint of the site. The development is a landmark residential tower at the west end of the Canary Wharf Estate and is directly above the Jubilee line tunnels. Though the building is residential, its design is not usual and many considerations have been taken into account from conception through to construction.

Foundations

A two-storey basement was constructed with secant pile retaining walls and in an open excavation method. The structure's core, internal columns and perimeter diagrid columns were supported by large piles located either side and between the Jubilee line tunnels. The 3m-thick raft helps span the Jubilee tunnels to the large-diameter bearing piles that predominantly support the tower. Some load is shed into the soil through bearing; however, this was intentionally limited to avoid overloading the Jubilee tunnels. Elsewhere the raft was 1.5m thick with local thickenings at the pile cap locations; the piles and raft will act in combination to support the building.

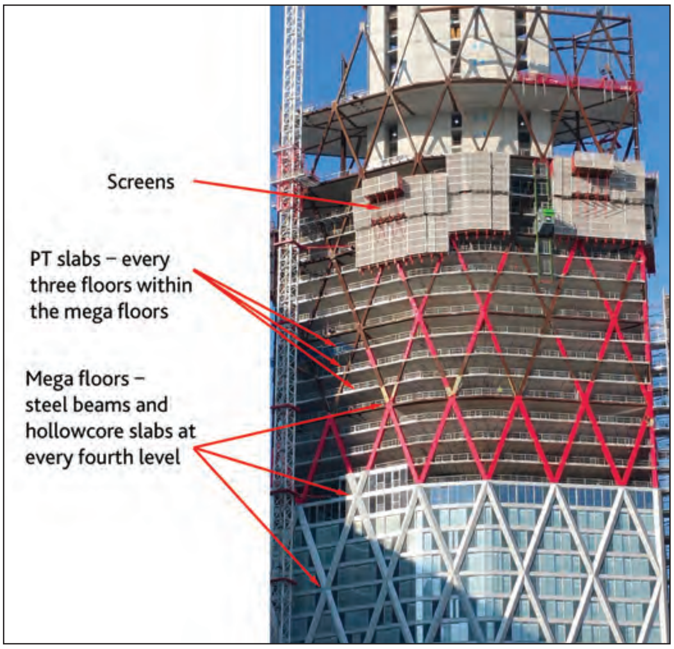

Figure 1: Building elevation during construction.

Superstructure

The 60-storey building is supported by a central core with perimeter diagrids and columns. A steel diagrid solution was proposed to create load paths in the structure to divert loads away from the Jubilee line tunnels. The standard diagrid layout is

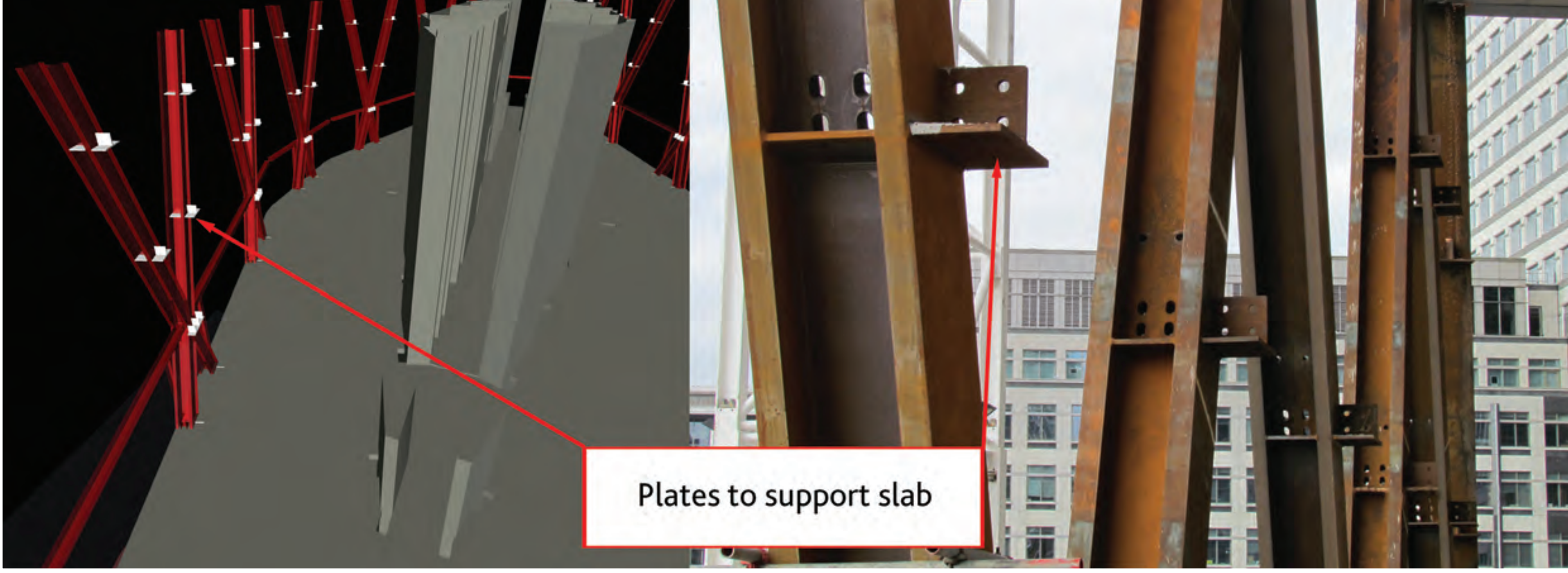

Figure 4: Edge supports for PT slabs.

transferred at the lower three levels to four points on each face of the building to span the tunnels and to open up the building architecturally. The diagrid is completed by the provision of braces along north and south faces of the building to enable the transfer of the lateral forces from one side of the building to the other.

The core was cast ahead of the floors and constructed using a jumpform system; 'pull-out' reinforcement bars were installed within the core for the floor slab connections. The overall lateral stability system of the tower is provided by the perimeter diagrid structure and the core.

A PT slab solution was adopted to ensure that the proposed slab thicknesses were optimal and the reduction in slab thickness helped reduce the overall self-weight of the building. This helped to provide an efficient foundation solution and minimise the load over the Jubilee tunnels. The tension forces along the diagrid tie members have been taken into account in the finite-element analysis of the frame.

Post-tensioned design

The typical floors from level 4 and above consist of PT concrete spanning slabs from the external diagrid to internal columns and the central core. Every fourth floor has been constructed using precast hollowcore slabs and are called 'nodal floors' (see Figure 1).

In order to maintain a quick construction programme, the sequencing of the steelwork external diagrid and the internal slabs had to be innovative to ensure that both construction methods could advance simultaneously. The steelwork diagrid that is repeated every four floors would be constructed ahead of the slabs and the nodal floor would then be constructed to support and tie in the diagrid nodes to the core and provide stability. The nodal floor would then allow the diagrid to continue for another four levels while the lower concrete slabs were constructed. A precast option at these nodal floors was chosen to separate the construction of the vertical elements (core, diagrid and columns) from the intermediate PT floor construction. This allowed the work to be carried out simultaneously and reduce the risk of delays due to winding-off of cranes etc, and also proved beneficial in terms of programme and safety. As such, these floors were designed with steel beams and precast hollowcore slabs, which did not require any supports below during construction. Then the three levels of PT slabs were 'inserted' between the two nodal floors (see Figures 5 and 6).

Each internal floor layout was similar, although six different types of analysis were carried out for typical loading cases due to the varying external support locations of the diagrid. Every PT floor was cast in two pours and the construction joint split the slab into almost equal areas. The dual pour arrangement allowed a quicker programme

Figure 5: PT slab is installed in between the nodal floors.

Figure 6: During construction. *(Photo: Peter Matthews.)*

Figure 7: Tensioning of TC tie bracket.

> In order to maintain a quick construction programme, the sequencing of the steelwork external diagrid and the internal slabs had to be innovative to ensure that both construction methods could advance simultaneously.

as one pour was installed while the other was concreted and/or stressed, meaning no downtime waiting for formwork erection.

Tendon layout

The PT tendon layout was designed to be distributed from the edge to core and banded in the other direction (see Figure 2). The tendon layouts were designed and detailed to give minimum disruption and greater ease of construction. Cast-in channels were co-ordinated with the tendon anchorages and tendon locations were adjusted where required. The soffits of the PT slabs were painted to identify the tendons (see Figure 3).

Reinforcement and punching shear

Plates were welded 90° to the supporting diagrids at floor levels as support for punching shear designs (see Figure 4). Preformed holes were introduced through the diagrid steel sections to pass through required reinforcement for robustness and disproportionate collapse.

A bottom fabric of A252 was provided throughout the slab as crack control. Additionally, top reinforcement was provided over the support locations for punching shear. In certain locations, an uplift force acted upon the supports, such as the corner columns at some levels where the diagrid diverges. At these supports additional reinforcement was provided at the bottom instead of top for the punching shear design.

Loads and back-propping

The PT slabs were designed to carry temporary construction loads from the erection methodology. Loads from the external hoist (for materials) and climbing screens were designed and co-ordinated with PT tendons. Tendons around the hoist area were stressed from the top of the slabs from 'pans' due to non-accessible slab edges.

The back-propping design was slightly different due to the nodal floors; an additional level of back-propping would be provided whenever the nodal floor would be part of the back-propping system due to the hollowcore slab layout.

The tower cranes (TC) were tied to the building slabs at various levels to provide stability for the cranes. The steel TC brackets were tied into the slabs by post-tensioning threaded bars (see Figure 7).

Finally…

This exemplar residential tower successfully uses the combination of an in-situ core and steel diagrid for its lateral and vertical stability, while making the most of PT slabs and precast hollowcore units to form the floors in the most structurally efficient manner. Lateral and gravity loads are transferred supported by the piled and raft foundations. The stiffness and the dynamic performance of the frame were chosen to limit overall drift (sway), inter-storey drifts to ensure compatibility with cladding and acceleration of motion within the tower. ■

Newfoundland Tower, London

Developer/main contractor	Canary Wharf Contractors
Frame contractor	Expanded
Post-tensioning	Praeter Engineering