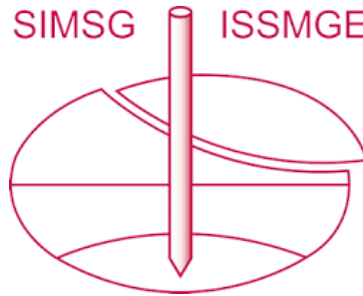


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Constructing a cut and cover tunnel under a four-storey heritage building without any damage

Construction d'un tunnel en tranchée couverte sous un édifice patrimonial de 4 étages sans aucun dommage

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ABSTRACT: The \$4.4bn City Rail Link is New Zealand's first underground railway. The project will transform the Britomart Station terminus into a through-station, thereby enabling a multiple increase in passenger capacity for the city's future. Extension of the railway required the construction of twin cut and cover tunnels below the 100-year-old Chief Post Office Building (CPO). The cultural significance of the CPO is recognised at a national level by Heritage New Zealand Pouhere Toanga and is also defined as an archaeological site. The CPO building is a four-storey structure with a heavy ornate masonry façade. Its foundations comprise of precast piles that were driven through reclaimed land and soft marine mud. This paper describes the integration of design and construction technique that allowed underpinning and excavation of the cut and cover tunnels with minimal disturbance to the building fabric. A key constraint required all work to be undertaken within a five-metre headroom below the first floor of the building. Ground support consisted of diaphragm walls with three rows of steel strutting. A specialised low-height diaphragm wall rig constructed foundations up to 17-metres deep. Many aspects of the diaphragm wall design required a specialised approach. This included construction of a piled working platform to protect the building's foundations, segmental reinforcement cages and the integration of jet grout arches to span under existing ground beams.

KEYWORDS: Heritage, underpinning, metro, Britomart

1 THE CPO BUILDING AND THE CITY RAIL LINK

The \$4.4bn City Rail Link is New Zealand's first underground railway. The project will transform the Britomart Station terminus into a through traffic station, thereby enabling a multiple increase in passenger capacity for the city's future. wall.

Britomart Station opened in 2003 to provide a terminal station within the CBD and that was a major component of the renaissance of rail transport in Auckland. The station is a below ground structure with the railway accommodated under a concrete roof that supports the city streets above. The rail head abuts the 110-year-old Chief Post Office Building (CPO), which was integrated into Britomart station as its main entrance with ticketing and other passenger facilities. The CPO building has four-storeys with a heavy ornate masonry façade that incorporates a large vestibule at its main entrance with an imposing set of steps leading to a raised ground floor level.

The CPO building is a well recognised landmark in Auckland, and its cultural significance is recognised at a national level by Heritage New Zealand Pouhere Toanga and is also defined as an archaeological site. It was constructed between 1909 and 1912 to serve as the central post office for Auckland and is one of only a few remaining buildings from that era.

A major obstacle to the connection of a tunnel to the end of the existing railway was the construction of the shallow rail tunnels under the CPO building, and moreover carrying that out without damaging the building structure or its heritage features.

And the commitment to preservation of the interior of the building excluded the method of surrounding the building with a temporary steel frame before gutting it and building a modern structure inside the heritage shell. The CPO building required extensive underpinning support to allow the cut and cover tunnels to be constructed under it.

2 THE CPO BUILDING

The CPO building has an impressive front façade, consisting of a massive brick wall with an ornate stone facing, totalling up to 1400mm thick. At its base, the façade opens into a series of arches that lead into the ground floor and lobby. The base of the

façade - within the excavation footprint - supported approximately 2000 tons of building mass.

The vestibule and lobby structure further increased the challenge of underpinning the building as it is divided into rooms by load bearing brick and mass concrete walls that prevented access to construct any foundation support within it. The underpinning would have to span across the vestibule structure. The lobby walls contributed an additional underpinning load of approximately 1400 tons.

However behind the façade and entry lobby the building structure is comprised of a light framing of steel beams, ornate cast iron columns at ground floor level, rivetted compound steel columns in the upper floors with some angle bracing and with brick external walls and timber flooring.

The floors of the building above first floor level surround a central quadrangle that is formed with a brick wall. The quadrangle wall is supported on the cast iron columns that are under it, many of which are over the railway tunnels and so required underpinning.

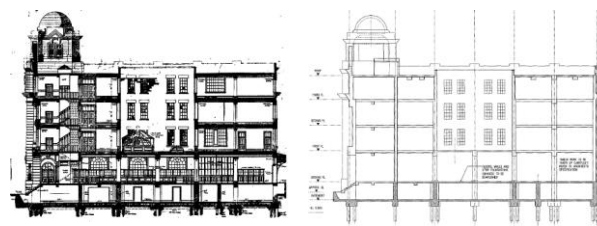


Figure 1. Existing CPO building

As with many buildings of that era it is both stiff and fragile. To avoid cracking of the masonry the underpinning would therefore have to be carried out without incurring differential deflection between columns or points along an external wall.

The building is close to the waterfront and it was constructed on reclaimed land over an existing shoreline flats of soft marine mud. It had a low headroom basement with a floor at groundwater level. Its foundations comprise of precast piles that were driven through reclaimed land and soft marine mud. The concrete that was used in the base slab and the façade is of low

strength [10-15MPa]. It was not a robust building, and a sister structure in Wellington was previously demolished because its upgrade to match the higher earthquake load there was deemed impractical.

3 HOW THE CPO BUILDING BECAME THE ENTRY PORTAL TO BRITOMART STATION

The development of Britomart Station twenty years ago required the refurbishment of the CPO building so that it could accommodate station to the western end of the station. The ground floor was reconstructed at a lower level to match that of the adjacent street, a pedestrian subway was constructed under the existing basement to provide for a street crossing and the building was also provided with strengthening against earthquake load to respond to the larger risk that applies with a public facility of that sort. The strengthening comprised of a reinforced concrete shear wall against the inside face of the façade and additional steel bracing at each floor level.

But challenging though this work was, it did not include any impact on the foundations. The reconstruction of the ground floor was carried out to a high level of finish that set the standard for future work on the site.

4 GROUND SUPPORT FOR THE CONSTRUCTION OF THE TUNNELS UNDER THE BASEMENT FLOOR

Extension of the railway required the construction of twin cut and cover tunnels below the basement level of the CPO building.

The work required an initial phase of construction of a ground support structure to allow for tunnel excavation and the temporary underpinning of the building columns that were over the alignment of each tunnel.

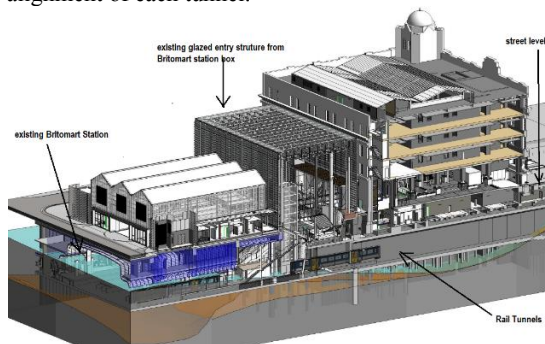


Figure 2. Britomart Station, the CPO Building & new train tunnels

The underpinning structures were then founded on the ground support walls.

The major challenge was in the construction of the ground support walls, which extend to a maximum depth of 17m. The headroom over the piling level is limited to 5m, but an even greater constraint was in the spacing of the building columns, which limited the size of the piling machine that could be used.

The reference design assumed the use of ground mix columns reinforced with steel beams, but the winning tender from Bachy had a more advanced plant application with the Soletanche HC05 piling machine, which facilitated the use of diaphragm walls for ground support. The HC05 is a unique and compact low headroom piling rig that uses outrigger arms for support to allow the tracked undercarriage to rotate between movements, so that the machine can accomplish a right angled turn about the centre of its turret without any travel. It comes with accessory items of plant including a coiled tremie tube and is electrically powered with a detachable diesel power unit. Excavation is carried out with a hydrofraise cutter of shortened length.



Figure 3. Bachy Soletanche HC05 piling rig

The combination of soft ground and a shallow ground water table provided a challenge to the provision of panel stability during excavation. The construction resolved that with the combination of a piling platform level just 1.5m below street level and a panel arrangement that was mainly comprised of single bite panels. The use of a cutter facilitates construction with single bite panels.

Many aspects of the diaphragm wall design required a specialised approach. This included construction of a piled working platform to protect the building's foundations, segmental reinforcement cages and the application of jet grout arches to span under existing ground beams.

The construction of the piling platform inside the building was itself a major task, with prior demolition of the existing ground floor and the placement of a large volume of fill on the basement slab. A Light weight fill that was partly comprised of polystyrene blocks was used to reduce the weight of fill as that was transferred to the existing foundations, but even with that allowance it was still necessary to first construct micropiles to strength parts of the existing building foundations, particularly in the deeper access subway constructed as part of the Britomart project.

The low headroom required the diaphragm wall cages to be installed in segments, and as there was insufficient headroom for lapped bar splices the vertical reinforcement in each segment is connected by threaded couplers.

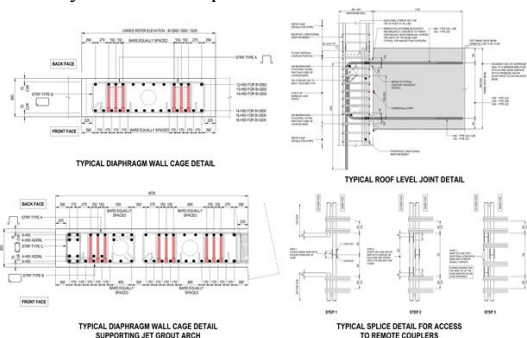
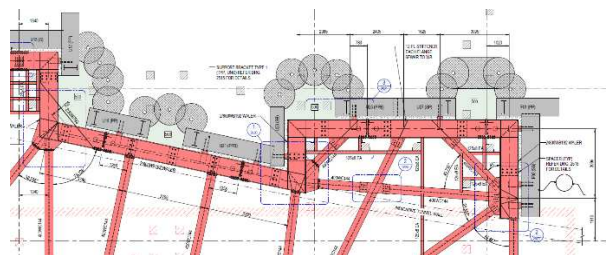


Figure 4. Typical diaphragm wall details

The ground support wall was set out to minimise intersections with the existing foundation structure, but at each of these there is then a gap in the ground support wall that requires a jet grout arch to span over it, and additionally jet grout arches were required to effect a junction with the Britomart station box. Each arch is comprised of vertical grout columns that intersect to provide a waterproof structure, and Bachy verified the consistency of the arches by retrieving cores at critical locations.



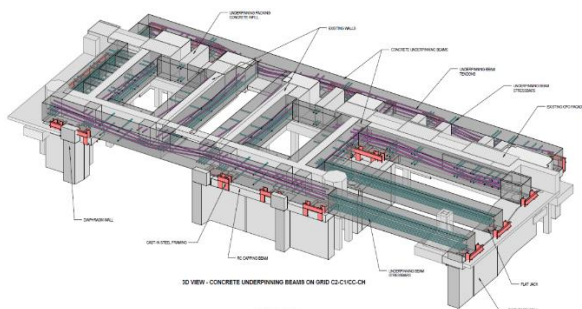
5 UNDERPINNING THE CPO BUILDING

The underpinning was carried out with two different types of structure:

-
- 3D VIEW-COLLAR TYPE 3

- A partially prestressed post tensioned concrete grillage to support the heavy masonry external walls and the vestibule. The grillage was supported on the diaphragm walls that also provide ground support and span the width of the vestibule and on each side of the vestibule, with adjacent spans over the width of the rail tunnels.

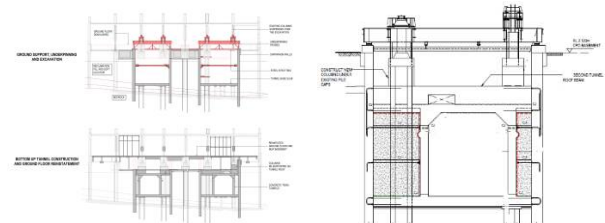
The design included two types of beams. Beams in the east-west direction clamped the base of the building walls through shear-friction and spanned onto the north-south beams. Subsequently, the north-south beams spanned over the tunnel alignment to supports at the diaphragm walls. This arrangement integrated the beams and existing walls to produce continuous structural members. Both sets of beams have with draped tendons so that the beams deflected up wards during stressing and in that way picked up the weight of the building without it being subject to settlement.



Both types of underpinning incorporated an assembly of flat jacks and follower packing plates being used for load testing of the foundation and level adjustment. Many of the steel

A crucial part of underpinning for a building of this type is the monitoring of jack movement and deflection. The contractor employed precision a fixed installation of laser measurement, with an accuracy of $\pm 0.5\text{mm}$, to ensure that the lift-off displacement did not exceed 1mm.

The integration of ground support walls and tunnel structure also accommodates a major upgrade to the earthquake resistance of the building through the transformation of the foundation from an unbraced assembly of flexible piles in soft ground to the new arrangement with a grillage of diaphragm walls that restrain horizontal movement from rock level.



7 CONSTRUCTION SEQUENCE

- A preparatory phase of demolition and construction of a piling platform in the ground floor of the building
- Construction of a ground support wall on each side of each rail tunnel
- Construction of underpinning for each building column that is over the excavation for the rail tunnels
- Construction of underpinning for the heavy front façade structure
- Excavation for the tunnels with progressive installation of 3 levels of temporary support
- Construction of the tunnels and the new basement that is next to them
- Re-construction of the entry from the Britomart box.

The CPO Building has been successfully protected while constructing the CRL railway tunnels under it, and the protection applied to strengthen the building against earthquake.

The writers wish to thank Auckland Transport for their foresight in undertaking this project and permission in writing this paper