THE DESIGN AND CONSTRUCTION OF BRITOMART ORIENTAL-ONE OF NEW
ZEALAND’S LARGEST SUSPENDED POST-TENSIONED FLOOR BUILDINGS

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ABSTRACT

Located within the Britomart Precinct in downtown Auckland is the Britomart Carpark that provides the car parking for the entire Britomart Precinct.

Due to strict site restrictions, only 300 mm structural depth was available for the floor and beam construction. Using a cast insitu post tensioned floor slab proved to be the ideal option. As the building footprint was approximately 140 m by 50 m and six storeys tall, this building is one of the largest post tensioned suspended slab buildings ever attempted in New Zealand.

In the design of modern car parks, walls are generally avoided due to safety reasons as they provide reduced sight lines and possible hiding areas. As a result of these safety concerns the design used buckling restrained braced frames (BRBF) as the lateral load resisting system. Using BRBF’s and post tensioned floors proved to be the perfect partnership as it allowed the braces to be installed after the floor was stressed and did no require infill pour strips at the completion of the various stressing phases of the floor.

The paper will focus on some of the design and construction challenges of this recently completed building.

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INTRODUCTION

The downtown section of Auckland known as Britomart has been significantly upgraded and improved over the last 4-5 years by the development company, Cooper and Company.

This redevelopment has included the upgrading of numerous heritage buildings, two new significant commercial buildings and a mixed use building that houses the carparking for the precinct. This building is called Britomart Oriental and will form the basis for this paper.

PROJECT REQUIREMENTS

Site description

The building is located at the Eastern end of the Britomart precinct on the corner of Quay St and Britomart Place, on a site bounded by Scene Lane to the South and the existing Countdown building to the East. The building consists of a six storey structure which is approximately 150 m long and 45 m deep.

Figure 1: Site location

The brief for the building was to house a minimum of 1200 carparks with ground floor retail and a gymnasium business.

Site constraints

Due to legal height covenants on the site, no part of the building (including lift overruns or TV aerials) were allowed to penetrate this height. Therefore in order to allow six storeys of carpark to be constructed, only 2.55 m floor to floor height was available in which 2.2 m of that must be a clear opening for vehicles. This gave 300 mm available for structural depth and 50 mm for tolerance.

Key drivers in a car park design

Traditionally in a car park building design an efficient structural grid is to have three car parking spaces between column lines in the longitudinal direction and columns located either side of the drive aisles.

As this building had a restricted structural depth available, we investigated various combinations to find a more efficient grid and still comply with the number of carpark spaces outlined in the brief but it did not prove cost efficient. The grid above was chosen, ie 8.2 m in the long direction with an alternating 7.7 m and 9.2 m grid across the building was chosen. Given this grid and the available structural depth, there was only one practical option for the construction of the floor slabs, this was post tensioned concrete construction.

Occupant safety was also a key driver in the choice of structural lateral load resisting systems for carparks. Walls are generally not the preferred system as these provide hiding areas for potential crime, open and unrestricted views are generally the preferred option.

DESIGN SOLUTION

Post-Tensioned floor design

Post-tensioned floor systems are a very efficient floor solution. Post-tensioned floors can provide many benefits including reduced floor thickness, the ability to balance load, excellent durability and reduced quantity of conventional reinforcing steel.

Post-tensioned floor systems are relatively rare in New Zealand, with most of the current examples being slab-on-grade. It is believed that this is due to lack of local knowledge and expertise in the construction of post-tensioned floors. Fast solutions using pre-cast systems are generally better known and more attractive to the industry.

As this building was one of the largest suspended post-tensioned floors attempted in New Zealand, careful consideration was needed in the design and construction of the large slabs, in particular slab shortening and the construction methodology.
Due to the large floor plate it was split into four pour zones of approximate equal dimensions of 35 x 45 m.

![Figure 2: Plan showing the four pour zones](image)

The most efficient post tensioned floor design is to use band beams with a one-way spanning slab. In this particular building, running the band beams across the building proved more efficient due to the required cantilevers on the north and south sides of the building.

The band beams in this building are 300 mm deep and their width varied between 1500 mm wide and 2500 mm. The typical band beams were 1500 mm, and the wider beams occurred at the ends of the building where there was only a slab on one slab, or when a large cantilever was required.

The one way slab is typically 160 mm thick for the continuous spans and increases to 180-200 mm for end spans or back spans for cantilevers.

**Slab design considerations**

Slab shortening can have significant effects on a post tensioned slab and the integral structural elements. Consideration of slab shortening was critical to the correct analysis and intended performance of the post tensioned slab.

There are three main components of slab shortening:

- The elastic component due to the applied prestress
- Slab creep due to the applied prestress
- Slab shrinkage

To reduce the effects of shrinkage the building was split into two during the construction phase, with a delayed pour strip between the two halves of the building. This delayed pour strip enables the two halves of the building to shrink independently of each other and hence reduce the shrinkage imposed deflection into the columns.

![Figure 3: Reinforcement adjacent to the delayed pour strip](image)

The concrete mix was ‘designed’ to limit the effects of slab shortening. Concretes with aggregates such as Basalt typically display lower levels of creep and shrinkage. The maximum 56-day shrinkage was specified as 560 microns.

Durability was also a key criteria due to the buildings proximity to the sea. Using appropriate covers and a good quality concrete mix design ensures good durability. Being post tensioned, the slab is designed as uncracked under service loads which means any cracks are kept to a minimum in width.

**Lateral Bracing**

As structural walls were not considered to be appropriate for this car parking building, the building was originally designed with eccentrically braced frames (K braces). However when the construction methodology was discussed with Hawkins Construction, K braces proved difficult as pour strips would be required around the columns and collector beams. These pour strips would have been required to enable the floor to be stressed without preloading the collector beam/K braces.

After some detailed investigation into how these pour strips could be avoided, we chose to use Buckling Restrained Braced Frames (BRBF’s). This technology is relatively new to New Zealand and to our knowledge they have only been used on two prior occasions in this country.

The advantage of a BRBF system over a traditional K brace system is that the end plates are cast into the floors and column, with the braces being installed after the post-tensioned floor has been stressed, hence eliminating the need to have a
series of pour strips throughout the building.

![Completed BRBF](image1)

**Figure 4: Completed BRBF**

Although a BRBF frame appears similar in nature to a K brace, it behaves as a totally different mechanism. The diagonal braces are designed to yield in both tension and compression. The brace legs consist of a yielding core section, typically flat hot-rolled plate that is encased within a steel hollow section, and filled with concrete or high strength grout.

The concrete filled steel hollow section provides confinement/lateral restraint to the inner flat plates so that it can yield in compression without buckling.

The hysteretic response of the brace is nearly symmetrical as can be seen in figure 5.

![Force-displacement plot for a BRB to a standard test cycle](image2)

**Figure 5: Force-displacement plot for a BRB to a standard test cycle [1]**

The design of a BRBF system is not fully covered in NZS3404 [2] so we used a combination of AS/NZS 1170[3], NZS 3404[2] and the AISC provisions noted above [4]. A design overview is provided by Steel Tips [5].

Another advantage of the BRBF braces is, should there be a significant earthquake during the life of the building the braces can be unbolted and new ones installed. This is considered a form of damage avoidance design.

**CONSTRUCTION**

Hawkins Construction Limited was the design-build contractors for this project so we worked very closely with them throughout.

The construction of the floors proved quite challenging initially as the detailing was significantly different to that of a traditional precast floor. At the end of the band beams there is a significant amount of conventional reinforcement that provided anchorage to the post tensioned strands (figure 6).

![End of band beam reinforcement](image3)

**Figure 6: End of band beam reinforcement**

Prior to the pouring of the floors we held an meeting with the concrete placer, pump operator, concrete supplier and general contractor to discuss how to correctly place the specified low shrinkage mix. This meeting provided invaluable as it meant that come the day of the first pour, everyone knew what to expect as low shrinkage mixes can be more difficult to work with than traditional concretes. It also meant the correct concrete pump was available.

![Detailing on band beam/column](image4)

**Figure 7: Detailing on band beam/column**
Originally the brackets for the BRBF’s were detailed as a single vertical plate with conventional stirrups to provide confinement and shear reinforcement the column. This provide extremely difficult to build as it allowed very little tolerance on site. Therefore we modified the design to use steel plates for confinement and shear reinforcement which gave a much better result (refer figure 8).

![Figure 8: BRBF hardware in place prior to pouring the slab](image1)

Once the floor was poured, the initial prestress was applied when the concrete reached 8 MPa. The floor was fully stressed once the concrete achieved 25 MPa and the formwork immediately removed and transferred to the next level.

As the band beams were designed to span between columns, temporary props were not required in the bays where the BRBF braces would eventually be installed (figure 9). The braces were not installed until late in the construction phase to allow most of the initial shrinkage to occur.

![Figure 9: Recently stripped floor, prior to BRBF braces being installed.](image2)

When the post tensioned floors were completed, the precast concrete façade panels were installed.

The last operations included casting the delayed pour strips in the centre of the building, and the BRBF braces were installed.

**SUMMARY**

The project was completed in February 2011 and is proving to be a very successful carpark.

Given the very tight structural depth available, the post tensioned slab system proved to be the best solution. In combination with the BRBF frames the post tensioned floor provided an ideal mix for this carpark building.

![Figure 10: The building part way through construction](image3)

![Figure 11: Completed Carpark (internal)](image4)
The use of the post tensioned concrete floors and precast concrete facades has provided Cooper and Company with a durable smart looking carpark.

![Figure 12: Completed Carpark (exterior)](image)

**ACKNOWLEDGEMENTS**

The author wishes to acknowledge Cooper and Company for their vision in creating this structurally innovative building.

A special thanks to my colleagues at Holmes Consulting Group who assisted on the project and the other members of the design and construction teams who contributed to the Britomart Oriental Building.

**REFERENCES:**


