COUNTDOWN WARKWORTH SUSPENDED POST-TENSIONED SLAB

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SUMMARY

The Countdown Warkworth project is located on a 5,500m^2 site between Mill Lane and Neville Street in Warkworth. The project consists of a 3,700m^2 supermarket, 310m^2 adjoining retail shops and a truck delivery area all on a suspended post tensioned floor structure above a basement car park. Due to the highly complex nature of the suspended slab, which included varying span sizes to accommodate the basement car parking layout, multiple services penetrations and steps to slabs and beams a post tensioned floor was used. This paper will focus on the design and construction challenges.

INTRODUCTION

The site is situated at 20-26 Neville Street, Warkworth. The site is constrained by Neville Street and Mill Lane on the eastern and western boundaries and by the RSA and Bowling Club on the southern and northern boundaries.

The site sloped approximately 4m between Neville Street and Mill Lane, making vehicle access ideal off Mill Lane and pedestrian access ideal off Neville Street.

Knowles Consulting Limited (KCL) was engaged by Progressive Enterprises Limited to provide the civil and structural engineering services for the project, which included design, documentation and construction observation.

The client's desire for a clean structural soffit, maximum clearance between the basement slab and suspended structure, plus a requirement for future flexibility in relocating services made a post tensioned slab the obvious solution.

The post tensioned suspended floor covers a total area of 4,600m^2 and is supported off perimeter basement walls, internal beams and columns, all on piled foundations.

The slab was constructed in three separate pours using a total of 1,650m^3 of concrete, 37.5t of post tensioning strand and 85t of reinforcing.

Figure 1: Countdown Warkworth Pour No 1

The software used to analyze the post tensioned floor system was RAPT, with several reviews being undertaken to optimize the design for constructability and cost perspective.

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The step downs and transitions required great attention and coordination between the design and construction teams.

DESIGN SOLUTION

Post-Tensioned Floor Design

Post-tensioned concrete slabs in buildings have many advantages over reinforced concrete slabs and other structural systems. These include; ability to span larger distances for a given structural depth, reduced level of deflections under service loads, early formwork stripping enabling faster construction cycles and quick re-use of formwork, plus, reduced material quantities in concrete and reinforcement greatly benefit on-site cranage requirements.

Key Design Issues

The design issues affecting the post tensioned slab were numerous and resulted in a complex solution.

The key design issues were;

Large slab and beams spans due to column arrangements dictated by car parking and traffic circulation. This column arrangement resulted in variable slab and beam spans, with slab spans ranging from 4 to 13m and beams spanning between 8 to 16m.

Numerous floor set downs within the supermarket to allow for fridges, freezers, sloping floor overlays and future flexibility. Steps up to 500mm within the retail buildings adjacent to Neville Street to ensure finished floor levels matched the sloping street levels.

Providing the required car parking clearances under the stepped retail units, while maintaining finished floor levels and allowing for services.

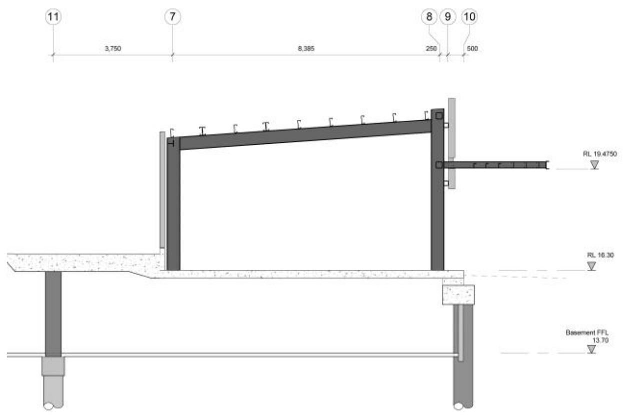

Figure 2: Stepped Floor within Retail Building

Sloping exposed concrete floors within the truck delivery area and steeply sloping truck entry ramps.

Complex loading patterns on the slabs and beams from the supermarket and retail structures buildings due to point loads from the portal frames, spine beam, mezzanine floors, perimeter precast panels and trucks..

To resolve these issues;

A one-way spanning slab and banded beam arrangements was proposed. Slabs ranged from 200mm to 300mm in thickness, banded beams ranging from 500mm to 600mm deep and 600mm to 2400mm in width.

Figure 3: Suspended Post-tensioned Floor Plan

To keep the band beams widths to minimum and maximise the duct spacing within the slabs, 15.2mm strand was used.

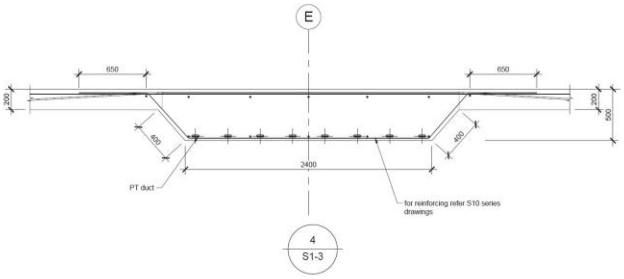

Figure 4: Banded Beam Cross Section

Floor set down and steps provided major issues with the final solution of locally lowering beams and tapering slab being dictated by the allowable tendon drapes.

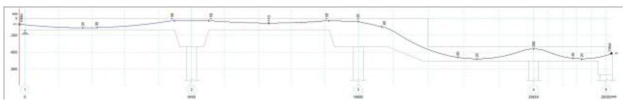

Figure 5: RAPT Tendon Layout through Retail Building

To maintain the required clearances under the retail units the thickness of the post tensioned slab was significantly reduced. This was achieved by introducing an additional row of columns, causing a reduction in the number of car parks.

In areas of sloping exterior slab, the beams and slab thicknesses were maintained by having the soffit mimicking the exterior sloped shape. Additional transverse post tensioning was added to the slab to reduce potential cracking and Aquron 300 was added to the concrete in case any cracking occurred.

Complex loading patterns were resolved by adding slab thickening within the slab to accommodate high point loads and by extending slab transitions where required.

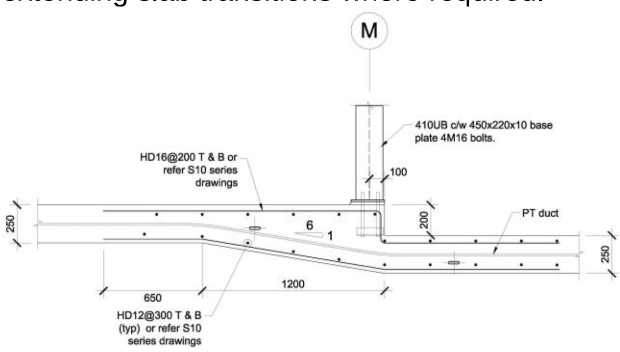

Figure 6: Slab Cross Section with Column

Restraint issues

Restraint issues play a large role in the detailing of a post tensioned slab as the slab needs to be able to elastically shorten during tensioning and creep and shrink post-tensioning.

This need for the slab to be able to move is at odds with the need for the slab to be laterally restrained. However failure to resolve these problems will result in significant forces accumulating at restraint locations and will result in cracking within the slab and overloading the restraining structure.

For this slab the potential restraints came from the perimeter basement retaining walls, shear walls and K braces.

To resolve this, temporary sliding joints where detailed over the perimeter basement retaining walls, shear walls had delayed pour strips installed at slab level and adjacent to columns and K braces had corrugated ducts at shear stud locations.

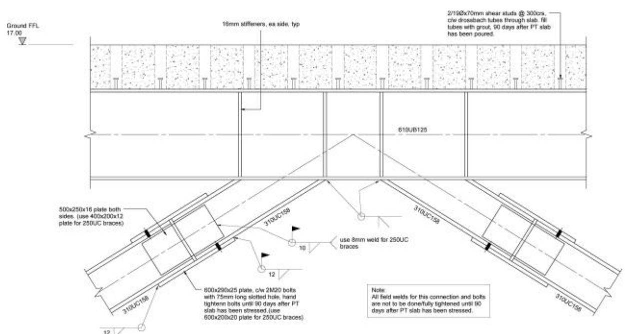

Figure 7: K Brace Restraint Release

CONSTRUCTION

Aspec Construction was appointed the main contractor.

The principal subcontractors engaged on the job were Highrise Construction (Ischebeck formwork system), Grouting Services (post-tensioning), Fletcher Reinforcing (reinforcement) and Conset Construction (concrete).

Figure 8: Ischebeck Formwork System

Figure 9: Complexity of Formwork

Formwork

Restricted access on site dictated that the conventional table formwork would not be appropriate as a means of supporting the suspended deck, and as a result the Ischebeck formwork system was selected which a well proven slab forming system with aluminium beams and standards providing for fast installation and removal without the need for a crane. The prop head also incorporates a double nut system that enables the plywood to be removed without disturbing the propping.

A total of 3,500sq.m of Ischebeck formwork was used which was enough to set up Pour 1 and Pour 2. The complexity of the set-downs in the slab was reflected in the time frame to prepare each slab which was ranged between 3 and 4 weeks.

Placement of the plywood sheets was co-ordinated to ensure a neat and consistent soffit line was created.

An 800mm access strip was supplied in critical areas around the slab perimeter to facilitate the strand installation and stressing operations.

A working crew of up to 25 men was used to carry out the formwork operations.

Post-tensioning & Conventional Reinforcement

The order in which the post-tensioning strand and reinforcement is installed is critical due to the profiled alignments of the post-tensioned tendons and the phrase “PT takes priority” was adopted by the site team to ensure a reasonable continuity was maintained between respective trades.

Once the formwork was erected and edge boards installed with pre-formed slots for the strand, the post-tensioning anchorages were bolted in place. The reinforcing steel installation commenced at the same time with a primary focus being the bottom mat to the beams and slab.

It was imperative that material placement on the formed deck was well planned and co-ordinated to ensure the duct installation could proceed in both directions. After the duct were placed and taped, the strand for the beam tendons were installed, followed by the strands for the slab tendons.

Figure 10: Post-tensioning and Reinforcement

Once the strand had been installed, the top mat of reinforcing steel was placed, and, during this time, the grout tubes, sealing of the ducts and final tendon profiling was undertaken.

Where access to the perimeter of the slab was not possible, pans were used within the body of the slab to enable the stressing operations to take place.

Figure 11: Stressing Pans

The installation of the reinforcement and post-tensioning for each pour was completed over a 3 week period for each slab with a combined workforce of 20 men.

Figure 12: Post-tensioning & Reinforcement

Concrete

The post-tensioned slab was broken up into three separate pours, with pour sizes of 595m3, 705m3 and 350m3 for pours 1, 2 & 3 respectively.

Figure 13: Pour Sequence

The geographical location of the project and large volume of each pour presented a challenge for Conset Construction and its ready mixed supplier, Holcim. The local batching plant operated by Allied Concrete worked very closely with Holcim's Avondale plant to produce a mix design that would have the same initial set times, despite the concrete coming from different locations.

Contingency planning required the support of local Firth and Warehine concrete plants. Both plants remained on standby with pre-delivered aggregate supplies and cement tankers at hand to ensure consistency in the mix design.

Concreting started at mid-night on each pour and a working crew of 26 men was employed in the concrete placing/finishing and post-tensioning/supervision operations. With exposure to the elements a constant threat, a continuous mist spray of antivap was applied to the concrete surface to reduce the risk of plastic shrinkage.

Conset engaged Pioneer Concrete pumps to utilise its 52m boom pump for each pour. Additional back up concrete pumps were also positioned on the site.

Concrete for the second and largest pour was supplied from Holcim's Avondale plant and Allied's Silverdale plant. With a combined fleet of 48 trucks servicing two boom pumps, a constant 125m3 per hour was supplied for the first 2 hours and the overall delivery / placement rate achieved was 105m3 per hour.

Figure 14: Concrete pumping and placing

Once each floor was poured, an initial stress was applied when the concrete strength reached 7MPa. The floor was fully stressed once the concrete reached 35MPa. Back propping was required on the 1st pour until the second pour had been fully stressed.

Grouting of the post-tensioned duct was completed after approvals had been obtained for the actual extensions achieved during tensioning.

Figure 15: Recently stripped floor

The slab surface achieved a FM3 flatness using free screeding. A combination of good vibration and quality plywood resulted in a very consistent finish to the soffit of the concrete slab.

When the post-tensioned slabs were completed, the precast concrete exterior panels were installed and this was followed by the structural steel erection.

Lessons Learned

The success of the post-tensioned concrete slab was very much the result of a team effort from all those involved.

As with all projects there are things that do not go according to plan.

For this project there were luckily only a few, and these were;

Delays in batching concrete for pour 1 caused unforeseen supply issues on site. This resulted in a cold joint as concrete deliveries were interrupted due to truck driver working limits being reached.

Elastic shrinkage cracking occurred between pours 1 and 2 due to the high stiffness of band beams at the pour interface.

Restraint cracking occurred in a column due to insufficient allowance for movement from elastic shrinkage and early creep.

Figure 16: Restraint cracking within column

References

[1] www.kclengineering.co

[2] www.consetconstruction.co.nz

[3] www.groutingservices.co.nz

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Summary

The project is due for completion in October 2012 and will likely be a benchmark store for Progressive Enterprises.

The suspended post-tensioned concrete structure is economical when compared to its composite precast equivalents and the New Zealand construction market is embracing this method of in-situ construction with several recent buildings and suspended car-parks being completed.