

Design & Construction of New Zealand's Largest Post-Tensioned Floor/Pavement

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INTRODUCTION

This paper describes some of the design and construction aspects of a post-tensioned floor and pavement for the Fonterra Co-Operative Group Ltd's. Te Rapa milk powder storehouse. The project posed several significant challenges. These included reducing the restraint on the slabs to mitigate the risks of cracking, planning and managing large concrete pours, and producing a high quality finish.

PROJECT DESCRIPTION

The Fonterra Co-Operative Group Ltd's milk powder storehouse in Te Rapa incorporates the largest post-tensioned concrete slab constructed in New Zealand, with a combined area of 50,000 m². The choice of a post-tensioned concrete slab on grade solution provided several key advantages to the project including large joint free bays, enhanced durability and the ability to cater for very high loads. The post-tensioned slabs on grade for the project included:

- A 35,000 m² post-tensioned floor internally for the dry goods storehouse.
- A 15,000 m² external pavement/ container stand.



Figure 1 Finished internal storehouse floor

The project also incorporated a steel fibre reinforced slab used for unloading material directly from trains and a heavily reinforced slab supporting the rail track.

All of the slabs were constructed using Somero Laser Screed's, to allow for the accurate placing of concrete. The Laser Screed is a completely self propelled driver operated vehicle, which uses a high specification laser to guide the strike off of concrete by a vibrating screed head. A laser screed is pictured in use in Figure 2 below. Note that specially designed ramps are used to allow the plant to cross post-tensioning ducts without crushing or damaging them.



Figure 2 Somero Laser Screed in use for internal storehouse construction

Internal Storehouse

The 75 m by 460 m internal post-tensioned floor, shown in Figures 1 and 4, provides the main storage/ operating surface for the storehouse. The building is divided into three separate storage areas by internal walls. The floor is 165 mm thick, and is designed to cater for forklifts with axle loads of up to 24.6 tonne. It was constructed in 12 pours, with the size of individual pours ranging from 2,300 m² to 3,345 m². The post-tensioning tendons in each pour were crossed over with the adjacent stage across the building, tensioning the pours together and holding the joint between them tightly closed. This resulted in bay sizes of up to 6000 m² that did not contain any joints.

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The joints between each 6000 m² bay were armoured using LESA Systems Type G steel joint armour, which incorporates a “sliding plate” type design to keep the joint opening covered after it opened. The armour protects the joint edge from spalling, and reduces fatigue/damage to forklift traffic crossing the joint. It helped to meet the hygiene requirements for the storehouse which required that there were no which would allow rodents or other animals into the building. Figure 3 demonstrate the armour. The joints were doweled to allow load transfer across the joint.

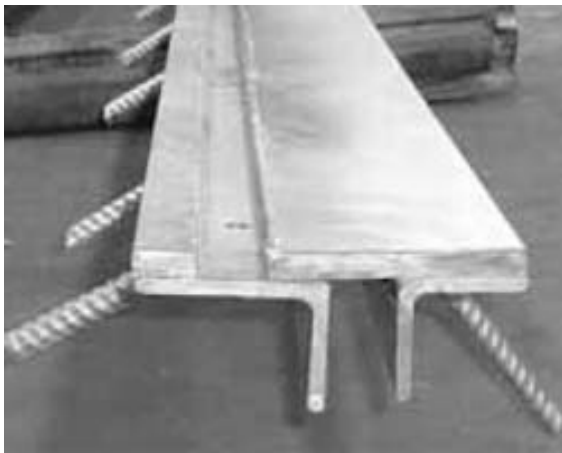


Figure 3 LESA Type G joint. The design ensures that any joint opening is kept covered.

The floor was constructed between the 17th of January and 26th of May 2005, and handed over to the client on the 6th of June. Over 6000 m³ of concrete was used to construct the internal storehouse floor.



Figure 4 – Finished storehouse in use

External Container Stand

The external pavement has dimensions of 30 m by 460 m. The pavement is 270 mm thick, designed to carry 84 tonne axle loads

and 40’ containers stacked two high. It was constructed in 6 separate pours, and incorporated 506 post-tensioning tendons. It was constructed only 2 m away from an operational railway track, which presented a real hazard despite being fenced.



Figure 5 The external pavement during construction.



Figure 6 Container lifting equipment with 84 tonne axle loads operate on the post-tensioned concrete pavement

Steel Fibre Reinforced Unloading Tunnel

The rail unloading tunnel sits next to the internal storehouse, allowing material to be directly unloaded from trains under cover. The tunnel incorporates a 4 m wide slab to support the railway, and a 12.5 m wide area for unloading. The tunnel runs the full 460 m length of the storehouse. A dish drain channel was formed along the full length of the slab to collect waste water when the area was washed down.



Figure 7 The 460 m railway unloading tunnel.

The 4 m wide slab that supports the railway tracks was heavily reinforced with continuous deformed bars. The depth of the slab varied from 250 to 350 mm, with the thickest part of the section directly beneath the tracks. Extremely accurate rebates were formed into the slab to allow for track placement. The slab is pictured prior to formwork being stripped in Figure 8.



Figure 8 Railway track slab, 4 m wide with rebates for tracks.

The remaining 12.5 m of the unloading tunnel was constructed as a “joint free” steel fibre reinforced floor. This was 175 mm thick, and incorporated 35 MPa concrete with 40 kg/m² of Novacon Xorex steel fibre. Figure 9 shows the fibre being loaded into the rear of ready mixed

concrete trucks using a purpose built conveyor.



Figure 9 Xorex steel fibre loaded into a ready mixed concrete truck

The design of the slab was unusual as the bays had dimensions of 39 by 12.6 m – representing an aspect ratio of 3:1. Traditionally a slab would not be constructed with bays of such high aspect ratios, because they significantly increase the risk of mid-panel cracking. The use of a high dose of steel fibre reinforcement was able to counter this effect.

The slab was constructed to a very light 0.3% grade. This was achieved accurately by using a Laser Screed with the guide lasers set to match the grade.

CHALLENGES

While post-tensioned slabs on grade have been used successfully in New Zealand for many years, the sheer scale of the floor and pavement at Fonterra Co-Operative Group Ltd’s Te Rapa milk powder storehouse gave rise to new challenges, and increased the challenges traditionally faced when constructing post-tensioned slabs on grade.

Reducing restraint on the slabs

A significant challenge in producing large joint free slabs, as employed for the Fonterra storehouse is reducing the restraint on the slab. This is necessary to reduce the risk of cracking – as the slab shrinks friction forces will be generated between the slab and the sub base. The sub base needs to be flat and even to reduce these friction forces.

To achieve this the sub base blinding layer was graded to a uniform tolerance of +/- 5 mm from target level. A laser guided machine control grader, which was mounted on a large 4wd tractor, was used to achieve this result. It was necessary to re-grade several areas prior to the first 2-3 sections of floor being poured, however after this the highly skilled machine operator was able to get a handle on what was necessary to achieve the tolerance and the remainder of the blinding layer

was completed to and excellent standard the first time around.



Figure 10 The sub base needed to be finished to tight tolerances to reduce the risk of the floor cracking.

In addition to requiring a smooth sub base to reduce restraint on the slab, penetrations such as portal legs needed to be well isolated. If they were not the floor would “hang up” on them and crack as it underwent its natural shrinkage movement. Slab penetrations were isolated using contoured polystyrene block outs, as shown in Figure 11.



Figure 11 Slab penetrations such as portal legs are isolated using contoured polystyrene block outs. Note that the portal leg has been wrapped in polythene to protect it from concrete splash.

Planning for Large Pours in Te Rapa

A typical concrete pour for the project required around 550 m³ of concrete to be delivered throughout the day. For each pour this was approximately 235 ton of cement, 570 ton of coarse aggregate, 480 ton of sand and PAP 7, and 1400 Litres of water reducer & retarder. Concrete was supplied by both Allied Concrete and Holcim, who stockpiled material at the plant and also had it continuously delivered during the pour. Clearly, pour dates had to be set well in advanced and adhered to, not only to ensure materials were available, but to make sure concrete supply to other customers was not unduly disrupted during the project.



Figure 12 Ready mixed concrete suppliers Allied Concrete and Holcim performed well.

It was also important that trades people were available for emergency call outs to plants, in case anything failed during a pour. Interruption of supply during a large pour would have spelled disaster.

The consistency of concrete was controlled by employing a trained technician on site throughout the pour to assess the slump of every truck. Concrete was to be delivered to site “dry” (below the actual target slump for placing). The technician could then adjust the slump upwards if this was required. This reduced the frequency of “wet loads” that would need to be rejected on the basis of high slump.

Pumping Concrete

It is not practical to discharge concrete directly from trucks when constructing a post-tensioned slab, as the trucks would have to cross a large number of PT ducts, which could be damaged.



Figure 13 PT ducting makes it impractical to discharge concrete directly from trucks.

For this reason concrete is pumped for the construction of PT slabs. For this project each pour employed 3-4 boom pumps and/or a telescopic conveyor. A back up pump was available on site in case of any break downs. Generally two “discharge” pumps would be driven across the PT ducts so they are able to discharge into the floor at the furthest point away from the

access points. These would be fed by two “feeder” pumps, situated off the slab on the prepared subbase or in doorways through the internal walls. Often additional line was required to feed the pumps.

The two “discharge” pumps were shifted backwards several times during each pour until they reached the doorways/access point. At this point the “feeder” pumps are no longer required. On average approximately 70 – 80 m³ was pumped per hour. The use of “discharge” and “feeder” pumps is demonstrated in Figures 14 and 15.

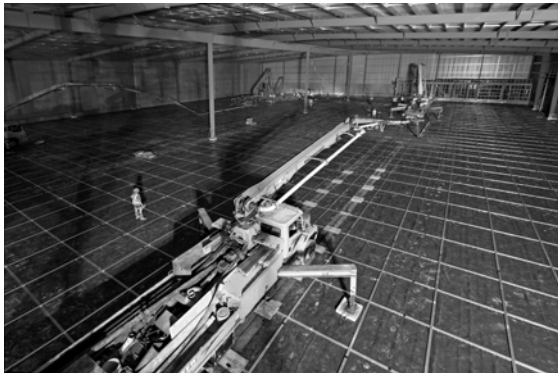


Figure 14 “Feeder” and “Discharge” pumps.



Figure 15 Concrete is discharged into a pump at a doorway

There were very few pump breakdowns experienced on the project, and breakdowns that did occur were minor.

Managing Individual Pours

The management of each pour required expertise and clear and consistent communication with the concrete dispatch team. The flow of concrete to site had to be constantly adjusted to account for changes in placing speed or delays caused by pump movements or minor breakdowns. Dosage of retarder was adjusted throughout the pour, and feed back on slump was given to the concrete supplier to help consistency.

To aid in managing the pour the concrete dispatch team were required to only accept instructions from a single nominated site supervisor. This vastly improved communication with the ready mixed concrete companies and helped reduce confusion. To often during large concrete pours dispatch will receive instructions or information from truck drivers, placers, technicians and pump operators – all of which can conflict.

Finishing Large Pours

Finishing such large pours can be a challenge. The biggest problem is caused by concrete in adjacent areas setting at different rates. This is normally the result of one or two “wet loads” of concrete being placed next to drier loads. The “wet loads” take longer to set than the dry loads and disrupt finishing.



Figure 16 Finishing begins at one end of the building while concrete is still being poured at the other end.

Approximately 8 ride on power trowels were used for finishing of the slabs. Internally the finish was specified as a burnished U3 finish.

Externally the pavement required a finish that would provide grip in the wet. This was specified as a swirl finish. After the first 2 pours this was deemed to be unsuitable as the surface was too smooth. Difficulties were also encountered with the wax based curing compound used on the slabs. In combination with the smoothness of the swirl finish the surface became too slippery for container moving equipment.

Removing the wax based curing compound from the concrete was a difficult operation. Hot water simply shifted it around and ultimately gravel was pushed over the surface to mechanically remove the curing agent.

It proved difficult to achieve a rougher finish and maintain good control of flatness and levelness, particularly on windy days. The slab would be setting up quickly in the drying conditions. Some

tiny areas of plastic cracking were evident despite water blasting an anti-evaporative spray over the slab.



Figure 17 Large container stand pour during finishing.

Thermal Effects

Thermal cracking was seen as a significant threat with pouring a thick, high strength concrete slab in Waikato through the middle of winter. Until the initial stress was applied there would be a slab of up to 85m long and only 30m wide sitting unreinforced and going through quite severe temperature movements.

Two layers of polythene were placed over the slab so that the intermediate air gap would provide some insulation. Thermocouples were placed in the slab at about mid depth and near the surface. The ambient air temperature was also measured. It was discovered that the depth of the slab resulted in enough heat being generated that the slab temperature never moved a degree despite going through frosty conditions.



Figure 18 The external pavement is 270 mm thick. This generated a large amount of heat of hydration.