ptNEWS

Newsletter 1 - 2011

POST-TENSIONING INSTITUTE OF AUSTRALIA LIMITED

President's Report

I wish all members of PTIA the very best for the New Year. We enter 2011 full of optimism for the prestressing industry and the economy in general. There are signs that available work is picking up and things in general should improve. Investors do seem to be proceeding with new projects to meet the shortage of supply now developing in Australia. We should see activity from this.

Prices for labour and materials are relatively stable at least for the coming quarters. This will make contracting a little more secure. Outcomes for member companies of PTIA should improve in 2011 if all continues as hoped.

With greater financial security we would hope that member companies might be able to strengthen their support and activities with PTIA. Growth of PTIA is what we seek for 2011.

This coming year we do intend to continue with training programs now in place. We will endeavour to provide further emphasis on assistance and training of Design Engineers in the industry. Courses we are making available relating to design should offer more value to our consulting engineer members and we hope we will encourage other consulting offices to join up.

This issue of the PTIA magazine has an emphasis on industrial pavements.

Slabs on-grade have always been a significant part of the post-tensioning market. Post-tensioned pavements provide many advantages when it comes to ground slabs. It is an area sometimes overlooked by designers. Some particular points in favour of post-tensioned slabs are:

- Elimination of joints allowing quicker pouring of large areas.
- Less joints means less areas for damage particularly from small forklift wheels.
- Post-tensioned slabs offer better control over poor sub-grade conditions.
- Waterproofing can be assumed
- Heavy point loads or variable loads can be more readily handled.
- Super flat floors necessary for some high bay stacking can be better prepared.
- Less joints often means economy of overall cost.

I trust articles in this month's issue are of interest - please feel free to contact the Institute if you do require more specific information or assistance on pavements.

Michael O'Neill
President

PTIA expresses its concern for all members, their families and friends who have been adversely affected by the devastating floods in Queensland. We acknowledge the great courage and optimism of the Queensland community during this disaster and trust that the recovery will be as fast as possible.

PTIA targets wider range of PT contractors as members

The Board of PTIA is targeting a wider range of PT contractors for membership. The aims of PTIA are to ensure high standards of construction and a trained and competent workforce in the PT industry. Responding to feedback which advises that membership criteria for PT Contractors are too strict and not relevant to many PT contractors, PTIA has developed revised criteria for PT Contractors who only undertake either 'supply and install' works or 'ground anchor' works, including a lower membership fee structure for these contractors. The criteria do require that PT systems be tested and approved, and that such members undertake to train their work force. Further details are available from PTIA at info@ptia.org.au.

Cherry Lane SPD Project

Location: *Cherry Lane, Laverton Victoria*
Client: *Toll Property / SPD*
Contractor: *A2Z Paving*
Post-tensioning contractor: *Structural Systems (Southern) Limited*
Consultant: *Hyder Consulting*

On Monday 11 October 2010, possibly the largest ever (area based) single pour PT slab on ground pavement was completed at TOLL-SPD's container storage facility, Laverton Victoria.

At 5,824 square metres, involving 1,590 cubic metres of 45 MPa concrete, this 260 mm thick slab is believed to be the largest pour area of post-tensioned concrete ever constructed in Australia and possibly the world!

Commencing at 3.30am, the pour took approximately 14 hours to complete using 3 concrete boom pumps, 2 laser controlled screed machines, 3 twin-head ride-on trowelling machines and over 260 concrete truck deliveries from 2 dedicated concrete batch plants.

This pour was the final slab section in a two year pavement replacement program undertaken at the site to repair approximately 20,000m2 of failed and badly cracked concrete pavement.

Hyder Melbourne office Structures team prepared the design and documentation and provided construction planning, advice and supervision services to TOLL SPD

The pavements were designed to support 35 tonne container boxes stacked up to 3 high and they can accommodate unlimited repetitions of 110 tonne axle load "reachstacker" forklift vehicles.

A 260 mm thick PT concrete pavement slab was adopted, using a range of pour sizes to suit the areas / extent of damaged slabs that needing to be replaced.

Reconstruction work included demolition and removal of the existing cracked, damaged and/or settled concrete, reworking of the underlying subgrade (generally reactive basaltic clays), provision of a 150 mm thick cement stabilized subbase, the addition of subsurface drainage and the reconstruction using high capacity post-tensioned concrete.

Close liaison between Hyder, client TOLL, site operator SPD, the contractor A2Z, PT contractor Structural Systems and concrete supplier Hy-Tec ensured that all parties were clear in their respective inputs and responsibilities to deliver the new pavements with careful consideration to the continued operation of the facility throughout the works

A feature of completed PT slabs is the large joint free areas produced. This was a particular attraction for this site given the problems experienced with maintaining and sealing the many closely spaced joints in the original pavements.

If you want to know more,
please contact: Frank Filippone,
Hyder Melbourne Office

Purpose of Post Tensioning in Concrete Pavements

PT in concrete pavements has two functions, firstly to counteract shrinkage cracking from about 18 – 24 hours onwards, then to pre-compress the concrete to counteract cracking due to ongoing shrinkage, flexural tensile stresses from service loads and temperature gradient in concrete.

As such, no particular tendon spacing limitations apply, and wider spacings are successfully used than for suspended slabs. From experience, tendon spacings of 12 – 15 times slab thickness provide good performance and economy. (Tendon spacing may influence the width of edge reinforcement required.)

Typical Post-tensioning systems for pavements

Slab system (also known as mono-strand) bonded strand post-tensioning is universally used.

Tendons comprise between two and six 12.7 mm strands, or between two and five 15.2 mm strands. Ducts are 70 wide x 20 high for up to five 12.7 or four 15.2 strands, 90 wide x 20 high for six 12.7 and five 15.2 strands. Anchorages are also flat. Well proven systems are available in the marketplace, these systems are almost identical to those used with draped profile in suspended slabs and beams.

The post-tensioning specialist contractor must be able to demonstrate their proposed system complies with AS/NZS 1314:2003 Prestressing Anchorages.

For pavements, the larger capacity multi-strand systems provide no advantages, are not necessary, are bulky, require greater slab depths to fit in anchorages and require heavier stressing jacks.

Tendons are un-profiled (flat) in one layer, with equal or close to equal quantities in orthogonal directions.

Post-tensioning couplers are available for up to five 12.7 strands, or five 15.2 mm strands, and are valuable for construction joints.

Occasionally two layers of un-profiled tendons are used, but these slabs, although cast on ground, are more accurately described as structurally suspended, with the tendons providing flexural strength through composite action.

AS3600-Concrete Structures permits unbonded tendons (as commonly used in North America) in slabs on the ground. However, these systems have limited availability in the Australian market.

Grout Tubes

Instead of unsightly grout tubes cut off on top surface of slab, grout tubes are usually looped at dead ends and run out through side of slab at live ends. This also avoids slab surface defects associated with grout tubes. Superplasticisers enable the successful grouting of tendons with looped grout tubes.

Length of Tendons, Single or Double Live?

The flat (un-profiled) tendons used in concrete pavements can practically run to 55 or 60 m long single live.

Longer tendons can be adopted with double end stressing, but this requires access to both ends for stressing, and anyway pour size limits mean this is rarely required.

Construction Joints: To Couple or Not to Couple Post-tensioning?

Construction joints are simply planned breaks in the otherwise continuously designed slab, hence they are intended to remain closed, and therefore do not require edge protection.

The post-tensioning across all construction joints should be coupled. Couplers are post-tensioning anchorages that provide a continuous tendon force across the joint, pre-compressing the concrete for optimal performance.

12.7 or 15.2 strand?

Strand size is usually selected by the designer and/or specialist post-tensioning contractor with reference to the design requirements and economical tendon spacing (as above). Often, light to medium slabs up to 180-200 thick use 12.7 mm strand, heavier slabs are more economically post-tensioned with 15.2 mm strand.

Initial, Final Stressing and Grouting

Initial stress is applied as early as practicable (consistent with avoiding failure of concrete at anchorages, especially dead ends) to counteract early shrinkage cracking. This is often in the evening of day of pour, or very early in the am of the next day. Concrete testing and edge formwork stripping needs to be managed to suit.

Final stressing is usually at four – seven days, dependent on concrete achieving required strength (usually 22 MPa for 12.7 mm strand, 25 MPa for 15.2 mm strand). The program needs to allow sufficient time for final stressing, approval of the extensions, cutting off tendons, sealing anchorages and (if grout tubes run through the edge board) grouting.

Post-tensioning Extensions

As for all post-tensioned structures, theoretical extensions should be calculated by the post-tensioning specialist contractor, and actual extensions submitted for approval by the party responsible for the structural design before tendons are cut off.

Theoretical extensions should not be shown on post-tensioning shop drawings.

The economical design of post-tensioned (PT) ground slabs is usually carried out in a rigorous manner based on engineering principles, considering the following factors and inputs:

Loads

The applied loads generate stresses in concrete pavements. It is essential to know the realistic design load details, including the load value, contact area geometry and spacing geometry etc.

Commonly considered loads include vehicle axle wheel loads, racking post loads, container "feet" loads and pallet stacking area loads etc.

Subgrade

The subgrade is the primary support to the slab and this interaction will dictate the slab strength requirement. Depending on the nature of the loading considered, short and/or long term subgrade properties are essential for design purposes and geotechnical advice is typically required.

Where the subgrade is poor or the loads are high it is often beneficial to provide some type of subgrade improvement (eg imported or insitu stabilised material) to reduce the overall slab cost.

Subgrade strength is given in terms of CBR, Subgrade Reaction Ks or Subgrade Modulus E.

Concrete

Concrete properties are selected to satisfy strength and durability requirements. Modern high performance slabs usually require 40 MPa concrete for surface durability and wear. However for load carrying capacity the concrete flexural tensile strength fcf is the critical concrete requirement.

As the full design loads are not usually applied until some time after the slab is poured, it may be possible to use the concrete 90 day flexural strength in the design, which is usually around 10% greater than 28 day value.

Shrinkage properties will influence the PT losses and slab joint/ edge movements.

The design concrete compressive and flexural strength and the maximum concrete shrinkage should therefore be clearly noted on the drawings.

Slab Analysis

Having determined the loads, subgrade properties and the concrete to be used, a rigorous structural analysis can be carried out to determine the slab moments and stresses due to loads.

Analysis can be carried out empirically using, say, a Westerguaard analysis (this tends to lead to conservative designs) or by employing FEA techniques to model the slab – subgrade interaction and the whole range of load combinations that are applicable to the design.

Temperature Stresses

PT slab panels are typically large between joints hence differential temperature between the top (exposed) surface and the bottom surface can give rise to additional thermal stresses not usually considered in jointed RC slab designs. Typically the critical case is when the top surface is warmer than the underside, which induces bottom tensile stresses that are additive to the stresses due to load.

Typical values of temperature gradients for internal slabs are 0.02 – 0.03°C/mm and for external slabs 0.04 – 0.06°C/mm (the higher end values apply to thinner slabs etc.).

Subgrade Friction

Again, as PT slab dimensions are typically large, friction between the slab and the underlying subgrade leads to restraint tensions which also need to be allowed for in the amount of prestress applied.

A friction coefficient "υ" of 0.5 is typically used in design for one layer of polythene over natural sand bedding. If crusher dust bedding is used υ = 0.6 or specify 2 layers of polythene.

Crack Control

In service, crack control is achieved by the net effective prestress compression applied to the slab. The PT slab on ground should be detailed free to slide on its poly / bedding layer hence the minimum level of effective prestress after long term losses and subgrade friction (P/A) can usually be as low as a 1 MPa.

Higher minimum effective prestress should be considered where a more stringent crack control criteria is appropriate (i.e. external slabs 1.0 - 1.5 MPa, Food and cool store slabs 1.2 - 1.8 MPa, tank floors 1.5-2.0 MPa etc).

Joints and Maximum Slab Size

The designer will need to consider the likely capability of the contractor and divide the required slab area up accordingly (eg country sites are likely to be size limited more so than sites closer to the city etc). The designer may also consider whether adjacent pours should be separated by a movement joint or a construction joint. If a construction joint is adopted, the tendon design length for losses and subgrade friction calculations will be the overall length of the 2 slabs so joined. If an MJ is adopted, each slab can be designed based on its respective shorter length.

Typical PT pour sizes are in the range 1500 m2 to 2500 m2. Larger pours can also be achieved subject to contractor capability and good site planning.

Typical maximum SOG tendon lengths can be 50-60 m or even up to 80-100 m by careful planning. Minimum practical tendon lengths would usually be around 8 – 10 m.

PT Design

Usually design iteration is needed to determine the most economical slab/PT combination considering the above items. For light to moderately loaded slabs the most economical design is usually achieved when the PT required to cover strength requirements is similar or close to the minimum effective P/A determined for crack control. Where Loads are particularly large or subgrade conditions are poor (necessitating thick slabs) then the optimum PT slab solution may yield a higher P/A.

For short term repetitive loading such as moving vehicles / wheel loads, allowance should be made for fatigue strength criterion.

Tendon Size Selection

Once the required effective P/A is a determined for the adopted slab thickness, the largest tendon size / spacing combination that provides this P/A needs to be selected.

It is noted that there is little published information on the maximum recommended tendon spacing for PT ground slabs. The author has found 12 – 15 times the slab thickness yields economical and practical installations. Tendon sizes (number of strands per tendon) being selected to satisfy this.

Post tensioned industrial pavements and the G.L.A.D principle

For many years, post-tensioning has been a viable option for industrial pavements and ground slabs handling high static and moving loads. Additionally, sites with poor ground conditions have also benefited from PT designs. McVeigh Consultants incorporates their G.L.A.D. Principle in order to provide a PT solution that responds to project requirements and is competitively priced.

The G.L.A.D Principle is comprised of the following four elements:

Geometry:

Completion of a site investigation is required to gain an understanding of the area's history and characteristics. Whilst geometry is more applicable to structures, it is also important to consider during pavement design as adequate geotechnical and survey information is critical. This will allow for the compilation of a site preparation plan and required pavement geometry.

Loads:

Post-tensioning of ground slabs is particularly beneficial where high loads are experienced. Therefore, for industrial structures, loads from forklifts, trucks, racking systems and storage containers must be considered.

Analyse:

The use of proper finite element methods and soil modelling is a critical step in obtaining design forces that accurately simulate real world results. McVeigh Consultants uses FEAR software which incorporates the Cement and Concrete Association's design charts.

Design:

A wealth of background information is referred to in order to construct a number of feasible options. During this stage, key rules of thumb are incorporated to ensure an acceptable design. For example, typical stress levels for an industrial slab on ground should be somewhere between 1.4 – 2.4 MPa for moderate to strong crack control respectively. This is a simple technique used to check that the slab is of adequate thickness. Secondly, PT commonly allows for pour panels of 2000 – 3000 m2 with joints at 30 to 60m apart.

Joints are important in controlling movement and shrinkage cracking in normally reinforced slabs. However, because stresses are managed through post-tensioning, a substantially higher crack resistance can be observed. The cost of joints can be up to 20% of the slab's final price and are recognised as the most common serviceability issue.

Above: Future project site.
Right: Implementation of post-tension design.
Below: Heavy loads to be considered.

Therefore, having less joins than traditional design methods will mean significant maintenance lifecycle savings.

When considering industrial slabs on ground, post-tensioning has the ability to meet project requirements and has the potential to provide significant lifecycle savings.

McVeigh's use of the G.L.A.D. Principle allows consulting engineers to identify all relevant information and systematically work towards a viable solution.

Clearly the widest tendon spacing will result in the least number of tendons to be installed. The designer also has the choice of strand size (12.7mm or 15.2mm) to further optimize tendon size / spacing. However, once a strand size is adopted on a project/stage, it's wise not to change or mix strand sizes. This could increase the site PT management requirements and/or potential for installation errors.

Movement joints and Slab Edge Protection

Movement joints allow thermal movements and normal concrete creep and shrinkage shortening to occur. As noted above they also dictate the design slab lengths in terms of friction loss allowances. As should be apparent, PT slabs enable the number of movement joints to be significantly reduced compared to other types of ground slabs.

However as the PT applies an active compressive force to the concrete, edge movements are likely and real. The designer should pay close attention to these joints, particularly the likely gap size that will develop over time. Gap calculations can readily be carried out based on AS3600.

As longer slabs will generate larger gaps, this consideration may warrant adopting reduced slab lengths in order to be able to effectively detail these joints.

Joints subject to normal pneumatic tyre vehicles usually only require tooled edges and an appropriately detailed flexible sealant to prevent ingress of debris, water and the like. On the other hand joints subjected to high repetitions of loads, particularly from small, hard wheeled vehicles often need to be detailed as armoured edge joints, using cast in edge angles and cover plates etc.

Load transfer across movement joints is usually achieved using round or square MS dowels. However it is important to remember that PT slabs move both perpendicular and parallel to the joint line hence lateral and telescopic dowel movement is required

Edge Thickenings

PT slabs are typically designed as continuous plates which enable the slab thickness to be kept to a minimum. As edges are discontinuities and thus points of structural weakness, they will need to be thickened to maintain general slab strength.

Normally the slab edge will need to be around 40 - 50% thicker unless additional local reinforcement is provide (eg as would be detailed in constant thickness freezer wearing slabs).

Anecdotally edge thickenings have also been found to reduce or inhibit edge curling. It is important that such changes in depth are achieved by tapers of around 1 in 10 slope, maximum.

Further Information:

Most PTIA members have developed in-house design procedures to automatically take into account the above considerations and are usually able to provide specific advice on request.

C&CAA document *TP49 Post-Tensioned Slabs-on-Ground (1990)* and paper by Sindal J.A. *A Design Procedure for Post-Tensioned Concrete Pavements (1983)* provide useful overview of these design considerations.

Construction Aspects of Industrial Pavements will be addressed in our next newsletter

MEMBER COMPANIES

Corporate Members

Australian Prestressing Services Pty Ltd (founding member)
Structural Systems Pty Ltd (founding member)
VSL Australia Pty Ltd (founding member)

Associate Members – suppliers

Ajax Foundry Pty Ltd
Ancon Building Products
Haggie Reid Pty Ltd
Holcim (Australia) Pty Ltd
OneSteel Wire Pty Ltd
Refobar Australia
Sanwa Pty Ltd
Severs Technical Systems Pty Ltd
Usha Martin Australia Pty Ltd

Associate Members – consulting engineers

ABC Consultants
Arup
Bornhorst + Ward Pty Ltd
Costin Roe Consulting Pty Ltd
Hyder Consulting Pty Ltd
McVeigh Consultants Pty Ltd
Parsons Brinkerhoff
SCP Consulting Pty Ltd
Taylor Thomson Whitting

"ENSURING EXCELLENCE AND ACCREDITATION FOR THE POST-TENSIONING INDUSTRY"