The New Glebe Island Bridge

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Introduction

The new Glebe Island Bridge is a high level crossing over Johnstons Bay at Pyrmont in Sydney. It carries seven lanes of traffic and a pedestrian / cycle way and replaces an old four lane opening bridge which was built in 1903. The bridge itself is an 805 metre long concrete structure comprising six spans with three cable-stayed central spans. The main span is 345 metres long. At the eastern end, the approaches form part of Darling Harbour Viaduct. It was officially opened on 3 December 1995 after a three and a half year construction time and at a total cost of $69 million. It is Australia's longest cable stayed bridge and one that is rapidly becoming another Sydney icon together with the Opera House, the Harbour Bridge and Centrepoint Tower.

Several years before the bridge itself was commenced, the footings and sub-structure piles were completed. There are 56 piles under each tower, each 1.5 metres in diameter and extend down as far as 35 metres below water level. The concreting of the pile caps took 26 hours of continuous pouring, each 2835 cubic metres, utilising up to four pumps at once.

Construction

The bridge construction was managed by the Roads and Traffic Authority of NSW and built by Baulderstone Hornibrook Engineering. It was built not under a QA contract, but under the older more traditional QC method requiring checks before each pour. The bridge was opened 15 months ahead of schedule by using some "innovative construction techniques" which you can read to mean "survey headaches". The towers are 121 metres high and there are 128 stay cables. Yes that meant we had to position 256 guide pipes before they could be cast in place. Each cable has between 25 and 74 individual strands inside it, each around 18 mm in diameter and plastic coated. Within each of these there are seven wires. There has been about 810 kms of strand used in the cables of the bridge.

I would briefly like to compliment Baulderstone Hornibrook because they are far in front of any other contractor I have been involved with over the years. They are very professional, take great pride and care in their workmanship and have been very co-operative to work with. They have their own quality system on board which obviously helps. They are the first contractor I know that actually tore apart and rebuilt some major formwork losing some days in the process on the results of their surveyors' checks and before we checked it!

Survey

I would now like to briefly mention some of the individual tasks that we were asked to check during the construction of the bridge and how we tackled the problem. The bridge was checked by us using a Leica TC1600 total station and interfaced to a Sharp E500 computer and using software that is commercially available and written by ex RTA

surveyor Bob Galton. Bob had to modify the program to suit a few of our unusual requests. Use of this program enabled us to be able to give answers in the field so that there was no likelihood of concrete pours being delayed.

We had six prisms on tops of surrounding buildings which we observed to numerous times every single day as nearly every set-up was using a resection. Bob's program not only enabled us to do a least squares adjustment in the field (using Bob's CHAOS routine) but look at the residuals as well. Nothing unusual I hear you all saying. Wrong! Three of the prisms were Topcon and three were Leica with prism constants that are 34 mm different. Not a problem for Bob. Resections had to be continually used because most setups were on concrete or girders that were subject to movement by the sun or cables or both.

The Tower Legs

The tower legs were constructed in four metre high segments using jump forms that were attached to the top of the concrete column. This was only in an absolute at rest position at dawn (or just before) which is when many of our surveys had to be undertaken. We had to do resections at this time from pillars attached to jump form girders to absolutely locate some local marks. These were used later in the day relatively, with an eccentric station fix determining position. Prior to cables being attached to the tower head, we found that the top moved in a circular motion each day as the sun affected each side of the tower leg as it passed. Around 50 mm movement was often encountered. By also starting early, we could have the alimak lift turned off for twenty minutes before most of the labourers started. This helped minimise movement during the resection as well. Level was transferred to the top for each pour using reciprocal vertical trig heighting. Accurate RLs weren't generally required for the legs because RL was only used for determining the offset (mainly) and chainage (to a lesser extent). These latter two varied with height.

These tower leg pours were generally about every 5 to 6 days but the record for adjoining pours on the same leg was three days! Timing for both setting up by the contractors surveyors, and checking by both parties was critical.

When the two legs met at the bottom of the tower head, the two jump forms were modified and merged to create one large jump form. The RTA Bridge Branch, which designed this bridge, also took a vital role in the construction by having an up-to-date computer model of the forces at all stages of construction. They wanted the complete tower head to be constructed vertically before cables were started to be connected to the deck below. Sounds easy doesn't it? However the contractor decided that they couldn't afford to wait till the tower was complete before cable assembly was commenced. The resultant was the tower head being pulled one way and then the other by cable installation and stressing. Needless to say, the poor surveyors still had to keep checking as though it was vertical.

The Cables

The positions for the cables or rather the guide pipes were defined in the plans with three points on each of the deck ones and the tower head ones. These points were just a simple chainage, offset and RL on the axis at the end, and at the points where it entered and left the concrete. The true angles of the cables were also quoted, as well as all the angles viewed in each of plan, elevation and end elevation. RTA engineers requested that when checking guide pipes, our reports indicate the position as though you were looking from the end of the cable toward the centre of the cable. The position square to the line was more important than the actual length of the cable.

The formwork for the tower head section containing the guide pipes was built on the ground so that it could be assembled and checked beforehand, and merely lowered into place by a huge ringer crane when it was required. This assembly on the ground certainly gave us more accessibility for sighting than if it were contained within the jump form. However, with many guide pipes crossing at different heights within the four or eight metre high formwork, sometimes visibility was a real problem. We had many poles of a variety of lengths, including a short adjustable one, and generally had to use a small prism. We found the Omni was one of the few to be able to satisfy our requirements which meant being able to use it inverted or upright.

For the open end of the guide pipe, we had an adjustable special tool made to temporarily fit in place and the centre was defined by a phillips head screw which was easy to pick up. At the top end (and similarly for the bases of the deck guide pipes), the centre was defined by the mean of two corresponding points. These were generally centre punched and the point of the pole would fit in without slipping. We would always try and be present at the same time as the contractor's surveyor was doing his final checks. Because of visibility problems, we quite often had to mark and observe different points from the contractor. Many a check of these units was completed under torch light as adequate time was generally not allowed and they always took ages to check. Just so things weren't too easy for us, the second lot of tower head units for the eastern pier were checked on the approach decks on the western side. This meant that one had to keep an eye out to make sure that nearby cranes moving during a check would affect not only your setup, but the verticality of the units which had been preset. You would always have to locate yourself with an eccentric station fix.

Similarly the bases for the deck guide pipes were pre-cast and actually had some concrete poured around them just to hold the guide pipe. This concrete was full width of the edge beam (1.5 metres) and a section two metres long and only 300 mm high was cast. This meant that a known chainage was marked on the concrete base and when placed into final position and clamped sideways by shutters, only the chainage had to be set to a nail previously placed on the final edge beam formwork at the known chainage. Checking these base pods meant a trial and error process to locate the chainage datum which was the end point of the base. The concrete for these pods was always poured with the preceding deck segment so that once the form traveller had been advanced for the next pour, the next pair of guide pipe bases were ready to drop into place.

The Deck

The deck was constructed in three ways. Under the actual tower head, the deck was formed on scaffolding off the ground. On the land side of the towers, a rolling form was used which enabled full width pour (32.125 metres) and two segments in length (each 10.335). The remaining decks were constructed on the form traveller which enabled only one segment to be poured before advancement. This form traveller was supported by the two leading cables during the pour. Segments were constructed on alternate sides of the tower in order to maintain stress levels within the tower. The cable installation and stressing had to fit in with this schedule as well. Obviously with some of the longer cables, this took quite some time. The rolling form scaffolding could be all lifted up at once and rolled forward to the new position. When this rolling form was finished with on the western side, it was put on to a barge and floated to the eastern side for re-use. Amazing but true.

Most levels for deck checks came from a full time American consultant DRC who was on site with an amazing computer program that determined everything from stresses to be applied to individual strands, deck levels, kerb profiles, pre-cambers to be used, and shimming adjustments for the form traveller to name a few. Early on we were checking the deck levels absolutely, but this had to be done at sunrise and without heavy cranes on the deck. This was found to be too restrictive so the method that was adopted was based on each segment being a chord of the vertical alignment. The vertical differences from an extrapolation of the previous segment were nominated at particular chainages. All this was fed into our pavement checking routine and answers were available straight away. Two lots of vertical offsets were supplied depending upon whether the checking was done before or after cable installation.

The control for both this vertical and the horizontal alignment was determined from three lines of hilti nails placed on the centreline and the north and south edges at the leading edge of each segment. Works as executed positions were continually being done by the contractor's surveyor who was feeding the information to DRC for processing.

This method for checking meant that it didn't matter if there was a large crane on the end of the deck as the relative differences between adjoining segments didn't alter. Temperature theoretically didn't effect it either but from when the datum control nails were picked up and the deck in question checked, a temperature variation could occur. We generally tried to do these checks at dawn to eliminate this problem.

Most deck checking was carried out from survey arms attached to both of the tower legs about six metres above the deck and extending in from the leg about two metres to clear the line of the cables. The observer stood on a separate scaffolding tower which rested on the deck. All observations were radiated with very good accuracy. Control nails were observed both faces but deck checks were found to be satisfactory with only one. The main checking of the form traveller was for line, level on the leading edge and relative differences between each side of the leading edge to make sure there was not too much twist in the segment.

Even checks from the survey arms required resections as cable installation at the top of the tower pulled the leg over enough to effect the chainage of the arm at the height we were attached to. This pulling affected the chainage of all the deck as during construction it was attached to the tower leg. Chainage datum was taken for each check at a reference nail on the deck at the centre of the tower. Due to creep and shrinkage of the concrete tower legs to which our survey arms were attached, we had to continually adjust the RL of the arm station. Once again reciprocal trig heighting either off the ground or from a deck station over one of the lower piers was more than sufficient.

Another complicated area of the deck for surveyors was the eastern approaches near what currently is the new Meriton apartments. Even though this was formed up off the ground, this was a problem due to a number of factors. This is the only location where the deck is not straight. There is substantial widening of the deck due to the original intention of an additional off ramp here, but changing land use of the Pyrmont peninsular meant that this ramp will be used by pedestrians and cyclists only. These last two reasons leave two different crowns in the deck. There is also a variable cross fall whereas the majority of the bridge is a constant width and constant three percent cross fall. The cross girder strengthening below the deck is actually square to the main straight of the bridge. These remain parallel even in the widened and curved section of this eastern end. With two different lots of pre-cambers in this area, it meant that some checks had to be run through seven different alignments! As a matter of interest, the actual bridge deck in between these cross girders (that are spaced over the entire length every 5.2 metres) is only 250 mm thick.

Joining the Deck

The last task that I would like to comment on is the final deck level adjustment prior to the central closure pour. Once the 260 tonne form traveller was lowered onto a barge, the two ends ended up very close to the correct level. Both sides of the gap had previously been surveyed a number of times pre-dawn. These levels were fed to DRC for examination and cable adjustment to correct the deck profile. After jacking apart the final two metre gap so that the closure pour would be done under compression, longitudinal steel girders were placed both below and above the deck. These were then clamped together to ensure that the two ends met. So that there was no chance of temperature creating movement, the pour was done at 2100 hours so that by sunrise the concrete had sufficient strength to stop movement and to be able to be stressed.

This I hope gives a little insight into this great bridge and a glimpse behind the surveying backdrop. I have concentrated on some of the tasks which I found frustrating but challenging, and I hope you have found to be interesting.

Acknowledgements

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