Australian Geomechanics Society

Sydney Chapter

A Note on Real Time Monitoring of Tunnel Invert Slabs During Stressing

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Mini-Symposium
Geotechnical Instrumentation and
Construction Works Compliance Testing

Presented at:

Eagle House, Milsons Point
Sydney, Australia
August 2003

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A NOTE ON REAL TIME MONITORING OF TUNNEL INVERT SLABS DURING STRESSING

by

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1. INTRODUCTION

The Burnley Tunnel in Melbourne is about 3.5km long and passes at a depth of about 60m beneath the Yarra River. In about mid-1999, prior to the tunnel being opened, problems developed with the invert lining within parts of the tunnel. These problems were widely canvassed in the Media and aspects of the remedial works were published in the Melbourne Age. This article deals with a small technical facet of material which is in the public domain. It does not deal with matters which have been in dispute between various parties associated with the tunnel.

The simple objective of this article is to record the level of accuracy which can be achieved in real time survey monitoring within a tunnel.

2. TUNNEL GEOMETRY

Figure 1 shows a cross-section through the final lining of the tunnel (Refs 1, 2 and 3). The lining is fully tanked by means of a continuous PVC membrane between the Primary Lining (rockbolts, sets and shotcrete) and the un-reinforced concrete Secondary Lining shown in Figure 1.

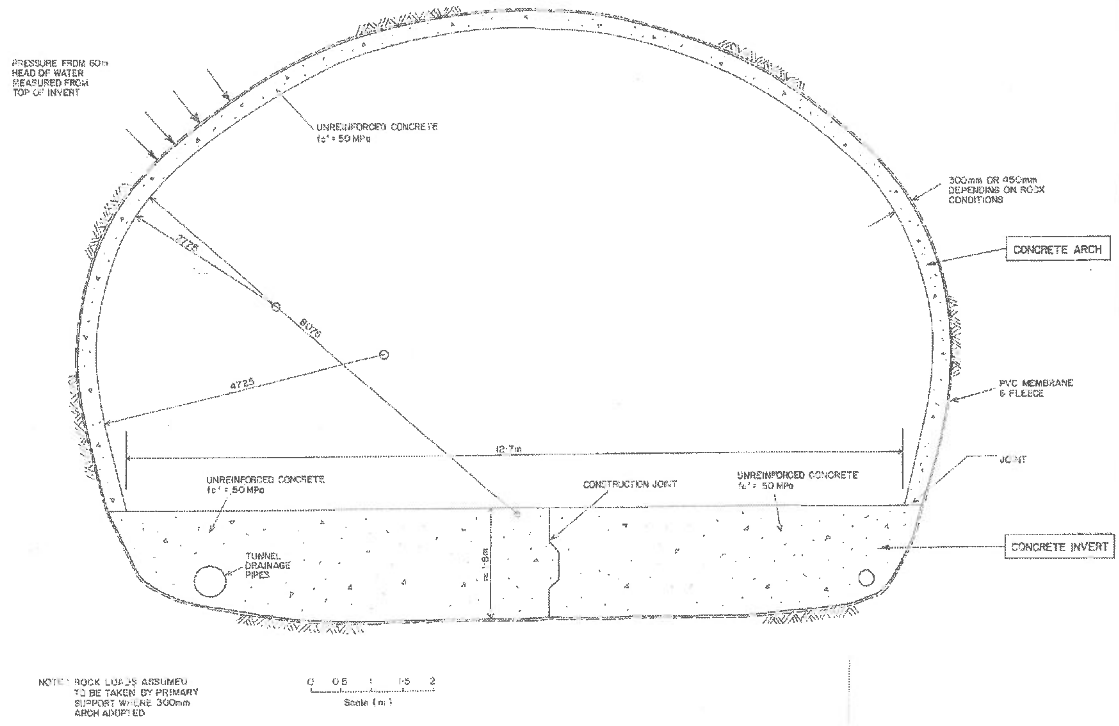


Figure 1 – Cross-section through final lining of Burnley Tunnel

The tunnel invert comprised thick slabs with a slightly arched underside. There is a longitudinal joint near the centreline as shown in Figure 1, and the slabs are 12m long along the tunnel, ie: there are transverse joints at 12m along the invert.

Each 12m long invert slab was given a number. The numbering is shown in Figure 2, which also shows the geological profile along the tunnel (Ref 4).

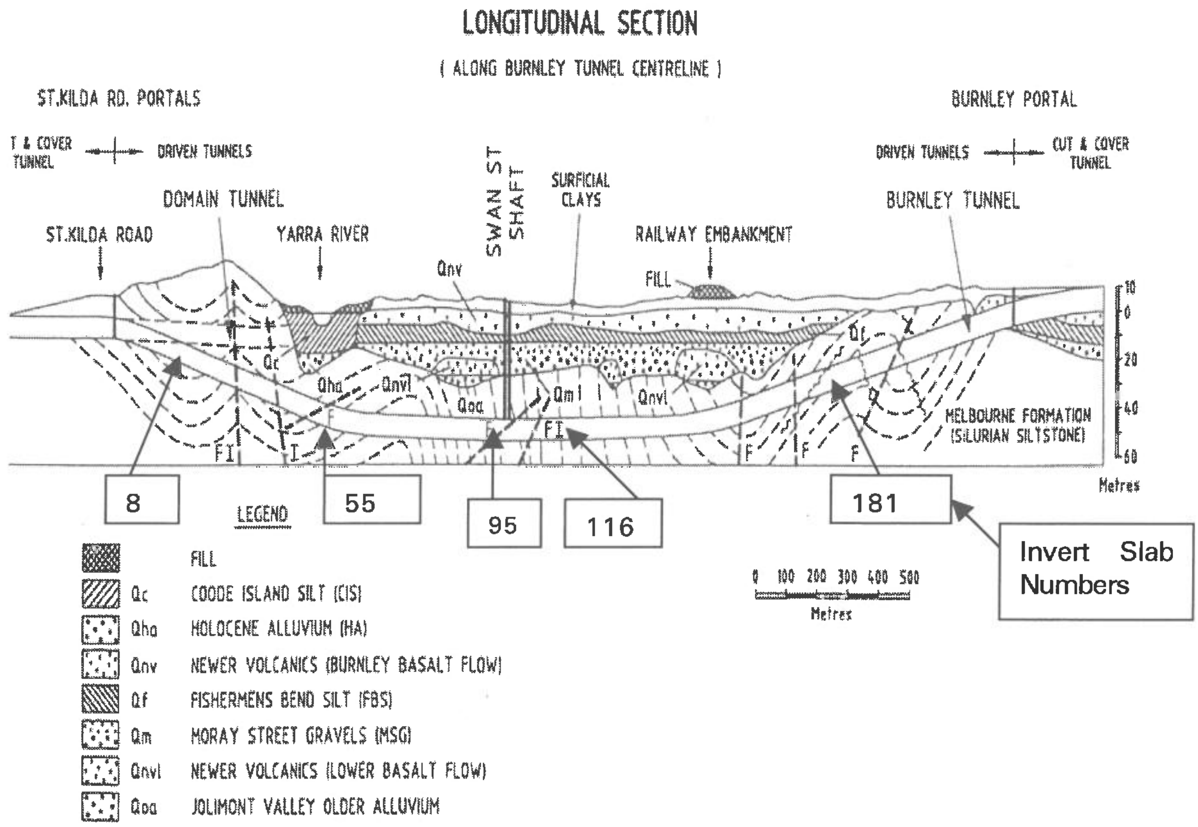


Figure 2: Longitudinal Section

This article deals mainly with invert slabs 95 to 116, ie: the slabs near the Swan Street Shaft where final hydrostatic pressures are of the order of 60m.

3. INVERT REMEDIAL MEASURES

Figure 3 shows a typical section through one of the central invert slabs where the remedial measures comprised:

- trimming about 400mm off the existing invert concrete,
- installation of sufficient anchors to resist the uplift pressures (typically 96, nominal 100 tonne working load anchors per 12m long by 12.7m wide invert slab),
- casting of a new reinforced concrete capping slab, and
- stressing of the anchors.

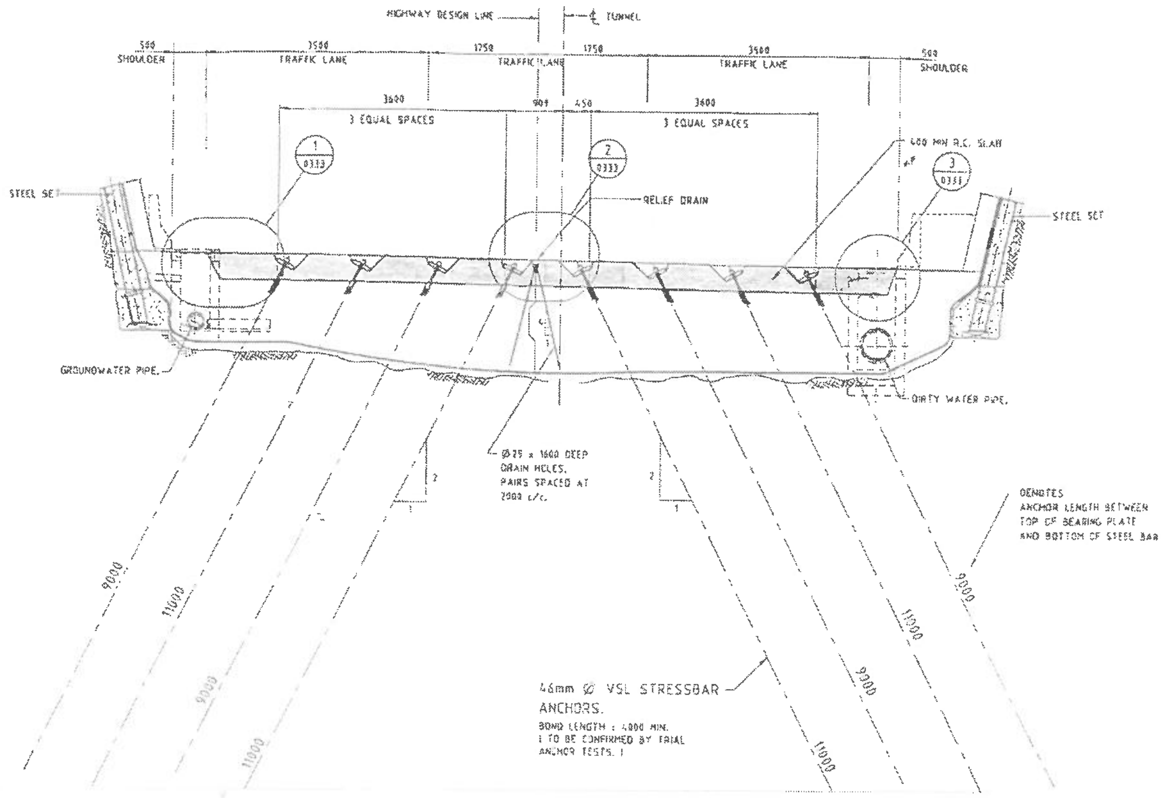


Figure 3: Multi-anchored slabs

Over the remainder of the tunnel, except for slabs 1 to 12 and 177 to 181, remedial work comprise central twin anchors, at average longitudinal spacing of about 1.2, as shown in Figure 4.

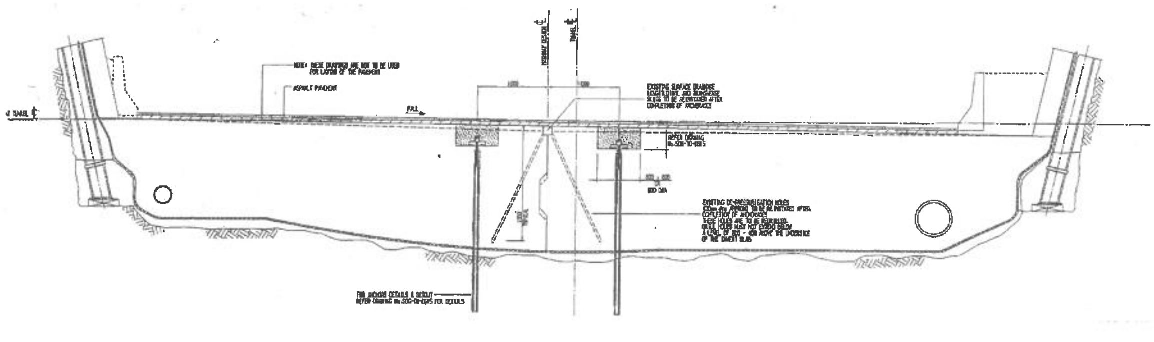
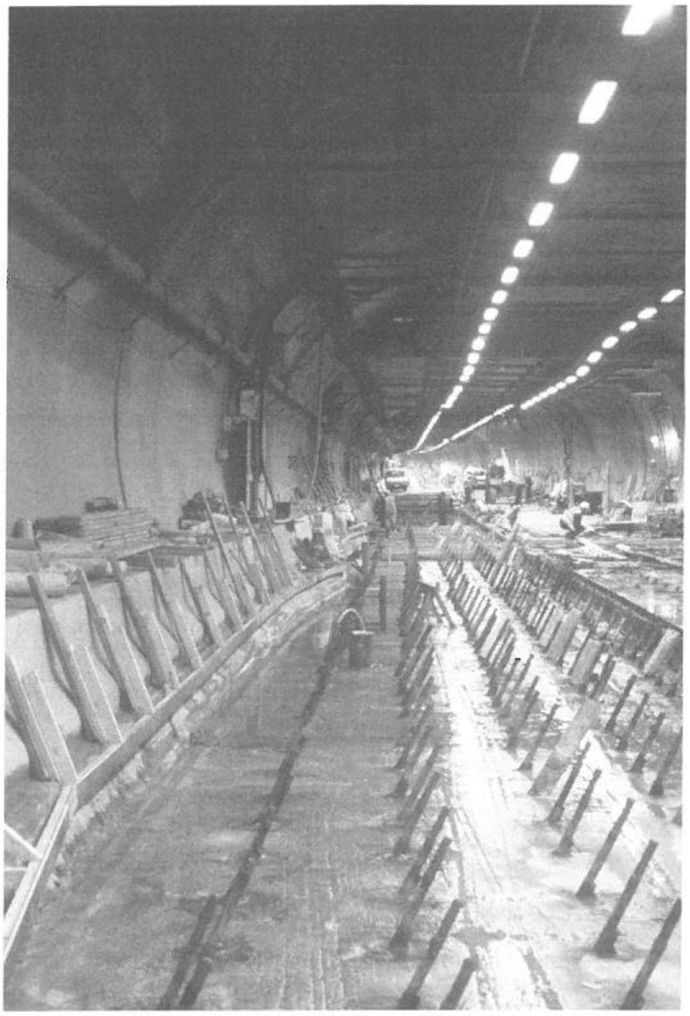


Figure 4: Twin Anchor Design

Photographs 1 and 2 show part of the central section of the tunnel during multi-anchor installation.



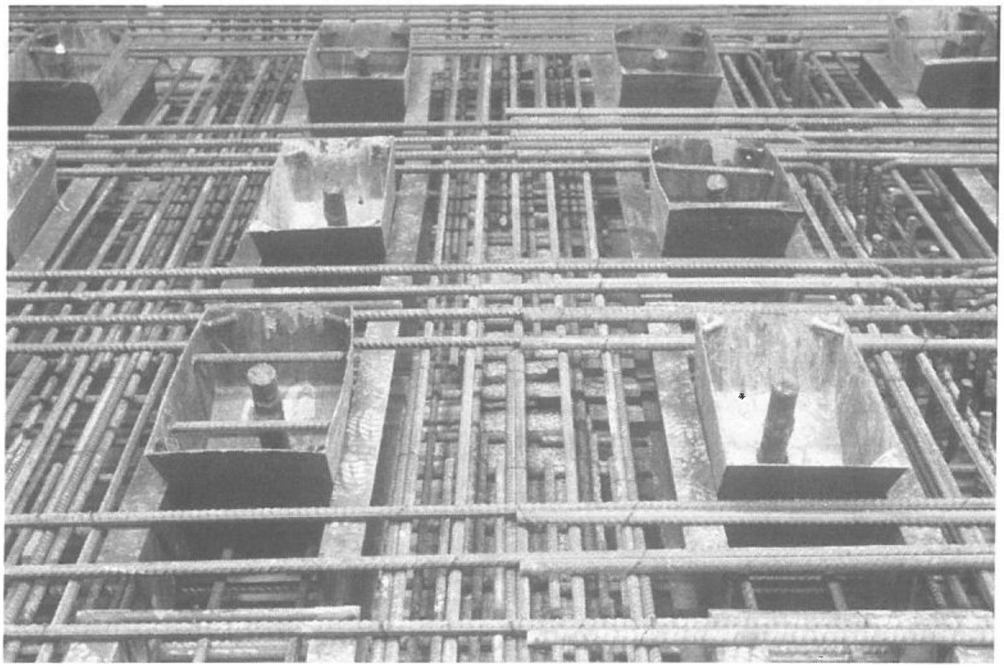
Photograph 1 – Drilling and installation of anchors

Photograph 2 – Anchors installed in one half of the invert

Photograph 3 shows stressing of a multi-anchored slab in the background, while in the foreground can be seen commencement of twin anchor remediation.

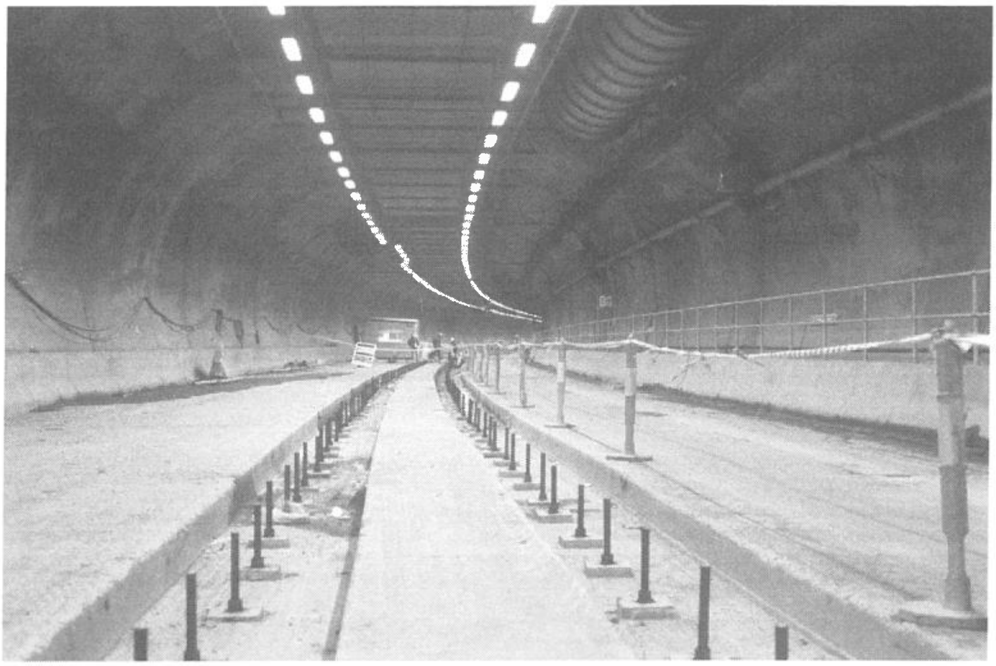
Photograph 3 – Twin anchored and multi-anchored slabs

Photograph 4 shows completed 46mm VSL stress bar anchors within the reinforced capping slab, prior to casting of the slab.



Photograph 4

Photograph 5 shows a typical length of twin-anchor remediated slabs.



Photograph 5

In total there were about 2500 anchors in the multi-anchored slabs and a further 2700 anchors in the twin-anchored slabs.

4. MONITORING OF THE INVERT SLABS DURING STRESSING

As already mentioned, each 12m long central slab was pre-stressed with about 96 anchors, with a combined load of about 10,000 tonne (ie: more than the weight of two Anzac Class Frigates). The key issue was to ensure that the slabs did not settle or twist more than a defined amount during stressing as this could have affected adjacent slabs and/or interaction with the arch lining. The task was to achieve the requisite monitoring accuracy (<2mm in level) and to be able to determine the three dimensional movement of each slab, in real time.

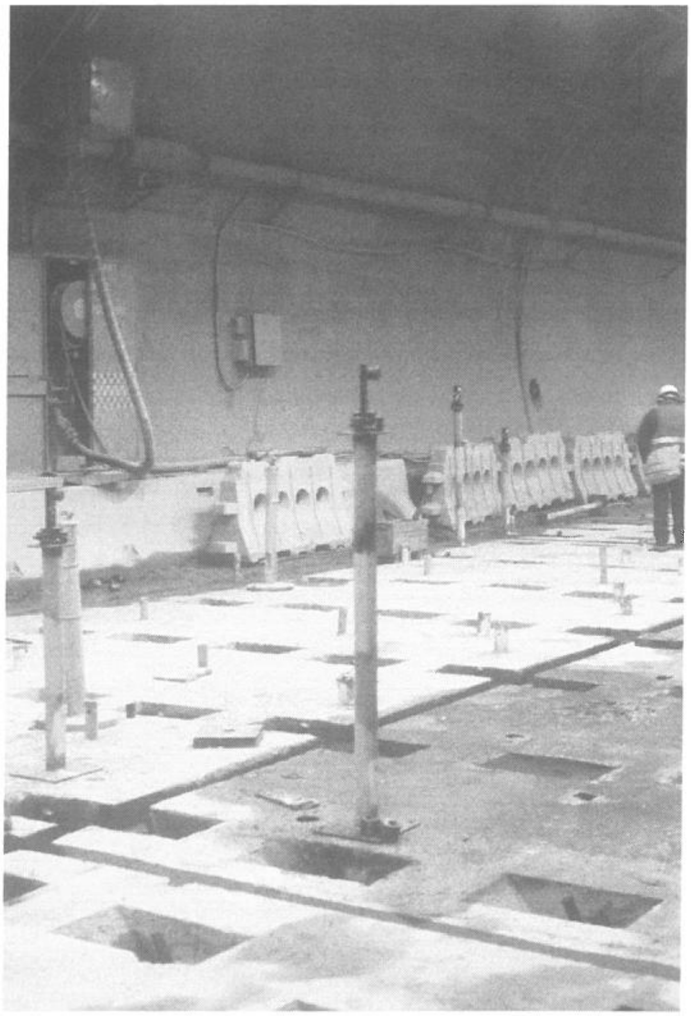
The system which was adopted comprised Geodimeter 6000 robotic theodolites mounted on heavy brackets fixed to the concrete sidewall of the tunnel. This system required the use of active prisms which in effect identify themselves to the theodolite. They also have the advantage of a light which flashes when a "hit" is registered and the visual telltale was helpful to supervisory staff casting an eye over the whole process. It should be noted that the equivalent Leica system does not need active prisms.

Each theodolite could handle about 30 prisms. At the peak of stressing operations there were about 90 prisms, requiring simultaneous operation of three theodolites. The system was supplied and managed by John Gertzel, a Melbourne surveyor.

The prisms were mounted on posts which ranged in height from about 1.2m to 2.0m. There were four prisms for each half of an invert slab (a half slab being defined by the near-central longitudinal joint and the 12m-spaced transverse joints). Photograph 6 shows the typical post arrangement. Survey distances were typically less than 30m.

Readings from the theodolites were processed and assessed in real time and the stressing sequence of the anchors within a half-slab was managed so that tilt and slab settlement was within the prescribed limits. The system consistently achieved accuracy of relative levels of better than or equal to 1mm.

When used to monitor sidewall movements within the tunnel, the accuracies were of the order of 2mm, mainly because the angles between theodolite and targets were typically much more acute than for the invert monitoring.



Photograph 6

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