GEOTECHNICAL INSTRUMENTATION & MONITORING PRELOAD PERFORMANCE - STAGE 3 EXPANSION KOORAGANG COAL TERMINAL, NEWCASTLE, AUSTRALIA

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ABSTRACT

Ground improvement to reduce post-construction settlements by way of staged preloading was undertaken prior to construction of the 1.4 km long coal pad and reclaimer berm at the Kooragang Coal Terminal. Geotechnical instrumentation including settlement monitoring plates, vibrating wire piezometers, inclinometers, earth pressure cells and a deep extensometer were utilised to monitor preload performance which was critical to the staging of construction works. Geotechnical monitoring was successfully utilised in difficult ground conditions to minimise potential delays to construction.

1 INTRODUCTION

The Stage 3 Expansion of the Kooragang Coal Terminal was a $330 million project which boosted the coal exporting capacity of the Port of Newcastle to 89 million tonnes per year. The Kooragang Coal Terminal, operated by Port Waratah Coal Services Limited, is located at Kooragang Island, in the port of Newcastle, some 160 km north of Sydney, NSW, Australia. Kooragang Island was formed through the extensive reclamation of small islands, shallows and channels and contains deep estuarine sediments which are susceptible to settlement via consolidation and creep.

The site contains the world's largest coal handling operation. Coal is transported primarily by rail from Hunter Valley mines, emptied in the receival (dump) station and conveyed to rail mounted stackers which place coal in designated stockpile areas. Coal is then reclaimed from the stockpiles by bucket wheel reclaimers and transported via conveyors to the shiploaders for export.

Port Waratah Coal Services engaged Bechtel Australia Pty Ltd to undertake engineering, procurement and construction management for the Stage 3 Expansion, which included a third stacking and receival conveying stream, rail receival (dump) station, stockpile pad and reclaimer, shiploading conveying stream and shiploader.

Due to the presence of deep, soft estuarine sediments, ground improvement by way of staged preloading was undertaken to reduce post construction settlements prior to the construction of the coal pad and reclaimer berm.

This paper discusses the successful implementation and results of geotechnical monitoring associated with preloading for the Stage 3 Expansion works.

2 SITE CHARACTERISATION

An extensive geotechnical investigation program was undertaken to assess site conditions (Douglas Partners 2000). The site was particularly suited to cone penetration testing (CPT), due to the presence of soft estuarine sediments. The investigation comprised a combination of CPT, piezocone tests, pore pressure dissipation tests, seismic CPT, conventional boreholes and jetted bores, shear vane tests and test pits. A range of laboratory tests including oedometer, triaxial, permeability, Atterberg, sieve analysis and hydrometer tests were also undertaken to characterize soil conditions.

The interpreted geotechnical soil profile generally comprised the following:

- Unit 1 - filling, mainly sand
  (up to 5m deep)
- Unit 2 - upper soft to firm clay layer
  (up to 4m thick)
- Unit 3 - dense to very dense sand
  (23m to 28m thick)

- Unit 4 - lower stiff estuarine clay
  (7m to 12m thick)
- Unit 5 - siltstone / sandstone bedrock.

An upper unconfined aquifer was present in Unit 1 fill materials (ie perched). A lower semi-confined aquifer was also present beneath the Unit 2 clays.

The main geotechnical issue at the site was the presence of the upper clay layer with respect to consolidation and creep. The presence of the dual aquifer system also had implications for deep excavation works.

Engineering parameters from CPT data were processed together with the results of laboratory testing to produce continuous profiles of parameters such as shear strength, over consolidation ratio, coefficient of volume change, drained modulus and friction angle. The output can be tailored to present a wide range of interpreted parameters. Data in this format made analysis of settlement / consolidation quick and efficient.

Settlement analysis indicated that settlements of up to 700 mm were likely over a 17 year period without ground improvement for the proposed berm and coal stockpile area. Settlements of the existing berm and pad facilities have previously been experienced at the site. Considerable maintenance costs could be incurred where re-levelling of stacker and reclaimer rails is required as a result of excessive settlements.

The objective of geotechnical design was to design a ground improvement system to limit post construction settlements over a 17 year period to 200mm beneath the reclaimer berm, and 300mm beneath the coal pad.

3 PRELOAD DESIGN

A number of options for ground improvement were considered to limit post construction settlements. Preloading was assessed to be the most feasible and economic option to meet the performance requirements. Settlement analysis indicated that a total preload height of about 9 m would be required to achieve the design objectives over a preload period of less than 12 months. The height of preload was also influenced by the availability of preload material, and the staging of construction works.

Stability analysis however indicated that slope failure would occur if the full height of preload was added in a single lift due to the underlying Unit 2 clays. A two stage preload system was therefore designed to address both settlement and stability issues during construction.

The 4 m high Stage 1 preload was initially placed and monitored to achieve sufficient strength gain in the upper Unit 2 clays to allow the placement of Stage 2 (additional 5 m) without the risk of slope failure.

The requirements for a two-stage preload increased the need for accurate and timely monitoring results, in order to ensure that the construction program remained on schedule.

4 PRELOAD MONITORING

Preload monitoring during construction was required to:

- assess progress of preload settlement.
- determine when Stage 1 preload had achieved appropriate strength gain (confirmed by further CPT testing).
- confirm stability of clay layer during preloading.
- determine when Stage 2 preload could be removed and allow berm construction to continue.

Monitoring of settlement plates, piezometers, inclinometers, extensometer and earth pressure cells were undertaken as discussed below.

4.1 SETTLEMENT MONITORING PLATES

A total of 45 settlement plates were installed prior to the placement of preload materials. The plates comprised a 500mm square steel base plate with 32mm diameter steel risers, added in sections as the height of preload was increased. The risers were encased within a protective PVC pipe.

Survey levels were measured on the base plates, and at regular intervals on the steel risers, by the project surveyors.

A typical settlement monitoring plot is presented in Figure 1.

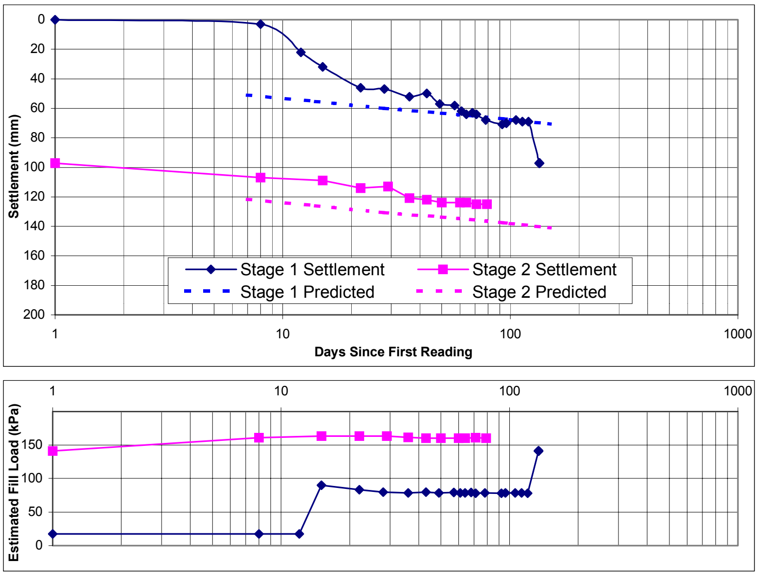

Figure 1: Typical Settlement Plot

The plot shows the recorded settlement compared to the predicted time-settlement behaviour. The lower plot shows the estimated fill load for each stage of loading, based on the recorded fill height and fill unit weight.

4.2 VIBRATING WIRE PIEZOMETERS

A total of 44 vibrating wire piezometers were installed beneath the preload within the upper Unit 2 clay layer to monitor pore water pressures. One piezometer was also installed within the lower Unit 4 clay layer.

Regular piezometer readings were measured, together with settlement plate monitoring, to monitor the dissipation of excess pore pressure and assist in determining when preload could be removed.

A typical piezometer plot is presented in Figure 2. The piezometer plot shows the recorded pore pressure and estimated hydrostatic pressure, with the difference being the excess pore pressure. The estimated fill load and total overburden stress are also plotted.

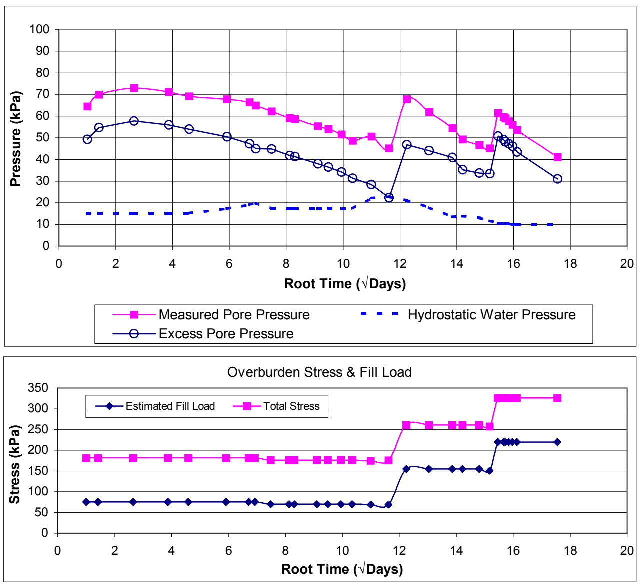

Figure 2: Typical Piezometer Plot

4.3 INCLINOMETER

A total of 28 inclinometers were installed to a depth of at least 1m below the upper Unit 2 clay strata, adjacent to the toe of the preload, to monitor lateral displacements during the placement of preload.

Regular readings were taken and processed as shown on the typical plot in Figure 3.

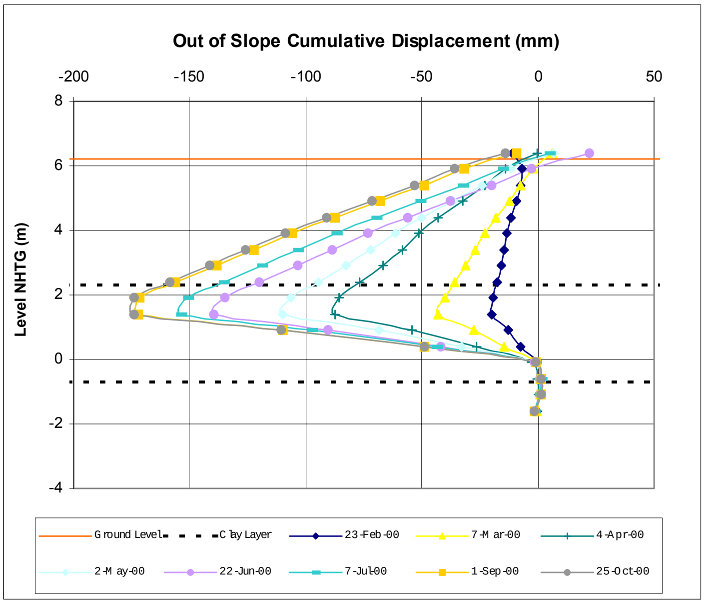

Figure 3: Typical Inclinometer Plot

The inclinometer plot shows deflection recorded perpendicular to the slope. The ground level and location of the upper Unit 2 clay layer are also shown. The total lateral deformation and rate of deformation was used together with the settlement plate and piezometer monitoring results to confirm the stability of the preload embankment and determine when the Stage 2 preload could be placed.

4.4 EXTENSOMETER

An extensometer was installed to bedrock (50m) at one location beneath the preload to measure the contribution of settlement in each layer to the total settlement, and in particular the deep Unit 4 clay layer.

Regular monitoring of the extensometer was undertaken. The settlement associated with each layer was measured. The results indicated that the majority of settlement occurred in the upper Unit 2 clay layer as expected.

4.5 EARTH PRESSURE CELLS

A total of four earth pressure cells were installed beneath the preload to confirm the magnitude of the load applied by the preload. Two types of fill material were used as preload: dredged sand (density ≈ 18kN/m^3), and Crusher Dust (density ≈ 20kN/m^3). The type of fill and the corresponding density were taken into consideration when determining the estimated fill load for settlement, piezometer and extensometer monitoring.

4.6 CONE PENETRATION TESTS (CPT'S)

A total of 90 CPT's were carried during preload monitoring to:

- confirm that appropriate strength gain had been achieved in the upper Unit 2 clays after Stage 1 preload (ie ensure that the addition of Stage 2 preload would not induce instability in the preload batter slopes).
- confirm final strength gain in the upper Unit 2 layer after Stage 2 preload, which was required to provide long term stability of the completed coal stockyard.

The results of the CPT's compared favourably with the predicted shear strength gains (ie approximately 30kPa after Stage 1 preload, and approximately 50kPa after Stage 2).

An example of strength gain measured in the upper Unit 2 clay as a result of preloading is presented in Figure 4.

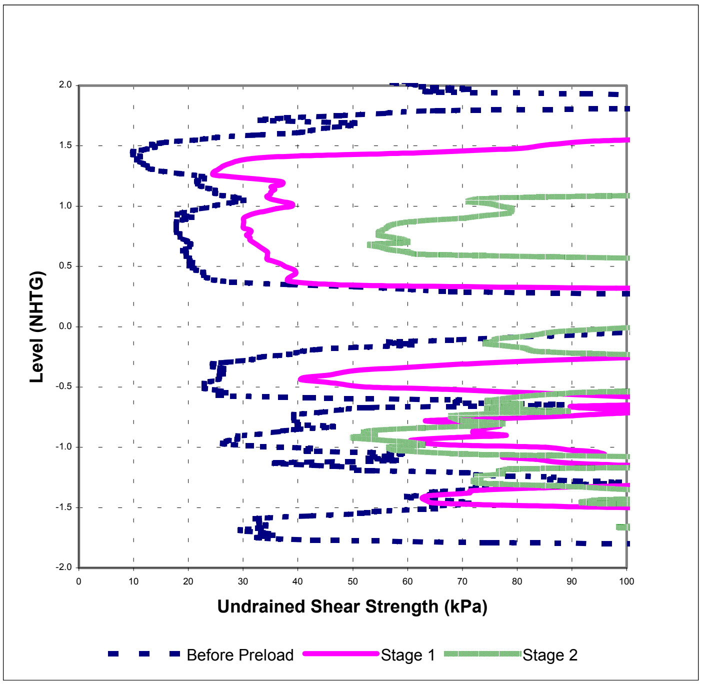

Figure 4: Strength Gain in Unit 2 Clay from Preloading (Ch 1300, Reclaimer Berm)

5 CONCLUSIONS

The monitoring results indicated that the preload generally performed as predicted, with target settlement and strength criteria being met. The success of the project has been attributed to the accurate and timely supply and analysis of monitoring results, together with regular communication and liaison with the project managers.

6 ACKNOWLEDGEMENTS

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7 REFERENCES

Douglas Partners Pty Ltd, 2000, 'Proposed Coal Stockyard, PWCS Stage 3 Expansion, Kooragang Coal Loader', *Unpublished report, Project 31100A, April 2000.*

Douglas Partners Pty Ltd, 2001, 'Geotechnical Instrumentation Monitoring, PWCS Stage 3 Expansion, Kooragang Coal Loader', *Unpublished report, Project 31100B, June 2001.*