Geotechnical Investigation & Construction Monitoring of Reclamation Project Harrington Waters Estate, Harrington, Australia

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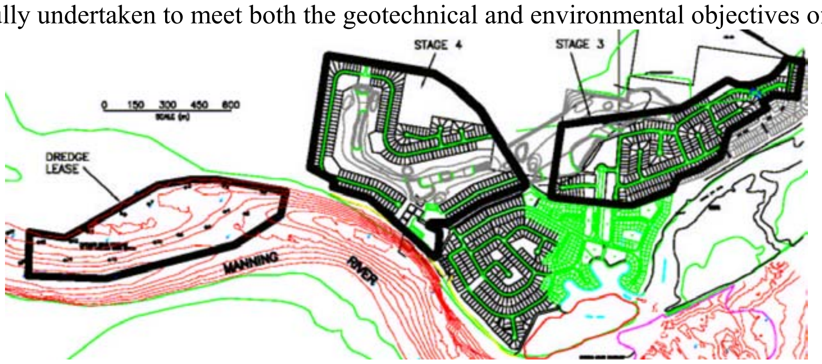
This paper describes some of the geotechnical and construction aspects involved with a large-scale reclamation project at Harrington, which is situated over a deep alluvial profile containing soft / loose compressible soils. The combined residential and golf course development comprised dredging of one million cubic metres of sand from the adjacent Manning River to raise site levels, and facilitate ground improvement by means of preload to limit post construction settlements. Construction monitoring of the preload, together with the hydraulically placed fill which contained a high proportion of pyritic silt, was successfully undertaken to meet both the geotechnical and environmental objectives of the project.



1 INTRODUCTION

Harrington Waters Estate is nestled on the banks of the Manning River on the mid north coast of NSW, Australia.

Site development comprised dredging of one million cubic metres of sand from the adjacent Manning River in order to raise site levels, and enable the creation of about 560 residential allotments together with the construction of several lake systems, golf course and bridges.

The earthworks project commenced late 2002, and was approximately 60% complete as of April 2004. Pavements, services and bridges have been constructed on fill areas during this period.

Douglas Partners Pty Ltd (DP) have been involved with the project and Project Developers (Roche Group) from the early 1980's and have conducted geotechnical, environmental and groundwater investigation and design, together with construction monitoring during dredging and fill placement.

The site is situated over a deep alluvial profile, which extends beyond depths of 30 m and includes very loose sand and soft to firm clay deposits. The upper profile was also assessed to contain potential acid sulphate soils and is susceptible to primary consolidation and creep.

This paper includes some aspects of investigation design and monitoring associated with the development.

2 SITE INVESTIGATION & GROUND CONDITIONS

Several phases of site investigation were undertaken to characterise the site and allow assessment of engineering soil properties for design and construction purposes.

The two main phases of geotechnical investigation program included:-

- Investigation of river sediments for dredging;
- Investigation of subdivision.

2.1 Assessment of river sediments

An investigation was undertaken within the Manning River to assess the suitability of river sediments for use as hydraulically placed fill and assess the presence of potential acid sulphate soils (PASS).

The investigation within the river comprised:

- Vibro-coring at a frequency of about 2 bores per hectare up to about 6 m depth below river bed levels (Total 110 bores);
- Grading / hydrometer testing & acid sulphate soil testing;

The above investigations indicated a fluvial profile consisting of sands with interbedded layers of clay, silty sand and clayey sand. Grading and hydrometer testing of the sediments indicated that a significant proportion (approximately 50%) of the dredged soil would contain a fines content of greater than 15%.

Laboratory testing was undertaken to assess PASS, which included screening tests and detailed laboratory analysis of the river sediments. The testing indicated that potential acid sulphate soils were present, however, there was no clear correlation between PASS with soil type, reduced level, depth or aerial distribution. The intensity of PASS, however, was, observed to be generally lower for sands with minor fines content.

2.2 Assessment of subdivision

The soil conditions were particularly suited to cone penetration testing (CPT) for the land-based investigation, particularly to assess the variability in the soft clay and loose sand profile. The CPT was supplemented with boreholes and test pitting to provide correlation with CPT interpretation, and enable samples to be recovered for laboratory analysis.

The land investigation revealed the site was generally underlain by the following:

CLAY	very soft to firm silty or sandy clay (up to 3.6 m deep) but interbedded with sand or clayey sand layers;
SAND	generally loose to medium dense (occasionally very loose), indurated sand layer also present, with clayey or silty zones (up to 8 m deep);
CLAY	further layers of clay generally firm to stiff and ranging between 0.2 m and 3.3 m thick;
SAND	medium dense to dense, to depths of up to 25 m;
CLAY	stiff to very stiff to depths of 33 m or greater.

The main geotechnical feature of the site with respect to the development was the presence of weak strata, comprising very soft to soft silty clays, sandy clays and very loose sand.

Engineering soil parameters used for primary consolidation analysis such as the vertical coefficient of consolidation (c_v) and coefficient of compressibility (m_v) were derived from CPT/CPTU dissipation testing. Secondary consolidation parameters (creep factor) were based on methods presented by Mesri (1973).

3 GEOTECHNICAL ANALYSIS

The primary objective at the site was to determine ground improvement requirements (where necessary) to limit post construction settlements to enable a Class M (AS 2870) site classification for residential allotments. In addition, due to the high proportion of fines identified within the proposed dredge area, an assessment was required to determine options to incorporate the fines with site filling, without compromising the required Class M site classification.

Settlement analysis was undertaken at each CPT location based on the proposed loading by the dredged sediments, typically compacted to a density of 20 kN/m^3, and the imposed load by single and double storey structures, (typically about 15 kPa).

The post construction settlements were estimated based on fill-induced settlement, plus the slab induced settlement, over a design life of 50 years.

Settlement analysis indicated post construction settlements ranging between 5 mm and 150 mm over a 50 year period without ground improvement.

An example of a time-settlement plot is presented in Figure 1 below.

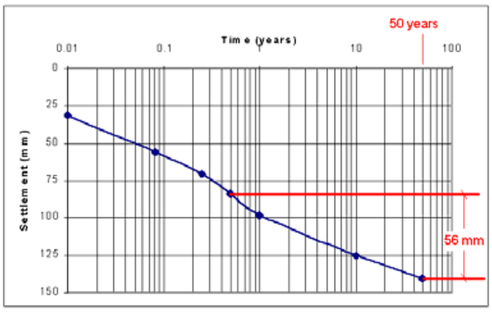


Figure 1: Typical Settlement Plot

The CPT results were also used to assess the likelihood of liquefaction of the very loose slightly silty sands at the site. The assessment was based on the results of the CPT and the methods presented by Lee *at el* (2001). A peak horizontal ground coefficient of 0.10g was adopted, based on AS 1170.4-1993.

A typical liquefaction probability plot is provided in Figure 2 below:

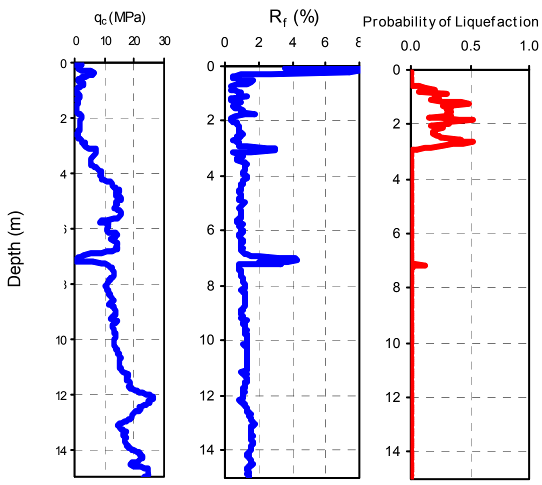


Figure 2: Typical Plot showing potential of Liquefaction (CPT 452)

The results indicated that liquefaction was unlikely to occur during an earthquake of magnitude M = 6 or less.

3.1 Ground Improvement Requirements

Based on the settlement analysis undertaken at each CPT location, the site was divided into geotechnical zones according to the magnitude of post construction settlement as described below:

Zone A - Post construction settlements would preclude the adoption of Class M site classification without ground improvement.

Zone B - Post construction settlements were commensurate with a Class M site classification. The majority of the development fell within Zone B.

Zone C - Zone C was dominated by a sand profile and lower estimated settlements.

Additional testing using the CPT was undertaken following the preliminary analysis to better define the depth and lateral extent of clay strata, (ie limit the size of the Zone A area requiring ground improvement).

Several options for ground improvement were considered for Zone A to improve post constructions settlements. Preloading by means of sand fill to a height of at least 1.5 m above the proposed fill level, however, was assessed to be the most feasible and practical ground improvement technique.

It was considered that the fines generated from the dredging process could be blended with the placed sand at a ratio of up to 15% dry weight, without compromising the required geotechnical parameters of site fill. In addition, due to the lower predicted settlements assessed within Zone C, it was considered these areas could accommodate up to 200 mm thickness of fines, subject to mixing with the base layers of sand fill, and remain a Class M site classification.

4 CONSTRUCTION MONITORING

4.1 General

Dredged slurry was pumped from the Manning River and discharged into bunded areas within the subdivision.

Ground conditions within the Manning River were suited to a bucketwheel cutter suction dredge. The hydraulic slurry was transported from the extraction site to the subdivision via 300mm ϕ pipeline. The dredge initially produced a discharge of about 300 m^3/hr but was upgraded to 600 m^3/hr for the second half of the project.

When the hydraulic slurry was discharged at the dredge head, sand materials with some fines were initially deposited. The remaining fine sediments discharged to adjacent designated sediment ponds.

A synthetic flocculant was added by injection to the hydraulic slurry at the dredge head to assist with the settlement of fines and improve overall tail-water quality.

The tail-water flowed from a series of sediment ponds, via a fixed weir arrangement, to a management pond where water was tested to confirm compliance prior to discharge to the Manning River.

4.2 Construction Monitoring Objectives

The main objectives during the monitoring program was to manage acid sulphate soils during filling operations, monitor tail-water quality prior to discharge, monitor preload, and undertake geotechnical testing of the placed fill to confirm a Class M site classification.

4.3 Acid Sulphate Soils

Daily acid sulphate tests were undertaken on the dredged sediments and tail water in accordance with an Acid Sulphate Soil Management Plan prepared by DP for the site.

Results of testing indicated that the PASS conditions within the dredged sediments were associated with the finer sediments (i.e. silt/clay), which were segregated during the dredging process and transported to designated sediment ponds. The sand materials deposited, therefore, did not require acid sulphate soil treatment (neutralisation).

Detailed testing of the fines indicated that treatment was required.

Upon raising site levels, the finer sediments within designated sediment ponds were placed over existing sand filled areas for treatment. Prior to placement of the finer sediments, a layer of lime was spread over the surface of the sand as a precautionary measure to counteract the generation of potential acid leachate.

The PASS sediments were treated by full lime treatment. Dozers and excavators were used to thoroughly mix agricultural lime with the soil.

Once neutralisation was achieved, clean sand was mixed with the treated sediments for re-use as engineering fill.

Tail-waters generated from the dredging process were also monitored and treated (ie pH adjustment), if required, prior to discharge to the Manning River.

Monitoring of the tail-water indicated that pH adjustment was generally not required.

4.4 Preload Monitoring

Preload monitoring during construction was undertaken to determine when the preload fill could be removed to allow development of the residential sites.

Installation of settlement plates was the preferred method to monitor the preload. Once the results of the monitoring indicated that the design settlement criteria was achieved, the preload was removed, and the excess sand utilised as fill on the adjacent area.

CPT's were used in preload areas following preloading to assess undrained shear strength within the clay profile and confirm whether sufficient strength gain and hence primary consolidation had occurred within the clay layers.

The strength gain with the clay after preload was based on a relationship between the increased effective overburden stress and undrained shear strength.

An example of strength gain measured in the clay as a result of preloading is presented in Figure 3 below.

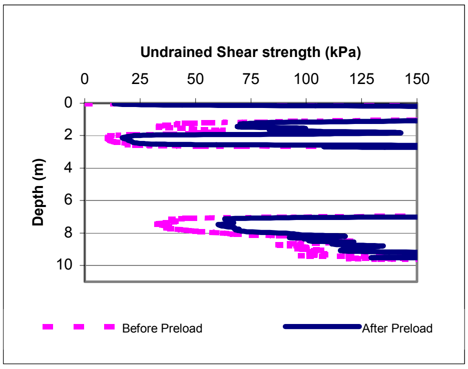


Figure 3: Strength Gain in Clay from Preloading (CPT 318)

The results of CPTs showing the strength gain within the clays, together with data from the settlement plots, confirmed the clays had undergone sufficient primary consolidation and allowed the preload to be removed.

5 CONCLUSIONS

A multi-disciplinary approach to investigation and construction monitoring has successfully been conducted for the above development which included geotechnical considerations (ie preloading, settlements, foundation and subgrade conditions), and environmental issues (treatment of PASS, and dredge tail-waters prior to discharge).

6 ACKNOWLEDGEMENTS

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7 REFERENCES

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