The paper was published in the proceedings of the 7th Australia New Zealand Conference on Geomechanics and was edited by M.B. Jaksa, W.S. Kaggwa and D.A. Cameron. The conference was held in Adelaide, Australia, 1-5 July 1996.

Memories of the Victorian Arts Centre

J.R. Morgan
B.C.E., Ph.D., F.I.E. Aust.
Principal, Golder Associates Pty. Ltd., Melbourne

Summary This paper is based on personal memories of the geotechnical studies performed for the Theatres Building of the Victorian Arts Centre. Two separate schemes required a range of investigation techniques to be used. Construction of the chosen scheme resulted in settlements around the site and ensuing litigation. Fortunately we did learn from these problems and can now confidently design in similar conditions.

1. INTRODUCTION

I was involved with the design and construction of the Theatres Building of the Victorian Arts Centre from 1969 to about 1980. It was a notable project and provided me with some memorable experiences, not the least of these being involved in litigation on damage to nearby buildings.

The challenges of the project arose from the combination of the poor ground conditions at the site with the desire to construct the major theatres below the ground.

2. THE SITE

The main features of the subsurface conditions are the presence of up to 17 m thickness of the highly compressible clays of the Coode Island Silt overlying the sands and gravels of the Moray Street Gravels. The Silurian Age siltstones and sandstones (the Melbourne Mudstone) form the bedrock of the area and occur at depths of about 20 m to 25 m.

The upper surface of the Coode Island Silt is at about RL 0 which is also about the level of the ground water table. Blanketing the Coode Island Silt is a layer of variable fill from about 4 m to 8 m in thickness, resulting in a fall in ground surface level over the site of about 4 m.

The properties of the Coode Island Silt have been discussed by Ervin (1992). Of particular interest here is its settlement behaviour. Moore and Spencer (1969) traced the settlement history of a building constructed in similar ground conditions in 1890 which by 1965 had settled about 790 mm.

We also collected observations of settlements of some buildings in the South Melbourne area over the period 1890 to 1990. These showed settlements in the range 650 mm to 800 mm. These buildings are all light structures so we inferred that the settlements resulted from regional effects rather than from the building loads.

In 1969 no permanent basements had been constructed in the Coode Island Silt to below the water table, and it was clear that there would be many challenges in constructing a major basement structure to accommodate the theatres building.

3. THE 1969-1970 YEARS

3.1 The Structure

In 1969, planning was proceeding on the basis of accommodating three theatres and the Concert Hall on the subject site. Subsequently the Concert Hall was constructed on an adjoining site thus reducing the amount of subsurface space required.

The challenge of the 1969 project was to construct a below ground space to house the massive auditoria. By their size and arrangement the auditoria prevented the use of cross-site struts to transfer the very large earth and water pressures developed on the basement walls.

The solution proposed was to construct a massive perimeter retaining wall spanning between a strutting frame at the top and the mudstone at the bottom. The wall types investigated included interlocking caissons and solid or cellular walls. Construction expedients considered included the use of ground freezing, pressure grouting and bentonite slurries.

3.2 The Investigation

It was clear that there would have to be a significant geotechnical investigation program to provide the data required for analysis of the basement wall.

The investigation was planned by Milton Johnson Associates in association with the writer, to the requirements of the civil and structural consultants, John Connell & Associates. It was notable for the wide range of field and laboratory testing techniques performed.

Drilling and Sampling

Thirteen boreholes were drilled around the perimeter, extending about 13 m into the mudstone. Tube samples of 4½ inch (114 mm) diameter were recovered from the Coode Island Silt, and rock cores of 5½ inch (140 mm) diameter from the mudstone.

A downhole television camera was used to observe the orientation of the joint features in the mudstone.

Laboratory Testing

Conventional classification, drained and undrained strength testing was performed on samples of the Coode Island Silt. Tests to estimate the coefficient of earth pressure at rest were performed at Sydney University.

An extensive program of tests on frozen soil samples was also performed. These included compressive and tensile strength and creep tests on frozen samples at a range of temperatures as well as tests on thawed samples.

Field Tests - Rock

A 1750 mm diameter steel lined caisson was sunk to the mudstone. Below this a chamber about 3.4 m in diameter was excavated to allow shear strengthtests on the rock mass to be performed and to provide opportunity for the rock to be inspected by potential tenderers for wall construction.

Field Tests - Soil

A second caisson was sunk to provide access for installation of earth pressure measuring cells with accompanying piezometers.

This caisson was also used to permit a pump test to be carried out in the Moray Street Gravels aquifer.

4. THE 1971-1978 YEARS

4.1 The Structure

In 1970 the planning was changed to move the Concert Hall to the Snowden Gardens site. This reduced the space required on the Theatres site so that it was possible to accommodate the structures in a basement extending to a maximum depth of about 15 m.

While this approach might at first sight seem to be simpler than to construct the full depth basement, in fact the geotechnical and structural problems were far more challenging.

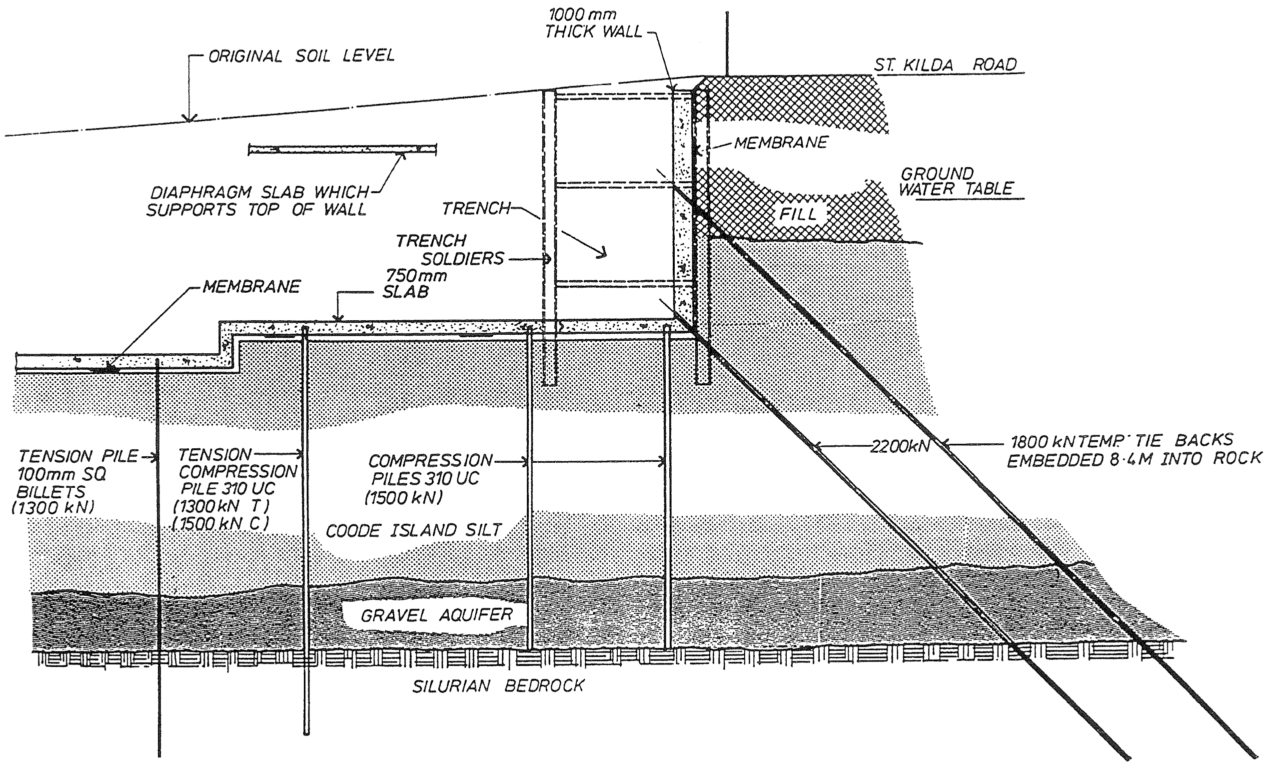

Figure 1. Section through site.
(Courtesy Connell Wagner Pty. Ltd.)

The approach to basement construction developed by John Connell & Associates is shown in Figure 1. This took into account the need to maintain lateral support to the surrounding area while excavating in the Coode Island Silt.

The permanent perimeter wall and a part of the basement floor slab was constructed inside a strutted trench about 6.5 m wide. Temporary tiebacks (rock anchors) were installed to take the earth and water pressures and allow the inner wall of the strutted trench to be removed and bulk excavation and floor construction to occur.

The vertical loads were taken by three types of piles acting in compression, tension or initially in tension changing to compression as the building load was developed.

4.2 The Geotechnical Challenges

The site and method of construction presented particular geotechnical challenges. While the overall site conditions had been characterised by the 1969-1970 investigation, further work was needed to develop solutions. In addition, a ground and structure instrumentation program was initiated to measure the effects of construction and allow modifications to take place.

Trench Instrumentation

The behaviour of the trench was monitored to assess the loads acting, to ensure the design assumptions were not exceeded, and if possible to relax the requirements in the light of the measured values.

The instrumentation for this work comprised

- trench strut load measurement by DEMEC gauges
- soil and water pressure measurements by KYOWA boundary pressure transducers embedded in the concrete construction (outer) wall of the trench
- inclinometers attached to the soldier piles on the inner wall of the trench
- soil inclinometers comprising steel casing installed outside the wall and reading deviation using an optical plummet

Some results of these measurements are given in Morgan (1992).

Swell Instrumentation

Unloading of the Coode Island Silt during bulk excavation was predicted to result in swell. Laboratory testing and field measurements were used to predict the time-swell relationship.

The laboratory swell behaviour showed a significant creep component, not surprisingly, in view of its known creep behaviour during compressive loading.

Field observations were made initially using downhole swell indicators installed in nine unlined boreholes inside the site. These devices used spring steel strips to anchor the sensors into the soil, but corrosion was so severe that they were replaced by sensors having a positive anchorage system.

Results of these analyses and measurements are given in Morgan and Walker (1977).

As a result of the observations and analyses, we recommended that 75 mm void former be placed beneath the slab to accommodate the swell expected after the permanent floor construction had been installed.

Settlements

Settlements around the site were monitored from the start of construction, since we knew that the Coode Island Silt was compressible and we expected any significant reduction in groundwater level would cause settlement.

The first indication of effects beyond the site was a drop in the levels of piezometers outside the site, soon after installation of the tiebacks commenced in 1975.

Over the period 1975-1978 considerable investigation was carried out into the extent of dewatering around the site. Recharge wells were installed which significantly reduced the extent of groundwater lowering, but did not totally prevent settlement continuing.

The reduction in groundwater level was followed by an increased rate of settlement, based on level observations on surrounding buildings and pavement surfaces.

Over the next few years the settlements continued. Litigation was instigated by the owners of a building located about 200 m from the site. The damage there appeared to be related to the use of a mixed footing system of piles and surface footings. Adjoining buildings underwent similar total settlements but were undamaged.
The litigation was notable in legal circles for the number of defendants and third parties named - the

writer being included among the latter. The litigation was settled, but not without a lot of anguish from those involved.

The settlements effectively ceased when the site was finally sealed in May 1978. The groundwater levels around the site returned to their pre-construction values about 2 months later.

We analysed the settlement behaviour at length, and established a complex interaction between the reduction in water level in the aquifer and that in the Coode Island Silt. In fact, we inferred that horizontal flow in the Coode Island Silt was a major factor in causing dewatering.

As a result of this experience, we have been able to confidently design basements at Southgate, the Esso site and the Casino. All of these have extended significantly below the groundwater table. These projects have usually included cut off walls, monitoring of behaviour and recharge systems in the construction stage.

5. CONCLUSIONS

The main conclusions I have drawn from these memories are:

- seldom have I been privileged to be involved in a project with such geotechnical challenges
- observation of behaviour is a great way to learn, but litigation is not conducive to arriving at the facts
- time heals all wounds so that 15 years after the last legal action has faded away, I am able to write about the project without the feelings of anguish present at the time.

As civil engineers we are and should be proud of our achievements. In the construction of the Victorian Arts Centre Theatres Building the team have created something of lasting beauty and value for the people of Victoria. At the end, we engineers have this as our memorial.

6. ACKNOWLEDGMENTS

I started my involvement with the project while on the staff at the University of Melbourne. There I was helped and encouraged by Len Stevens. From 1975 with Golder Associates Pty. Ltd., Len Walker in particular gave great support.

Soilmech Pty. Ltd. provided a lot of the instrumentation and testing under the able direction of Ken Chandler. Finally John Connell & Associates Pty. Ltd. provided great leadership, and I particularly thank Andrew Goad for his advice and assistance over the (to me) tumultuous years of the project.

7. REFERENCES

Ervin, M.C. (1992) Engineering Properties of Quaternary Age Sediments of the Yarra Delta. Engineering Geology of Melbourne, Ed. Peck et al. A.A. Balkema, Rotterdam.

Morgan, J.R. and Walker, L.K. (1977) Observations of Creep During Heave. Proceedings IX Int. Conf. on Soil Mechanics and Foundation Engineering. Vol. 1, p203.

Morgan, J.R. (1992) Basement Construction. Engineering Geology of Melbourne, Ed. Peck et al. A.A. Balkema, Rotterdam.

Moore, P.J. and Spencer, G.K. (1969) Settlement of Building on Deep Compressible Soil Proc. A.S.C.E. JSMFE V95:SM3:p769.