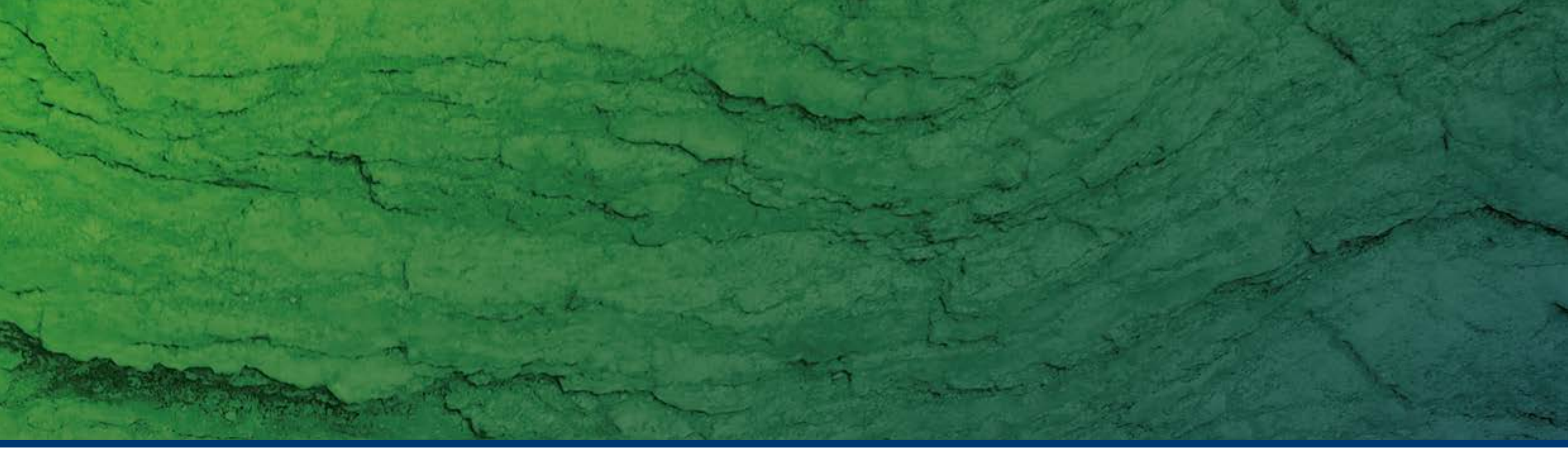
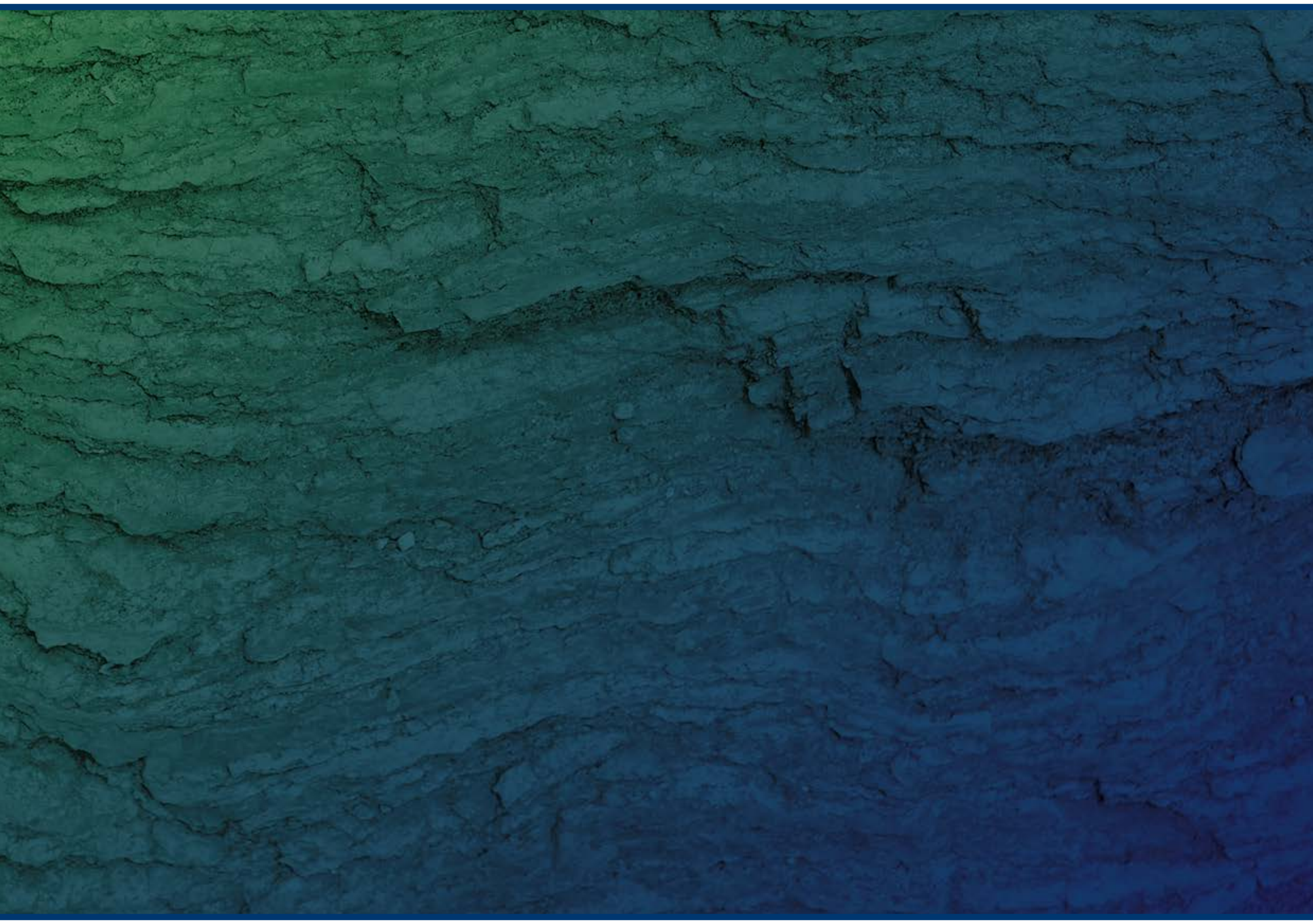


PROCEEDINGS

2019 AUSTRALIAN GEOMECHANICS SOCIETY VICTORIAN SYMPOSIUM

Geotechnical characterisation – managing design and construction risk

Wednesday, 30 October 2019, 8:00am – 7:00pm
Rydges Hotel, 186 Exhibition Street, Melbourne



AUSTRALIAN GEOMECHANICS SOCIETY
VICTORIA CHAPTER

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PREFACE

The Victorian chapter of the Australian Geomechanics Society invited academics and practitioners in the field of geotechnical and ground engineering to attend the 2019 Australian Geomechanics Society Victorian Symposium held on 30 October 2019.

In recent years Victoria has seen significant growth in the construction industry. Investment in both public infrastructure and commercial real estate is growing, and as our cities and infrastructure grow, so too does the need to develop parcels of land with challenging ground conditions. Economical and safe geotechnical design requires efficient and well thought through ground investigation and characterisation to identify and manage ground risks and opportunities.

The 2019 Australian Geomechanics Society Victorian Symposium presents an overview of current state of-the-art practices, innovation, new research results and case studies relating to geotechnical characterisation with an emphasis on its implications for addressing and managing design and construction risk. The 2019 Symposium brought together professional engineers, researchers, specialist contractors, regulators, educators and students to share and discuss their experiences on the topic of ground characterisation.

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Performance of a 7.5m high post and panel wall under a 120t piling rig load

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ABSTRACT

Melbourne Metro Rail Infrastructure Alliance (RIA) project is currently under construction as part of the larger Melbourne Metro Rail Tunnel Project in Melbourne. The works at the Eastern entrance to the Metro Tunnel include construction of a cut & cover tunnel and decline structure which will form the entrance to the metro tunnel when completed in 2025.
Restricted site access including proximity to residential properties and operational live rail necessitated a purpose built temporary retaining structure as a working platform to support a 120 tonne piling rig for the installation of 18 m long CFA piles for the cut & cover tunnel structure. A post and panel wall comprising 900 diameter CFA piles with 310UC steel sections was considered a feasible solution for constraint site conditions. The maximum height of the wall was 7.5 m including a piling platform to support a piling rig track pressure of 345 kPa operating behind the wall. Ground conditions comprised cemented sandy soils of Brighton Group underlain by Fyansford Formation and high ground water level.

This paper discusses geotechnical characterisation of the site, design development, challenges and site constraints, monitoring of the wall during construction and performance of the retaining wall during the operation of the piling rig from a design and construction perspective.

Keywords: Retaining wall, post and panel wall, geotechnical risk, piling rig

1 INTRODUCTION

The Melbourne Metro Tunnel project comprises construction of a twin 9km tunnel under the Melbourne CBD and five new underground stations. An alliance between Rail Projects Victoria (RPV), CPB Contractors, John Holland, MTM and Aecom was formed in 2018 to deliver the package of works which comprises construction of the tunnel entrances at South Yarra (Eastern Portal) and Kensington (Western Portal) and connect the twin TBM tunnels to the existing rail network, along with a new platform at West Footscray Station. The alliance is formally known as Melbourne Metro Rail Infrastructure Alliance (RIA). CIMIC's engineering and technical services business EIC Activities (EIC) provides design and technical support to the project and Golder Associates (Golder) are engaged to provide design of the temporary works.
The works at the Metro Tunnel's eastern end located at South Yarra includes construction of a cut and cover tunnel and decline structure which will form the entrance to the future Melbourne metro tunnels when they open in 2025. Extents and location of the proposed works at the Eastern Portal is shown in Figure 1. Construction of various structures commenced in 2018 and is currently under way.

2 CHALLENGES AND CONSTRAINTS

Metro Tunnel's Eastern Portal is located in a built up urban environment and one of Melbourne's busiest and densely populated inner-city neighbourhoods. The existing Frankston and Dandenong lines' up and down tracks are located inside a lowered rail cutting constructed in the 1950s. Multi-storey residential and commercial properties are located adjacent to the existing rail corridor near the edge of the cutting. Numerous services and utilities are in and around the existing rail corridor.

Figure 1. Location of the eastern portal

One of the main challenges and also requirements set out for RIA project was minimum disruption to the operation of the existing Frankston and Dandenong lines during construction of the project. Limited periods of occupation of the existing Frankston and Dandenong lines were allowed to enable completion of the critical packages of work within the existing rail cutting.
Presence of existing commercial and residential properties at close proximity of the rail corridor in South Yarra restricted access to the site and availability of work space for large number of heavy construction equipment and movement of these equipment in and out of the site.

2.1 Piling near existing William St Bridge

A row of 1200 mm diameter Continuous Flight Auger (CFA) piles comprising the northern wall of the future rail cutting widening retaining wall were located at the crest of the existing rail cutting within 3.5 m from an existing two storey residential building. The existing Frankston line down track were located within 2m of the toe of the rail cutting with steep batter slopes of up to 1.15H:1V in some parts.
A 120 tonne Leibherr LB28 type piling rig was required to install the proposed 18 m long CFA piles for northern

wall of the cut and cover structure. However, close proximity of the existing two storey building at the edge of the crest restricted the working space required during the operation of the piling rig and movement of other construction equipment for the installation of the piles. The existing William St Bridge (before it was demolished), location of the future cut and cover tunnel piles at the toe of the crest and requirement for clearance from the existing operational train tracks further restricted the site conditions. Location of the proposed wall is shown in Figure 2.

As part of the planning and construction risk management, several options were considered. Construction of a 7.5 m high post and panel wall to support the proposed piling rig was considered a feasible solution for the constrained site conditions in South Yarra. The post and panel wall was required to support an operational 120 tonne piling rig with maximum track pressure of 345 kPa sitting within 3.2m from the edge of the retaining wall.

3 ADOPTED SOLUTION & STAGING OF THE WORKS

The proposed post and panel wall comprised 310UC158 'I' sections embedded into 900 mm diameter CFA piles with a typical spacing of 2 m between the piles. UC sections were split in to half and bolted on site to allow for ease of handling and transportation to site. Wall infill panels comprised 2.5 m by 1 m by 150 mm reinforced concrete panels installed between the steel posts, backfilled with Cement Stabilised Sand (CSS). CSS was selected as the backfill material given the ease of placement, minimal compaction requirements (given the space and time constraints) and overall strength and stiffness of the CSS material. Although a 3% cement was assessed as likely to meet the strength and stiffness requirements, 5% was proposed to provide certainty that all test results during placement of the backfill would achieve the required strength and to minimise risks associated with delays as a result of failed tests. A typical wall section is shown in Figure 3. For safety of construction personnel, timber hoarding was installed at the edge of the wall connected to king posts, for both edge protection and isolation from the rail conductor wire.

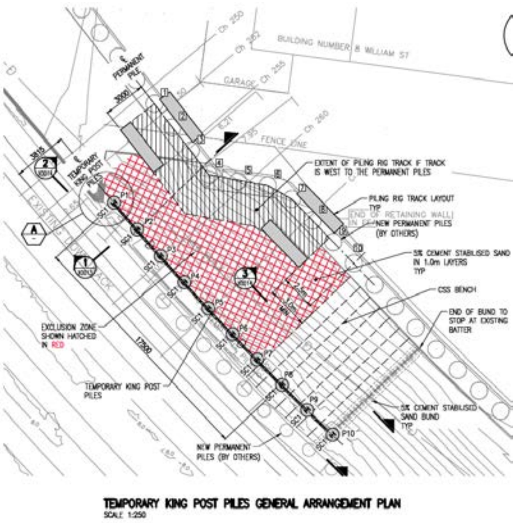

Figure 2. Proposed post and panel wall location plan

The construction of the retaining wall was proposed to be completed in two stages. The first stage comprised installation of the CFA piles below existing rail level during temporary occupation planned for the installation of the cut and cover tunnel piles together with installation of the king posts. The same piling proposed for the installation of the cut and cover piles was proposed to be utilised for the installation of the post and panel wall piles to maximise rig use and avoid mobilisation of additional piling equipment.

While the second stage of works which included progressive installation of infill panels, excavating into the existing batter in '1m steps' and backfilling with CSS in 1 m layers was planned to be undertaken during normal train operation, was also completed during the same occupation period. Backfilling was undertaken at 12 hr intervals for the CSS to gain adequate design strength. It was critical that the first package of the work is completed within the planned occupation period.

4 GEOTECHNICAL SITE CHARACTERISATION

Geological conditions across the project site are generally consistent with published information and the information gathered for the project during tender and delivery phases. Multiple phases of geotechnical investigation were undertaken at pre-tender stage, feasibility stages continuing into detailed design and delivery phases. Geotechnical conditions has also been assessed as part of construction site verification during piling and excavation works across the South Yarra site to date. A brief description of the site conditions is provided below.

A shallow layer of fill up to 1 m covers most parts of the site, underlain by up to 16 m of Tertiary (Pliocene) aged fluvial sediments of Red Bluff formation which forms part of the broader Brighton Group Formation. Red Bluff sand was encountered in all boreholes across the site and predominantly as cemented clayey sands. The unit is mottled grey and orange-brown with cementation caused by deposition in an iron-rich groundwater environment. Multiple layers of clayey and sandy material were encountered in many boreholes across the site. Although the material is generally described as sand, however, the presence of up to 30% fines and the cementation of the unit provides a significant apparent cohesion to the unit. This is evident from up to 8 m high existing rail cuttings with batter slopes steeper than 1H:1V within the project area which has been stable for decades. Based on the above observations and back analysis of existing

slopes, geotechnical parameters assigned for the unit has improved significantly from those proposed as part of the reference design and pretender stages.

The Brighton Group formation is generally underlain by the Silurian age Melbourne Formation siltstone/sandstone unit. Melbourne formation was encountered within the top few meters as residual soil gradually increasing in strength to weathered rock of varying strength. However, at the location of the proposed retaining wall, layers of silts, clays and sands of Fyansford formation (formerly Newport formation) was encountered underlaying the Brighton Group. Fyansford unit was in turn underlain by weathered Granite unit at this location with the Melbourne Formation bedrock unit encountered at 33 m below existing ground surface.

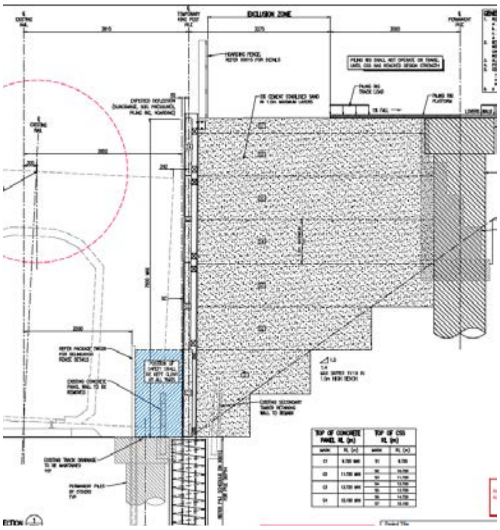

Figure 3. Typical wall section

Groundwater level has been recorded consistently between RL 4 m to 4.5 m AHD across the site which is approximately 3.5 m below the existing rail formation level. Subsurface ground profile and associated geotechnical parameters are presented in Table 1.

5 GEOTECHNICAL ANALYSIS AND DESIGN

Analyses to assess the global stability, wall movements and structural actions for the design of the king post was undertaken using the 2D finite
element package PLAXIS. A typical analysis section from PLAXIS is shown in Figure 4. Assumed ground profile with associated geotechnical parameters are summarised in Table 1.
The modelling considered the proposed construction staging and backfilling of the retaining wall in 1 m layers. Backfilling was to be undertaken in 1 m lift for CSS to achieve a minimum strength of 250 kPa before the next lift. Given the temporary nature of the wall, design adopted a minimum global factor of safety (FOS) of 1.30. Due to risks involved with working in close proximity of operational rail environment it was considered prudent to limit the maximum wall movements to 100 mm to prevent wall movements from encroaching into transit space clearances. For this reason, slightly conservative geotechnical parameters were adopted in the analysis to provide a level of confidence in the design and certainty in the program that wall movements would not exceed the set limits during construction or an occupation period.
A maximum track pressure of 345 kPa was advised by the piling rig operator with an equivalent track pressure of 112 kPa and 65 kPa assessed to act over each of the two 0.9 m track width in a two-dimensional analysis.

In addition, bending moment and shear force to account for loading due to timber hoarding was also included in the PLAXIS model as shown in Figure 4. The piling rig load was applied to a distance of 3.2 m from the back of the wall. A 1500 kN rail impact load acting perpendicular to the wall was also considered in the global stability analysis of the wall.

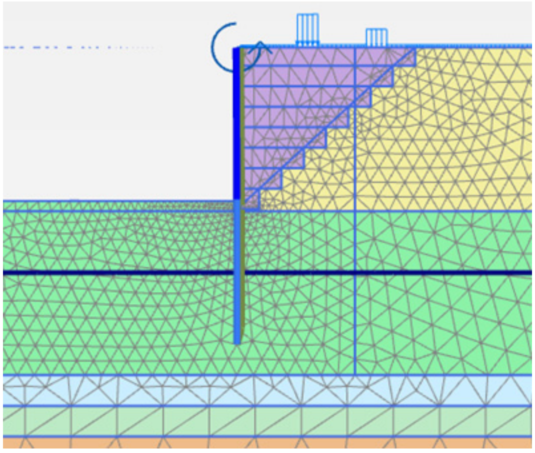

Figure 4. PLAXIS 2D model set up

A minimum pile embedment depth of 7 m within the upper cemented clayey sand of Brighton Group Formation above the weaker Newport Formation was assessed sufficient to achieve a minimum FOS of 1.30. Piles were spaced at 2.5 m with king post member size of 310UC158. A maximum horizontal wall movement of 55 mm was calculated at the top of wall at the end of backfilling with further 10 mm imposed due to piling rig operation. Pile structural actions were assessed to be within the structural capacity of the specified member sizes.

6 WALL CONSTRUCTION AND MONITORING RESULTS

After extensive planning, it was possible to construct the proposed post and panel wall (refer Figure 5) within one occupation, so no additional work was required for the wall construction after the planned occupation to complete the wall and backfill. CSS layers were placed in 1 m lifts at 12 hour intervals for the CSS to gain minimum strength required. Samples obtained during backfilling of CSS were tested in the lab which indicated minimum of 1.1 MPa unconfined compressive strength.
Based on the calculated wall movements (refer section 5), wall movement alert levels were set at 45 mm and 55 mm for the construction of working platform and piling work, respectively.

Table 1. Adopted ground profile and design parameters

Soil Unit	Depth Range (m)	Unit Weight (kN/m^3)	Cohesion (kPa)	Friction Angle ϕ'	Elastic Modulus, E (MPa)
Existing batter* (dense to very dense Sand/clayey sand)	0 to 7.5	20	2* (5)	40* (37)	80
Pile embedment (dense to very dense Sand/clayey sand)	7.5 to 16	20	2 (5)	40 (37)	80
Silt (medium dense)	16 to 20	19	5	30	30
Cement stabilised sand (CSS 5% cement)	Backfill behind wall	21	25	35	50

*Back calculated parameters for batter stability to achieve a nominated Factor of Safety (FoS) of 1.2 based on the given slope conditions. Parameters adopted in the design of permanent works results in similar design outcomes.

Figure 5. Backfill in progress

Monitoring results obtained from the project indicated a maximum wall movement of 19mm at the end of backfill placement up to the working platform level. Subsequent positioning of piling rig induced a further wall displacement of 4 mm whilst the piling rig was working atop the retaining wall, resulting in a total displacement of 23 mm. After removal of the piling rig, the wall movements returned to 20 mm total displacement. The recorded wall movements were less than half those predicted in design and well below the set alarm levels as shown in Figure 6.

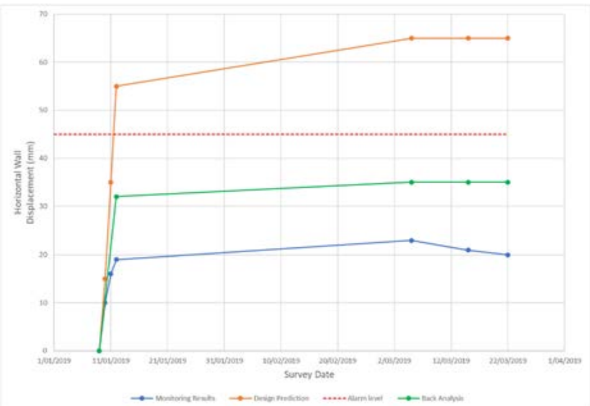

Figure 6. Calculated wall movements vs monitoring results

Back analyses were carried out by varying the design parameters to mimic the recorded wall displacement. The main difference in wall displacement may be attributed to assumed lower strength and elastic modulus values for the CSS and underlying cemented clayey sand. Although less sensitive to the wall movements, observations made during the bulk excavation and piling works at the eastern portal indicated that parameters adopted for the cemented Brighton Group Sands (above groundwater table) may be improved considerably. A parametric study showed that a minimum cohesion of 200 kPa and modulus of 200 MPa for CSS would result in wall movements similar to those recorded on site taking into account the incremental wall movement during placement of CSS in 1 m lift. It is further noted that that CSS was modelled as undrained material in the PLAXIS analysis during the backfilling process i.e. a pressure equivalent to 1 m height of liquid CSS was considered during the placement of each lifts of CSS. Observations made during CSS backfilling (and results of wall movement monitoring) indicate that considering CSS in liquid form may have also contributed to the larger than measured wall movements. Furthermore, differences between predicted wall movements and those recorded on site may also be attributed to modelling of the track pressure. Although retaining walls of this type can generally be modelled in plain strain two-dimensional analysis reasonably accurately, however the rig loading is three-dimensional in nature. Assumptions were made in modelling of the rig load in the two-dimensional analysis which is likely to have resulted in overestimating the wall displacements.

7 CONCLUSION

The temporary post and panel retaining wall allowed for the construction of the permanent retaining wall piles, without the need for acquisition of adjacent properties, or extended disruption to the rail passengers. The construction of the post and panel wall was efficient and cost effective, especially utilising the same piling rigs as used for the permanent decline structure plies. Splitting the 310UCs in half, in a post IFC change, allowed the installation to be more manageable on site. The use of CSS as the backfill allowed works to be completed in a short time frame during the same initial rail occupation. CSS also ensured there was no issue in compaction, where there could have been with crushed rock or similar materials, when working to a tight programme in a restricted area.

The movement recorded during construction and once the piling works commenced on top gave the team great confidence while carrying out the permanent works, with rail traffic passing a mere 1.8 m from the face of the wall. The wall design and construction also allowed for quick removal during the subsequent rail occupation, again giving confidence to the construction teams to hit their occupation dates and handover back to authorities.

Adopting slightly conservative design parameters was considered prudent given the space and time constraints and risks associated with the operation of large piling rig atop a 7.5 m high retaining wall next to live rail in a tight corridor. In addition, lower than expected strength and modulus values were adopted for the CSS backfill to ensure that tests achieved the required strength to avoid delays to the construction during the occupation. A 3% CSS was assessed sufficient in the design, with 5% recommended to provide a level of confidence that tests would meet design requirements. Given the three-dimensional nature of rig loading and assumptions made in converting triangular track pressures to an average rectangular pressure may have resulted in overestimating the rig loading and subsequently lower than expected all movement results.

8 ACKNOWLEDGEMENTS

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