WEST GATE TUNNEL PROJECT, MELBOURNE, AUSTRALIA NORTHERN PORTAL GROUND ENGINEERING WORKS SECANT PILING AND CUTTER SOIL MIX WORKS

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ABSTRACT

The Northern Portal ground engineering works on the West Gate Tunnel Project in Melbourne required a wide range of specialist foundation techniques to provide the client with a robust and economic solution to the challenges presented by the scope of foundation works required and the ground conditions encountered.

This paper looks at several of these challenges including highly congested reinforcement within secant piles, achieving tight pile verticality requirements and working with several foundation activities on a congested site, and the steps that the ground engineering joint venture took to ensure the works were completed to the satisfaction of the client.

Keywords: foundations, reinforcement congestion, congested work areas, secant piles, CSM

PURPOSE OF WORKS

To cope with a rapidly increasing population and to provide an alternative to the congested West Gate Bridge, the West Gate Tunnel is being constructed in Melbourne. The 4.0 km outbound and the 2.8 km inbound twin tunnels will link the West Gate Freeway to a bridge over the Maribyrnong River and an elevated freeway over Footscray Road, which will then connect to the existing CityLink Freeway.

The Northern Portal of the West Gate tunnel is being constructed adjacent to Whitehall Street and will be the launching area for the tunnel boring machines being used to excavate the twin tunnels.

CPBJH JV, a joint venture of CPB Contractors and John Holland, is principle contractor for the works. The ground engineering works were subcontracted to WPBA JV, a joint venture of Wagstaff Piling and Bauer Foundations Australia.

CONCEPT AND DESIGN

The Northern Portal comprises a cut-and-cover tunnel section approximately 330 m in length with an excavation depth that varies from 23m to 5m. The retaining walls in the areas of the deepest excavation consist of 1500mm and 1200mm diameter hard-hard bored secant piles. Bauer proposed hard-hard secant piles, with reinforcement to primary and secondary piles, as an alternative to the conforming hard-soft piles to improve constructability and be more cost effective. The sections requiring intermediate excavation depths use 900mm diameter hard-soft CFA secant piles and the shallow excavation areas adopt anchored sheet piles as the retaining structure.

Bored and continuous flight auger (CFA) foundation piles are required to support various temporary gantry cranes, tunnel boring machine (TBM) assembly frames and excavation strutting and also to provide tension capacity beneath the cut-and-cover base slab. A number of king posts are also required; these being installed as plunge columns. A CFA secant pile shaft is also designed and installed to launch 3m diameter North Yarra Main Sewer TBM at 12m depth below the ground surface.

A cutter soil mix (CSM) block was constructed behind the head wall, as shown in Fig. 1 below, to provide a stabilised block from which the TBMs were to be launched.

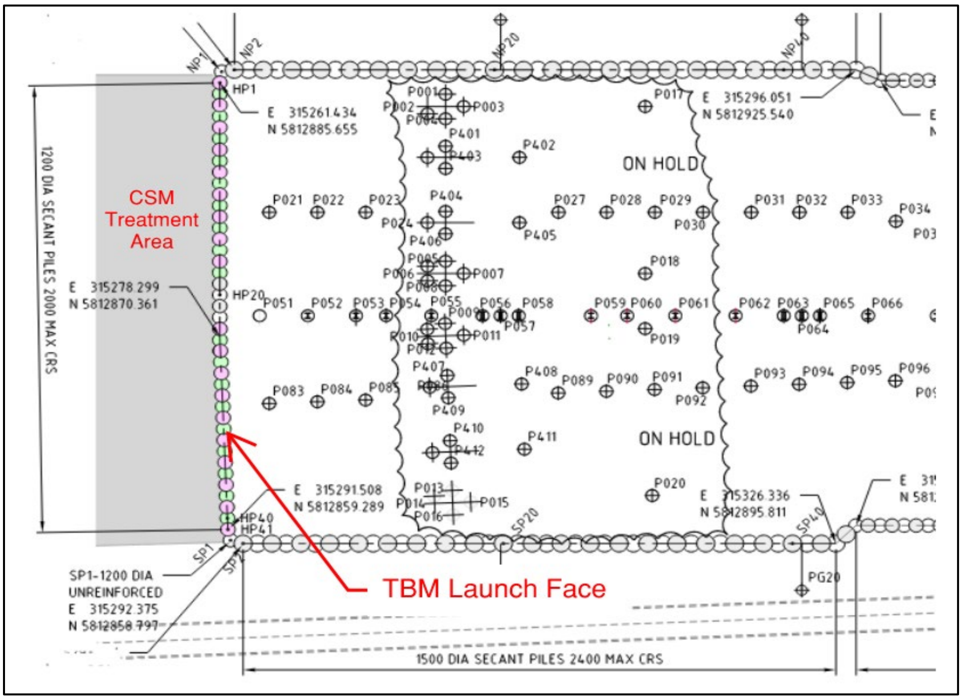

Fig 1 Layout of CSM block and head wall secant piles

SCOPE OF GROUND ENGINEERING WORKS

To deal with the varying depth of the cut-and-cover box and provide the most cost effective solution, an impressive range of foundation techniques was utilised by WPBA JV at the Northern Portal, with the ground engineering works comprising the construction of:

- 88 No. 1500mm diameter bored secant piles
- 185 No. 1200mm diameter bored secant piles
- 304 No. 900mm diameter CFA secant piles including 29 piles forming a circular TBM launch shaft
- 213 No. bored piles 900, 1050 and 1350mm diameters
- 47 No. plunge columns
- 384 No. CFA piles 750, 900 and 1200mm diameters
- 309 linear metres of sheet piling
- 8,140 cubic metres of cutter soil mix panels
- 31 no. driven piles

GROUND CONDITIONS

The site consists of a shallow depth of backfill materials, mainly sands and gravels. Below, the natural soil consists of Coode Island silts, clay and sands. The basalt bedrock level commences from between 12m and 15m below existing ground level. The rock has an unconfined compressive strength ranging from 10 to 60MPa, generally increasing with depth.

OVERCOMING DESIGN ISSUES AND OPTIMISATIONS

There were a number of challenges required to be overcome to successfully deliver the ground engineering works at the Northern Portal. A form of Early Contractor Involvement (ECI) whereby the specialist foundation contractor could have early access to the ground engineering designers allowed the contractor to make modifications to the reference designs to provide value engineering and optimisations to the client.

Hard-hard Secant Pile Wall to Overcome Highly Congested Reinforcement within Piles

A major revision of the proposed reference scheme for the secant pile retention walls at the deepest parts of the cut-and-cover box was to change from a hard (40MPa concrete)-soft (25MPa concrete) pile layout with unreinforced primary piles to a hard-hard pile layout with both primary and secondary piles reinforced.

During the tender for the ground engineering works, a review of the reinforcement details for the reference scheme for the 1500mm and 1200mm diameter secant piles quickly resulted in the conclusion that the reinforcement within the secondary piles was overly congested and would have made installation impractical and have resulted in poor flow of concrete around the reinforcement cages.

Typical reference scheme reinforcement details are shown in Fig. 2a below.

To resolve this issue and improve constructability and quality, WPBA JV offered a hard-hard pile layout with both primary and secondary piles being reinforced and installed using grades 40 and 50MPa concrete, respectively. With reinforcement cages (rectangular cages in the primary piles and circular cages in the secondary piles) installed into both types of piles, this allowed for a more balanced distribution of the reinforcement, which enabled the cages to be practically installed and greatly improved the concrete flow resulting in a better-quality outcome for the final product.

Typical reinforcement details from the adopted design are shown in Fig. 2b below.

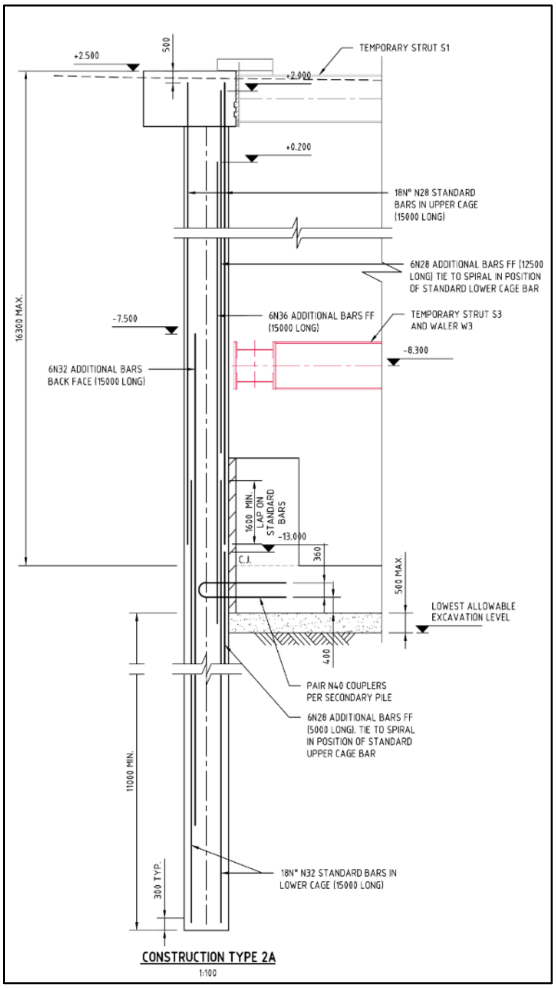

Fig. 2a Typical reinforcement in reference scheme secondary piles

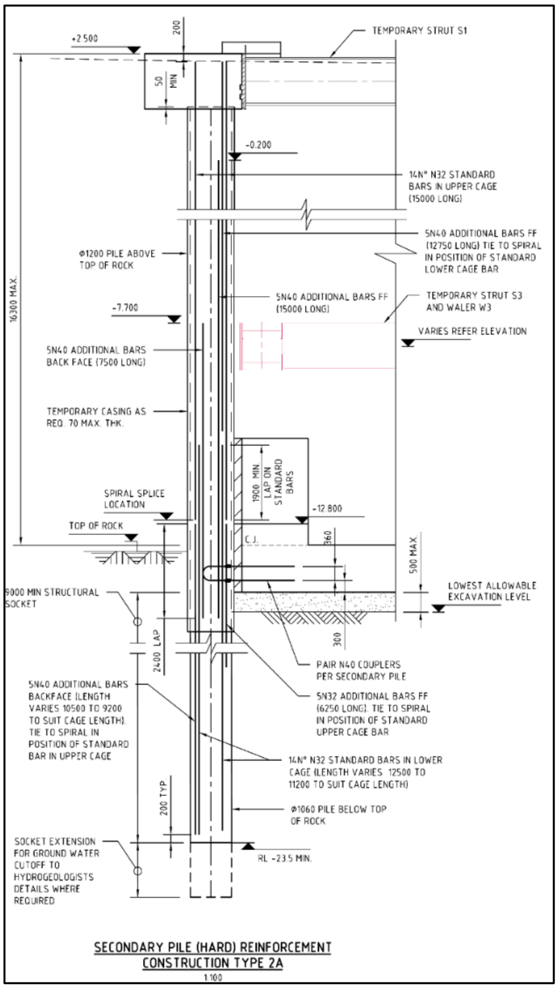

Fig. 2b Typical reinforcement in adopted secant pile wall scheme

The revised scheme also resulted in reduced costs for the principle contractor as the spacing of the piles could be increased compared to the hard-soft secant pile wall where only the secondary piles are reinforced. The original arrangement is shown in Fig. 3a and the typical hard-hard bored secant pile reinforcement arrangement adopted is shown in Fig. 3b.

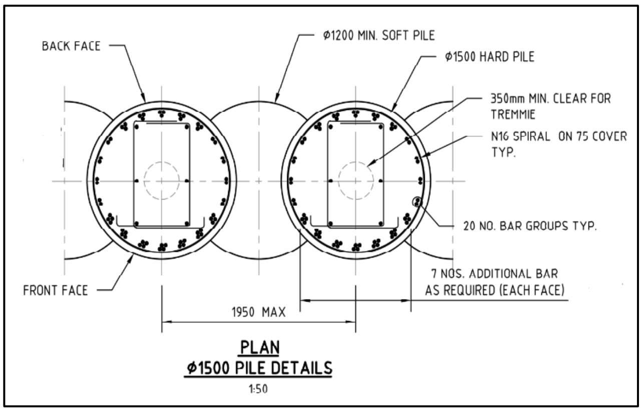

Fig. 3a Initial design reinforced secant soft-hard retention piles

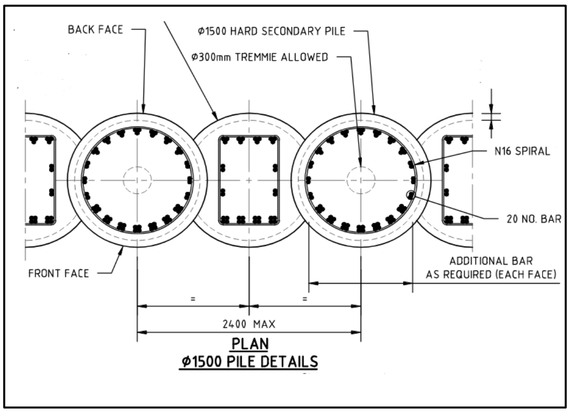

Fig. 3b Adopted reinforced secant hard-hard retention piles

Ground Improvement by Cutter Soil Mix Technique

The Cutter Soil Mixing (CSM) method was used for ground improvement in alluvial material at the Northern Portal, where a TBM would be launched. The TBM launching face was located in a transition between the upper alluvial material overlying weathered basalt of variable strength, generally becoming stronger with depth. CSM was chosen ahead of other techniques, such as jet grouting, because the relatively shallow treatment needed to extend all the way to surface, and by mechanical mixing using the CSM tool with its rectangular profile, 100% treatment could be assured, therefore eliminating the risk of piping at column/panel interfaces.

The umbrella of ground improvement was advanced from the surface down to meet the competent basalt, and therefore provide a uniform profile at the face of the TBM, providing sufficient stability in the alluvial material and overall resistance to groundwater inflow. The CSM panels were arranged in a pattern 42.5m wide to cover twin tunnels, in multiple rows extending 13.5m behind the secant piled headwall of the dive structure, providing a total CSM volume of 7,000m3. Installation of a CSM panel is shown in Fig. 4 and the face of the completed block is shown in Fig. 5.

The CSM block is designed with a target unconfined compressive strength of 600kPa. Based on trial mixes carried out on samples collected from the holes drilled in the CSM block area, an initial cementitious content of 400kg of cement per cubic metre of untreated soil was adopted for the CSM mix. Extensive testing was conducted by shallow wet grab sampling and full profile sampling using a double-tube in-situ technique, with progressive strength results allowing the water/cement ratio and cementitious content to be optimized during the works. Strength results for various sampling methods are shown in Fig. 6. The CSM technique proved to be very successful in the variable soil profile, and good production rates, up to 420m^3 soil mixing in a double day and night shift, were achieved. The average production rate was 200m^3 soil treatment per day in a double shift. Confidence in the quality of the treatment block was progressively gained through analysis of the installation parameters and analysis of the ongoing test results. The eventual TBM launch is due in late 2019.

Fig. 4. Installation of CSM panels

Fig. 5. Excavated face of CSM block

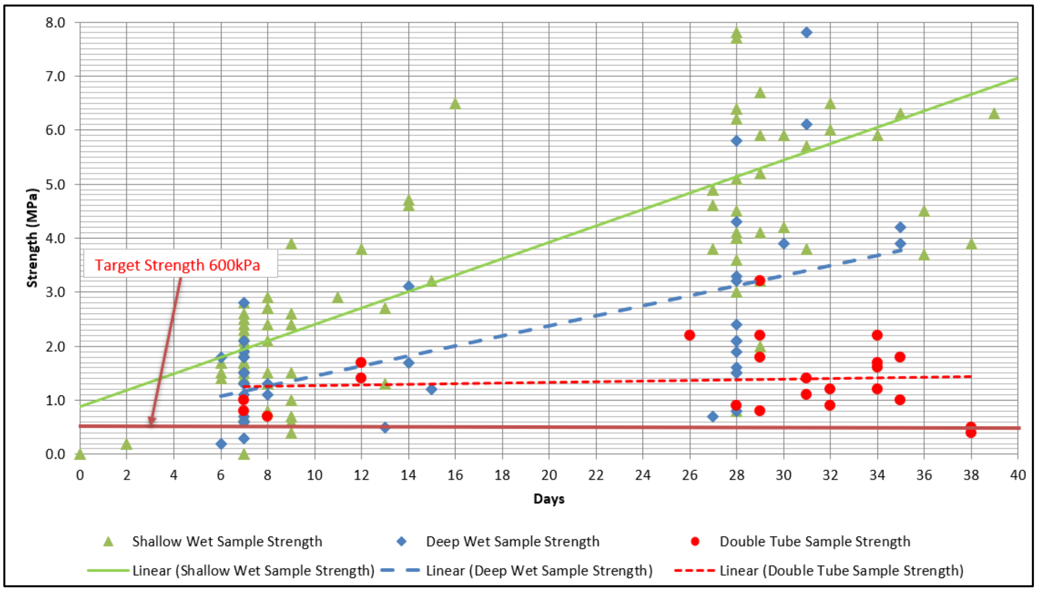

Fig. 6. CSM samples strength results

COMPLEXITY OF THE CONSTRUCTION TASKS

The construction tasks undertaken by the foundation contractor had a significant level of complexity and resolving these issues of complexity was essential to delivering the ground engineering works safely, within budget and on schedule.

Wide Range of Foundation Techniques within a Congested Works Area

The ground engineering works at the Northern Portal involved a large number of different processes and each required detailed planning, set-up and execution. The works area was restricted and the number of large pieces of plant required to achieve the programme meant that the site was highly congested.

Figure 7 provides an indication of how congested the works area was.

The logistics of utilising ten large items of specialist piling plant and up to seven service cranes to complete the ground engineering works meant that the sequencing of the works, down to pile-by-pile sequencing, had to be planned on a weekly and daily basis. Daily supervisors' meetings were held to ensure that works being performed by each of the teams did not disturb the works by other teams. Dedicated spotters and traffic controllers were engaged to ensure there was no plant-to-plant interaction and that spoil removal trucks and concrete delivery trucks were able to safely access the site where required.

Fig. 7. Congestion at the works area

Site layout plans were continually updated as the various foundation activities moved around the site and different access routes to the work faces were developed, Fig. 8 provides an example layout plan. These plans were developed in coordination with the principle contractor, who was responsible for providing suitable works platforms and access to the work areas.

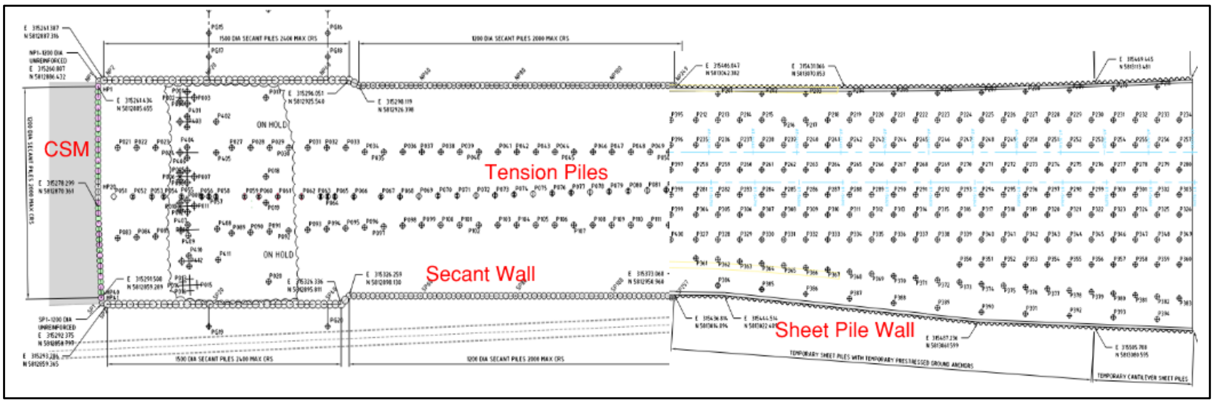

Fig. 8. Typical site layout plan

Towards the completion of the ground engineering works interfaces developed with follow-on contractors including those responsible for capping beam construction and a shaft construction for a sewage pipe diversion. To mitigate the risk of these interfaces, daily planning meetings were held with the various contractors and work exclusion zones were established on site to ensure each contractor's work could proceed in a safe manner.

Achieving the Required Verticality Tolerances

The deepest parts of the cut-and-cover tunnel were required to be excavated to a depth of 22m, a relatively deep excavation for a secant pile wall. To achieve the specified degree of watertightness and to install the piles within the allowable physical space, a verticality tolerance of 1 in 200 was specified.

This verticality tolerance is half of the common specification of 1 in 100, on occasions 1 in 150 is required by specifiers.

WPBA JV took several steps to ensure that the required verticality would be achieved.

Firstly, a relatively deep (1200mm deep for the large 1500mm and 1200mm diameter piles) reinforced concrete guide wall that exactly followed (with allowance for positional tolerance at ground level) the layout of the secant piles was installed to a positional accuracy of 5mm.

Secondly, both the primary and secondary bored piles were installed using heavy, double-wall segmental casing. The extreme stiffness of the casing (total wall thickness of 40 mm for 1200mm diameter casing and 50mm for 1500mm diameter casing) together with the stiff joint connection ensures a vertical hole even in the most difficult ground conditions. Figure 9 shows sections of double wall segmental casing being used.

Thirdly, a robust quality assurance system was enforced during pile excavation, which required regular verticality checks both by the rig operator using the rig's electronic measuring system and the banksman utilising physical checks.

These measures ensured that the required verticality of 1:200 was achieved in all locations.

Fig. 9. Double wall segmental casing

Installation of Long Cages in Single Lengths

Although the change in the arrangement of the reinforcement from just the secondary secant piles being reinforced to both the primary and secondary secant piles being reinforced significantly improved the practicality of installing the cages, performing the splicing of the cages vertically at the pile bore was considered to be too time consuming and inefficient. The cages still required additional steel to resist bending moments through the splicing zone and this made connecting the cages in the vertical position complex. The decision was therefore taken by WPBA JV to splice the individual cages on the ground horizontally and then lift and install the complete cage in to the pile bore in a single length, as shown in Fig. 9.

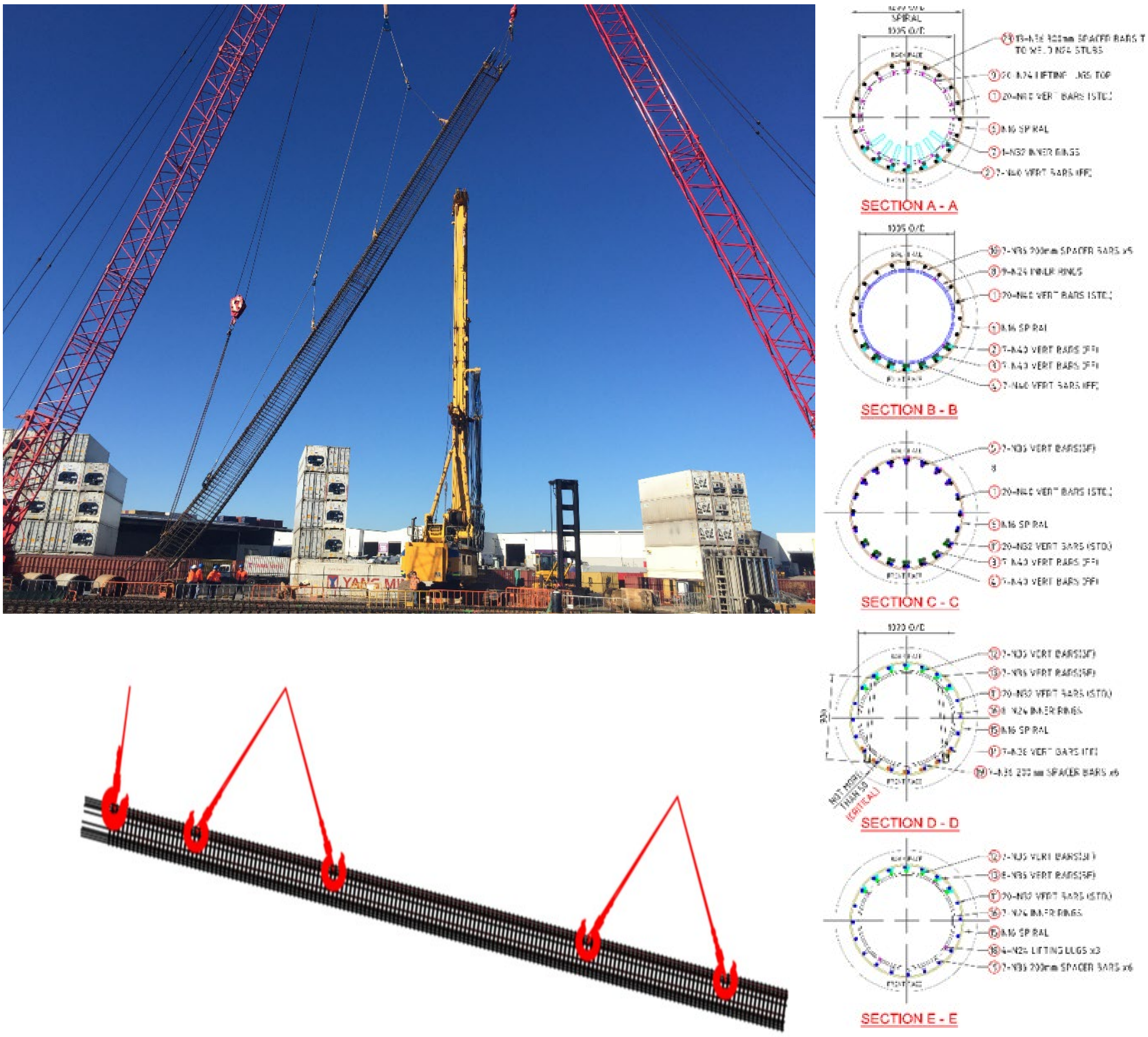

Fig. 9. Lifting of full length cages

Single-section cages were manufactured by reinforcement fabricators in their yards and delivered to the site storage area for splicing, and fine-tuning of coupler levels and lifting points. A dedicated steel cage team was assigned to ensure the steel reinforcement and fibre-glass cages were ready in time and in the correct sequence to suit the installation sequence of the secant and bored piles. Lifting plans were carefully prepared, assessed and engineered for each type of cages to facilitate dual-lifting of single length cages up to 27.5m long. By eliminating the necessity to perform complicated cage splicing over the bore holes, the installation of a long cages in single operation improved piling production, improved the quality of steel cage in particular in regards to the accuracy of coupler positions and enhanced the safety of site workers.

Glass fibre reinforcement cages were required for 35 piles to provide “soft eyes” within the alignment of the tunnels along the headwall of the launch shaft to facilitate their future partial removal by the TBMs. These cages were also spliced on the ground and lifted and installed in single lengths.

SUMMARY AND CONCLUSIONS

The ground engineering works at the Northern Portal of the West Gate Tunnel Project presented a number of challenges for WPBA JV to overcome in order to deliver the original contract scope of works plus additional piling works for the client on time, within budget and to the high standard of quality specified. This was achieved by offering the client a wide-ranging suite of geotechnical processes that were developed specifically for the bulk excavation and loading requirements in each area of the works.

This paper has described how some of the issues unique to the site were dealt with including design issues with the secant pile walls and how the CSM method was developed to deal with mixed ground conditions at the TBM launching area.

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