MINED TUNNELLING WORKS UNDER THE 6 LANES LIVE EXPRESSWAY IN SINGAPORE

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This paper is to present the grouting technique used and the effectiveness, comparison between the predicted settlement and actual settlement, behavior of settlement during excavation, volume loss and how to mitigate it during construction.

1. INTRODUCTION

Several cross passages (CPs) has been constructed to link twin tunnels under Contact T207 of Thomson East Coast Line MRT project in Singapore. Four out of seven CPs and Adit were under 6 lanes live expressway at the northern part of Singapore (Fig.1) namely CP CA1, CP1, CP2 and CP3.

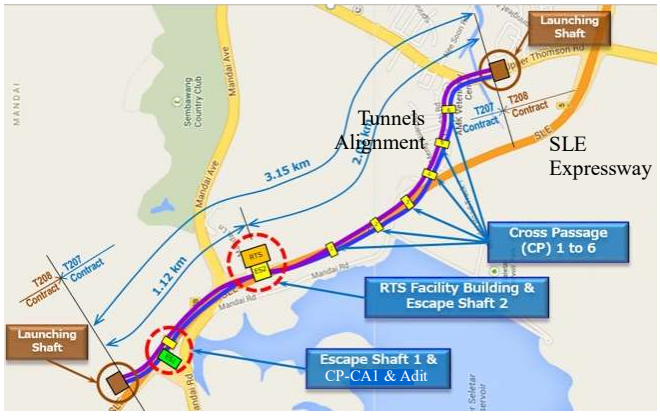

Figure 1: Project Layout

Overburden above CPs are 15-25m only. All cross passages were in GV (Completely Weathered granite) and GVI (Residual soil) Grade of Bukit Timah Granite formation (Fig.2). Soil is very soft compared to other mined tunnel work in Singapore and permeability is also very high at some locations. Therefore, it is necessary to improve the ground condition before and during the excavation work specially to control water ingress.

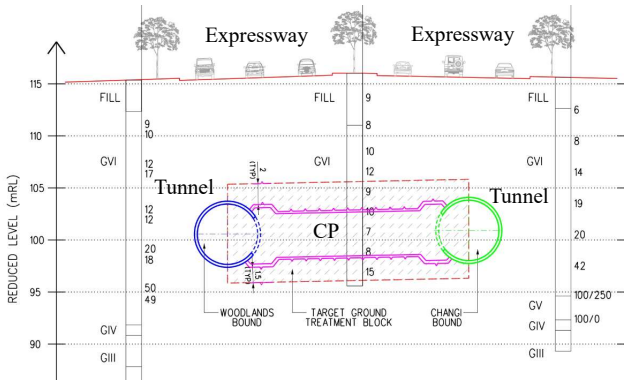

Figure 2: Cross section of Cross passage-CP3

2. GEOLOGICAL CONDITION

Soil is Sandy SILT in high plasticity range (LL is around 50-70%). SPT range of CP3 excavation area is 8-10 which is lowest. Other four locations are around 13-41. Permeability of the GVI soil is 2 x 10^{-7} m/s based on GIBR (Geotechnical Interpretative Baseline Report), However, few boreholes next to Adit show less value such as 1.3 x 10^{-6} to 5 x 10^{-7} m/s at the tunnel level. It is mainly due to high gravel content (Fig.3).

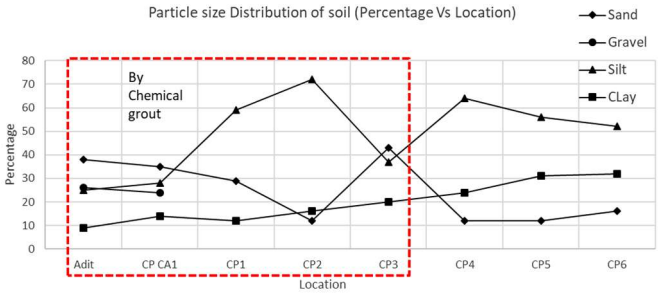

Figure 3: Particle size distribution of soil

3. CHEMICAL GROUTING

CPs away from the expressway were improved by Jet grouting (JGP) from ground surface. Systematic horizontal chemical grouting was proposed for other CPs below the expressway from Bored tunnel due to space constraint for vertical grouting from surface.
Special tunnel segment lining was constructed at CP area. 6 nos of additional grout sockets were introduced onto each segment (Fig.4). Special segments were placed only at CP excavation side for cost and time savings. Additional sockets were installed at dimple points and there was no impact to stiffness of segment lining.

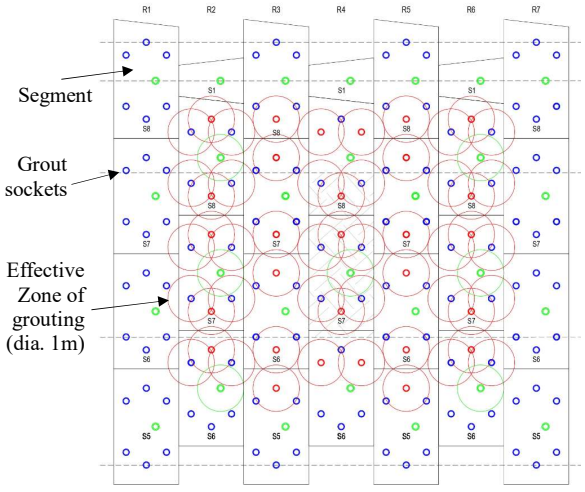

Figure 4: Grout hole and grouting pattern thru segment

LW grout (Sodium silicate and cement) with grouting ratio 30% and 30-50s initial setting time was used. 1.5m non-grouted zone was kept outside segment lining to protect tunnel lining from excessive grouting pressure. Grout holes were grouted (back fill grout) using 5 bar pressure at this zone.

Keywords: Cross passage, NATM, Water ingress, Settlement, Soft soil, Chemical grouting

Mid area (around 5-6 m) of CP2 and CP3 was not grouted from tunnel. Post- probe drilling showed that there is no grouting required. Grouting pressure was maintained at 10 bar except special zone highlighted early. Quality of grouting was determined using probe drilling.

BIM(3D) modelling was also implemented for quality control, planning and optimization (Fig.5).

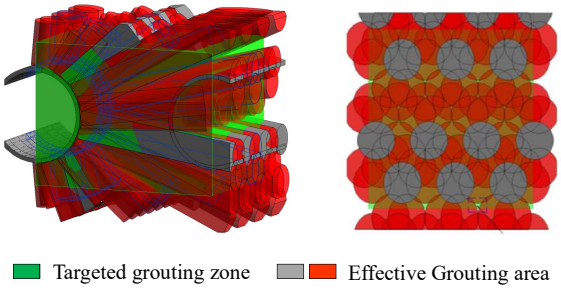

Figure 5: Grouting layout

4. EXCAVATION WORK

Chemical grouting and excavation work carried out during TBM operation due to time constrain.
Excavation work carried out using NATM method. Top heading was excavated first with temporary invert. Bench and invert were excavated separately with some lapping to minimize time to open ring as much as possible (Fig.6). 200-250mm thick temporary shotcrete lining was applied with 2 layers of reinforcement mesh.

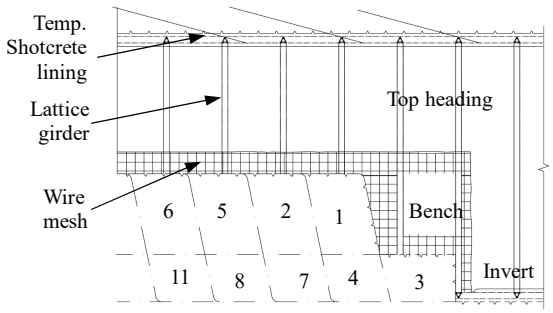

Figure 6: Steps of Bench/Invert Excavation sequence

Predicted settlement was around 20mm except for Adit tunnel. Road was monitored based on performance-based approach because there is no structure near vicinity of CP's other than Expressway. Maximum settlement of 30mm and 1:500 differential settlement at 5m interval were adopted as monitoring criteria on expressway.

Adit tunnel had higher settlement due to water table lowering effect than volume loss (VL) due to excavation work (Fig.7). It shows when comparing with Rod extensometer (RX) reading which was placed 2m above tunnel crown level. The reading of RX should be higher than ground settlement normally.

Quantity of water discharge during excavation was the key controlling measurement of settlement even though there is no soft clay layer above the tunnel. It was found that 4.6mm additional settlement due to 1m water draw down at middle part of Adit tunnel excavation without pre-grouting (JGP or Chemical).

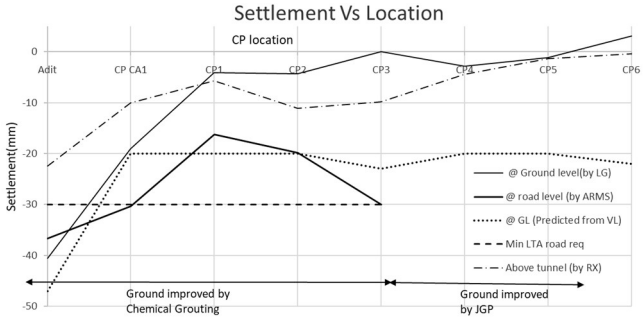

Figure 7: Settlement comparison

5. ROAD SURFACE MONITORING

Monitoring was one of major challenge to overcome before work start. Road surface was monitored by Automatic real time monitoring system (ARMS) which was used in Singapore for the first time in additional to conventional monitoring system (Ground settlement marker (LG)) at accessible locations. Predetermined small patches (500x100mm) of the road along the lane marking at 5/10m interval were scanned every time.

It was monitored throughout the excavation at predetermined intervals. All management staff were could be alerted by automatic SMS system if the readings breached alert levels and suspension level. Interval were adjusted based on site conditions such as false readings, exceed alert levels etc. Settlement readings were published on web within 4-6 hrs after the reading, which took more than 12hrs for conventional system.

6. CONCLUSION

Horizontal Chemical grouting (HCG) technique can be used as underground water controlling measurement specially for stiff ground SPT higher than 15.
Quality of JGP can be evaluated month later, it is difficult and costly to rectify it again if it does not meet the criteria. HCG is performed base approach. Quantity and setting time will be determined based on ground condition.
Quickest closing of tunnel face and ring that has been opened is more essential. Bench and invert construction should be done separately by stages to reduce lateral earth pressure acting against excavation even though there is no wedge effect.
ARMS can be used most locations that having access difficulties such as expressway, Airport runner ways, high security zones, etc.

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