UNDERPINNING AND TUNNELLING THROUGH TRAFFIC VIADUCT PILE FOUNDATION

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1. INTRODUCTION

Contract C882 covers the construction of the Keppel Station, cut & cover tunnels and its associated twin bored tunnels connecting to Harbourfront Station and Cantonment Station as a part of Circle Line 6 (CCL 6) Mass Rapid Transit (MRT) Project in Singapore. Two existing live traffic viaduct piers' pile foundation along Keppel Road namely Pier FP9 (Fig.1) and Pier P51, were found to be in the alignment of bored tunnel between Keppel Station and Cantonment Station. Underpinning work was carried out prior to the arrival of tunnel boring machine (TBM) and the left-in piles were then removed during TBM mining. This paper summarises the construction methodology of underpinning work, tunnelling work and the structural movement during the key construction activities namely, load transfer, disconnection of existing piles from pile cap and TBM mining through the left-in piles for one of the piers, Pier FP9.

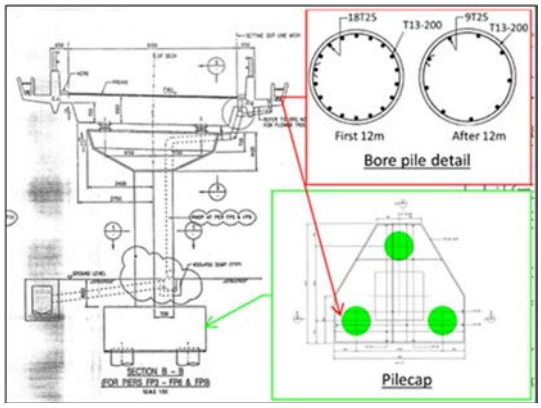

Fig. 1 Pier FP9's foundation detail

2. UNDERPINNING WORK

New transfer beam with micropiles foundation was constructed underneath the existing pier's pile cap for load transfer. Cofferdam with sheet piles and struts was constructed for the underpinning work. Upon the new transfer beam achieved required strength, the load from the existing pier foundation was transferred to the new foundation system by hydraulic jack system placed in between existing pile cap and new transfer beam. The load transfer was carried out in stages and pier movement in each stage was closely monitored prior to proceed to next stage. After that, the existing piles were detached from the pile cap sequentially by wire saw cutting method. Then, second stage concrete (1.2m thick reinforced concrete) was cast to encase the existing pile cap.

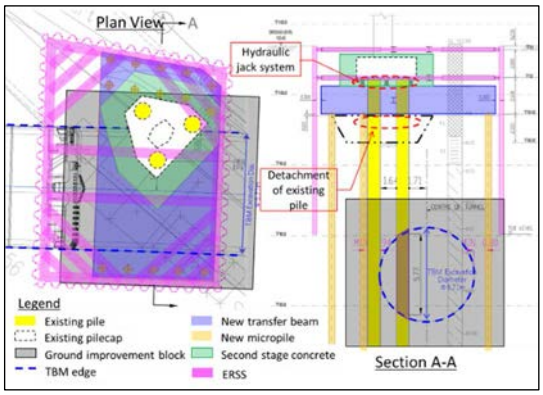

Fig. 2 Typical cofferdam for underpinning work

Various provisions were made to ensure the underpinning work was executed in safe manner:

1. Additional bracings were strutted to existing pile cap to act as lateral restraint prior to detachment of existing piles
2. Existing piles encased inside transfer beam were de-bonded to ensure they were not damaged during load transfer
3. Hydraulic jack system was retained until the detachment of existing piles completed for adjustment of pier movement
4. Existing piles were disconnected from existing foundation system by using wire saw cutting method in 2 cuts for a 100mm cut section in order to minimise vibration induced to structure

3. TBM TUNNELLING WORK

The geological condition at the tunnel level at Pier FP9 is mainly Jurong Formation of S(IV) and S(V) mudstone with SPT N values ranging from 35 to 100. Earth pressure balance tunnel boring machine (EPB TBM) with roller cutter was deployed for the bored tunnelling work but it cannot cut the left-in piles' rebar. As such, Cutter Head Intervention (CHI) was required initially to hack and cut the left-in piles into pieces manually. This will be a high-risk work which is also labour intensive and time consuming as it will be required to work outside of excavation chamber and temporary earth retaining structure will be required to be constructed (Fig. 2). In view of this, specialised tungsten carbide cutter (Fig. 3) was proposed and used to replace the roller cutter for TBM cut through the left-in piles without hack and cut the left-in piles manually.

The tungsten carbide cutter has high hardness sufficiently to cut rebar and was designed to form a cone shape profile at the cutterhead that designed to grind the left-in piles from centre outwardly to edge of TBM. The tungsten carbide cutter was also spaced at small interval to cut the rebar into small pieces that can be discharged easily by screw conveyor. In addition, proper TBM operation parameter allowed sufficient time for cutting of the rebar. The TBM excavation speed was controlled less than 2mm/min while the cutterhead rotation was maintained at around 2rpm. As a result, the TBM mined through the FP9's left-in piles successfully without much difficulty.

Keywords: Live traffic viaduct, underpinning work, TBM cut rebar, special cutting tools
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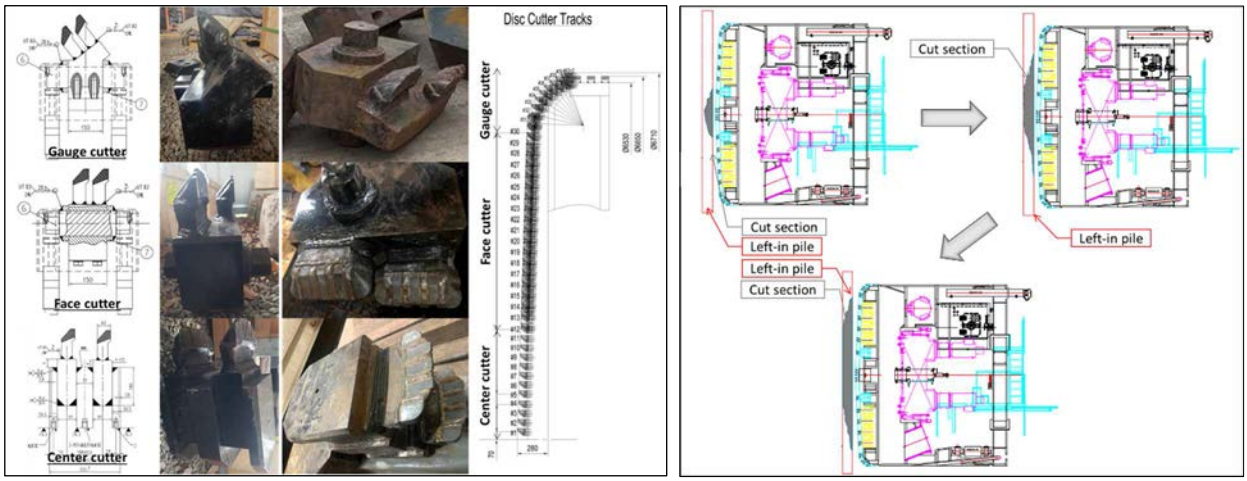

Fig. 3 Specialised tungsten carbide cutter (left) and cutting profile (right)

4. INSTRUMENTATION MONITORING WORK

During load transfer and detachment of existing piles, the land surveying of accuracy ±1mm is not sufficient to detect the movement of the pier as the stop work level was 2mm uplift of pier or 5mm settlement of piles. Therefore, additional dial gauges (DG) of accuracy ±0.01mm were installed to measure the structural movement before proceed to next stage.

The pier was uplifted by 0.6mm and 1mm measured by DG and surveying respectively after load transfer. Meanwhile, the settlement of pier measured by DG and surveying was 0.55mm and 1mm respectively after detachment of piles. The pier was observed to be settled down around 1mm when CHI was carried out to change special tungsten carbide cutter. Then, it remained almost stable throughout the TBM cutting through the left-in pile and CHI for changing back to roller cutter. On overall, the pier remained stable at the end of the underpinning and tunnelling work.

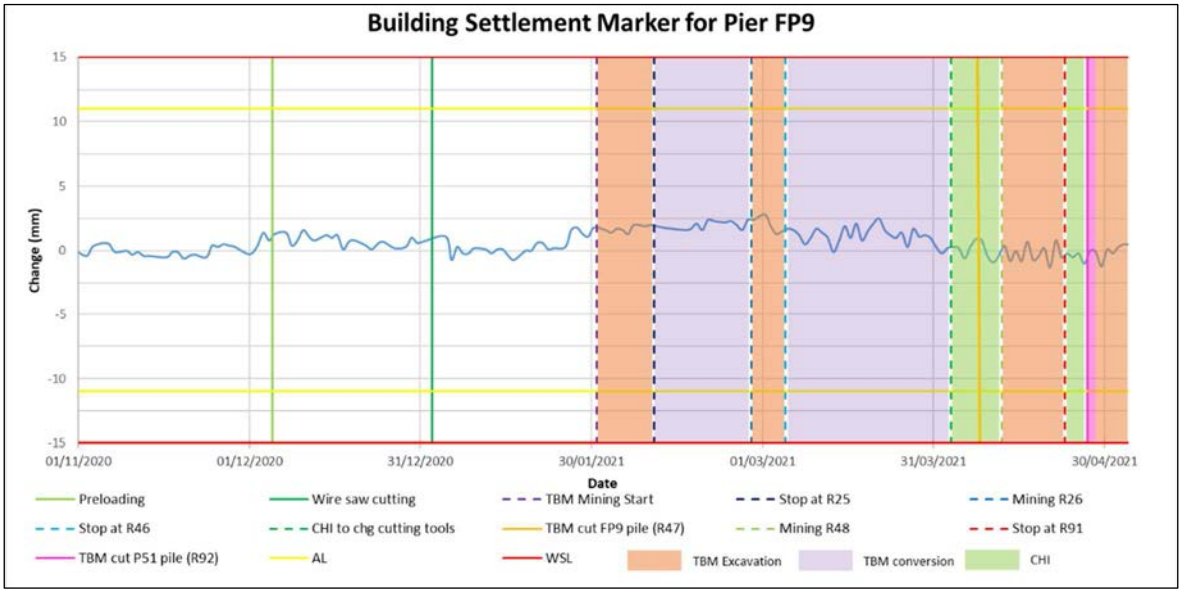

Fig. 4 Building settlement marker reading (normalised before preloading work) for Pier FP9

5. CONCLUSION

The underpinning and bored tunnelling work for live traffic viaduct at Keppel Road, Singapore completed safely and successfully with pier movement within the allowable design limit for Pier FP9 as well as another Pier P51 encountered in this project. From the instrumentation reading and TBM operation parameter, a promising result for the adoption of specialised tungsten carbide cutter on TBM for removing the left-in piles' rebar was shown.

REFERENCES

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