Construction of SCL Tunnel with Ground Freezing Underneath Existing MRT Tunnels in Singapore

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A Marina Bay Station is part of new Thomson East Coast Line and constructed in southern part of Singapore. There are two existing MRT Tunnels, North South Line (NSL) and Circle Line (CCL), operating within the proximity of the new construction area. New railway tunnels were constructed by SCL (Sprayed Concrete Lining) method directly underneath these two existing 'live' MRT tunnels with vertical alignment (Fig. 1). Ground Freezing method was used to cut off the underground water for safe tunnel excavation. This was the first time that the Ground Freezing had been applied for an underground railway project in Singapore. The advanced 3D FEM Analysis was carried out to predict the movement of the existing MRT tunnels caused by the Ground Freezing and SCL Tunnel excavation.

Fig. 1 Freezing Pipes

1. Ground Freezing

The subsurface conditions consist of hydraulically reclaimed Sand Fill followed by Kallang Formation which includes Marine Clay. This is underlain by Silty Sand Layer, so-called Old Alluvium (OA). The Kallang Formation which are very soft and unstable was all treated by JGP (Jet Grouting Pile) and the upper SCL tunnel was excavated all the way in the treated JGP. Because of the density and potentially flowing characteristic of the underlying OA, the JGP could not be enough to stabilize this deposit and Ground Freezing was adopted to stabilize the zone at the interface of the Kallang Formation and the OA. Ground Freezing Pipes (GFP) and Temperature Monitoring Pipes (TMP) were installed from the inside of the Linkway tunnel which was constructed directly above the subsequent two SCL Tunnels. A total 96 of GFP (Bluer Arrow) and 20 of TMP (Red Arrow) were installed (Fig. 2). The length of pipe of GFP and TMP was 26 m and the spacing of GFP was basically 0.9 m except for 1.2m at the existing NSL pile (OD 1.0m). The brine comprised of calcium chloride, CaCl2 and was cooled by Refrigeration Unit set at ground surface. The brine was chilled to a targeted temperature of -30 oC and was pumped down to the bottom of the GFP buried in the targeted freezing zone in the ground. The monitoring of the growth of the frozen soil was carried out carefully by 2D temperature distribution map and 3D data using BIM based on the actual temperature data from TMP.

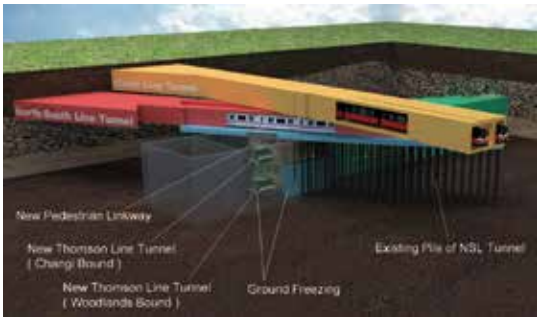

Fig. 2 3D Section Wide view black

2. Construction of SCL Tunnel

The excavation of lower SCL Tunnel commenced after the confirmation of the targeted form of the frozen soil wall based on the temperature monitoring. The diameters of tunnel excavation were 7.0 m (Lower Tunnel) and 7.1 m (Upper Tunnel). The primary shotcrete (G30) thickness was 300 mm. The Tunnel cutting face was divided into 2 parts for safe excavation, i.e., the top heading and bench/invert (Photo. 1). The surface of the frozen soil was encountered and some of GFP were exposed adjacent to the existing barrette piles during the tunnel excavation. The insulation sheet was placed on the surface of the frozen soil and GFP before the shotcrete was applied to ensure the quality of the shotcrete. The construction sequence was the activation of ground freezing, the excavation of lower tunnel, the de-activation of ground freezing, the excavation of upper tunnel and the lining of both tunnels.

Photo 1

3. Conclusion

One of the critical concerns was the excessive movement of the existing MRT tunnels caused by Ground Freezing (Frost Heave and Thaw Shrinkage) and SCL Tunnel excavation. Construction control was achieved based on actual monitoring data compared to predicted values by FEM analysis, and the work was completed successfully without breaching the Work Suspension Level.