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Directors' Research and Development Activities

Use of Silent Piler in Bangkok MRT Orange Line Project Thailand

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Introduction

Thailand's capital city, Bangkok has been planning to construct many underground infrastructure development projects. MRT Orange line is one of the most challenging projects in Bangkok because the tunnel alignment passes through the congested urban areas in the city. There are inevitable interactions between existing structures and new construction, such as tunnels, intervention shafts and stations. Many underpinning works are required along the route. The low headroom, limited working space and vibration have become concerned issues to be considered during construction. Silent Piler is used in those constraint areas. MRT Orange Line Project is implemented by The Mass Rapid Transit Authority of Thailand (MRTA) to develop a train system network in Bangkok Metropolitan Region. MRT Orange Line is divided into two sections, i.e., East Section (Thailand Cultural Centre – Min Buri) and West Section (Bang Khun Non – Thailand Cultural Centre). Ch. Karnchang PLC. and Si-no Thai Engineering and Construction PLC. (CKST Joint Venture) have been awarded for MRT Orange Line (East Section) Project, Contract E1 and E2. I was a member of the design team for this design and build project. Contracts E1 and E2 involve the construction of about 9.73km, comprising 7 underground stations, ventilation and intervention shafts, cut-and-cover tunnels, depot access, and stack and parallel twin tunnels. The Diaphragm wall is used as a retaining wall with the aid of a base slab and bored piles or barrettes for deep excavation.

The soil condition in Bangkok consists of a thick soft to very soft clay layer on the top deposit, namely Bangkok clay, and encountered with stiff to very stiff clay before reaching the first dense silty sand layer. The hard clay is encountered below the first silty sand and underlain by the second very dense silty sand layer. The subsoil profile of MRT Orange Line Contract E1 and E2 are presented in Fig.1 and Fig.2, respectively. Bangkok clay is very sensitive to deformations and has low shear strength. Most of the foundations in Bangkok is the pile foundation. For low-rise buildings, the piling work consists of a driven pile and a jack-in pile. For high-rise buildings and highways, BTS sky train and MRT subway, bored pile and barrette pile with the tip penetrated in the second dense silty sand are utilized. The tunnel alignment needs to be adjusted to evade the existing buildings and elevate the expressway as much as possible. However, underpinning work must be conducted in some parts of the project to mitigate the settlement of existing buildings in congested spaces. The working space, vibration, and pollution, especially PM 2.5, have become concerned issues to be considered during construction.

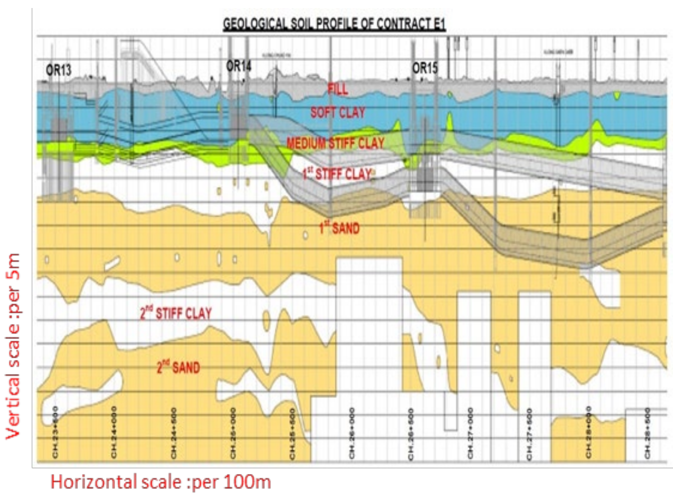

Fig. 1. Geological soil profile of Contract E1

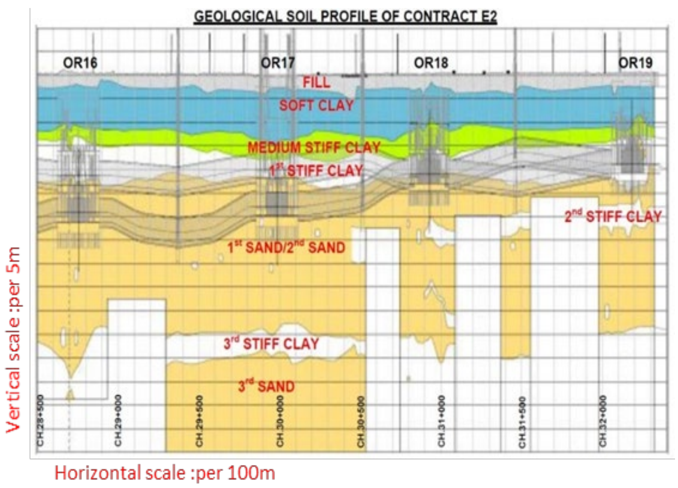

Fig. 2. Geological soil profile of Contract E2

The tunnel alignment compels the underpinning works required for the project. As a result, attention has been paid to the alignment design such that minimal clashes occur between the tunnel alignment and the existing structures. In addition, if such a clash is unavoidable, the underpinning work needs to be conducted. Underpinning for the existing structures may be required if the existing structures either clash with the tunnel alignment or are in its proximity. For example, if the clearance between the edge of the existing pile and the exterior surface of the tunnel is less than 900mm, this location requires underpinning. This clearance is inclusive of a tunnel driving tolerance of plus or minus 100mm and a construction tolerance of 1 in 100 for the verticality of the existing pile. The following information will be taken as the bases for the design development of the underpinning work on the project: Tunnel alignment, Station layout, Topographic survey of the site, As-built information and condition survey of the existing structures, and Right of Way (ROW) of the project.

Underpinnings at Ram Khamhaeng Junction Flyover in Contract E1 and Contract E2

The location of Ram Khamhaeng Junction Flyover in Contract E1 (Chainage 28+200) and that in Contract E2 (Chainage 29+300) need to be underpinned as shown in Fig. 3 and Fig. 4. One at Chainage 28+200, the proposed bored tunnels will pass underneath the existing flyover, and it will cause an adverse effect on the existing foundation system. Underpinning work is required to reconstruct a new supporting system with minimal impact on the operation of the viaduct. In the beginning, the associated barrettes and temporary steel portal frame will be constructed as the supporting structure for the existing flyover structures. Sheet piles will be installed around the pile cap by Silent Piler, as presented in Figs. 5 and 6. Where it is acted as a permanent structure. The conventional method of pile installation could not be applied due to insufficient headroom under the flyover. Temporary vertical jacks between the portal frame and the existing girder will be placed. Subsequently, preloading will commence to alter the load path from the existing flyover piled foundation to the new barrette foundation through the vertical jacks and portal frame. After the preloading, the existing steel pier will be disconnected, followed by demolishing the existing pile cap and piles. Thereafter remaining portions of the transfer beam will be constructed. A steel pier will be reinstated and connected to the transfer beam to remove the temporary jack to complete the load transfer. Finally, TBM works will be carried out underneath the underpinned foundation structure after the completion of load transfer.

For the site location at Chainage 29+300, as the proposed bored tunnels will pass underneath the existing flyover and will be partly in conflict with the existing foundation system, underpinning work is required to reconstruct a new supporting system with minimal impact to the operation viaduct as presented in Fig. 4. Headroom under flyover is less than 5.0m. Therefore, Silent Piler needs to be used for sheet pile installation, as shown in Fig. 7. The sheet pile needs to be divided into short lengths and reconnected by welding during the sheet pile installation, as presented in Fig. 8. The sequence of underpinning is similar to the underpinning at CH. 28+200. However, after the pre-loading, a gap between the existing deck soffit and the portal beam will be grouted in order to remove the temporary jack. The second cast of pile caps for connecting to the existing cap will be constructed. TBM works will be constructed underneath the underpinned foundation structure after the completion of load transfer.

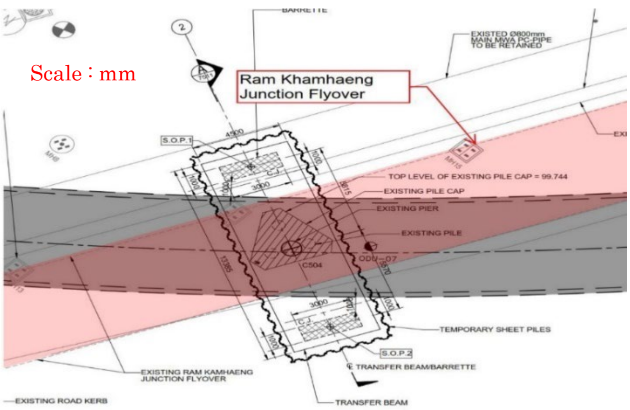

Fig. 3. Site location plan at Chainage 28+200

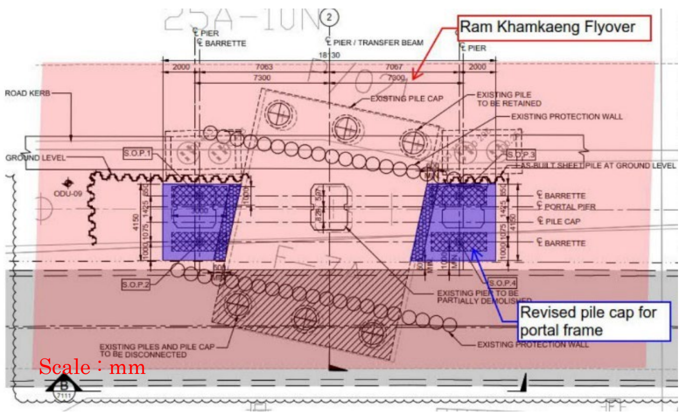

Fig. 4. Site location at Chainage 29+300

Fig. 5. Sheet pile installation at Chainage 28+200

Fig. 6. Site condition after sheet pile installation

Fig. 7. Sheet pile installation at Chainage 29+300

Fig. 8. Sheet pile connection

Design Analysis Approach

For underpinning works, internal forces of the structural members have been carried out by two computer programs – PLAXIS2D and SAP2000. PLAXIS2D is used to analyze the effects due to TBM tunneling. However, the load transfer and the loads from the flyover will be analyzed by SAP2000. Fig. 9 shows the section of the load transfer system in SAP2000. Jack loads were installed between the existing deck and the newly constructed portal beam. Installation of a sheet pile by Silent Piler will be applied around the newly piled cap and the existing pier to act as a retaining wall. The load transfer due to volume loss during tunneling will be acquired by PLAXIS2D, as shown in Fig. 10. The flyover structures are supported on piled foundations where it is affected by sub-surface soil movement due to TBM tunnelling works. The vertical soil movement induces negative skin friction on the piles. The lateral soil movement also induced additional bending moments on the piles. These additional stresses on the piles and the consequences of underpinning works are analyzed on PLAXIS 2D. The results will be checked against the structural and geotechnical capacity of piles to assess the impact on the piles due to ground movement by tunnelling works.

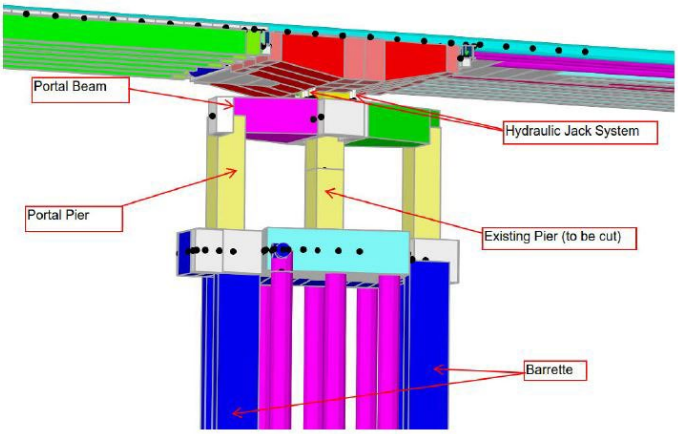

Fig. 9. Load transfer at CH.29+300 by SAP2000

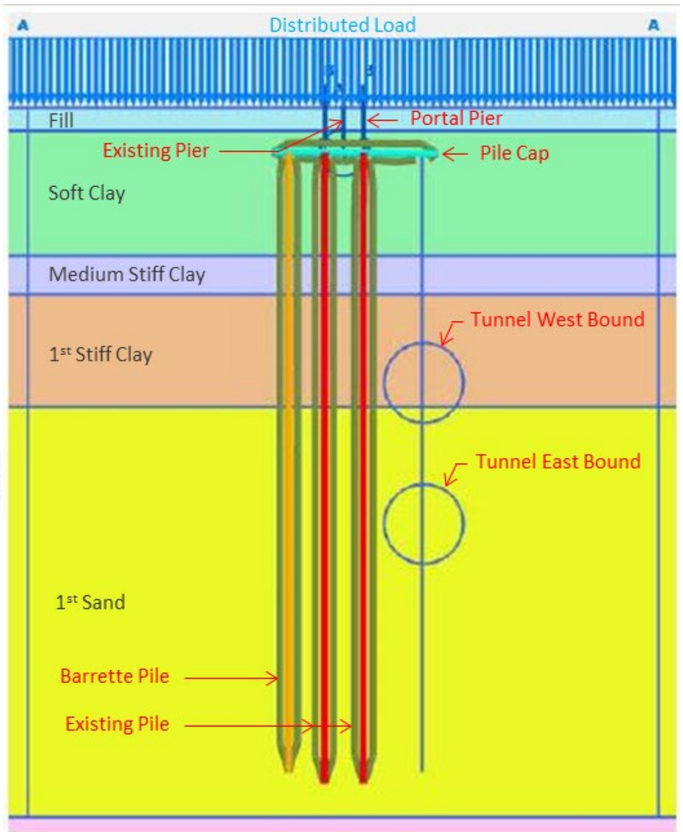

Fig. 10. Plaxis2D model with TBM at CH.29+300

Conclusion

Silent Piler is very useful to be applied in the constraint condition such as low headroom, limited working area and nearby operating transportation. For MRT Orange Line Project, it is compulsory that the traffic needs to be operated during the underpinning process. The conventional sheet pile installation using a Vibro hammer causes excessive noise and ground vibration. The vibration may generate adverse effects on existing buildings.

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