THE CHALLENGING SUBWAY PROJECT IN BANGKOK : NEW HOPE OF THAIS IN SOLVING TRAFFIC PROBLEM

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Abstract. This paper describes the overall delivery of the Chaloem Ratchamongkhon Line, the first subway project in Bangkok as a challenging tunneling project in an urban environment. Eight pressure balance shields were employed under two major civil works contracts (North and South sections) to drive approximately 20 kilometers of twin-tunnel underneath congested area. As a international well known project, multinational workforces exca vated tunnels for the large subway system intended to carry a half million people daily over several lines through the central city in order to minimize traffic jam. Tunnel problem includes many existing structures along the tunnel route as well as flooding, ground subsidence, and fire problems.

Project Introduction

As the undisputed cultural, industrial, educational and political center of Thailand, Bangkok crams around 10 million people into a rapidly growing, unzoned area. Anyone travels through the city braces for an ordeal of wasting hours in impenetrable traffic (Figure 1). While a sky-train speeds up traffic for some commuters and tourists around a small central loop (Figure 2), it hardly dents the general chaos. The intractability of Bangkok's congestion has attracted transportation engineers from around the world challenged by the situation. For several years, multinational workforces had been boring tunnels for a large subway system intended to carry a half million people daily over several lines through the central city. This will make the subway project one of the world's largest tunneling projects in an urban environment.

The first subway project in Bangkok or the Chaloem Ratchamongkhon Line is the first stage of an integrated transportation plan for Bangkok (Figure 3) to be implemented in conjunction with other schemes, by the Mass Rapid Transit Authority (MRTA). The project of 20-kilometers of twin tunnels is subdivided into two main tunnel sections namely, the North Tunnel Section and the South Tunnel Section, The South Section involves construction of a twin bored tunnel subway (Figure 4) from the inter-city railway terminal at

Hua Lamphong near the Chao Praya river eastwards for 5 km beneath the busy Rama IV Road to the Queen Sirikit National Convention Center, then 4.5 km north beneath Asoke and Ratchadaphisek roads ending at Rama IX station with a connecting line to the depot. The northern section of the subway continues from Rama IX station for 4.5 kilometres north along Ratchadaphisek Road to Lat Phrao Road then turns west to Chatuchak Park and finally terminates beneath the Bang Su yards of the State Railway of Thailand. Tunnel axis level is typically between 16 and 23 m below the surface. Each section is approximately 10 km long and includes 9 underground stations. Rail levels are typically 21 m below ground level. The tunnels are 5.7 m nominal inside diameter with a 0.3 m thick by 1.2 m wide concrete segmental lining.

Along Rama IV Road, the presence of an elevated four lane road necessitated that the two tunnels stack one above the other in order to fit within the road easement and avoid the foundations of adjacent buildings and the overpass foundations. In this location the lower south bound tunnel was driven first at an axis depth of about 16 to 28 m below the surface followed by the shallower north bound tunnel at a typical axis depth of 12 m. The adjoining three stations consequently have a stacked platform configuration (Figure 5). Two stations at Silom and Phahonyothin are located beneath overpasses necessitating their underpinning or reconstruction respectively. Other design and construction issues involve consideration of the tunnels passing close to a high pressure water supply tunnel at two locations, removal of piled foundations which interfere with the tunnel alignment beneath five bridges over canals (known locally as khlongs) and avoidance of overpass and expressway pier foundations.

Implementation

The major civil works are being implemented under two principal design and construct contracts. A contract for the South section was let to a joint venture consisting of Bilfinger + Berger Bauaktiengesellschaft, Ch Karnchang Public Co. Ltd., Kumagai Gumi Co. Ltd. and Tokyu Construction Co. Ltd. (BCKT) in November 1996. The north contract was let to the ION Joint Venture comprising Italian Thai Development Public Co. Ltd., Obayashi Corporation and Nishimatsu Construction Co. Ltd. in August 1997. These contracts are supervised by the Construction Supervision Consultant (CSC1) comprising a consortium of Louis Berger Inc, Lahmeyer International GMBH, Sverdrup Civil Inc., Sea Consult Engineering Co. Ltd, Arun Chaiseri Consulting Engineers Co Ltd, Roge Consultant Co. Ltd, Project Planning Services Co Ltd and P.U. Associates Co Ltd. The project management consultant MPMC was engaged by MRTA at the outset to assist and advise MRTA with the implementation of these civil works contracts and other track work, lift and escalator, depot and concessionaire contracts. BCKT appointed Sindhu Maunsell Consultants to provide design services in the civil, structural, geotechnical, architectural and mechanical and electrical disciplines in conjunction with Philip Schuetz for tunneling services. ION appointed Ove Arup and Partners (Thailand) for similar services.

Geological Environment

Bangkok is a city lying in the Chao Praya delta plain. Its topography is low and flat being approximately 0.5 to 1 meter above sea level. Characterization of the soil properties found along the alignment is based on pre-tender investigations undertaken on behalf of the MRTA in 1993 and 1996 and post tender investigations undertaken by the main contractors in 1996 and 1997. Extensive field explorations and laboratory programs were carried out by contractors. Subsurface conditions along the MRTA project can be subdivided into the North Tunnel section and the South Tunnel section as described earlier. For the North section (i.e. from Thiam Ruam Mit station to Bang Sue station), the soil profile is very uniform with soft clay underlain by stiff clay along the tunnel alignment (Figure 6). In this tunneling section, a horzontal-twin tunnel is excavated mostly within the stiff clay layer (i.e. about 15-25 m below ground surface). For the South section (Figure 7), most of the tunnel alignment is also located within a stiff clay layer. However, in some part of the route, tunnels are stacked so that the lower tunnel is excavated in a sand layer.

Tunneling Excavation

A total of eight Earth Pressure Balance (EPB) shields were used for tunneling of the entire project. As described earlier, the project of 20-kilometers is divided into 2 main tunnel sections namely, the North Tunnel Section and the South Tunnel Section. The North Tunnel Section in turn is composed of Tunneling Sections A and B, whereas the South Tunnel Section is divided into Tunneling Sections C, and D. Each of four sections used two shields for excavating northbound and southbound tunnels.

For Section A in the North Tunnel Section, two machines (i.e. No. 1 and No. 2) operated by Nishimatsu were driven northward from Thaiam Ruam Mit station to Ratchada station. Obayashi operated the other two machines (i.e. No. 3 and No. 4) which excavated the twin tunnels from Ratchada station to Bang Sue station known as Section B. For the South Tunnel Section, two machines (i.e. No. 5 and No. 6) were lauched from Rama IX station and driven southward to Sirikit station in Section C, which was excavated by Kumagai Gumi. The last section is Section D starting at Sirikit station to Hua Lumphong station. This section was excavated by Bilfinger & Berger using two EPB shields, which were refurblished from the machines used in Taipei Rapid Transit Systems. Six EPB machines (i.e. No. 1 to No. 6) were the same model manufactured by Kawasaki and the other two (i.e. No. 7 and No. 8) were Herrenknecht machines (Figure 8). All of the shields had very similar specification.

The tunneling conditions principally involve excavation in stiff to hard clay, which is self-supporting, and dense fine silty sand as the drives become deeper between stations. Although six of the eight machines are Kawasaki, they are operated differently by each of the operators and have slightly different specifications. The machines are all high speed capable of up to 10 cm per minute cutting speed. They can operate in dual mode but typically have been operated with slurry injection using polymers or bentonite to control the consistency of the clays as the moisture content of the stiff clay is close to the plastic limit.

Generally, the North Section's approach was to start tunneling as early as possible and drive through the launching station prior to their excavation. The North contract (i.e. Tunneling Sections A and B) was awarded one year after the South contract (i.e. Tunneling Sections C and D). Hence, to achieve the promised schedule, contractors had to start the tunneling work before the excavation of stations had been completed. For example, in Section A, the EPB shield driving from Thiam Ruam Mit station progressed from a launch shaft inside the north end of the station to Pracharat Bamphen station, through each diaphragm end wall and the un-excavated station as shown in Figure 9a and similarly at Sutthisan station until its arrival at Ratchada station, which had by that time been fully excavated and the base slab constructed. Temporary segmental lining rings were used as the shield excavated within the un-excavated station box. These segmental rings were then removed during the excavation of the station.

By contrast, in the South Tunnel Section, where the station work started earlier, it was possible to complete intermediate station excavation in advance of the shields. The South contractors started tunneling later but avoided an extra length of temporary tunnel by not having to tunnel through un-excavated station boxes. In the case of Section C, the shield cut through the station end walls and was skidded through the station to the far end where tunneling re-commenced as shown in Figure 9b. For Section D, with Herrenknecht machines (Shields No. 7 and No. 8), the diaphragm wall was broken out by hand as shown in Figure 10 and Figure 11. This approach required the construction of large blocks of ground treatment by jet grouting to stabilize the ground and permit safe entry and launching of the shield at the stations.

Flooding, Ground Subsidence, and Fire Precautions

With its tropical monsoon climate, Bangkok normally floods to some extent during the rainy season. To address this problem, the MRTA has been taken precautions during entire construction period. A watertight concrete barrier surrounded each excavation for structures with stop logs at the gates to prevent any water flooding into the excavation and the tunnel. After completed, the project will have a 1.2 m high podium at each subway station entrance as a water protection for the subway project. The protection was designed to withstand a water level of 1 m above the highest flood level occurred in the last 200 years. Precautions for this were implemented by having all openings of the ventilation buildings and intervention shafts above this level. The glass walls at the entrance can also resist the potential water pressure exerted by such a water height. Furthermore, with the help of stop logs across the entrance, the system can be completely protected from flooding.

Besides flooding, the other main problems in the public mind are sinking and fire protection. While the cut-and-cover construction method would have been much cheaper than bore tunneling, it would have resulted in unimaginable chaos on Bangkok streets. Earth pressure balance shield tunneling proved to be able to control surface subsidences or settlements and cause minimal effects to existing structures along the tunnel alignment.

For fire precaution, based on the individual lengths of each tunnel and to comply with emergency requirements, intervention shafts were constructed at three locations. Separate horizontal adits which were excavated by hand-mining technique (Figure 12) for uses in emergency evacuation, and for ventilation were connected to each tunnel. Scenario analyses have to be performed to simulate actual evacuation time in the event of an emergency. Such analyses take into account factors of the life emergency systems including fire alarms, sprinklers and smoke-extract system, selection of materials for finishes and building fabric and the degree of fire resistance provided in the system.

Conclusion

Both civil works contractors for the MRTA Chaloem Ratchamongkhon Line have successfully employed in a challenging urban environment beneath the busy streets of Bangkok. The major successes have been the ability to control ground movements and ground stress relaxation to such a degree that adjacent structures have not been adversely affected. The project has also successfully demonstrated that with not inconsiderable effort, ground movements and effects on deep piled foundations and tunnels can be reliably predicted. The EPB machines can reliably be operated within pre-defined operational limits to avoid damage to deep piled foundations of major high rise buildings and other sensitive structures such as adjoining water tunnels and bridges. Expected problems of flooding and fire were carefully analyzed to determine reliable solutions. In 2004, the first subway project in Bangkok will be opened to public and in the future, its two extension systems as well as the orange line and the green line will become the new hope of Thais in solving their traffic problem.

Figure 1. Traffic jam in Bangkok

Figure 2. Skytrain (BTS) operated in Bangkok

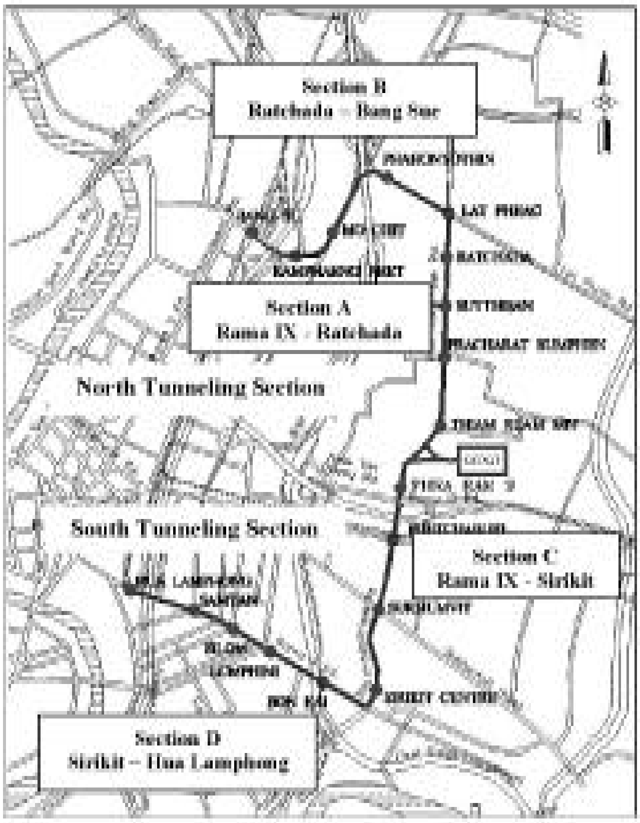


Figure 3. MRTA Chaloem Ratchamongkhon Line

Figure 4. Twin tunnel in the MRTA Project

Figure 5. Stacked platform station in the MRTA project

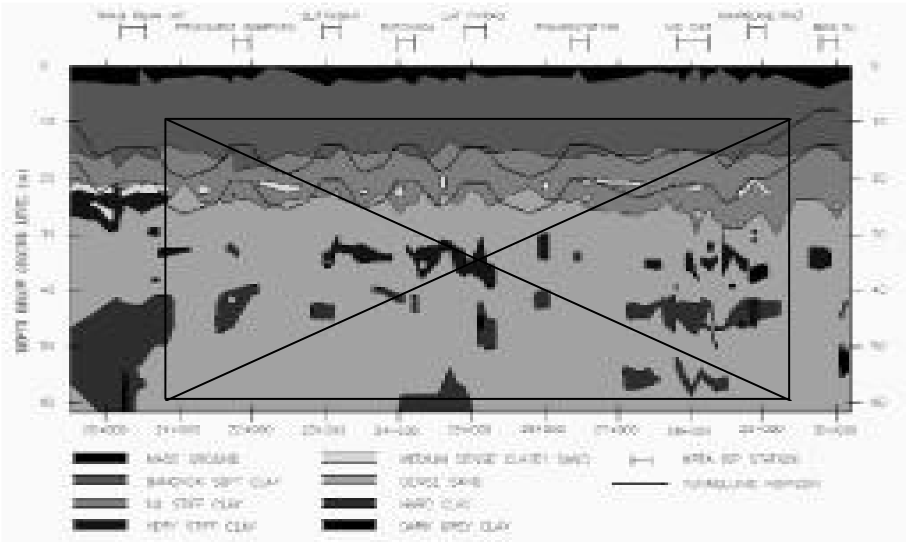


Figure 6. Soil profile of the North Tunnel section

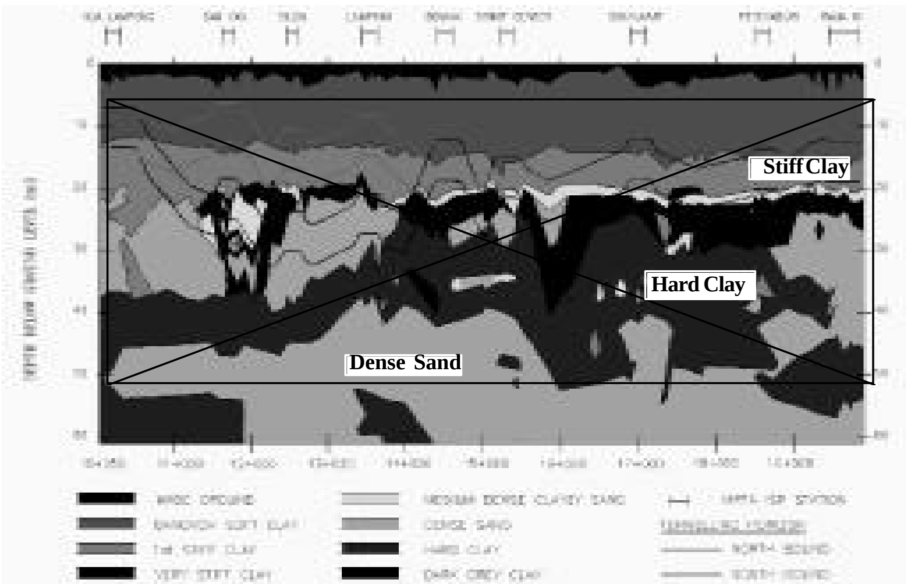


Figure 7. Soil profile of the South Tunnel Section

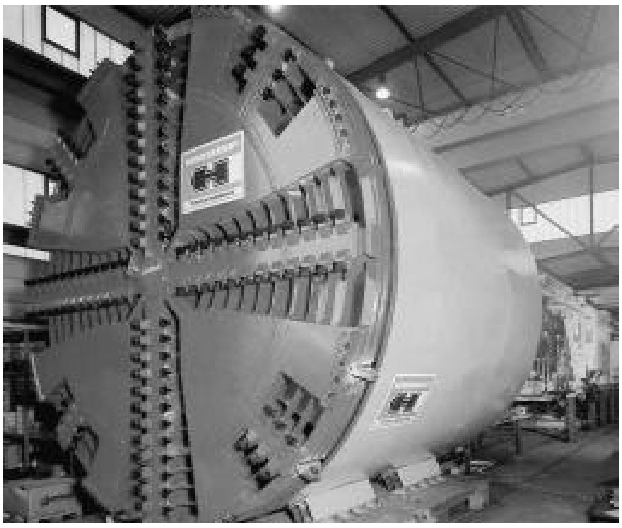
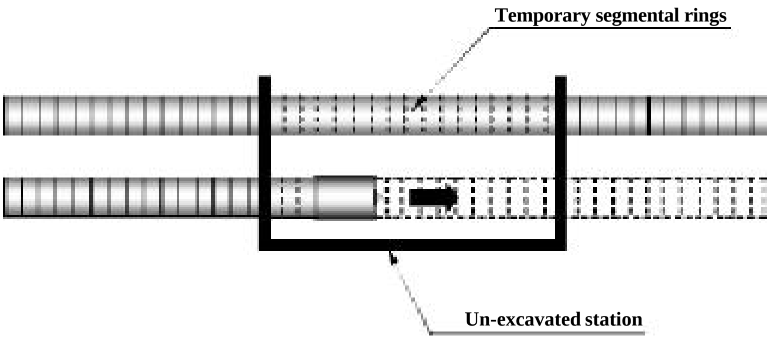
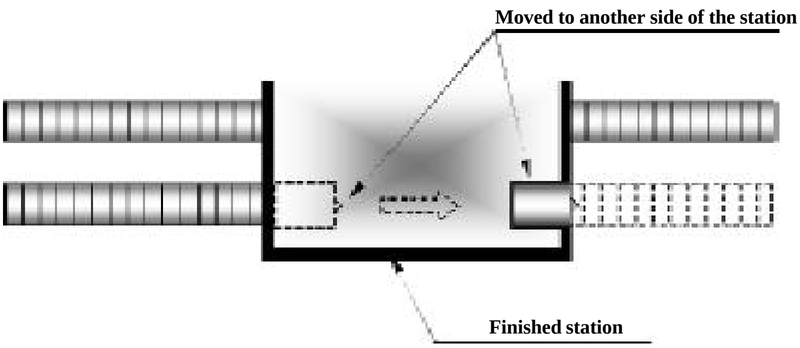


Figure 8. Earth Pressure Balance Shield used in the MRTA project



(a) North Tunneling Section (Sections A and B)



(b) South Tunneling Section (Sections C and D)

Figure 9. Tunneling procedures of the North and the South sections

Figure 10. Breakthrough at Lumphini station (South Tunnel Section)

Figure 11. Breakout at Sirikit station (South Tunnel Section)

Figure 12. Hand-mining excavation of adit for emergency use