EPB Tunneling Bored Underneath Through Underground Obstructions in Bangkok Subsoils

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Abstract

The Premprachakorn flood diversion tunnel was the the shortcut tunnel to divert the flood water in rainy season into the Chaopraya river. The tunnel bored by means of EPB shield tunneling in very stiff silty clay layer at about 20-24 m. depth. During flood diversion tunnel bored underneath the existing Bangkok main water supply tunnel and pile foundation of the prevention risk potential by means of predicting damage assessment is also presented and discuss.

1. Introduction

In rainy season flooding in Bangkok city is the one of the crisis to the city which is responsible by the Bangkok Metropolitan Administration (BMA). The first flood diversion tunnel so called Klong Premprachakorn flood diversion tunnel was constructed to divert the flood water in the area North area of Bangkok city (Laksi, Donmuang) to Chaopraya river as shown in Figure 1. This first shortcut tunnel was about 1.88 km. long. Along the route, the tunnel was bored underneath through two underground obstructions as the existing Bangkok main water supply tunnel and the bridge crossing the cannel

2. Tunnel Alignment and Subsoil Conditions

The Premprachakorn flood diversion tunnel was the first diversion tunnel shortcut the flooding water from Premprachakorn cannel to Choapraya river. The tunnel has outside diameter of 4.05 m. with reinforced concrete segmental lining of 180 mm. thick and bored by means of Earth Pressure Balance (EPB) shield. The tunnel was seated in the very stiff silty clay layer alternated with dense silty sand layer at about 20-24 m. below ground surface as shown in Figure2. At station 1+534 from Choapraya river, the flood diversion tunnel was bored about 3 m. underneath through the existing Bangkok main water supply tunnel (MWA tunnel) as shown in Figure 3. Generally the TBM was bored based on the face pressure of about 100-120 kN/m^2 which is about 45-55 % of the at rest earth pressure, however at portion where the tunnel have to pass underneath the existing main water supply tunnel, the face pressure was applied up to about 380 kN/m^2 in order to minimize the ground loss as well as soil displacement. This technique could be over come the obstruction, however, polymer and foam lubricant had to add to solve the slip of stiff clay and sand sample in the cutting process. After just 18 m. through this water supply tunnel, at station 1+552 and 1+573 the diversion tunnel was also bored about 0.5-1.5 m. below pile foundation of the main bridge across to the raw water cannel (Klong Prapa) as shown in Figure 4. This bridge is quite old and its as-built drawing is not available. Therefore, the side echo integrity test were carried out under water to determine the pile length. Therefore, the exact pile length was not clear. At the area of this tunnel bored through the substructure obstruction, the detail instrumentation were installed at 3 sections as station 1+502, 1+512 and 1+522 as shown in Figure 5 and monitored.

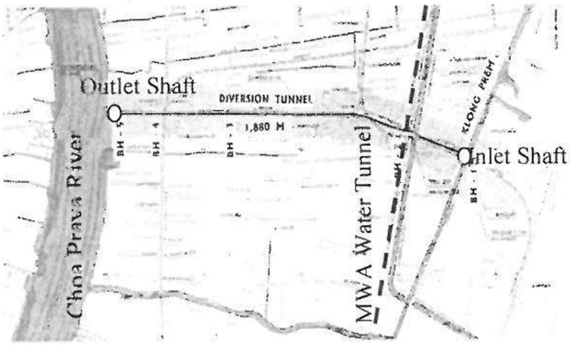

Figure 1. Layout of Premprachakorn flood diversion tunnel

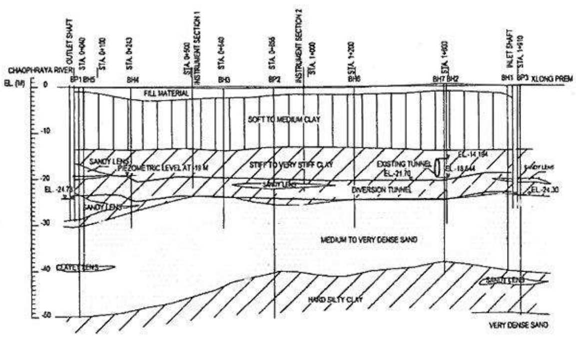

Figure 2. Cross section of flood diversion tunnel

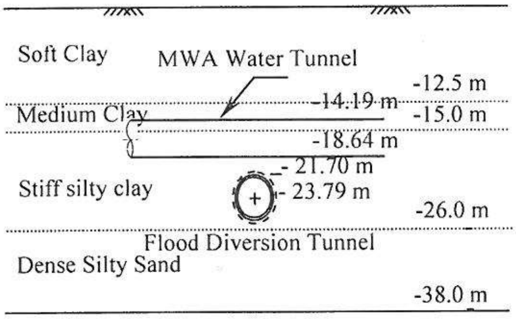

Figure 3. Diversion tunnel bored underneath water tunnel

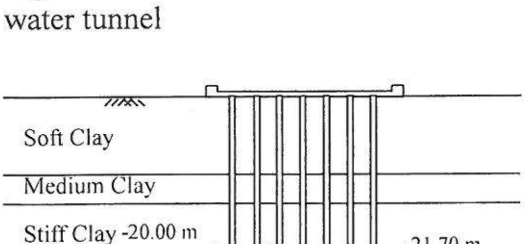

Figure 4. Bridge crossing the raw water cannel

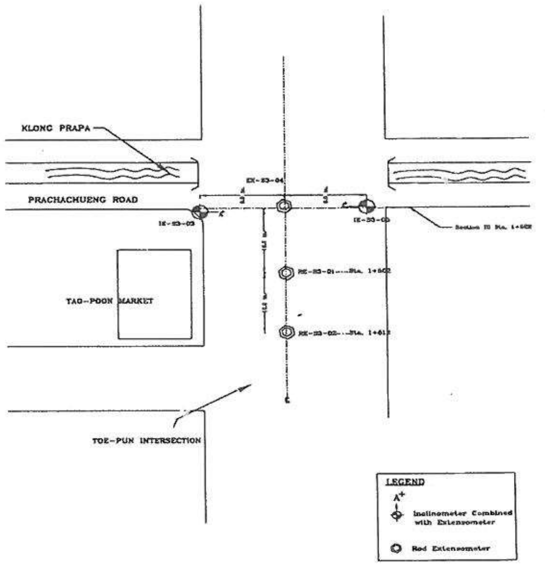

Figure 5. Layout of the instrumentation

The general subsoil conditions of Bangkok subsoils consists of 13-15 m. thick soft marine clay underneath by stiff to very stiff silty clay layer to about 22-24 m. depth. This soft clay is the sensitive clay having anisotropic behavior with water contents about 85-95 % with undrained shear strength about 15.5-16 kN/m^2. The first dense silty sand layer is found beneath the very stiff silty clay layer to about 30-35 m. depth and alternated by hard silty clay and second very dense silty sand layer. The piezometric draw down water level was found at about 23 m. depth below ground surface (Teparaksa, 1999 a, b, c and 2000 a) due to deep well pumping and lead to induced land subsidence in Bangkok city.

3. Damage Assessment Before Tunnel Bored Through Obstruction

In order to prevent the risk potential on both Bangkok main water supply tunnel and pile foundation of the bridge across the raw water cannel, the damage assessment by means of FEM analysis was carried out. Two tested sections at station 0+506 and 0+980 were fixed with fully installation of instrumentation to verify the ground displacement response (Ground surface settlement point, extensometer and inclinometer).

3.1 Ground Modeling

The constitutive model was based on an elasto-plastic (Mohr-Coulomb) failure criteria. As the recorded ground displacement response (Teparaksa, 2000 b and 2001), it was occurred in the short term conditions, therefore undrained soil parameters were assumed for the cohesive soil layers. The effect of ground water flow as well as consolidation was not considered in the model. The standard ground model used for the FEM analysis was based on the soil stiffness parameters. Generally the stiffness of the Bangkok subsoils has the non-linear behavior depended on the shear strain level. For practical point of view, the plain strain concept with the Mohr-Coulomb soil model was used in the FEM analysis. Menzies (1997) proposed the soil stiffness depending on the order of the shear strain as shown in Figure 6. The range of shear strain for bored tunnel was recommended in the range of 0.1-1.0%. Six number of self boring pressuremeter test were carried out along the MRT route. Teparaksa (1999 c) reported the results of the self-boring pressuremeter tests in Bangkok subsoil that the soil stiffness was depended on the degree of shear strain. According to the shear modulus from pressuremeter test and the order of shear strain for tunneling works recommended by Menzies (1997) between 0.1-1 %, the soil stiffness was assumed for FEM analysis as Eu/Su = 240 and 480 for soft clay and stiff clay, respectively. The strength and stiffness soil parameters were summarized in Table 1.

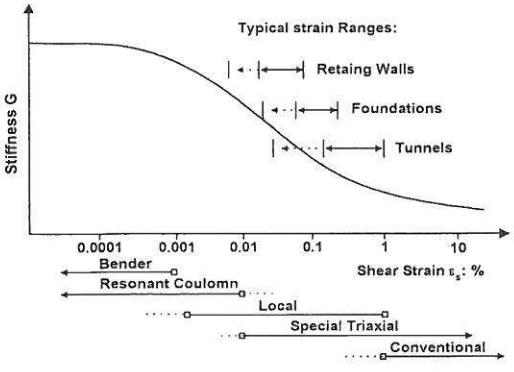

Figure 6. Typical shear modulus and shear strains for foundation works (after Mair 1993).

Table 1. Soil parameters for FEM Analysis

Soil Layer	Su (kN/m^2)	Eu/Su	E′ (kN/m^2)
Made	35	300	-
Ground	17 – 22	240	-
Soft Clay	100 –	480	-
Stiff Clay	150	-	$2000N_{60}$
Silty Sand	-		

Su : Undrained shear strength, Eu : Undrained modulus, E′ : Drain Modulus

3.2 Damage Assessment

The damage assessment was carried out by the author (Teparaksa, 2000 c) to predict the ground surface and subsurface response caused by EPB shield tunneling. Figure 7 presents the predicted ground surface and subsurface response by means of FEM analysis compared to field measurements at station 0+980. The prediction agreed well with field performance.

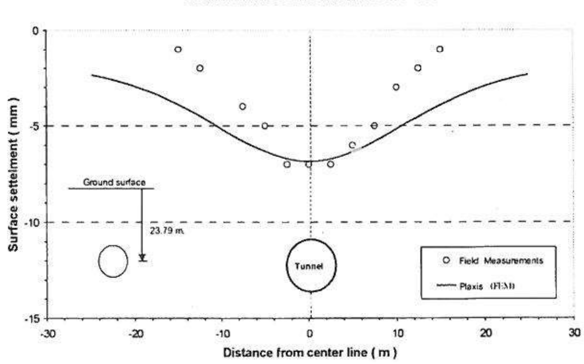

Figure 7a. FEM prediction of surface deformation compared with field measurement (station 0+980)

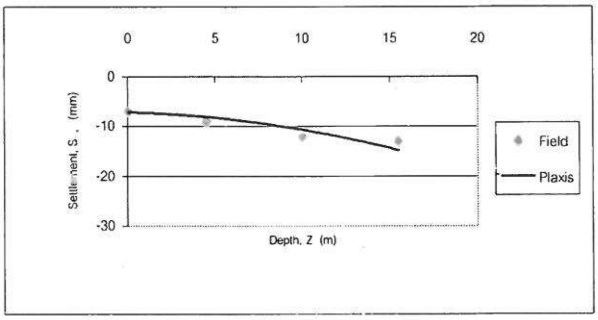

Figure 7b. FEM prediction of subsurface deformation compared with field measurement (station 0+980)

4. Ground Displacement Caused by Tunnel Bored Underneath Obstructions

At station 1+522 where is about 10 m. before crossing the MWA water tunnel, the predicted displacement of MWA water tunnel was about 19 mm. at about 15 m. below ground surface. Figure 8 presents the FEM predicted vertical ground displacement compared with field measurement by surface settlement point and deep rod extensometer. At the station where the Premprachakorn flood diversion tunnel passed underneath the MWA water tunnel (station 1+534) and pile foundation of the bridge (station 1+522 and 1+573), only ground surface displacements was monitored. In the area of protection zone of MWA tunnel, there were not allow any drilling or boring even for deep instrumentation.

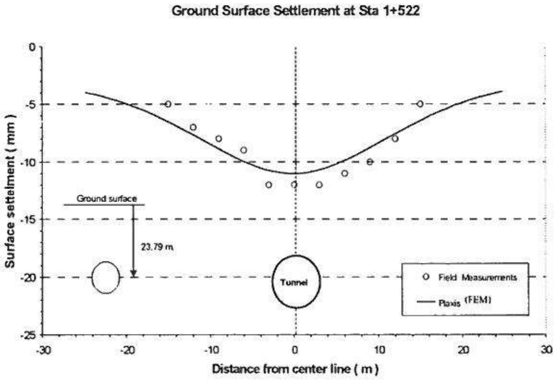

Figure 8a. FEM prediction of surface deformation compared with field measurement (station 1+522)

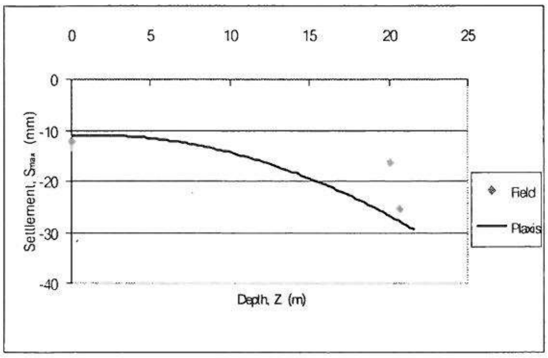

Figure 8b. FEM prediction of subsurface deformation compared with field measurement (station 1+522)

Figure 9-11 present the ground surface response predicted by means of FEM analysis compared with field measurement at station 1+534 (crossing the MWA tunnel), station 1+522 and 1+573 (crossing the bridge foundation), respectively. The FEM prediction agreed well with field performance.

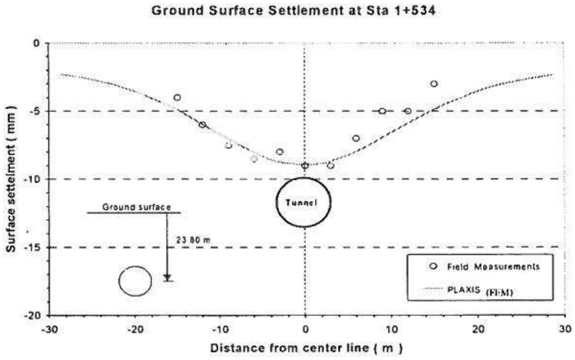

Figure 9. FEM prediction of surface settlement compared with field performance at station 1+534 (on centerline of MWA tunnel)

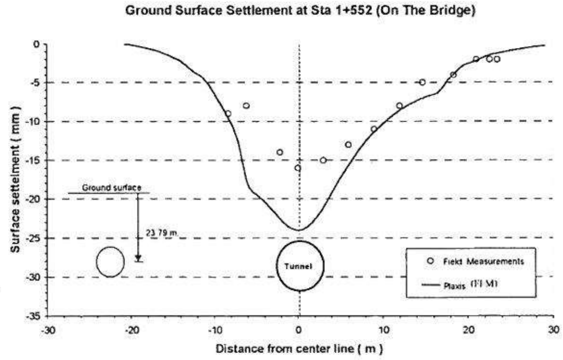

Figure10. FEM prediction of surface settlement compared with field performance at station 1+552 (at left side of bridge abutment)

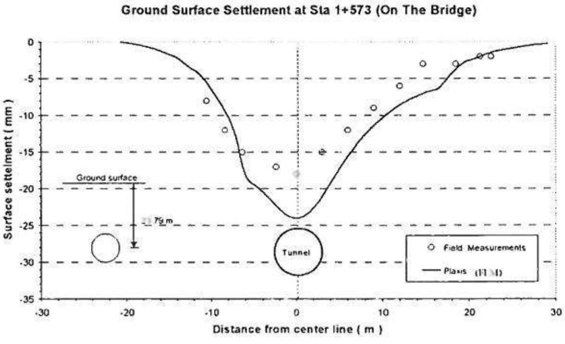

Figure11. FEM prediction of surface settlement compared with field performance at station 1+573 (at right side of bridge abutment)

5. Conclusions

The flood diversion tunnel was bored underneath two underground obstructions as existing main Bangkok water supply tunnel, and the bridge pile foundation crossing the raw water cannel. The damage assessment by means of FEM analysis to verify the risk potential was carried out and compared with measurements before reaching the obstruction. The behavior of ground surface and subsurface response during and after passing the obstruction was also presented.

6. Acknowledgment

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