Deep Basement Construction of Bank of Thailand Along Chao Phraya River closed to Tewavej Palace and Bangkhumphrom Palace

Construction du sous-sol profond de la Banque de Thaïlande le long de la Chao Phraya près des palais de Bangkhumphrom et Tewavej

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ABSTRACT: The Bank of Thailand (BOT) head office is a large building constructed in the inner Ratanakosin Island of Bangkok along Chao Phraya River, a main river of Bangkok, where high-rise building construction with more than three stories is not permitted. The BOT building consists of five basements with excavation depth of 15.8 meters and only three stories of super structure. The basement construction was constructed only five meters away from Tewavej Palace and ten meters away from Bangkhunphrom Palace. The damage assessment by means of Finite Element Method (FEM) with simulation of basement construction method was carried out to predict the influence on both palaces. Finally, the top-down construction method was selected for basement construction with one meter thick and 20 meters long of diaphragm wall which was designed together with the 50 meters long bored pile to support the whole building. The full set of instrumentation was installed at the palaces, diaphragm wall and ground surface for monitoring the field performances during and after basement construction. The field measurement and FEM prediction will be compared and the time dependent of lateral wall movement will be discussed. The construction was completed without any damage or effect to both palaces.

RÉSUMÉ : Le siège social de la Banque de Thaïlande (BDT) est un grand édifice construit sur l île intérieure de Rattanakosin dans Bangkok le long de la Chao Phraya, un fleuve principal de Bangkok, ou la construction de bâtiments haut de plus de trois étages est interdite. La BDT est constituée de cinq niveaux de sous sols avec excavation jusqu'à 15.8 mètres de profondeur et seulement trois étages de superstructure. La construction du sous-sol a été effectuée seulement à cinq mètres du Palais de Tewavej and à dix mètres du Palais de Bangkhunphrom. L'évaluation des dégâts par simulation de la construction du sous-sol par méthode des éléments finis (MEF) a été effectuée afin de prédire l'impact sur les deux palais. Enfin, la méthode de construction 'du haut vers le bas' a été sélectionnée pour la construction du sous-sol ainsi qu'une paroi moulée d'un mètre d'épaisseur et 20 mètres de long qui a été dimensionnée avec des pieux forés de 50 mètres de long pour supporter l'intégrité du bâtiment. Les mesures sur le terrain ainsi que les prédictions par MEF sont comparées et la dépendance en temps du mouvement latéral du mur est discutée. La construction a été effectuée sans qu'il n y ait de dégâts ou d'impacts sur les deux palais.

KEYWORDS: Deep Basement, FEM Analysis, Deep Excavation, Historical Building, Palace.

1 INTRODUCTION

The demand for deep underground basement construction is increasing in Bangkok city especially in the inner zone due to the optimized land use for underground car park and retail of the department store. The design and construction of deep basement in the large city have to take the impact of the nearby structure as well as public utilities into account. The designs of the deep basement in Bangkok subsoil done by the author are the Bai Yok II tower with 12 m. deep (Teparaksa, 1992), Library of Thammasat University with 14 m. deep (Teparaksa, 1999a), Central World with 9 - 14 m. deep and Millennium Sukhumvit hotel next to Bangkok Mass Rapid Transit (MRT) Tunnel with 14 m. deep (Teparaksa, 2007).

The head office, Bank of Thailand (BOT) is located in the inner Ratanakosin Island where high-rise building construction more than three stories is not allowed. The location of the new head office of BOT is planned along Chao Phraya riverbank and closed to two historical palaces; Tewavej Palace and Bangkhunphrom Palace as shown in Fig. 1.

The design and construction of the deep basement for head office of the BOT consists of five basements for underground car park with 15.8 m deep excavation and three floors of head office above ground surface.

The analysis and the diaphragm wall design as well as the impacted assessment of two palaces were carried out by Finite Element Method (FEM) analysis by simulating the full method of excavation and construction in the model. The instrumentation was installed in both diaphragm wall and at the palaces to monitor the safety and stability of the palaces. The behavior of diaphragm wall movement will also be discussed and compared with FEM prediction.

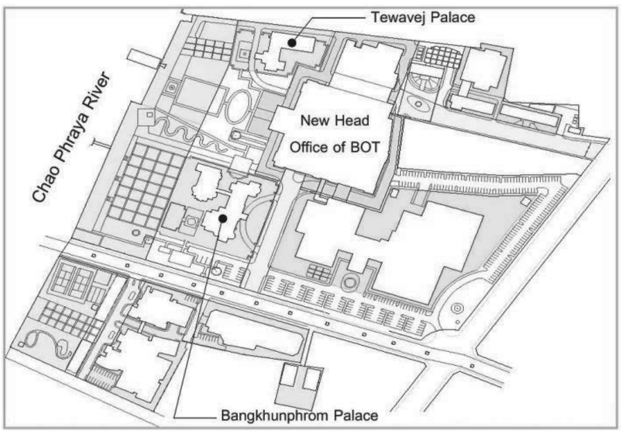

Figure 1. The location of new head office, Bank of Thailand (BOT) and the surrounding palaces.

2 SOIL CONDITIONS

The soil conditions at BOT site based on nine boreholes soil investigation consists of 12.5 m. thick soft dark grey clay and followed by medium stiff clay and stiff to hard clay until reached the first dense sand layer at about 28.5 m. deep. The second very dense sand where the pile tip of the building is seated is found at about 46 m. deep below ground surface. Table 1 presents the soil condition and the engineering properties.

Table 1. Soil conditions and engineering properties.

Depth (m.)	Soil Description	γt	Su	N	Eu	E'
0 - 12.5	Soft Clay	16.0	15	-	8750	-
12.5 - 15.0	Medium Stiff Clay	16.5	40	-	18000	-
15.0 - 20.0	Stiff to Very Stiff Silty Clay	19.0	-	12	85000	-
20.0 - 28.5	Hard Clay	20.0	-	35	300000	-
28.5 – 39.0	Dense Silty Sand	20.0	-	40		80000
39.0 – 46.0	Hard Silty Clay	20.0	-	45	-	-
46.0 – 65.0	Very Dense Silty Sand	20.0	-	>50	-	-

Note: γt = Total Unit Weight (kN/m^3)
Su = Undrained Shear Strength (kN/m^2)
N = SPT N-Value (Blows/ft)
Eu, E' = Undrained and Drained Young's Modulus (kN/m^2)

3 PROJECT DESCRIPTION

The basement design and construction of the new head office of bank of Thailand aims to solve the problem of car park from both staff as well as visitors. The surface area of excavation is approximately 10790 m^2 with 5 m. and 10 m. away from Tewavej Palace and Bangkhumphrom Palace accordingly as shown in Fig 2. The Tewavej Palace and Bangkhunphrom Palace are the historical palace constructed by brick and bearing wall seated on shallow foundation. In order to minimize the influence on these two palaces, the basement of BOT was designed to be constructed by top-down construction method which has been used only in Bangkok city restricted area such as the subway station of MRT project.

The diaphragm wall (D-Wall) of 1.0 m. thick and 20 m. deep was designed as the temporary wall for 15.8 m. deep excavation and used as permanent wall at the final stage. Five basement floors consist of F_1 ,P_1 ,P_2 ,P_3 and P_4 floor at -1.20 m., -4.70 m., -7.70 m., -10.70 m., and -13.70 m. deep respectively as illustrated in Fig 3.

The top-down construction method was started by casting the first basement F_1 at -1.20 m. then moving to third basement floor (P_2) at -7.70 m. and constructing the fifth basement floor and mat foundation at -13.70 m. deep as shown in Fig 3. Loading of the permanent basement floor during construction was transferred through the stanchion at the centerline of the column which was installed into the bored pile during construction of the bored pile.

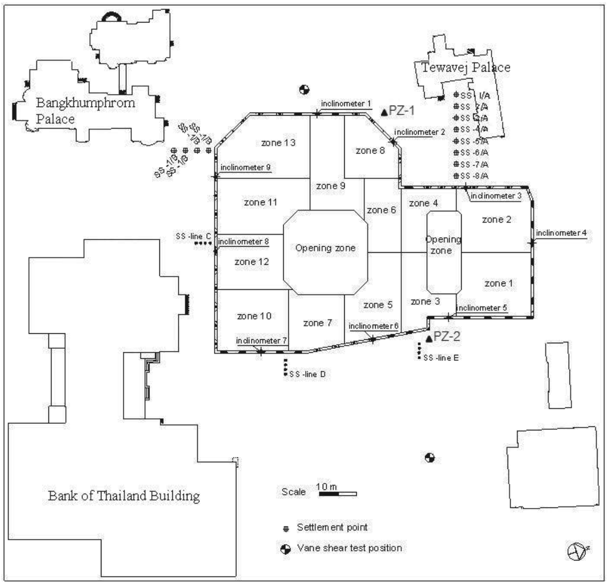

Figure 2. The BOT project plan view.

4 INSTRUMENTATION

The head office of BOT was constructed in the large area of more than 10790 m^2; therefore, the excavation area for top-down construction was divided into 13 zones as presented in Fig 2. Two large opening zones were provided for excavation work. The excavation at the deeper basement required to excavate step by step from far corner to the opening zone where the excavated soil was moved out of the project area. For safety reason and to monitor basement wall behavior, the full scheme of instrumentation was installed at the palaces on the ground surface and in the diaphragm wall as shown in Fig 2 and Table 2.

5 ANALYSIS AND DESIGN OF DIAPHRAGM WALL

The analysis and design of the diaphragm wall was carried out by means of the FEM. The construction sequence was simulated in the FEM analysis. The sequence of basement construction consists of 8 steps as follows:

1.Excavating to -1.75 m. deep and casting lean concrete.
2.Casting the first permanent basement floor at -1.20 m. (thickness 0.45 m.)
3.Excavating to the third basement floor at -8.10 m. deep and casting lean concrete.
4.Casting the third permanent basement floor at -7.70 m. (thickness 0.30 m.)
5.Excavating to the fifth basement floor (base slab) at -15.60 m. deep and casting lean concrete.
6.Casting the fifth basement floor (base slab) at -13.70 m. (thickness 1.30 m.)
7.Casting the permanent fourth basement floor at -10.70 m. (thickness 0.30 m.)
8.Casting the permanent second basement floor at -4.70 m. (thickness 0.30 m.)

The detail of construction sequence is presented in Fig. 4.

The analysis and design of the diaphragm wall for 15.6 m. deep excavation were carried out by FEM. As the basement constructed in soft clay layer, the undrained concept based on bi-linear Mohr-Coulomb failure theory was used for FEM analysis. The Young's modulus (Eu) was used in terms of an undrained shear strength (Su) of Eu/Su = 500 and 1000 for soft clay and stiff clay respectively (Teparaksa, 1999b). The value of Young's modulus is also presented in Table 1.

The Young's modulus or shear modulus (G) of clay depends on the shear strain of the system as proposed by Mair (1993) as shown in Fig. 5. The relationship of the Eu/Su and strain level presented in Fig. 6 is the modulus of soft and stiff Bangkok clay based on the results of self-boring pressuremeter test during construction of MRT Subway Blue Line in Bangkok city. Fig. 7 presents deformed mesh of the FEM analysis at the final stage of excavation at 15.6 m deep.

The result of FEM analysis presents the envelope of lateral movement of D-wall at final stage of excavation in the order of 28.2 mm. and maximum ground surface settlement of 23.7 mm. This maximum ground surface settlement behind the D-wall and lateral movement of the D-wall was set as the trigger level to control the method of excavation as well as the stability of Tewavej Palace.

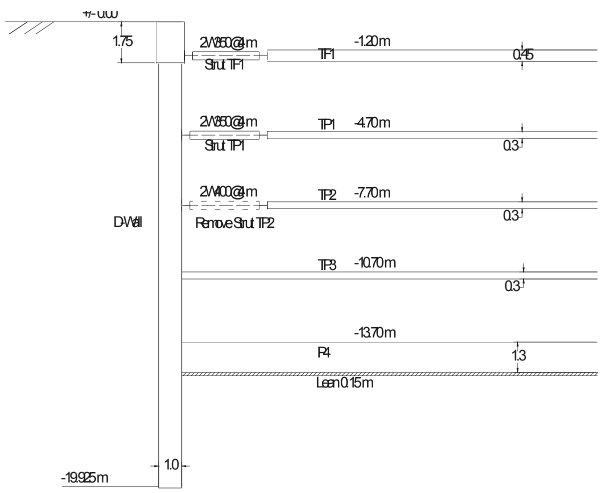

Figure 3. Typical section of underground basement.

6 INSTRUMENTATION AND PERFORMANCE OF DIAPHRAGM WALL

The full set of the instrumentation was proposed to monitor the behavior of the diaphragm wall and surrounding palaces as presented in Table 2 and Fig. 2. The results of the piezometer monitoring by pneumatic type in soft clay was constant with hydrostatic pore water pressure of ground surface water at 1.00 m. below ground surface.

Table 2. Instrumentation at the Palaces and Diaphragm Wall.

Instrumentation	Location	Purpose
Vibration Sensor	At Tewavej Palace and Bangkhunphrom Palace.	Vibration at the palace
Tiltmeter	At Tewavej Palace and Bangkhunphrom Palace.	Tilt of the palaces
Ground Surface Settlement point	Ground Surface	Ground Surface Settlement
Inclinometer	In the Diaphragm Wall	Lateral D-Wall movement
Piezometer	Outside the D-Wall	Ground water level

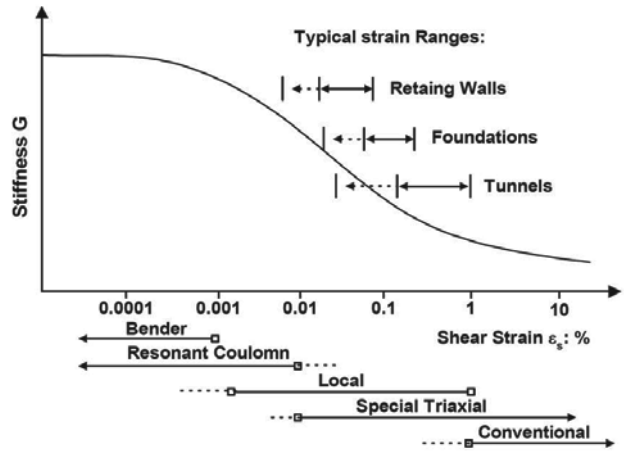

Figure 5. The relationship between modulus and shear strain level (Mair, 1993).

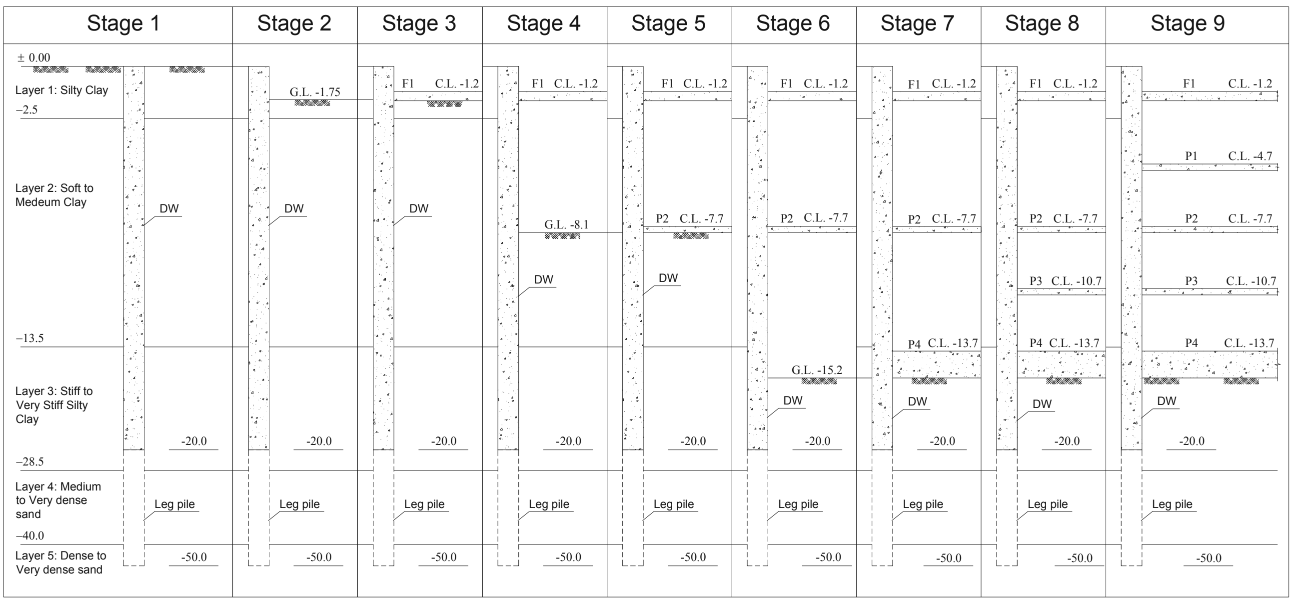

Figure 4. Detail of construction sequences.

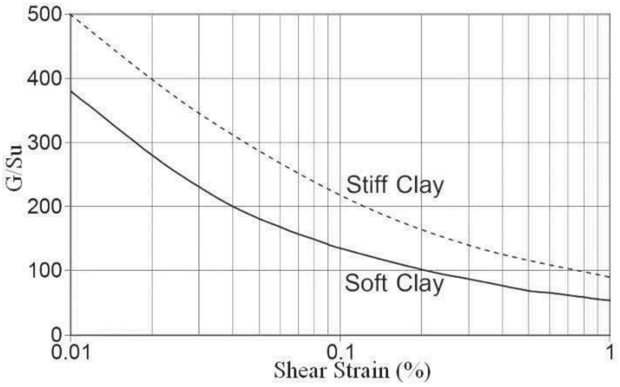

Figure 6. The relationship between modulus and shear strain level of soft and stiff Bangkok clay (Teparaksa, 1999b).

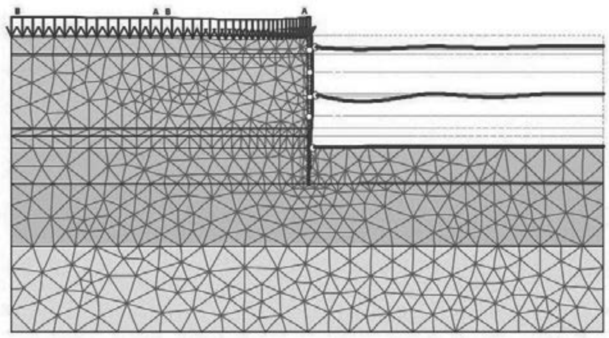

Figure 7. Deformed mesh of FEM analysis at the final stage excavation at -15.6m.

The measurement of the lateral diaphragm wall movement at all steps of excavation and basement floor casting at inclinometer no. I-3 next to Tewavej Palace is shown in Fig. 8 together with the predicted maximum envelope of diaphragm wall movement estimated by FEM.

It can be seen that the predicted wall movement by FEM agrees well with field performance. The tiltmeter measured at the Tewavej Palace is also less than the trigger level. The basement construction of the new head office of Bank of Thailand was completed without any disturbance to both Bangkhunphrom Palace and Tewavej Palace.

7 CONCLUSIONS

The basement of 15.6 m. deep excavation was constructed at the new head office of Bank of Thailand. The deep basement consists of 5 basement floors at -1.20 m., -4.70 m., -7.70 m., -10.70 m. and -13.70 m. depth. The basement constructed area is closed to two palaces; Bangkhunphrom Palace and Tewavej Palace, which are the historical buildings and also located close to the Chao Phraya river bank. The top down construction method was used for basement construction. The prediction of diaphragm wall movement and its effect to the palaces were carried out by FEM analysis. The instrumentation was installed in D-wall, ground surface and the palaces in order to measure the wall behavior and their effect. The lateral movement of D-wall by means of inclinometer at all stages of construction is compared with FEM prediction. The FEM prediction agrees well with measured values. The deep basement was completed without any disturbance to both palaces.

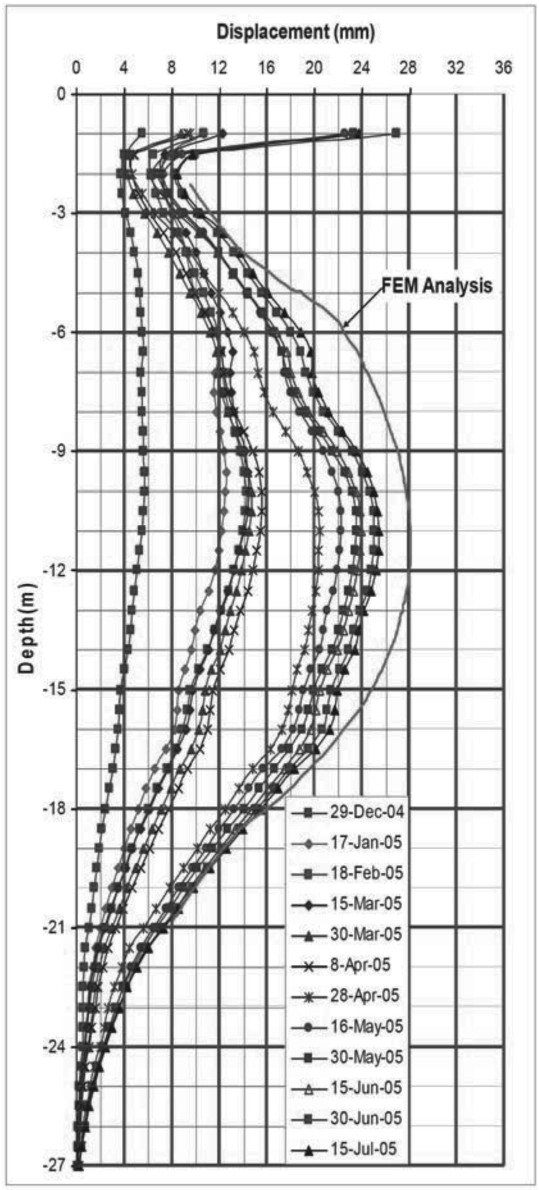

Figure 8. The inclinometer I-3 monitoring results with the predicted maximum movement by FEM analysis.

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