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Basement Excavation in Soft Marine Clay in Bukit Tinggi, Klang

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ABSTRACT: Thick deposits of very soft marine clay can be found in Klang which lies along the West Coast of Malaysia. Basement excavation up to 3.5m below the existing ground level has been carried out in Bukit Tinggi, Klang using three ground retention methods namely propped sheet pile wall, cantilever sheet pile wall and cantilever contiguous bored pile wall. This paper elaborates on the implemented ground retention methods and explores the ground's response to the excavation in soft marine clay through the recorded instrumentation data.
The estimated wall deflections from the 2D FE analysis were compared against the measured field data to verify the adopted soil model and the FE analysis. The results show that the adopted soil parameters are realistic and the sequence of work adopted in the FE analysis and subsequently in the basement excavation work has minimized the wall deflections.
Keywords: Soft clay, propped excavation, cantilever excavation,

1. INTRODUCTION

The coastal areas of Peninsular Malaysia are typically composed of thick deposits of very soft marine clay generally deposited during the Holocene period. The soft marine clay can extend to depths exceeding 50m below the existing ground level close to the coast.

Bukit Tinggi in Klang, Selangor is a fast developing township which is predominantly composed of low-rise residential and commercial development. Basements are rare in this area due to the difficulties and high cost usually associated with deep excavation in very soft marine clay.

Mixed commercial and residential development has been proposed in this area in two (2) adjoining plots i.e. Plots A and B with one (1) level of basement. The plots are flanked by existing commercial and residential development on either sides. The basement excavation works were carefully planned to minimise the settlement of the surrounding and to avoid distress to the adjacent structures.

A soil model was developed using the available soil investigation (SI) data and a Finite Element (FE) analysis was carried out by simulating the full excavation and construction process. Instrumentation was installed to monitor the ground movement. The field behaviour of the retention system is compared with the FE analysis and discussed.

2. SITE GEOLOGY

The proposed site is underlain by Quaternary Deposit as shown in Figure 1.

This formation consists of extensive deposits of unconsolidated/semi-consolidated marine deposit consisting of mainly CLAY deposited under marine environment. This is likely to be underlain by the Pre-Quaternary sedimentary formation.

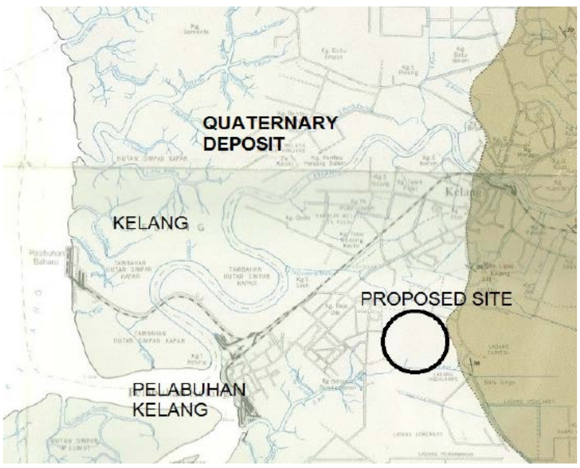

Figure 1 Site Geology

3. SOIL CONDITION

The subsoil at this site based on the boreholes that were carried out indicates that the site is underlain by very soft clay with depths varying from 24m to 30m below the existing ground level. Thin sand lenses were found at selected locations across the site. The hard clay layer is typically found at depths ranging from 32m to 40m below the existing ground level.

Table 1 shows the summary of the soil description and properties where γ is the bulk density of the soil (kN/m^3), Su is the undrained shear strength of the soil (kPa), N is the SPT N of the soil (blows/ft) and Eu is the Undrained Young's Modulus of the soil (kPa).

Table 1 Summary of the soil description and properties

Depth (m)	Soil	γ	Su	Eu
0 – 8	Very Soft Clay	16	10	1200
8 - 20	Very Soft Clay	16	15-25	2200-3500

4. PROJECT DESCRIPTION

The proposed development comprises of two (2) plots which share a boundary as shown in Figure 2.

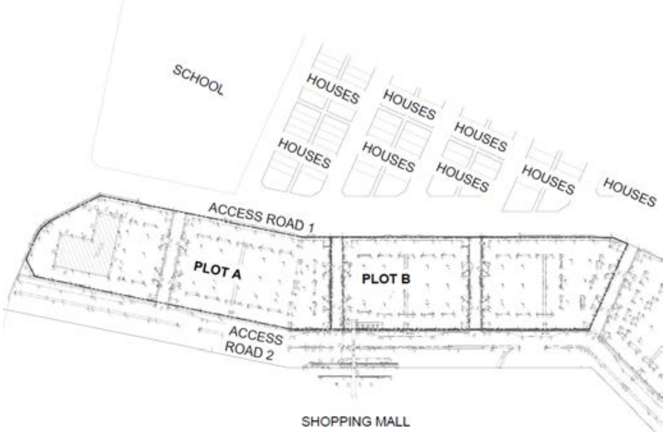

Figure 2 Site Layout

Plot A is located 5m away from the closest residence and 10m away from a five (5) storey shopping mall with one (1) level of basement car park while Plot B is located 5m away from a primary school and 10m away from a five (5) storey shopping mall with one (1) level of basement car park.

A 1.2m diameter functioning water pipe which is the main water supply for this area is located along the site boundary at Access

Road 1 located approximately 1m below the existing ground level. Access Road 1 is a busy public road catering to the residential area and the school. Access Road 2 is a private road which predominantly caters to the shopping mall. The mall can also be accessed from several other entry points apart from Access Road 2.

5. ANALYSIS & DESIGN OF RETENTION SYSTEM

For both Plots A and B, one (1) level of basement was proposed with maximum excavation depth of 3.5m from the existing ground level. The permanent basement wall comprised of a reinforced concrete (RC) wall integrated with the building structure.

The piling for both plots comprised of jack-in spun piles which were installed to set from the piling platform level.

To cast the basement slab and permanent RC wall, temporary ground retention was required. Taking into consideration the functioning water pipe along Access Road 1, the temporary ground retention systems for Plots A and B were proposed as follows.

- Plot A : Propped temporary sheet pile wall
- Plot B : Cantilever permanent contiguous bored pile (CBP) wall along Access Road 1 & Cantilever temporary sheet pile wall along Access Road 2

The analysis of the propped temporary sheet pile wall, cantilever sheet pile wall and the cantilever CBP wall was carried using Finite Element Analysis by considering an undrained analysis for the soft clay.

5.1 Plot A

Propped temporary sheet pile wall was proposed for Plot A. The sequence of works for Plot A is shown in Figures 3 - 8 and is elaborated below.

Stage 1 : Install temporary sheet piles along project boundary. Allow 1m working space from temporary sheet pile to permanent RC wall.

Install first two (2) rows of foundation piles to set using jack-in method from existing platform level

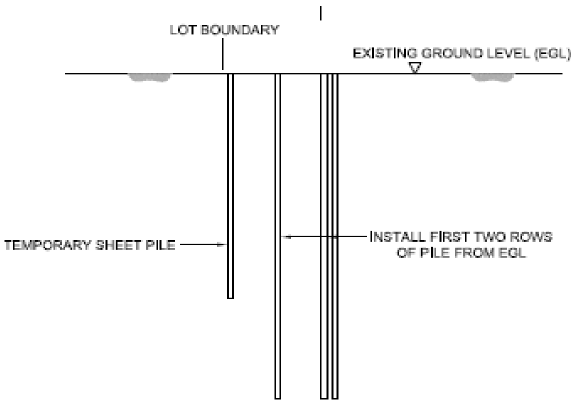

Figure 3 Stage 1 Construction Sequence

Stage 2 : Excavate to form stable temporary slope with slope gradient 1V:4H. At the base of excavation, remove and replace 1.5m thick of soft marine clay with suitable compacted fill.

At the toe of the slope, remove and replace 2m thick of soft marine clay with suitable compacted fill.

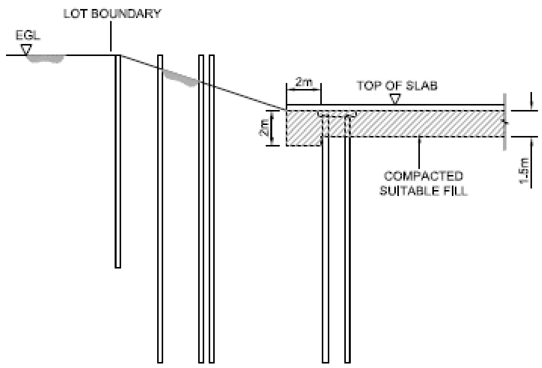

Figure 4 Stage 2 Construction Sequence

Stage 3 : Install remaining spun piles from base of excavation and cast pile cap and base slab up to the slope toe. Install waler and strut on sheet pile wall and prop against basement slab.

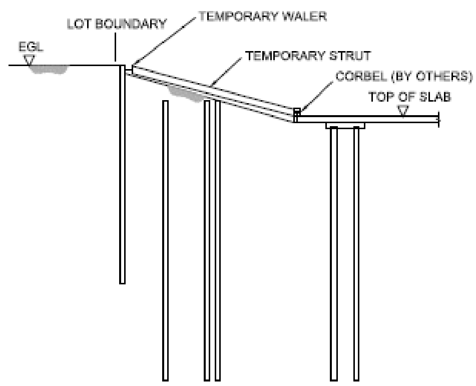

Figure 5 Stage 3 Construction Sequence

Stage 4 : Excavate temporary slope and cast pile cap.

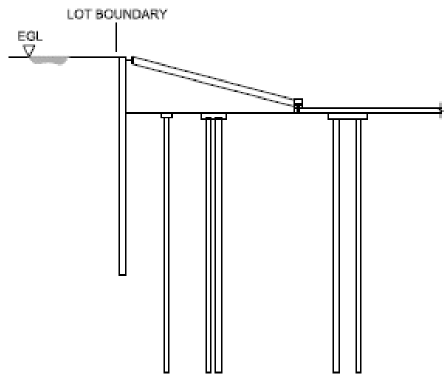

Figure 6 Stage 4 Construction Sequence

Stage 5 : Cast remaining slab and RC wall. Allow for opening in the wall for the strut. Repeat Stages 4 and 5 between alternate struts without removing the soil berm beside these struts until the full slab and RC wall has been cast.

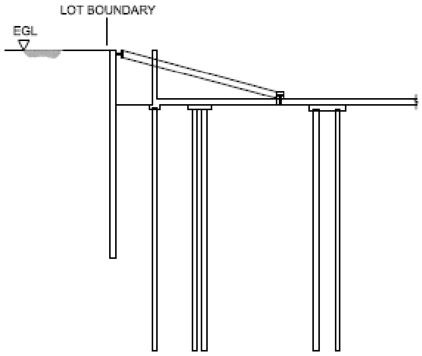

Figure 7 Stage 5 Construction Sequence

Stage 6 : Fill the gap between the RC Wall and the sheet pile wall up to maximum 2m using suitable fill.

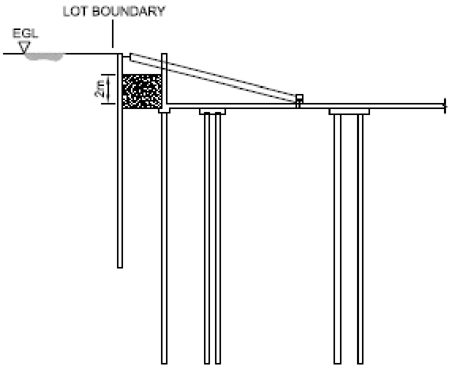

Figure 8 Stage 6 Construction Sequence

Stage 7 : Remove the temporary strut, waler and sheet pile wall. Backfill to the existing ground level.

5.2 Plot B

Along the site boundary adjoining Access Road 1, cantilever CBP wall was installed taking the functioning water pipe into consideration. Along the site boundary adjoining Access Road 2, cantilever sheet pile wall was installed.

The sequence of works for the cantilever CBP wall is shown in Figure 9 and is elaborated below.

Stage 1 : Install 600mm diameter bored piles at 675mm centres and 15m length to form the CBP wall from the existing ground level. The top of the CBP wall is 1m below the existing ground level.
Stage 2 : Construct the capping beam. Excavate to form stable temporary slope with height of 1m and slope gradient 1V:4H behind the CBP wall. The exposed height of the CBP wall is 2.5m

Stage 3 : Excavate to base of excavation in front of the CBP wall. Remove and replace 1.5m thick of soft marine clay with suitable compacted fill.

Stage 4 : Install foundation spun piles from base of excavation and cast pile cap, base slab and skin wall.

Stage 5 : Reinstate the ground behind the CBP wall to the finished platform level.

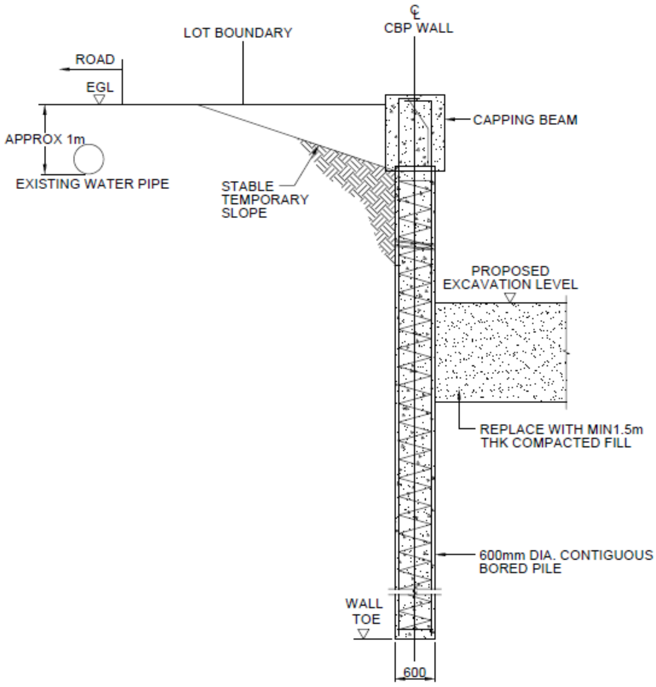

Figure 9 Permanent CBP wall construction sequence

The sequence of works for the cantilever temporary sheet pile wall is shown in Figure 10 and is elaborated below.

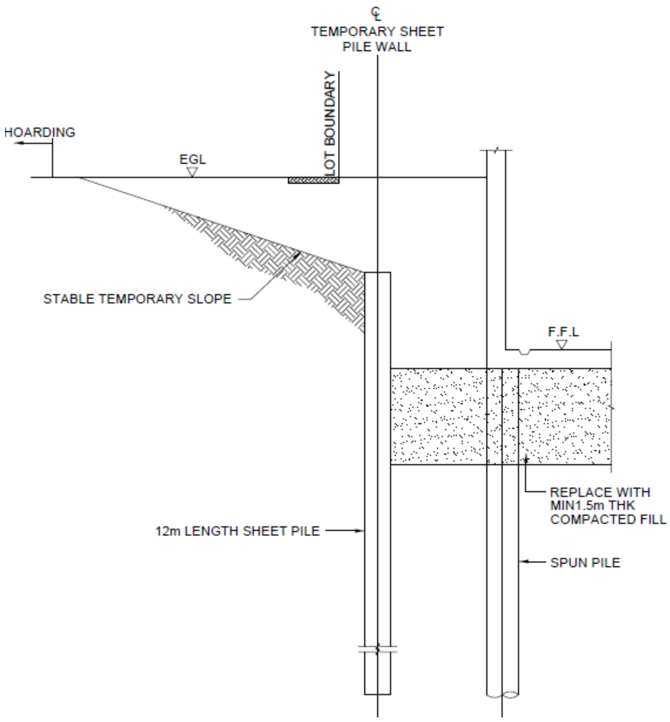

Figure 10 Temporary sheet pile wall construction sequence

Stage 1 : Install 12m length temporary sheet piles along project boundary at Access Road 1. Allow 1m working space from temporary sheet pile to permanent RC wall. The top of the sheet pile is 1.5m below the existing ground level.

Stage 2 : Excavate to form stable temporary slope with height of 1.5m and slope gradient 1V:4H behind the sheet pile wall. The exposed height of the sheet pile wall is 1.5m

Stage 3 : Excavate to base of excavation in front of the sheet pile wall. Remove and replace 1.5m thick of very soft marine clay at base of excavation with suitable compacted fill.

Stage 4 : Install foundation spun piles from base of excavation and cast pile cap, base slab and RC wall.

Stage 5 : Fill the gap between the RC Wall and the sheet pile wall with suitable granular fill.

Stage 6 : Remove the temporary sheet pile. Reinstate the ground behind the RC wall to the finished platform level.

6. INSTRUMENTATION

Instrumentation in the form of ground settlement markers and inclinometers were installed behind the temporary sheet pile walls and CBP wall for both Plots A and B.

The monitoring was carried out on a daily basis during the excavation works to monitor the wall deflection and ground settlement. The monitoring was terminated when the ground floor slab was fully constructed.

7. FIELD PERFORMANCE OF RETENTION SYSTEM

7.1 Plot A

The performance of the temporary sheet pile wall was evaluated by studying the recorded instrumentation data and a comparison has been made between the recorded wall deflection and the data extracted from the FEM analysis, as shown in Table 2 below.

Table 2 Summary of Estimated & Recorded Wall Deflection for Plot 1

Location	Estimated Deflection from FEM (mm)	Actual Deflection (mm)
Along Access Road 1	15	7
Along Access Road 2	15	15

As can be observed from Table 2, the estimated wall deflections are quite comparable to the actual wall deflections recorded on site. The actual wall deflections were lower along Access Road 1 as the excavation for the temporary slope restraining the temporary sheet pile wall was carried out in very short intervals of 6m as compared to the excavation along Access Road 2 which was carried out at 12m intervals.

7.2 Plot B

The performance of the temporary sheet pile wall and the permanent CBP wall was evaluated by studying the recorded instrumentation data and a comparison has been made between the recorded wall deflection and the data extracted from the FEM analysis, as shown in Table 3 below.

Table 3 Summary of Estimated & Recorded Wall Deflection for Plot 2

Location	Estimated Deflection From FEM (mm)	Actual Deflection (mm)
Along Access Road 1 – Permanent CBP Wall	20	19
Along Access Road 2 – Temporary Sheet Pile Wall	30	31

As can be observed from Table 3, the estimated wall deflections are quite comparable to the actual wall deflections recorded on site. A higher wall deflection was allowed along Access Road 2 as there were no critical structures located here. Along Access Road 1, the water pipe was monitored during the excavation works and no distress was observed on the pipe at the end of the construction works. The cantilever CBP wall and sheet pile wall also allowed for speedier construction.

8. CONCLUSION

Basement excavation up to 3.5m below the existing ground level has been carried out in Bukit Tinggi, Klang using three ground retention methods namely propped sheet pile wall, cantilever sheet pile wall and cantilever contiguous bored pile wall.

A FE analysis was carried out to confirm the details of the retention system. The estimated wall deflections from the 2D FE analysis were found to be comparable to the measured field instrumentation data thereby validating the adopted soil model, the FE analysis and the construction sequence.

The ground retention systems elaborated in this paper provide simple and economical methods of retaining very soft clay where excavation depths do not exceed 3.5m below the existing ground level.

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