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Modeling of Combipile Application in Soft Soil for Excavation Using PLAXIS 2D

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Abstract: Soft soil is one of the most difficult soils to deal with due to its characteristics such as low permeability, low strength, and volume instability. Thus, there is a challenge mainly concentrated on the stability of the soil for the excavation of such construction. A flooding bypass project at Sungai Kesang, Johor faces a problem where the method of excavation that was implemented at soft soil fails in terms of stability. The objective of this study is to produce a combipile model and analyze the stability due to excavation on soft soil. Also, to calculate the required depth of combipile using a manual calculation. The study will mainly be focused on the flooding bypass project at Sungai Kesang, Johor. Thus, two types of combipile which are Single H-King Pile and Double H-King Pile were used in this study. Three models will be used which are Conventional Excavation (Model 1), Single H-King Pile (Model 2), and Double H-King Pile (Model 3). The model which gave the lowest lateral movement is Model 3 with 18 meters combipile. Expectedly from this study, the use of combipiles can reduce the lateral movement of soft soil significantly and a good agreement will be obtained from manual calculation and simulation method.

Keywords: Soft Soil, Combipile, Plaxis 2D.

1. Introduction

Malaysia is one of the fastest-growing countries in South-East Asia where economy and development has spiked rapidly. The result of such growth is the increasing demand for infrastructural development. Despite the increasing demand, the soil distribution in Malaysia is commonly soft soil along the coastal area and has caused inconvenience to civil engineers especially in the construction of infrastructures mainly in the scope of civil engineering projects. Rapid development in urban and rural areas compelled engineers to reroute rivers and the construction over soft soil deposits which usually have excessive settlement and low bearing capacity characteristics [3]. As stated by Balasubramaniam et al., (1985) [2] the soft soil distribution that was located in peninsular Malaysia was located in the vicinity of the west coast of Perlis, Butterworth, Penang, Teluk Intan Perak, and other areas. While as stated by Abdullah (1983)[1], the thickness of the soft clay stratum at various location in west coast Malaysia is about 5m to 30m deep and are generally greater than that is in east coast Malaysia which is 3m to 12m.

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Constructions under soft soil have become a major problem in construction engineering. In research done by Krahn (2004)[4], soft soil can be defined as soil that contains high moisture content. It also has extreme properties such as low shear strength, sensitivity, high compressibility, and easily obstructed by activities on it [5]. Soft soil is a common problematic and poor soil whereby these soils are commonly very weak and compressible. Thus, are subjected to problems such as bearing capacity and settlement problems. Therefore, in the excavation phase, the method of excavation is the most important element to ensure the stability of the soil is maintained. So, the selection of the excavation method is important to ensure the stability of the soil is maintained.

1.1 Research Objective

The objective of this study is to produce a model of the combipile excavation method.To calculate the required depth of combipile using a manual calculation. To model and analyze the stability of combipile due to excavation of soft soil using Plaxis 2D. Lastly is to compare the stability results of the various depth of pile models.

2. Materials and Methods

There are several steps that need to be taken to accomplish the aims of the study. Such measures are important because they provide extensive protocols and a deeper understanding of the mechanism and workflow. The appropriate material models were chosen after reading and interpreting the appropriate literature materials, and the parameters needed for analysis were also specified.

2.1 Materials

King pile foundation is a combined foundation which has a substantially good bending stiffness from the incorporation of the following elements. Steel H-piles are rolled sections of steel with wide flanges so that the depth of the steel part and width of flanges are rough of similar dimensions. The H-piles cross-sectional area and volume displacement are relatively small, making them well suited for driving through compacted granular materials and into soft rock.

Steel is the most common form of sheet piles since it has good resistance to high driving stresses, excellent water-tightness, and can be increased by welding or bolting in length. They are connected through the interlocking process.:

2.2 Methods

The modeling and analyzing tool used is PLAXIS 2D. A set of three main models were produced whis is Model 1, Model2, and Model 3. The first model illustrates a conventional way of excavation and the other two models illustrate the usage of Single-H Kingpile and Double-H Kingpile Combipiles acting as a retaining wall. Another set of models was produced for the models using combipile to represent a 10 meter and 18 meter lenghted Combipile.

2.3 Soil Parameter

The soil properties used in this study were based on the soil properties at Sungai Kesang, Johor with two different soil layers which are very soft clay and silty clay. The depth of the excavation is 4 meters and the width of excavation is 35 meters. The detailed soil parameters of each layer used in FEM analysis are shown in Table 2.1.

Table 2.1: Soil Parameters Used in the FEM Analysis

Material	Model 1	Model 2	Model 3	Very Soft Clay	Silty Clay
Material model	-	Plate	Plate	Soft Soil	Soft Soil
Type of material behavior	-	-	-	Undrained	Undrained
Soil unit weight, γ_{sat} (kN/m^3)	-	15.5	15.5	15.5	15.5
Poisson Ratio, v'	-	-0.2	0.2	0.15	0.15
Young's Modulus E' (cm^3)	-	7555	9185	-	-
Cohesion, c'_{ref} (kPa)	-	50	50	1	0.5
Initial Void Ratio, e_{init}	-	0.5	0.5	0.5	0.5
Friction angle, ϕ' (°)	-	30	30	20	20
Dilatancy angle, φ (°)	-	0	0	0	0
0Modeling swelling index, κ^*	-	-	-	0.05	0.08
Modeling compression index, λ^*	-	-	-	0.13	0.11

2.4 Model 1: Conventional Excavation

In the first model,excavation is performed at the rate of 10 days per layer as shown in Figure 1. As a measure of safety to prevent soil collapse, the slope ratio is presented as 1:1.75. After the excavation process is completed, settlement predictions will be carried out. For the other two versions, the arbitration effect is then contrasted with the settlement.

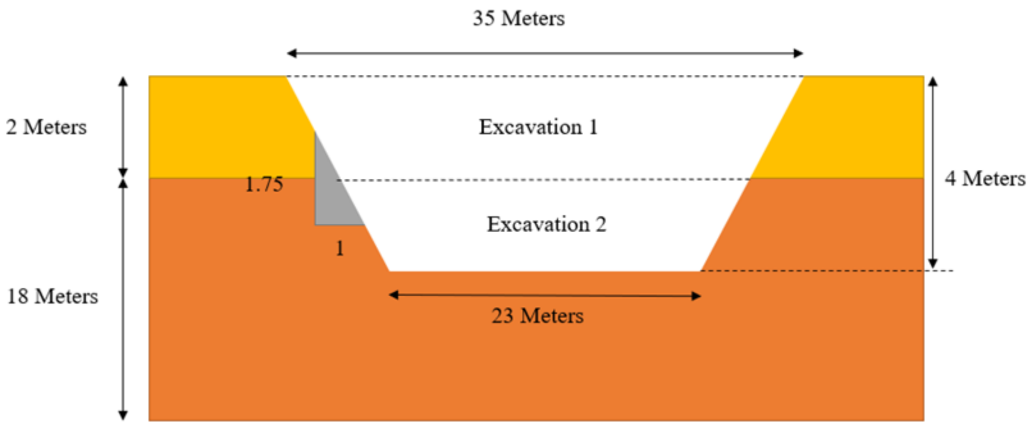

Figure 1: Geometry for Model 1

2.5 Model 2: Single H King Pile

A similar excavation period is assumed where 10 days of excavation is required for each layer with a total of 20 days to achieve the required depth. However, unlike the first model which is only excavation, a Single H King Pile wall is introduced on both ends of the excavation acting as retaining walls. The installation of the pile would take approximately 7 workdays. The geometry ot the second model is as shown in Figure 2. Another two models created from this model are an decreased length of combipile to 10 meters and increased length to 18 meters.

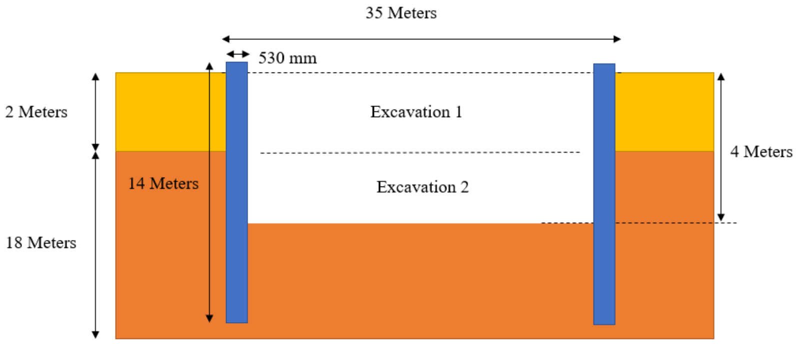

Figure 2: Geometry for Model 2

2.6 Model 3: Double H King Pile

Model three represents the Double H King Pile which has a higher elastic modulus than Model 2 with it being 2.94 x109 kN/m. The excavation takes up the same amount of time as the other two models as it needs to be constant in order for the data to be valid for comparison. Two other versions of this model was made shich are the shortened combipile length to 10 metres and increased length to 18 metres, Figure 3.

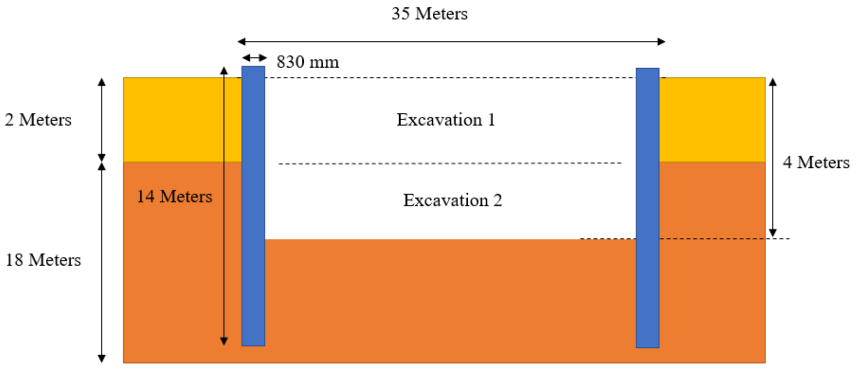

Figure 3: Geometry for Model 3

3. Results and Discussion

A total of seven models were made and analysed with different conditions. The unchanged elements throughout all the models were the soil parameter and the soil profile. Graphs illustrating the data obtained from the analyzation of models were made. The graph for Model one was the settlement versus the position of the nodes as shown in Figure 4. However the other graphs were plotted as settlement versus time for each of the models as shown in Figure 5, Figure 6, Figure 7, Figure 8, Figure 9, Figure 10.

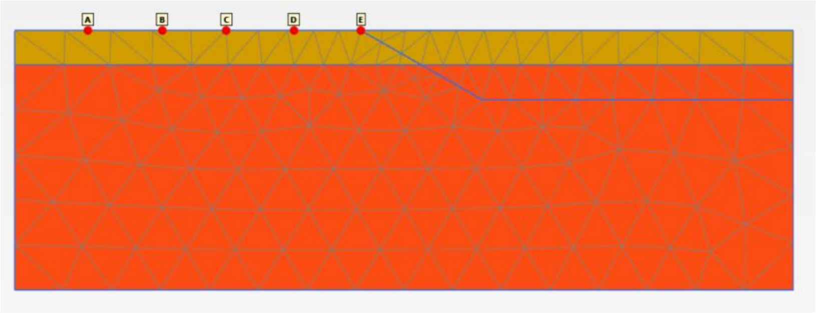

Figure 4: Points for Model 1 in FEM Analysis

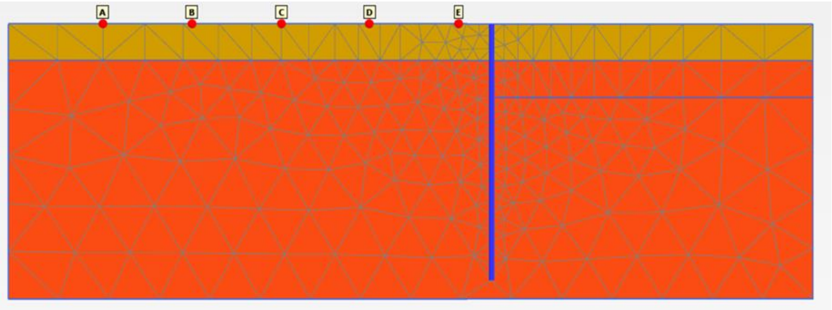

Figure 5: Points for Model 2 and Model 3 in FEM Analysis

A number of five points were selected to achieve the ground settlement calculation, as seen in Figure 4 for Model 1 and Figure 5 for the rest of the models. For the conventional method and the methods using combipiles, the points were chosen because the observation concentrated on the settlements behind the excavation region.

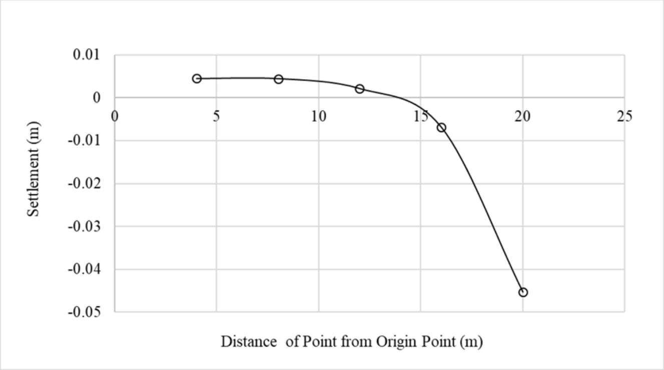

Figure 6: Settlement graph for Model 1

The predicted settlement produced from the FEM analysis shows the settlement relative to the distance of the points from the origin point. The settlement gradually decreased the further the point from the origin point. A noticeable decreasing of the settlement value beginning at 12 meters indicates swelling of the soil due to the excavation. The swelling of the soil continued to the lowest of -0.04528 which was the nearest to the excavation.

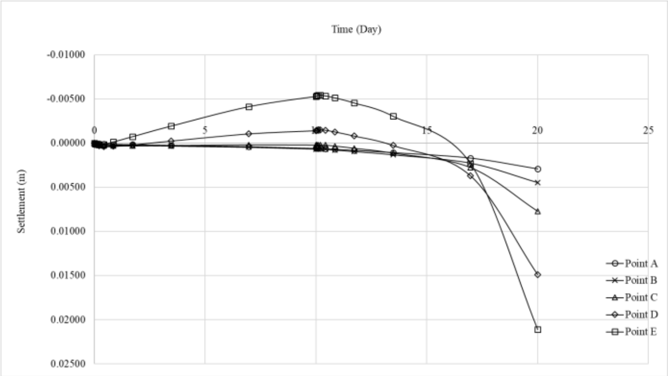

Figure 7: Settlement versus Time for Model 2

From Figure 7, point A the soil settlement shows to be negative for the first ten days indicating inflammatory or bulking of soil. The reason behind this is probably due to the initiation of excavation for the first layer which was conducted in the first 10 days. The excavation of the first layer seemed to cause an upward movement of soil at point A before causing the soil to settle after the excavation of the second layer at the next 10 days. This patterns shows an increase as the points gets nearer to the pile causing a greater upward movement of soil at point E during the first excavation period resulting a lowest reading of -0.00541 m on the 10 day mark before increasing in settlement reading during the second layer of excavation and giving the highest reading of 0.02112 at day 20. The negative settlement values interpret an upward movement or the swelling of soil in the area and time which was due to the excavation activity. Meanwhile, the positive settlement value interprets the movement of the soil downwards or settling which was due to the excavation activity.

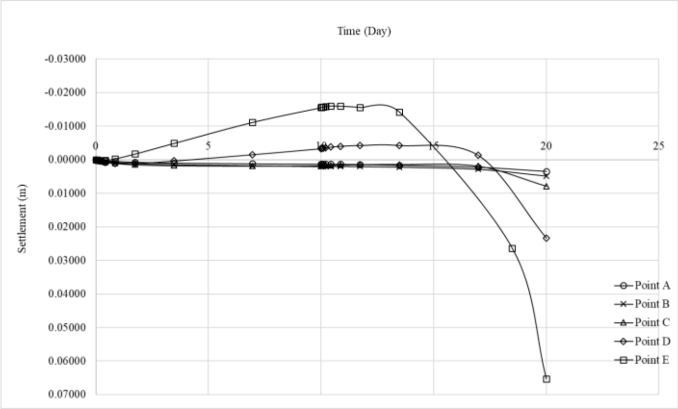

Figure 8: Settlement versus Time for Model 2 with 10 m Length Combipile

The points in Figure 8 which were furthest from the combipile gave the least settlement reading change over the course of 20 days excavation. However, Point D and Point E gave substantial change in settlement value where both points results were negative on the first 10 days and drastically increased after the 15-day mark for Point D and 13-day mark for Point E. Focusing on Point E, as shown in Table 4.3 the settlement reading on the 20-day mark was 0.06526 meters indicating a much higher value than that of Point A which was furthest from the combipile showing a settlement reading of 0.00353 meters.

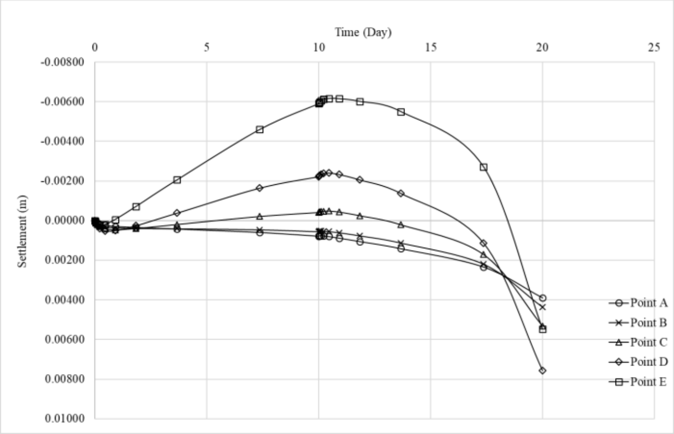

Figure 9: Settlement versus Time for Model 2 with 18 m Length Combipile

Points A, B, and C gave small settlement reading changes over the course of 20 days. On the other hand, Point D and Point E gave higher reading values that peaked at -0.00241 for Point D and -0.0066 for Point E. The values of both points were negative throughout the first layer of excavation was done and increased when the second layer of excavation was done which gave a reading of 0.00756 for Point D and 0.00548 for Point E at the 20-day mark. However, the highest settlement value for this particular model was Point D where it surpassed the maximum value for Point E at day 19.

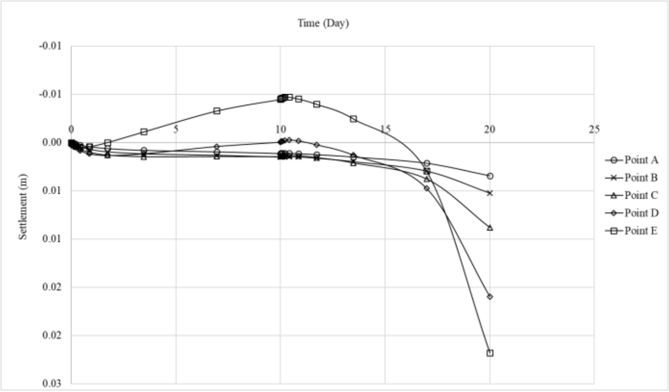

Figure 10: Settlement versus Time for Model 3

In the course of 20 days of excavation, the points that were farthest from the combipile gave the least settlement reading. The most noticeable change in settlement reading was at Point E where it recorded the lowest settlement value of -0.00457 meters. In Figure 10, the settlement reading of Point E on the 20-day mark was 0.02182 meters indicating a much higher value than that of Point A which was furthest from the combipile which showed a settlement reading of 0.00345 meters.

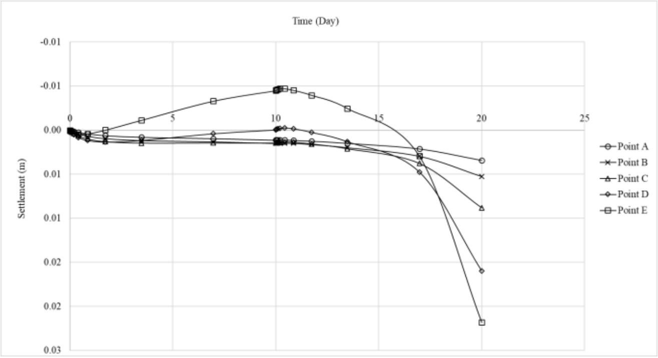

Figure 11: Settlement versus Time for Model 3 with 10 m Length Combipile

From Figure 11, Point D and Point E showed a noticeable shift in the settlement value where the results of both points were negative throughout the excavation of the first layer and rose significantly after the commencement of excavation of the second layer. The settlements at locations A, B, and C showed a static reading throughout the excavation of first layer which then increased slightly at the 20-day mark.

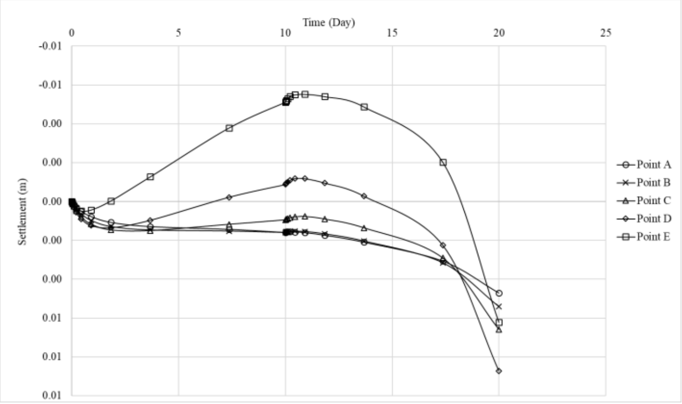

Figure 12: Settlement versus Time for Model 3 with 10 m Length Combipile

Minor changes in settlement readings were spotted at Points A, B, and C over the course of 20 days. Figure 12 shows Point D and Point E gave lower reading values which were at -0.00118 meters for Point D and -0.00552 meters for Point E. By the first 10 days, almost all of the locations indicated a downward reading which meaned an increase in the surface level before noticeably increased after the 10-day mark.

From here it was determined that the excavation of the first layer affected the soil surface behind the combipile positively and later affecting it negatively as the second layer was excavated. The highest recorded settlement value in this model was at the location of Point D with a reading of 0.00872 meter at the 20-day mark.

3.1 Lateral Displacement at Day 20

In the FEM analysis, locations which was represented by points was chosen in generating lateral displacement of the pile at day 20 as shown in Figure 13. This is because the lateral displacements of the pile indicate the stableness of the pile designed. Each model was compared with the respective depth to see the difference each model gave. A total of five points were placed at an equal distance to capture the lateral displacement of the combipile.

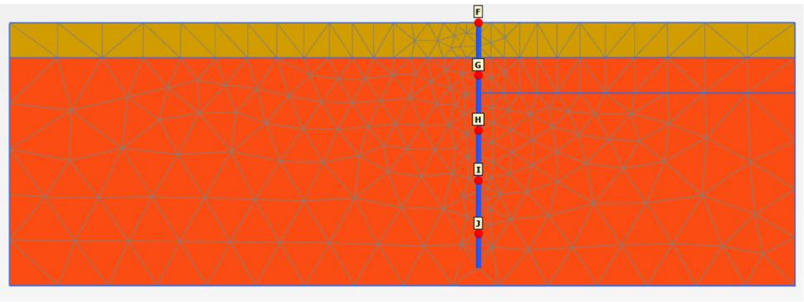

Figure 13: Lateral Displacement Position used in PLAXIS 2D

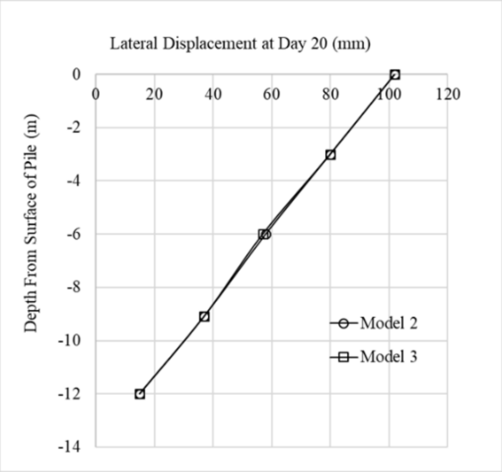

Figure 14: Predicted Lateral Displacement for Models with 14 meters Combipile

From Figure 14, the lateral displacement steadily decreased during both excavation layer. There were no sudden spikes indicating the combipile experienced no bending throughout the excavation period.

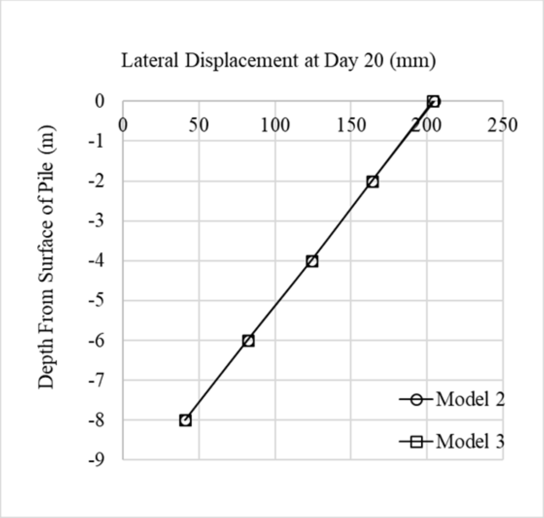

Figure 15: Predicted Lateral Displacement for Models with 10 meters Combipile

The lateral displacement in Figure 15 and 16 showed gradually decreased during both excavation layers. The difference in the lateral displacement at almost every depth had a difference by 40 mm. Throughout the excavation time, there were no sudden spikes showing that the stiffness of the combipiles were enough to withstand the lateral displacement emitted.

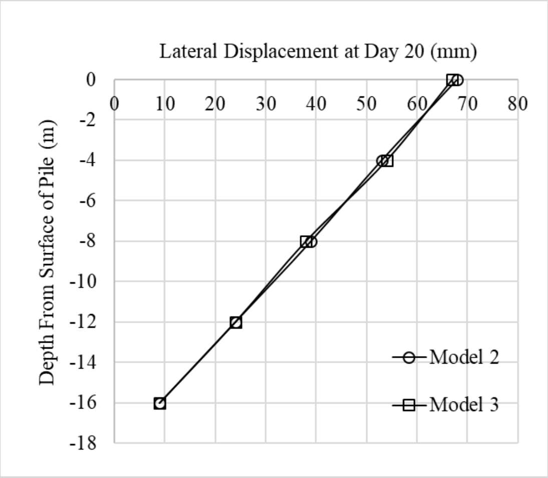

Figure 16: Predicted Lateral Displacement for Models with 18 meters Combipile

During both excavation layers, the lateral displacement steadily decreased. There were no sudden curves during the excavation time which suggested the stiffness of the combipiles was adequate to withstand the lateral displacement.

4. Conclusion

In a nutshell, when it comes to settlement and lateral displacement the highly recommended model to be used is the Model 3 which used the Double-H Kingpile with the depth of 18 meters. In addition, a couple of improvements could be made such as consideration of water table and a varying stiffness of the Combipile.

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